Colorado Nonnative Fish Stocking Regulation Evaluation

Final Report

Upper Colorado Endangered Fish Recovery Program
Project No. 106

February 2004

Colorado Division of Wildlife
Wyoming Geographic Information Science Center

FINAL REPORT

Colorado Nonnative Fish Stocking Regulation Evaluation

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Key Words: nonnative fish, GIS (Geographic Information System), stocking regulations, floodplain ponds, backwaters, centrarchids, largemouth bass, green sunfish, critical habitat, Upper Colorado River Basin.

EXECUTIVE SUMMARY

In accordance with Procedures for Stocking Nonnative Fish Species in the Upper Colorado River Basin, the Colorado Division of Wildlife adopted regulations in 1999 to control the stocking of nonnative fish species below 6,500 feet in elevation in the Colorado River Basin, excluding the San Juan River Basin. The Colorado Wildlife Commission conditioned its approval of these new regulations by requiring that an evaluation be conducted to assess whether this strategy contributed to the control of target nonnative fish species within critical habitat for endangered fishes.

The methodology chosen to address this question included use of a Geographic Information System (GIS) to provide a comprehensive framework for examining diverse information. This information included pond locations, fish sampling data, and reclamation treatments within the Colorado and Gunnison River corridors surrounding critical habitat, stocking activity for nonnative, nonsalmonid fishes, and sampling data from backwaters within the Grand Valley reach of the Colorado River.

The original premise in the Stocking Procedures that 6,500-feet in elevation would serve as an ecological demarcation above which few private waters would be stocked with nonnative, warmwater sport fish appeared to be generally true, based on available data. Triploid grass carp and fathead minnow were the most widely stocked nonnative, nonsalmonid species with stocking sites ranging from ponds within or near the floodplain in critical habitat for endangered fishes to waters near the Continental Divide. Based on available data for floodplain ponds sampled and those ponds that received treatments to control abundance or escapement of nonnative fish species within the Grand Valley reach of the Colorado River, green sunfish and largemouth bass pose the highest risk of reaching critical riverine habitat for endangered fishes.

The poor response to the request for voluntary submission of private sector stocking data for 1998-2000 precluded performing a meaningful risk assessment of the potential for stocking nonnative fish in the general study area to serve as a source of these species entering critical habitat for endangered fishes. Inadequacies in the reporting of stocking location descriptions limited the spatial utility of a considerable number of stocking sites, compromising the capacity to fully document or evaluate the relationship of locations and species stocked with other available data.

The abundance of stocked fish species (e.g. fathead minnow and largemouth bass) generally remained the same before and after treatments to control nonnative fish abundance in or escapement from floodplain ponds or to control nonnative fish density in backwaters. While there was no evident change in the backwater densities of the species examined during this study, it appeared that the highest densities of some species shifted locations from year to year, which could be a result of removal efforts dampening populations in particular locations. There was no spatial pattern demonstrating a definitive relationship between nonnative species location and density in critical habitat or potential sources of nonnative fishes such as nonnative fish stocking events or fish populations in floodplain ponds.

Due to data limitations and the short timeframe of this study, it remains inconclusive whether Colorado's nonnative fish stocking regulations were effective in controlling or reducing nonnative fish proliferation. This outcome should be viewed as an opportunity to clarify the existing regulation to facilitate compliance and to improve its potential to serve as a preventative control strategy rather than a basis to eliminate or relax the existing regulation. It is increasingly evident that the prevention or control of nonnative fish before they proliferate and become problematic in rivers is likely a better strategy than removal or reclamation after the fact.

INTRODUCTION

General

Nonnative fish species are suspected of having a significant negative impact on the current status and recovery potential of the Colorado River endangered fishes (common and scientific names, including species codes for fishes mentioned in this report are found in Appendix I). Attempts to control and minimize these impacts have been reviewed by Hawkins and Nesler 1991, Lentsch et al. 1996, PDO 2002, Tyus and Saunders 1996 and 2000. Shallow, shoreline habitats with little or no current (backwaters, embayments, side channels) are considered to be vital nursery habitats for native fishes, particularly for the young of endangered Colorado pikeminnow (Byers et al. 1994, Osmundson 2000). Seasonally inundated bottomlands and floodplain depressions are considered to be important nursery habitats for the young of endangered razorback sucker (Burdick 2002, Osmundson 2000). Recent data show that backwaters within the Colorado and Gunnison rivers are dominated by nonnative fishes which comprise 90-99% of the species composition (Anderson 1997, Bundy and Bestgen 2001, Burdick 1995, McAda et al. 1994 and 1996, Trammell 2002). In addition, recent examinations of floodplain habitats reconnected to the Colorado River have also shown a seasonal preponderance of nonnative fishes (Burdick et al. 1997 and 2002).

Control of nonnative fish in the Upper Colorado River Basin (UCRB) is defined as "reducing the numbers of one or more nonnative species to levels below which they are no longer an impediment to the recovery of endangered fish species" (Tyus and Saunders 1996 and 2000). Control of nonnative fish within Colorado has been pursued through several approaches. These include: (1) removal of bag and possession limits on nonnative, predatory gamefish species within designated critical habitat (Martinez 1998 and 1999), (2) authorization of Recovery Program participants to remove nonnative fish incidental to approved project sampling objectives through scientific collection permits (T. Nesler, CDOW, personal communication), (3) removal of nonnative fish from backwater habitats in the Colorado River by seining and electrofishing (Bundy and Bestgen 2001, Osmundson 2003, PDO 2002, Trammell et al. 2002) (4) removal of nonnative fish captured in the Redlands passageway on the Gunnison River (Burdick 2001), (5) removal of nonnative fish from backwater, slough and main channel habitats in the Yampa River during spring runoff (Hawkins and Nesler 2001, PDO 2002, Pfeifer and McAda 2001), (6) removal of channel catfish in the lower Yampa River (Modde and Fuller), (7) removal of nonnative fish from ponds in the Colorado and Gunnison river floodplains via chemical reclamation and water level management (Martinez 2001a, PDO 2002), and (8) regulation of the release of non-native fishes via stocking into public and private waters within designated critical habitat and a buffer zone bounded by the 6500-feet elevation isopleth, and in other waters via lake licenses and stream stocking permits (Martinez 2001b and 2002, Nesler and Martinez 2001, PDO 2002). This latter component is the primary focus of this investigation.

Background

The Procedures for Stocking Nonnative Fish Species in the Upper Colorado River Basin (hereinafter Procedures) were adopted by the state wildlife agencies of Colorado, Utah and Wyoming, and the U.S. Fish and Wildlife Service (USFWS), Region 6, on 5 September 1996

(CDOW et al. 1996). The Cooperative Agreement for implementation of the Procedures was approved by the Wildlife Commission on 19 September 1996, and by the Directors of the state wildlife agencies in Colorado, Utah and Wyoming, and the U.S. Fish and Wildlife Service, Region 6, on 6 November 1996 (CDOW et al.1996). The Agreement states that the States "will ensure that all State and private stocking of nonnative fishes in the UCRB are in compliance with the Procedures. This will include, but not be limited to, enacting/clarifying appropriate regulations for stocking of public and private waters." The intent of the Procedures is "to reduce the potential for negative impacts on the endangered fishes in the UCRB and to ensure that their recovery is not inhibited by controlling stocking and escapement of stocked, nonnative fish."

Colorado addressed the requirement to "ensure that all State and private stocking of nonnative fishes in the UCRB is in compliance with the Procedures" in January 1999 by restricting nonnative fish stocking in waters below 6,500 feet in elevation in the Colorado, Gunnison, White, Yampa, and Green River basins. This demarcation at 6,500 feet is found in the Procedures (CDOW 1996) which basically state that most areas above this elevation are coldwater habitats that will not support warmwater fishes. Further, it was believed that there were very few floodplain situations above 6,500 feet, and that those ponds present are typically stocked with salmonids.

Adopted in 1999, these new regulations in conjunction with the existing lake license permit regulations are intended to meet the intent of the Procedures. The Colorado Wildlife Commission conditioned approval of these new stocking regulations by requiring an evaluation of the regulations' effectiveness in achieving a biological response. The Commission will review the overall effectiveness of these regulations, and consider the continuation or replacement of these regulations, based in part, on the findings of this project.

The regulatory approach to nonnative fish control affects river reaches subject to one or more active nonnative fish removal projects, making such effects cumulative and difficult to separate. Stocking regulations are also influenced by uncertain and uncontrolled variability in participation, compliance and accuracy of records. Thus, the chosen approach by the Colorado Division of Wildlife (CDOW) was to document: (1) the extent of aquatic resources that constitute sources of nonnative fishes and receiving waters for stocked fish, (2) waters affected by nonnative fish control actions, (3) the distribution and composition of fish species associated with source and control waters, (4) the biological response of target native and nonnative fishes to cumulative control actions within critical habitat, and (5) the extent of private waters and businesses affected by the regulation and permit system.

Purpose and Objectives

Ultimately, the goal of this project was to evaluate the effectiveness of Colorado's fish stocking regulations in achieving the desired biological responses of fish communities within critical habitat for endangered fishes. Primary objectives were:

(1) To determine if the administration of fish stocking regulations and permits is contributing to the reduction in riverine abundance of target nonnative fish species.

(2) To monitor the trend in distribution and abundance indices for target nonnative fish species in riverine habitats, and compare the indices to concurrent public/private fish stocking data.

(3) To conduct a risk analysis (RAMC 1996) of nonnative fish stocking in the UCRB in Colorado to identify its relative significance and potential for introducing nonnative fish species into critical habitat for endangered fishes.

METHODS

Study Area

A variety of data sources were required to depict locations of ponds and reservoirs, including the locations of ponds by floodplain position within critical habitat for endangered fishes along the Colorado and Gunnison rivers. Four general geographic areas were delineated to examine nonnative fish stocking activity and encompass various levels of detail with regard to pond abundance, fish sampling data and stocking records (Figure 1):

1) Colorado, west of the Continental Divide, the general study area.
2) Western Colorado below 6,500-feet in elevation, excluding the San Juan River basin, the regulatory study area (technically, the new regulations do not apply to the San Juan basin, but it was included for some data depictions and discussions).
3) The Colorado and Gunnison River corridors within and adjacent to critical habitat for the endangered fishes, the primary study area. This included the Colorado River from river mile 240 to 152 on the Colorado River and the Gunnison River from river mile 52-0.
4) The Grand Valley reach of the Colorado River and its associated 50 and 100 year floodplains between river miles 185-152, the intensive study area (ISA).

Overview

The overall methodology chosen for this project involved use of the Geographic Information System (GIS) to provide a comprehensive framework for examining diverse information. The CDOW solicited bids from potential contractors for the GIS component of this study and selected the Wyoming Geographic Information Science Center at the University of Wyoming in Laramie, with Nathan Nibbelink, Ph.D., as the principal investigator.

The acquisition and examination of data in this report fell into four primary categories. These included:

1) Pond, lake and reservoir locations and associated hydrography in western Colorado.
2) Available data for fish species composition and nonnative fish control treatments in floodplain and adjacent ponds along the Colorado River.
3) Pre- and post-regulation nonnative fish stocking data.
4) Pre- and post-regulation abundance of selected nonnative fishes in backwaters within the Grand Valley reach of the Colorado River.

Pond, Lake and Reservoir Locations, and Hydrography

The goal of this section was to determine the number and distribution of pond, lake, and reservoir resources below 6,500 feet in elevation surrounding the critical habitat reaches of the Gunnison and Colorado rivers. Also, there was a need to produce GIS-based maps of ponds, floodplains, lakes and reservoirs in the Colorado and Gunnison River basins below 6,500 feet in elevation, and an associated descriptive list. To illustrate the distribution of standing water resources in western Colorado, a GIS-based map was also produced for the state west of the Continental Divide. The pond data for the ISA were digitized and attributed from the four primary sources listed below. The accuracy and utility of these data is dependent upon the quality, completeness, and dates of these sources.

1) The hydrography created and maintained by the CDOW's Aquatic GIS Coordinator in Fort Collins, CO (Colorado Division of Wildlife, 15 February 2000, co_lakes3).
2) The pond maps provided by Anita Martinez, CDOW Nonnative Fish Control Biologist, for the Colorado River from river mile 150 to 186.
3) Aerial photography from 1997 provided by Mesa County.
4) Aerial photography from 2000 provided by the USFWS.

The map creation and analysis of pond, floodplain, lake and reservoir resources took place at two scales. The lakes and reservoirs were viewed, and associated fish stocking and/or composition data analyzed, for all of Colorado west of the Continental Divide. This GIS data layer came from the Aq_GIS_DOW-CD; specifically the "co_lakes3" layer that was used for this work. The pond resources layer, including analyses of associated fish populations, if known, were created, viewed and analyzed at a much finer resolution for only the primary study area. This included river miles 152-185 on the Colorado River and when data allowed, through river mile 240 on the Colorado River and river miles 0 to 52 on the Gunnison River (Figure 1).

Aerial photography obtained from Mesa County had been orthorectified, so no transformations were necessary in order to digitize ponds. The photography from the USFWS was rectified by the contractor using both Digital Raster Graphics (DRGs) and Digital Orthophoto Quarter Quads (DOQQs), as available. The rectified photography from the USFWS should not be used for accurate spatial positioning of other features. Features were rectified to maximize the accuracy of the spatial position of standing water resources visible in the photo.

Pond outlines were digitized for the Colorado River and Gunnison River within the ISA. The ponds were attributed interactively with "Mitchell codes" (Mitchell 1995), with the aid of the pond maps, described above, compiled by Anita Martinez, CDOW. This allowed us to link the geographic features of ponds having codes to data on pond attributes, including information on control structures and fish species composition available from Anita Martinez. The final version of the primary study area pond dataset is an ArcView shapefile (spatial data layer) called "ISAPonds" and it includes all attributes available from the floodplain pond database of Martinez (2004).

The 50- and 100-year floodplain data for the primary study area (Colorado and Gunnison rivers) were scanned and digitized from a series of reports produced by the Colorado Water

Conservation Board (CWCB 1995c, d, Vols. 3 & 4). These floodplain data layers for the Yampa and the White Rivers were also completed from CWCB (1995a, b, Vols. 1 & 2) maps, and are included on the project data CD, but were not used in any analyses in this report.

Pond Sampling and Reclamation Data

The goal of this section was to describe fish species composition of known ponds in the ISA. These data were available from the pond reclamation project targeting reduction in nonnative fish abundance and sources in Colorado and Gunnison River floodplain and adjacent ponds, 1996-2002 (Martinez 2004). Anita Martinez provided a database containing a list of known ponds in the ISA, and fish sampling records, if available. This database included information on fish populations (for a subset that were sampled), and information on ponds receiving reconnaissance and/or treatments to remove, eliminate and/or control escapement of nonnative fishes. This database was linked to known ponds with “Mitchell codes” as described above (ISAPonds). This GIS layer allowed us to look at the fish species composition of ponds stratified by floodplain position, and also to identify ponds for which we have no information on fish species.

We developed an index that would roughly identify a relative threat presented by each fish species present in these ponds. Several key points are explained below to clarify the utility of this index given the available data. The selection of ponds for sampling or reclamation of their fish populations, while distributed throughout the primary study area, were selected on the basis of practical factors such as accessibility, both physical and legal (most were private) rather than in a random or stratified fashion. For our purposes here, we assumed that the ponds sampled for fish species composition and the occurrence of fish in this subset of ponds sampled by Martinez (2004) were representative of this resource. However, we knew that this data was not necessarily the result of exhaustive sampling of the fish in these ponds. The manner in which Martinez (2004) sampled ponds was influenced by several constraints. These constraints included 1) extremely high conductivity (> 3,000 μmhos) which precluded electrofishing, 2) concern about inadvertent sampling mortality of endangered fishes that might inhabit some ponds limiting the use of certain gear types, and 3) at least for the period of our evaluation, treatments to control nonnative fish were assumed to actually have an affect in greatly reducing or eliminating fish escapement from treated ponds into the river. We now know from Martinez (2004) that certain measures to control nonnative fish abundance or escapement were temporary, but for the period of this evaluation it was assumed the fishes sampled in ponds were representative and that nonnative fish control treatments were effective. Last, it was assumed that nonnative fish in untreated ponds could in fact escape, thus contributing additional, problematic nonnative fishes to critical habitat.

Our Index of Threat indicates the relative threat posed by any one nonnative fish species, accounting for both its overall occurrence in the study area, and the control measures that have been taken on ponds containing that species. Theoretically, the value will scale from 0 (no threat) to 1 (maximum threat). The calculation is as follows:

$$\textbf{Index of Threat} = (1 - C) * P$$

where…
P = prevalence = the number of ponds containing species **A** divided by the number of ponds in which the most prevalent fish species (**X**) occurs, so **P = #A / #X**; we divide by the most prevalent species to scale **P** to a maximum of 1, realizing that some ponds are fishless

C = control = the number of ponds in which species **A** occurred that have received a control treatment (poison, screen, etc.), divided by the number of ponds in which species **A** occurs, so **C =** $\mathbf{\#A_{controlled} / \#A}$

Example: if species **A** is present in 20 ponds, and species **X** (the most prevalent species) is present in 40 ponds, the prevalence of species **A** is calculated as **P** = 20 / 40 or 0.5. Further, if 10 of the 20 ponds containing species **A** have been treated to effectively control nonnative fish abundance or escapement, the relative control of species **A** is **C** = 10 / 20 or 0.5. Therefore, the overall threat of species **A** (the proportion of uncontrolled ponds containing species **A** multiplied by it's prevalence in the study area) is Index of Threat = (1 – 0.5) * 0.5 or 0.25. Comparatively speaking, if the number of ponds treated to control nonnative fish increases, and some or all of these ponds also contain species **A**, the Index of Threat will decline. If the number of ponds containing species **A** increases due to additional sampling, invasion or stocking, the index will increase. Now two examples will briefly show the integrity of the Index of Threat by defining the endpoints. Theoretically, if effective control has occurred in all ponds that contained species **A**, then **C** = 20 / 20 = 1; therefore, the Index of Threat = (1 – 1) * 0.5 = ZERO. So, as expected, no threat is perceived if control in complete. Also, if species A exists in all ponds and control is zero, C = 0 / 40 = 0; P = 40 / 40 = 1; therefore Index of Threat = (1 – 0) * 1 = 1. Thus, as expected again, the maximum threat to critical habitat would be perceived by a prevalent nonnative fish species occurring in all ponds, and no control measures have been applied.

Pre- and Post-Regulation Fish Stocking Data

The goal of this effort was to compile data on nonnative, nonsalmonid fish stocking in western Colorado for the years 1998 to 2001. It was decided that 1998-1999 would serve as pre-regulation data, and 2000-2001 would represent post-regulation data. Although new stocking regulations were adopted early in 1999, it was understood that the remainder of the year would be required to make the private sector, vendors and purchasers of nonnative, nonsalmonid fishes, aware of these new restrictions. Available data was sought or acquired from five categories of records believed to document stocking activity.

1) Vendor sales receipts
2) CDOW private stocking permits
3) CDOW importation permits
4) CDOW private and commercial lake licenses
5) CDOW stocking records for public waters

Vendor sales receipts

Due to data inadequacies within CDOW for documenting private-sector stocking activity, particularly for the pre-regulation period, written and verbal requests were made to vendors asking for voluntary submission of their stocking records or copies of sales receipts for the years 1998-2000. Data submitted via this request constituted the bulk of the data available for the pre-regulation period for the years 1998-1999. Records that could be cross-validated with importation records were removed to avoid duplication. Those with specific location information that were not identified in the importation database were added to the final "StockingAll" GIS layer.

CDOW private stocking permits

Data on private landowner fish stocking permits for the year 2000 were derived from the CDOW's Fish Health Section files (Linda Chittum, former CDOW Fish Pathologist). These data for 2001 were obtained from Lori Martin (CDOW Nonnative Fish Control Biologist). These data had been compiled into a database designed by Lori Martin, greatly facilitating their utility. It was assumed for the purposes of mapping and analyses herein that permitted stocking was actually carried out. An important caveat, however, is that this dataset is considered incomplete. Non-permitted or non-reported stocking would add to this data set, but the extent of compliance with permitting requirements was and remains unknown, but is expected to be substantive.

CDOW importation permits

The DOW fish importation database (K. Konishi, CDOW Special License Administrator) provided another potential source for information on fish stocking for the years 1997-1999. Importation records were sometimes useful in locating individual stocking events, but often simply indicated "statewide" as the destination for the fish.

CDOW private and commercial lake licenses

The CDOW lake license database (K. Konishi, CDOW) provided additional commercial and private records from 1997-2001, although indirectly, of potential stocking activity in standing waters of Colorado. The lake license information was subject to the same difficulty in mapping the spatial location of a lake if specific information was not provided.

CDOW stocking records for public waters

We summarized nonnative, nonsalmonid fish stocking performed by CDOW for the years 1997-2001 relative to the receiving water's position on the landscape. The total number of nonnative species stocked relative to both the 6,500-foot elevation contour and to the flood plains were summarized. Unlike the private stocking, the spatial locations of these data were accurate to the center of the water that was stocked, so the flood plain designations are accurate.

Nonnative fish stocking events for select species of particular concern to the Recovery Program were mapped (triploid grass carp, channel catfish, bluegill, black crappie, largemouth bass, and fathead minnow). The mapping of this information was limited to the available spatial information in the records we received. Often there were addresses, cadastral information, or lake/pond names that did not allow us to link the potential stocking activity with particular waters. If the receiving water was thought to have been located within one square mile, the best approximation of the location was used.

We used spatially explicit queries in ArcGIS 8.1 to determine whether these stocking events intersected both the 6,500-foot elevation contour and the 50- and 100-year flood plains. However, since many of the stocking events were accurate only to a section, or about a square mile, it should be kept in mind that the flood plain designation of these events is prone to error.

Pre- and Post-Regulation Abundance of Selected Nonnative Fishes in Backwaters

The goal of this portion of the study was to determine the change in backwater distribution and density of selected, regulated nonnative fish species in the ISA of the Colorado River from river mile 185-152 in response to regulatory restrictions on the stocking of nonnative, nonsalmonid fishes. Data sources referenced or utilized for this effort included four projects in the Grand Valley reach of the Colorado River, whose time frame coincided with the period investigated during this study, 1997-2001:

1) Recent data from the Interagency Standardized Monitoring Program's (ISMP) Fall seining in backwaters of the Colorado River, 1997-2000 (Elmblad 2003)
2) An evaluation of the (ISMP) sampling protocol, 1997-1998 (Bundy and Bestgen 2001).
3) The removal of cyprinids from backwaters by seining, 1999-2001 (Trammell et al. 2002).
4) The removal of centrarchids from backwaters by electrofishing, 1999-2001 (Osmundson 2003).

Due to known deficiencies in the fish stocking permit record, particularly the pre-regulation stocking period of 1998-1999, much of the effort in this section was devoted to spatial pattern analyses intended to detect patterns relating potential sources of nonnative species. These potential sources included post-regulation stocking events in 2000-2001, and floodplain pond populations based on locations or high densities of nonnative species in critical habitat in the Colorado River.

In order to detect spatial patterns in the presence and abundance of nonnative species within critical habitat in relation to potential sources, we employed three primary approaches: 1) visual pattern detection, 2) proximity analysis, and 3) geostatistics (spatial correlation analysis). It was difficult to focus exclusively on pre- and post-regulation data given the distribution of dates for particular datasets. We could not use many pair-wise comparisons between potential sources and riverine populations that were consistent throughout the relevant time periods because there were few consistencies among data across years. Where possible and appropriate, we indicate pre- and post-regulation data. Also, it was understood that nonnative removal efforts in the river and backwaters, pond treatments, and stocking regulations were all completed/ implemented by spring 1999. This renders many analyses irrelevant for determining what may have caused any change observed.

Visual pattern detection

Visual pattern detection involves primarily the use of maps and symbology that carefully represents point locations and values. By using, for example, symbols whose size are related to the fish density at a particular location, we can detect whether or not there are clusters of locations that have high values for a particular species. Sometimes the visual patterns observed can lead directly to spatial anomalies that are very useful in identifying problem locations, or developing further testable hypotheses (Nibbelink and Rahel, in review). Furthermore, by combining point pattern maps of riverine densities with those of fish stocking densities or floodplain pond fish densities, we can potentially see whether high densities from particular sources may be related to high densities of nonnative fishes in critical habitat. This approach looked for clusters that might indicate potential sources of nonnative fishes to backwaters within the ISA. Furthermore, we looked at whether treated ponds related to lower densities of nonnative fishes in backwaters. The analyses conducted were as follows:

1. Comparison of stocking (all known stocking events) densities vs. backwater fish densities.
2. Comparison of treated ponds to backwater fish densities.
3. Comparison of nonnative fish densities in ponds vs. backwaters.
4. Nonnative fish densities in backwaters, pre- and post-regulation periods.

It was not possible to simply pool and compare all of the fish data from backwater sampling due to different sampling protocols (Table 1), so we had to choose carefully when using data to reflect species composition and density in the ISA. Most of these data were collected using river miles or kilometers as indications of location. Therefore, data for species and number were linked in the GIS to the nearest 0.1-river mile designation. To get a robust picture of the density of species in the riverine backwaters, we used only the data sets from Bundy and Bestgen (2001) and Trammel et al. (2002) as their methodologies were the most thorough and similar. To further facilitate comparisons among these data sets, only the first-pass removals were utilized due to the different levels of effort expended by each project.

We mapped nonnative fish densities for each of these sampling programs to visualize hotspots for nonnative species in critical habitat, and to describe the relative densities of each for select species of interest. Three nonnative species were of particular interest in backwaters, due to their prevalence. These included largemouth bass and fathead minnow, which can be stocked under the new regulations, and one species that is not stocked, green sunfish. The inclusion of green sunfish was due to several factors: 1) these fish are ubiquitous and appear to be self-sustaining in a variety of stream sizes and habitats, and 2) there has been recent interest in the concept of concentration areas for centrarchids, referred to as “hot spots”, within the Grand Valley reach of the Colorado River (Nesler 2002), and 3) there is some evidence that green sunfish share the top trophic position in backwater food webs in the Grand Valley along with largemouth bass and black crappie (Martinez et al. 2001).

Proximity analyses

We next looked more formally at whether high densities of nonnative fishes in backwaters were closer than expected to stocking locations or high densities in ponds (“high” densities are locations that fall in the top 10% of density for the species being considered). This analysis was performed by first measuring the nearest distance from high density backwater locations to stocking locations (or high density pond locations), then measuring the nearest distance from backwater locations with the species absent to the same potential source locations. Theoretically, if the high density backwater locations are closer to pond or stocking locations than locations where the species was absent, this lends evidence to stocking events or pond fish populations being sources of a particular species to critical habitat (Figures 2 and 3). Of course, if there is no difference between these two proximity measurements, this does not mean that the ponds or stocking events are not potential sources. Rather, the ponds and stocking events simply are not spatially related in the way we may expect, and therefore are not likely to be identifiable sources using spatial pattern analysis. The proximity analyses we performed were as follows:

1. Comparison of stocking events vs. high backwater densities.
2. Comparison of high density pond locations vs. high backwater densities.

Geostatistical analyses

We used three primary geostatistical approaches to evaluate further potential spatial patterns between potential sources of nonnative fish in the ISA and nonnative fish densities in critical habitat. Two of these approaches expand on analyses described above by focusing more formally on explicit spatial relationships between sources and backwater populations. The third method concentrates explicitly within the backwater populations to describe how these populations are distributed in the ISA, and how their distribution may influence the identification of nonnative fish sources and direct nonnative fish control efforts.

All three of the techniques we describe below and employ here are based on the fact that the correlation between fish densities at any two locations may vary depending on the distance between those locations. For example, we may expect a riverine location that is close to a floodplain pond to have similar densities of similar species, IF that pond is a potential source to the riverine location. Similarly, fish densities at locations that are very far apart will not, on average, be correlated to one another. These geostatistical approaches can be more powerful than visual and proximity approaches because they consider all densities of fish (not just high ones) and many inter-site distances (not just the closest locations).

1. The modified h-scattergram

The h-scattergram is a plot of all pairs of measurements of the same attribute (i.e. fish density) at locations separated by a given distance (h) in a particular direction (Goovaerts 1998). We have modified this approach here by plotting the fish density at a backwater location vs. the sum of the density in ponds (or number of ponds containing that species) within a specified buffer distance from the backwater location. This analysis was performed by first buffering the backwater locations, then summing the ponds and species-specific fish density within 250, 500, 750, and 1000 m buffers extending out from the backwater locations. If fish densities at these backwater locations are related to densities of fish or ponds at particular scales, there should be relationships at those scales. Specifically, we may expect a strong relationship at 200 m, but a declining or non-existent relationship at 1000 m (Figure 4).

2. The cross-correlogram

A cross-correlogram is a plot of the inter-site correlations as a function of increasing separation distance between locations (Goovaerts 1998). Cross-correlograms can be used in two ways. The most common application is to consider the relationship between different attribute values (e.g. fish density and temperature) within a sample dataset. An alternative, and the way in which we applied the cross-correlogram here, involved focusing on correlations among a similar attribute (fish density, or index of density) across two datasets. The correlation coefficient that is used here was Moran's *I*. Moran's *I* is an extension of the cross-product correlation coefficient. A typical pattern in a correlogram is shown and described in Figure 5. We developed cross correlograms between fish density in backwater locations and fish numbers sampled in floodplain ponds. Theoretically, we would expect to see positive correlations at short distances, just as with the scattergram if there were positive associations between pond fish densities and backwater fish densities. The correlogram can also suggest the distance at which this relationship no longer exists. When the correlation is not significantly different from zero, we have reached the distance beyond which there is no longer any "influence" of the source. Therefore, correlograms can be used to suggest spatial scales at which certain patterns exist (Nibbelink 2002). The term "influence" is in quotations because the correlogram does not necessarily imply causation. It is merely a suggestion of pattern.

3. The semivariogram

Semivariograms are often used in the geostatistical literature to describe spatial patterns in terms of dissimilarity instead of similarity (as with the correlogram). A semivariogram is the average dissimilarity between data separated by a distance (h). A semivariogram is computed as half the mean squared difference between the attributes (fish density) of every data pair (Goovaerts 1998). The primary advantage of the semivariogram is that it is relatively easy to fit one of several types of models to the data it generates. The fitting of a model can yield useful parameters called the range and the sill, which describe components of the spatial relationship observed (Figure 6).

RESULTS

Pond, Lake and Reservoir Locations, and Hydrography

Figure 7 shows the distribution of ponds, lakes and reservoirs above and below the 6,500-foot contour in Colorado west of the Continental Divide. Out of 3,616 standing waters in the database we compiled (Appendix II), 31 percent (1,104 waters) are located on or below the 6,500-foot contour (Table 2).

The pond layers in the primary study area were put together at a much finer resolution than much of our ponds, lakes and reservoirs database. Many ponds were included in the co_lakes3 layer, but our new pond layer is more recent and more complete, so data and analyses provide a more accurate representation of the resources immediately surrounding the Colorado and Gunnison rivers in the primary study area.

Figure 8 depicts a sample of ponds in the ISA with respect to the 50- and 100-year floodplains. GIS layers are provided on CD that contains the complete data available on floodplains for the Colorado, Gunnison, White and Yampa rivers (Appendix II). Of 896 suspected ponds (uncertainty comes from inability to confirm ponds' existence in aerial photography) in the primary study area, 59% are within the 100-year floodplain and nearly 50% are within the 50-year floodplain of the Colorado and Gunnison rivers (Table 3).

Pond Sampling and Reclamation Data

The fish species composition in ponds as determined by Martinez (2004) was mapped in GIS using the new shapefile (spatial data layer) ISAPonds. As an example of this, Figure 9 depicts a section of the Colorado River and the associated 50- and 100-year floodplains from river miles 175.5-178.8 showing ponds containing green sunfish. Table 4 stratifies the occurrence of several species by floodplain zones in 307 ponds sampled for fish by Martinez (2004) within the primary study area from 1997-2001. This table also includes occurrence of nonnative, nonsalmonid fishes from CDOW sampling records in eight reservoirs below 6,500-foot that are on tributaries to the Colorado and Gunnison rivers. Over 78% of nonnative fish occurrences below 6,500-feet were within the 100-year floodplain, and almost 73% of nonnative fish occurrences were within the 50-year floodplain.

Of the 896 suspected ponds that we were able to locate and link to existing pond data obtained from A. Martinez (CDOW), 86 ponds (or 9.6%) along the Colorado and Gunnison Rivers within or adjacent to critical habitat for endangered fishes had been treated to control nonnative fish (Table 5). Chemical reclamation was the most common method (45 ponds), with various combinations of pumping to de-water ponds, screening pond inlets or outlets, water management or application of black plastic. Figure 10 shows the ISA of the Colorado River from river miles 152 to 185, highlighting the treated ponds (GIS layers are on the project CD).

Table 6 summarizes the occurrence of nonnative, nonsalmonid fish species in ponds within the ISA that were sampled by Martinez (2004), and the number of ponds containing these species that were treated as part of the nonnative control program (Table 5). Overall, about 31.8% of the ponds containing nonnative species have been controlled. Figure 11 graphically depicts the index of threat (= prevalence), showing the potential threat each nonnative species poses to recovery efforts (both before and after control measures) based on the fish's prevalence and on the proportion of the waters lacking control measures in which the species is known to occur. For example, common carp and white sucker occur in roughly the same number of ponds (47 and 45, respectively), so the index of threat prior to control (Index of Threat = prevalence) is nearly equivalent. However, with nonnative fish control measures (piscicide or screening) implemented, the index of threat for common carp is more greatly reduced than that of white sucker. This result is due to more ponds containing common carp having had nonnative fish control measures applied (common carp 44% controlled, white sucker 26% controlled).

The index of threat is highest for green sunfish and largemouth bass. This is largely driven by their prevalence because control measures for these species are about average compared to other species (controls in 30-40% of ponds). White sucker, black bullhead, common carp, bluegill, and black crappie all show a comparatively intermediate level of threat after control, but as stated above, the effectiveness of control of each species depends entirely upon which ponds are controlled. For example, although the overall threat posed by channel catfish and western mosquitofish prior to control measures being applied is low compared to that of other species, their level of threat changes minimally after control measures have been implemented. This indicates that very few of the ponds known to contain these species were subject to control measures, thus these ponds could potentially become future sources of channel catfish and western mosquitofish. The potential threat of mosquitofish and channel catfish in ponds reaching critical habitat would decrease further if control measures were applied to ponds known to contain them, or possibly rise if it was learned that they exist in many more ponds than is currently documented.

Pre- and Post-Regulation Fish Stocking Data

From discussions with both private sector and CDOW personnel, it was determined that ten in-state private aquaculturists were likely recent suppliers, from 1998 to 2000, of nonnative, nonsalmonid fishes to Colorado's west slope. Additional inquiries internally indicated that three to four of these vendors probably supplied 90% of the nonnative, nonsalmonid fish species sold to private pond owners in western Colorado. Table 7 summarizes the response of the ten vendors to written requests for voluntary submission of their stocking records for the years 1998-2000. Only three vendors replied to this request for stocking data, with one vendor indicating that they did not sell any nonnative, nonsalmonid fish species during 1998-2000. One vendor provided stocking location information based on DeLorme's (1997) Colorado Atlas & Gazetteer grid coordinates. Another vendor provided address locations specifying a known reservoir name or "pond at residence." The third vendor provided client addresses, but did not specify the pond locations.

Based on the three responses received, there were approximately 200 individual stocking incidences for various nonnative, nonsalmonid fish species from 1998 to 2000 in Colorado west of the Continental Divide. Using this rate of stocking activity from the three respondents, it was estimated that an additional 400 stocking incidences of nonnative, nonsalmonids may have occurred, based on presumed sales for the six non-respondents, during 1998-2000 for which records were unavailable to CDOW via voluntary submission.

In November 2002, a preliminary summary of this project was presented to the Colorado Fish Health Board to provide an update on the project's progress, and to reiterate the low level of response to the voluntary request for private stocking records. One private attendee at that meeting indicated that the State's legal access to the stocking records (1998-2000) had expired, and that there remained no recourse for requesting or acquiring the data. Given that response, this report was finalized with the knowledge that much extant private stocking data for nonnative, nonsalmonid fishes was inaccessible. Further, it was determined that this known deficiency in the private sector stocking data would preclude any meaningful risk analysis of stocking as a potential source of nonnative, nonsalmonids entering critical habitat for endangered fishes. As a consequence, the third objective for this project, assessing the relative significance of nonnative fish stocking and its potential for introducing nonnative fish into critical habitat, could not be achieved (Tom Nesler, CDOW Native Fishes Coordinator, personal communication).

Appendix III provides a complete summary of the spatial utility of all of the stocking records received from various sources from 1998 to 2001 (Appendix II). Because many of these records were not specific enough with respect to spatial location, many were not suitable for mapping, therefore limiting our knowledge of the extent of nonnative stocking activity throughout the study area. For example, Figure 12a is a plot of all the known stocking events (336). If we assume a random distribution of the remaining unknown stocking events (243), there is a substantial amount of missing information (Figure 12b). However, in looking at Figure 12a, we can assume that there is not a random distribution of unknown locations. In fact, these locations are likely distributed much like the known locations, primarily below the 6,500-feet contour, with many probably falling within at least the 100-year floodplain within the primary study area.

Table 8 summarizes available private sector stocking records found in Appendix III, including importation permits, private and commercial lake licenses, stocking permits and voluntarily submitted vendor records, and their "spatial" utility in GIS. Importation records do not provide spatial data as they are typically issued as "statewide," therefore, the ultimate destination of the fish within the state is unknown. Private and commercial lake licenses typically provide usable location data, however, the frequency of stocking and the numbers and sizes of fishes stocked, if any, is unknown. In fact, it is unknown whether the fish species permitted for stocking on lake licenses are even stocked at all.

For the purpose of this project, it was assumed that the fish listed on the permits were in fact stocked, but this is simply a stocking occurrence, as the other details of the stocking activity cannot be documented. Stocking permits and vendor's records are a mixed bag in terms of having sufficient detail to document the locations where fish were stocked. However, these records tend to be more specific (believable) on the number, size range and frequency of individual species being stocked than importation records or lake licenses. Stocking locations with sufficient information to be pin-pointed within one square mile, and thus be considered "spatial" data included 21 sites in 1998, 60 sites in 1999, 132 sites in 2000, and 106 sites in 2001. Many stocking events from vendor records could not be tracked to a spatial location (Appendix III).

Figures 13a-f show the spatial distribution of stocking events for six species in western Colorado: triploid grass carp, channel catfish, bluegill, black crappie, largemouth bass, and fathead minnow. The events are ranked as being high, medium, and low-density events. The density ranges used for these designations for each species are given in Table 9. By far the most frequently stocked species was triploid grass carp at 89 locations west of the Continental Divide. The species stocked at the highest densities was fathead minnow at up to 250,000 individuals per stocking event. Triploid grass carp was the only species known to be stocked by the private sector in designated floodplains (12 stocking events in 100-year and 11 stocking events in 50-

year; Table 10). Stocking activity from available vendor records was included in the stocking information provided above if a spatial location for individual stocking events could be determined.

In general, importation records have not been intended to track locations where fish stocking occurs. The records often indicated “statewide” in the “destination” column. Given the large number of nonnative species with unknown destinations, we thought it important to outline the variety of species being imported into Colorado (Table 12). The most frequently imported species were consistent with stocking activity known to occur in western Colorado. Black crappie, bluegill, channel catfish, fathead minnow, largemouth bass, and grass carp each composed 8-12% of the importation events, accounting for the majority of fish species imported. Hybrid striped bass, smallmouth bass, walleye and yellow perch were the next most frequently imported species at 4.5 to 6% of all importation events. All other species composed fewer than 2% of total imports.

Private lake licenses for the years 1997-2001 were most frequently issued for stocking triploid grass carp, bass species and fathead minnow (Figures 14a-f). Commercial lake licenses were rare (Figure 15), consisting only of 3 locations from 1997-2001. The limitations of the lake license database for our purposes were that we had little information on existing licenses (issued earlier than 1997) or what stocking activity occurred in these waters. It is possible that we in fact were in possession of records of stocking activity under these licenses, but there was no consistent code or other information linking the databases in such a way as to track actual stocking activity. Further, private lake licenses are issued as lifetime licenses, allowing functionally a one time reporting of stocking activity when the licenses are obtained. Commercial lake licenses require annual renewal.

No detailed information was available for denied permits. Lori Martin (CDOW, Grand Junction) indicated that denials were rare, and she was unsure whether or not any detailed, denied permit records were commonly retained by the CDOW. In the private fish stocking permit database we had in which permitted stocking is described, there were six permits listed as denied for the year 2000 in western Colorado (Table 13). The reasons given for denial included screening requirements and fish species that were not permissible for the stocking site indicated on the permit.

The CDOW’s nonnative, nonsalmonid fish stocking records for public ponds and reservoirs in western Colorado from 1997-2001 is provided in Table 11. The CDOW stocked bluegill, channel catfish, black crappie, triploid grass carp, and largemouth bass below the 6,500-feet elevation contour. Additionally, bluegill and largemouth bass were stocked in the 100-year floodplain and only bluegills were stocked within the 50-year floodplain. The CDOW only stocked waters with permissible species that were adequately isolated from riverine critical habitat areas in accordance with the Stocking Procedures (CDOW et al. 1996).

Pre- and Post-Regulation Abundance of Selected Nonnative Fishes in Backwaters

Visual pattern detection

1. Comparison of stocking (all known stocking events) densities vs. backwater fish densities

Figure 16 shows known stocking densities of largemouth bass and densities of largemouth bass in backwater sample locations within the intensive study area of the Colorado River. The sizes of the symbols reflect the relative density of largemouth bass stocked or sampled. Visually, the large symbol (triangle) near the center of the figure suggests that there may be a concentration of largemouth bass stocking events. There are also some relatively high densities of largemouth bass found in the Colorado River near these stocking locations. A visual relationship between known stocking densities and backwater densities for fathead minnow was not observed (Figure 17). In general, fathead minnow appear to be widespread and prolific and their riverine distribution appears to be independent of stocking events. Green sunfish is not known to have been stocked at all in western Colorado, but as previously stated, it too appears to be widespread and prolific.

2. Comparison of treated ponds to backwater fish densities

Largemouth bass in the ISA tended to show high densities in proximity to ponds that were slated for treatment to control nonnative fish (Figure 18). With few exceptions, however, densities remained relatively high in close proximity to these ponds after they had been treated (Figure 19). Green sunfish showed high densities throughout the backwater sample locations both distant and proximal to ponds that were to be treated (Figure 20). High densities of green sunfish remained in the sampled backwaters within the ISA even after ponds had been treated (Figure 21). Fathead minnow exhibited patterns very similar to green sunfish, and did not reveal any further potentially interesting visual spatial pattern.

3. Comparison of nonnative fish densities in ponds vs. backwaters

High densities of green sunfish in the ISA appear distributed throughout the river as indicated above, and show no obvious relationship to ponds with high densities of the same species (Figure 22). This pattern holds true for both largemouth bass and fathead minnows as well.

To summarize our findings using visual pattern detection, in general there were no strong spatial patterns observed. However, identification of clusters of stocking events or high density locations for nonnatives can be useful in targeting field efforts or future work. Examining this pattern with a complete data set for nonnative, nonsalmonid fishes could prove valuable. It may be worth following up on largemouth bass stocking events to determine whether or not these particular sample locations are connected via stream courses to the main channel of the Colorado River. Unfortunately, we did not have good enough data on stream connectivity to accomplish this during this study, but connectivity can override spatial location for obvious reasons. If good connectivity exists between stocking locations and/or ponds containing nonnative species, the "effective distance" is minimized. A. Martinez (CDOW) has a strong database on many ponds, and some evaluation on the effectiveness of treatments in controlling nonnative fish in ponds.

4. Nonnative fish densities in backwaters, pre- and post-regulation periods

Figure 23 shows the sampling locations for three intensive nonnative fish sampling or removal efforts in backwaters of the ISA of the Colorado River from 1997 to 2001. Note that the only dataset that contains information pre-regulation is the Bundy and Bestgen (2001) dataset, which has less spatial coverage than the more recent data sets of Trammell et al. (2002) and Osmundson (2003). This situation posed potential problems in examining trends over the years, but nonetheless, visual comparisons can be made in reaches of the river that have been resampled in later years.

Table 14 shows the percent composition for several nonnative fish species in backwater collections of Bundy and Bestgen (2001), Trammell et al. (2002), and Osmundson (2003) within the ISA. Fathead minnow was clearly the most abundant nonnative present in backwaters at more than 50% over all sampling efforts. Fathead minnows were not caught during the sampling efforts of Osmundson (2003) due to the fact that it was an electrofishing effort which favored the capture of medium- and large-sized species. Green sunfish, largemouth bass, black bullhead and white sucker were the next most prevalent species, respectively, based on the samples from these studies collected by various methods.

Relative densities of five nonnative fish species of interest (largemouth bass, green sunfish, fathead minnow, bluegill and black crappie) were based on the first-pass sampling efforts of Bundy and Bestgen (2001) and Trammell (2002) and are mapped in Figures 24a-e for 1997-2001, and for the pre- (1997-1998) and post-regulation time periods (1999-2001). Each sampling approach varied in intensity, resulting in large variation in the number of individuals caught for any particular species. In general, these figures indicate no obvious change in the densities of each species over the years, but they do indicate that the highest densities are shifting locations from year to year. This could have been a direct result of removal efforts which may have dampened populations in the subsequent year in particular locations, but these efforts appeared to have had little effect on the overall populations of nonnative fishes in the river. Further, there appears to have been little change in the composition of fish species with respect to native vs. nonnative proportions from 1997-2001 (Figure 25).

Proximity analyses

1. Comparison of stocking events vs. high backwater densities (“high” densities are locations that fall in the top 10% of density for the particular species being considered)

Proximity analyses in the ISA, although expected to potentially reveal patterns not visible to the naked eye, indicated a similar lack of pattern as did the visual analysis. Figure 26 shows that the proximity of high largemouth bass density in backwaters to largemouth bass stocking locations was not different from a comparison of random backwater locations with low/absent abundance of largemouth bass to the same stocking locations. Fathead minnow also showed no pattern, and as previously mentioned, green sunfish were not stocked.

2. Comparison of high density pond locations vs. high backwater densities.

Figure 27 shows a familiar lack of pattern for the proximity of pond locations with high densities of largemouth bass. The proximity of high largemouth bass density in backwaters to ponds having high largemouth bass density was not different from a comparison of random backwater locations with low/absent abundance of largemouth bass to the same pond locations. As before, green sunfish and fathead minnow also showed no pattern.

Geostatistical analyses

The geostatistical analyses, more than either of the previous two approaches, focused globally on the dataset searching for the presence of spatial patterns. These analyses were not limited to a single distance or to visual interpretation, and should therefore be the most robust. The visual analysis is more likely to pick up anomalous events or patterns, while the geostatistical approaches should detect overall spatial trends in the data warranting further attention.

1. The modified h-scattergram

Our modified scattergram served to support the previous findings that there appears to be no relationship at any scale tested between green sunfish densities in ponds and riverine sites within the ISA (Figure 28). This random pattern is also upheld for a number of ponds containing green sunfish and for largemouth bass and fathead minnow as well. The scattergram shows no evidence that pond fish populations were spatially associated with backwater riverine populations.

2. The cross-correlogram

The Moran's *I* cross-correlogram confirms our scattergram approach as an even more robust analysis. There were no positive correlations at short lag distances as would be expected if pond populations were at all spatially associated with backwater densities. The results for green sunfish are shown in Figure 29. As before, largemouth bass and fathead minnow showed very similar patterns.

3. The semivariogram

The semivariogram was used to examine a slightly different kind of relationship. Because of the lack of spatial pattern among data sets, we were curious to see whether there was in fact any evidence of spatial correlation within the backwater populations. In other words, would sites in the river that were close together have more similar populations than those that were farther apart? We would expect this relationship if habitat was similar close by, or if fish densities in adjacent backwaters are similar due to "overflow" of the best habitat. What we found was that both largemouth bass and fathead minnow displayed no spatial pattern even within backwater sample locations.

Green sunfish exhibited a slight positive spatial correlation at a couple different scales, as indicated by the standard Moran's *I* correlogram (Figure 30). An exponential model fit to a semivariogram for the data gives a "range" or distance over which there is spatial correlation as 9,908 meters (Figure 31). Consequently, this range is approximately the distance between clusters of high densities of green sunfish in the river (Figure 32). This is not a unique result; it simply shows how the semivariogram is reflecting the spatial pattern of green sunfish in the river. However, what the presence of spatial correlation indicates for green sunfish is perhaps an interesting result. The lack of spatial pattern in largemouth bass and fathead minnow suggests that these species may be more selective about habitat and/or are being displaced by the large densities of green sunfish. Green sunfish, on the other hand, because adjacent backwaters have similar densities of fish, are apparently less selective in their choice of backwaters, or they simply occur at high enough densities throughout the river to "spill over" into adjacent backwater habitats.

DISCUSSION

Pond, Lake and Reservoir Locations, and Hydrography

The focus of this section was to collect and create geographic layers describing the standing water resources in Colorado west of the Continental Divide and especially within the ISA surrounding the Colorado River. The results, based on currently available digital sources, indicated that there are likely more than 1,000 standing waters west of the continental divide that are below the 6,500-feet elevation contour. Fish composition data was available on 307 out of 896 (or 34%) of the ponds and reservoirs in the primary study area immediately surrounding the Colorado and Gunnison Rivers. Approximately 60% of these 896 ponds lie within the 100-year floodplain, and only 86 of 896 (or 9.5%) have been treated to control nonnative fish. Martinez (2004) reported a 30% reinvasion of the treated ponds by nonnative fishes. The results of this study can help identify the highest priority waters for sampling and/or nonnative fish control treatments. However, to more fully assess the potential impacts of existing nonnative fish populations on recovery program objectives, then:

1) the fish populations in a majority of the ponds need to be determined,
2) nonnative fish control treatments and anti-escapement structures (if any) must be known, and
3) the effectiveness of such treatments in controlling target nonnative fish species needs to be assessed.

In addition to the standing water resources within the ISA, lakes and reservoirs outside of the ISA which contain nonnative, nonsalmonid fish species may pose a concern. Because 31% of the standing waters west of the Continental Divide are below the 6,500-feet elevation contour, the status of many waters remains unknown. Further, new ponds and wetlands continue to be constructed, even within critical habitat and it may become necessary to survey these standing water habitats for:

1) nonnative species presence,
2) connectedness to stream courses that could provide passage for nonnatives to critical habitat areas, and
3) adequate measures, features or structures to control nonnative fish escapement, if connected.

In summary, two major results emerge from our examination of the distribution of standing waters in western Colorado. First, little is known about more than 50% of the standing water resources below 6,500-feet west of the Continental Divide. The species composition of these standing waters and their connectedness to critical habitat may influence the degree to which these resources pose a threat to the recovery of native species. Second, a series of geographic layers have been created from this project that can be built upon to track water resources west of the Continental Divide, particularly in the primary study area where changes in these resources are quite dynamic. These data layers have value for continuing to track and summarize knowledge of waters and nonnative species in western Colorado, and for creating maps to communicate critical information to managers and the public.

<u>Pond Sampling and Reclamation Data</u>

The primary thrust of this section was to characterize the fish community in standing waters within the ISA. We only know the fish species composition of 34% of the known ponds in the ISA, and only 23% of all these ponds are known to have received treatments to control nonnative fish. It is also now known that some control measures (including chemical treatments, pumping, etc.) intended to eliminate nonnative fish from individual ponds, thus reducing the number of potential sources of nonnative fishes reaching riverine habitat, served their purpose only temporarily as many ponds were reinvaded by nonnative fish following treatment (Martinez 2004).

The index of threat explored as part of this effort can be a useful indicator of which species may represent the biggest problem in terms of nonnative control. This index could also be useful in the future as a baseline for comparison as more information becomes available. While this index reveals data gaps to some extent, it also suggests that the threat of nonnative fish accessing critical habitat for endangered fishes could be reduced if the control measures implemented thus far proved to be effective in controlling the abundance or escapement of nonnative fishes. While the cumulative effect of nonnative fish control treatments appears limited to date (PDO 2002), once we gain an understanding of the effectiveness of a particular control measure, then the index can be modified by multiplying C (control) by E (a percent effectiveness term).

<u>Pre- and Post-Regulation Fish Stocking Data</u>

The focus of this section was to describe and map private permitted fish stocking, CDOW stocking events, and stocking activity associated with lake licenses and importation records from 1997-2001 as available. Based on available records with adequate spatial information, about 44% of permitted stocking in western Colorado occurred below the 6,500-feet contour, while only 8% occurred within the designated 50- or 100-year floodplain within the primary study area. The only species known to be stocked by the private sector within the 100-year floodplain was grass carp. However, due to the known incompleteness and potential inaccuracy of private sector stocking data at this time, the position of stocking events that occur within about 1 mile on either side of the floodplains of the Colorado or Gunnison Rivers in the primary study area is unknown.

Complete information about stocking events in the future would more accurately assess the distribution of these events, and how they relate to the characteristics of particular waters and critical habitat. In particular, to correctly assign a spatial location to each stocking event, providing geographic coordinates such as UTMs or latitude and longitude is suggested. In addition, a water code (if it exists) would allow the CDOW to link the stocking event to any other information that exists on that particular water. This would also facilitate linking databases such as the lake license database with the permitted stocking database. This process would ensure that stocked waters are indeed licensed, and that stocking activity is being performed and documented via the permitting process.

A GIS data layer of all known standing waters (e.g., co_lakes, ISAponds) could be used to track much of this information. The database could be queried to determine whether or not a specific water of interest is included in the database, and what the water's characteristics are. If the water was not included in the database or information is lacking or incorrect, the database could be updated at that time. In this way, the standing water database could serve as a decision support framework to improve information and consistency about which stocking permits and lake licenses are approved or denied.

The primary summary items for this section are: 1) potentially, there is a great deal of stocking information that we are not aware of, 2) there is a lack of consistency between databases in tracking the activity regarding nonnative fish stocking in Colorado, and 3) vendor records that were not provided may have facilitated linking imported species to permitted stocking events.

Pre- and Post-Regulation Abundance of Selected Nonnative Fishes in Backwaters

The primary focus of this section was to map the numbers and densities of nonnative species sampled in the main-stem Colorado River and its associated backwaters within the ISA, as available. The GIS layers created, despite differences in sampling protocols among efforts, should provide good base data in which to compare and add future sampling or monitoring efforts. An examination as to whether any change in the distribution and/or density of these fish species could have been due to removal efforts or efforts to control their potential sources was also performed. While overall densities did not appear to change, spatial patterns changed from year to year, potentially due to the removal efforts causing temporary declines in numbers in particular locations. However, any effort to examine site specific, reach- or river-wide changes or trends in the distribution and abundance of nonnative fish species in response to control effort or environmental factors should be facilitated by a standardized protocol tailored to target species (Bundy and Bestgen 2001).

The overall results of spatial pattern analyses are summarized in Table 15. There is a predominance of NO SPATIAL PATTERN among data that might demonstrate a definitive relationship between nonnative species location and density in critical habitat, as well as potential "source" populations such as nonnative stocking events or floodplain pond fish populations. While interpreting results comparing stocking data to backwater data, bear in mind that stocking information was incomplete. Thus, there are potentially many more events that were not mapped due to lack of spatial information or other problems in acquiring appropriate data.

In general, the spatial pattern analysis was not revealing given the available data for fish stocking and pond fish populations. These data should be improved and mapped for future comparative analyses. The available data show a lack of spatial pattern in this study, verified through several approaches, indicating that the nonnative species focused on, largemouth bass, fathead minnow and green sunfish, are quite prolific, and may not be spatially associated with their source. Spatial pattern analyses would improve in their ability to detect any patterns present if data were improved for fish stocking events and for physical connectivity in water courses. However, due to the obviously prolific nature of these species within critical habitat in the Colorado River, alternative methods of tracking the provenance of target nonnative fishes within riverine critical habitat should be explored. Isotopic analyses of water sources and biota in these habitats show promise for tracking origins of nonnative fish species in critical habitat (Martinez et al. 2001), and should be more fully investigated.

CONCLUSIONS

In summary, the degree of achievement of the primary objectives of this study are briefly reviewed below, with the specific conclusions of the report following.

(1) To determine if the administration of fish stocking regulations and permits is contributing to the reduction in riverine abundance of target nonnative fish species.

No reduction in riverine abundance of target nonnative fish species was observed. An optimal evaluation of the administration of the fish stocking regulation and associated system of permits was hampered by incomplete reporting of stocking activity and deficiencies in the data contained in available stocking records.

(2) To monitor the trend in distribution and abundance indices for target nonnative fish species in riverine habitats, and compare the indices to concurrent public/private fish stocking data.

This objective was met, although it must be recognized that there were incompatibilities in the collection of fish and associated indices of fish occurrence and abundance in backwaters that make tracking population trends of these fish difficult, hence our recommendation of a standardized monitoring program (below). The major limitation of the results for comparing the distribution and abundance of these species to concurrent stocking data, however, was related to incomplete records for public/private fish stocking.

(3) To conduct a risk analysis (RAMC 1996) of nonnative fish stocking in the UCRB in Colorado to identify its relative significance and potential for introducing nonnative fish species into critical habitat for endangered fishes.

Data deficiencies (nonnative stocking records) did not allow for a risk analysis for nonnative fish stocking in the URCB. In addition, both the prevalence of nonnative fish already present throughout critical habitat and lack on information on connectivity of potentially contributing waters upstream of critical habitat, would make it difficult to complete a meaningful risk analysis.

Conclusions

- Of 896 suspected ponds (uncertainty due to aerial photographs) in the primary study area of the Colorado and Gunnison rivers, 59% were within the 100-year floodplain and almost 50% were within the 50-year floodplain.

- The original premise in the <u>Stocking Procedures</u> that 6,500-feet in elevation would serve as an ecological demarcation above which few private waters would be stocked with nonnative, warmwater sport fish appeared to be generally true, based on available data.

- Triploid grass carp and fathead minnow were the most widely stocked nonnative, nonsalmonid species with stocking sites ranging from ponds within or near the floodplain in critical habitat for endangered fishes to waters near the Continental Divide.

- Based on available data for floodplain ponds sampled and those ponds that received treatments to control abundance or escapement of nonnative fish species within the ISA (Grand Valley reach of the Colorado River), an Index of Threat incorporating these data suggests that green sunfish and largemouth bass may pose a high risk of reaching riverine habitat, primarily due to their widespread occurrence in floodplain ponds.

- The poor response to the request for voluntary submission of private sector stocking data for 1998-2000 precluded performing a meaningful risk assessment of the potential for stocking nonnative fish in the general study area to serve as a source of these species entering critical habitat for endangered fishes.

- Inadequacies in the reporting of stocking location descriptions limited the spatial utility of a considerable number of stocking sites, compromising the capacity to fully document or evaluate the relationship of locations and species stocked with other available data.

- Despite recent improvements in the permitting process for private sector stocking of nonnative, nonsalmonid fish species, difficulty remains in fully tracking or accounting for all stocking activity in western Colorado due to minimal reporting requirements above 6,500-feet in elevation, unknown destinations of fish listed on importation permits, no means to acquire stocking records for sales directly from out-of-state vendors, and an unknown rate of compliance with existing permitting requirements, including confirmation of connectivity to stream courses or installation, maintenance, and function of required screens or other measures to control escapement.

- The abundance of fish species that could be stocked in ponds (e.g. fathead minnow and largemouth bass) generally remained the same in backwaters before and after treatments to control nonnative fish abundance in or escapement from floodplain ponds or to control nonnative fish density in backwaters.

- Available data sets for fishes collected in backwaters sampled using various methods, applied at various intensities, for different species and with different goals, were not optimum for making direct comparisons among years.

- While there was no evident change in the backwater densities of the species examined during this study, it appeared that the highest densities of some species shifted locations from year to year which could be a result of prior removal efforts dampening populations in the subsequent year in particular locations.

- There appears to have been no change in the composition of fish species within the ISA with respect to native-nonnative proportions from 1997-2001.

- There was no spatial pattern demonstrating a definitive relationship between nonnative species location and density in critical habitat or potential sources of nonnative fishes such as nonnative fish stocking events or fish populations in floodplain ponds.

RECOMMENDATIONS

Recommendations falling primarily under CDOW's purview

Due to the demonstrated sensitivity of acquiring, reporting and analyzing private sector stocking records, the following recommendations lie primarily within CDOW's purview in terms of practical, legal, and confidential access to stocking data. However, implementation of the recommendations below would benefit from and may require Recovery Program support, logistically or financially, for implementation.

- Compare private stocking records with stocking permits issued by CDOW.

  Monitoring of nonnative fish stocking activity to maintain its compatibility with recovery efforts should seemingly be among the easiest and least expensive actions to control potential deleterious effects of nonnative fish on native and listed fishes. While documenting stocking activity may have improved with Colorado's recent permitting process, the rate of compliance with this program remains unknown. It may be prudent to compare private sector stocking records, which are maintained and available by statute to CDOW for three years with permits issued by CDOW, for a period of time to determine this rate of compliance.

- CDOW should continue to track and improve reporting of stocking activity.

  CDOW should continue the tracking of annual nonnative, nonsalmonid stocking data in order to monitor this activity in relation to recovery efforts. Coordination between CDOWs' licensing and permitting staff and their respective record storage and retrieval systems for private stocking should be prioritized, stressing the annual reporting of nonsalmonid stocking to the USFWS to comply with the Stocking Procedures.

- GIS should be used to track and report annual stocking of nonnative, nonsalmonid fishes.

  The GIS methodology for tracking nonnative fish stocking activity and the distribution and density of these species in ponds and backwaters has considerable potential for visually and statistically identifying concentrations of these species in either habitat, if reasonably complete and comparable data are available. At a minimum, CDOW should strive to maintain this tool to track and report annual nonnative, nonsalmonid stocking activity per the Procedures.

- Receiving waters for nonnative, nonsalmonid fishes should be explicitly identified.

  Future reporting of nonnative fish stocking should require explicit site details to facilitate digital spatial location of species specific stocking data. Stocking permits continue to be issued that lack adequate information to identify receiving waters for nonnative, nonsalmonid fish species. Scrutiny should be applied to fish importation permits with generic or statewide destinations to identify if the fish are destined for the UCRB. At a minimum, information on stocking restrictions in the UCRB within Colorado should be provided when importation licenses are issued. Documenting stocking activity by out-of-state vendors of nonnative, nonsalmonid fishes remains vague, as no method presently exists to detect all such transactions or acquire past records of such stocking activity.

- CDOW should develop and implement consistent reporting requirements for stocking.

  There appear to be several inconsistencies for reporting stocking activity among the lake license and Colorado's Chapter 0 Regulations for species and locations that can be stocked. Basically, there remain gaps between these regulations that may allow ongoing stocking of nonnative, nonsalmonid fish species without reporting it annually to CDOW. Further, some conditions for stocking events for which a stocking permit is issued remain unconfirmed or unmonitored. Examples include connectivity to critical habitat, risk of escapement of nonnative, nonsalmonid fish species, and whether screens are installed as required in a permit and maintained to minimize fish escapement.

- Require adherence to reporting requirements for stocking activity above 6,500 feet.

  Current regulations for stocking nonsalmonids above 6,500 feet within the UCRB, and anywhere within the San Juan Basin may allow stocking activity to occur without reporting of these stocking details, including information on fish species and location. These deficiencies in documenting potential sources of nonnative fish reaching critical habitat, including potential stocking of nonsalmonids directly into streams and rivers in these areas. These potential sources of nonnative fish entering critical habitat should be discussed and addressed to maximize the effectiveness of a GIS framework to track stocking activity related to protection and recovery of native fishes.

- Verify connectivity of ponds and provide options and oversight to control fish escapement.

  Current permitting often relies on verbal assurances from private pond owners regarding connectivity of ponds to stream-courses ultimately connecting to critical habitat. Further, onsite inspections to determine connectivity, recommend screening or other strategies to control escapement of stocked fish also depend on assurances that screens or other strategies to control escapement will be monitored and maintained to ensure function and effectiveness. While such assurances are well intended, the function or maintenance or screens or other strategies to control escapement are rarely monitored or verified as to their effectiveness. Providing options for screening or controlling fish escapement and periodically inspecting stocking sites to verify the function of these treatments is recommended.

<u>Recommendations requiring guidance, support, or funding from Recovery Program partners</u>

The recommendations below are distinguished from those above in that they are dependent on cooperative efforts of Recovery Program partners for review, funding and implementation.

- Develop and implement a standardized monitoring program for backwater fish communities.

  Questions about the comparability of data collected in backwaters by various sampling techniques may limit the capacity to detect changes in the distribution or abundance or nonnative fishes in response to environmental factors or targeted removal or control efforts. Quantitative comparisons may be further limited by the amount of sampling effort expended and seasonal factors including river flow, water temperature and the amount of cover in backwater habitats due to vegetative growth and inundation. A standardized sampling protocol would facilitate detecting changes in the populations of both nonnative and native fish species, and provide a consistent sampling protocol to aid in the evaluation of specific cumulative nonnative fish control treatments via GIS or other means. Such a monitoring program, as specified in the Stocking Procedures, should be developed and implemented.

- Identify provenance of largemouth bass and green sunfish in backwaters.

  The index of risk reported here identifies the ubiquity of green sunfish and largemouth bass in floodplain ponds. Further, the top predator niche of these species in backwaters warrants attention with respect to native and endangered fish conservation. Understanding the provenance of these fish in backwater nursery habitats is essential for formulating strategies to control their distribution and abundance. Determining whether these fish proliferate primarily from riverine habitats or floodplain ponds will facilitate tailoring methods for the control of these species.

- Maintain regulations to control impacts of stocked nonnative fishes in critical habitat.

  If regulations are relaxed or modified as a result of the findings of this report, there remain some existing restrictions, some of which were adopted/adapted from the Stocking Procedures that provide protection in critical habitat and which received no objectionable debate to date. These include no stocking of any nonnative fish species, including trout, directly into a river within critical habitat or its immediate habitats (backwaters, directly connected sidechannels, sloughs, etc.), prohibitions of certain nonnative species (e.g. flathead catfish), and requirements for sterile fishes for certain management applications (triploid grass carp, tiger muskie and other hybrids).

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Table 1. Backwater sampling data sets [1].

Project	Data set	Years of data used	Sampling method		
			Seine	Electrofish	Trap net
ISMP Young-of-year	Elmblad (2003)	1997-2000	No. of fish & percent species composition		
ISMP evaluation	Bundy and Bestgen (2001)	1997-1998	No. of fish/10 m^2	No.of fish/min. of electrofishing time	No. of fish/hour
Cyprinid seining	Trammel et al. (2002)	1999-2001	No. of fish./m^2		
Centrarchid electrofishing	Osmundson (2003)	1999-2001		No. of fish/10m^2	

[1]Sampling goals may affect compatibility and comparability of backwater fish sampling data due to different sampling gears, time of year, river flow and backwater abundance and manner of expressing, calculating or comparing catch per unit effort.

Table 2. Number of pond, lake and reservoir resources that are above and below the 6,500-foot elevation contour in Colorado, west of the Continental Divide.

Number of Lakes Above and Below 6500'	Number	Percent
Below 6500'	1104	31
Above 6500'	2512	69
Total	3616	100

Table 3. Number of ponds and the associated floodplain positions for the primary study area surrounding the Colorado and Gunnison rivers.

Pond Floodplain Position	Number	Percent
Ponds below 50-year floodplain	448	50
Ponds between 50- and 100-year floodplains	79	9
Ponds above 100-year floodplain	369	41
Total	896	100

Table 4. Known occurrence of native and nonnative fish species in the Colorado and Gunnison River basins for 307 floodplain and upland ponds sampled from 1997-2001 below 6,500-feet, and within the 100-year and 50-year floodplains below that elevation. Also listed is the occurrence of fishes in eight reservoirs on tributaries to these rivers sampled from 1997-2001.

Common name	Occurrence in floodplain and upland ponds				Occurrence in tributary reservoirs below 6500
	Species Code	Below 6500- ft asl	Within 100-yr floodplain	Within 50-yr floodplain	
Black bullhead	BBH	59	40	33	1
Black crappie	BCR	32	20	17	4
Bluegill	BLG	39	25	21	5
Bluehead sucker	BHS	6	3	3	
Brown trout	LOC				1
Channel catfish	CCF	17	13	13	3
Common carp	CPP	63	42	35	2
Fathead minnow	FMW	26	17	16	
Flannelmouth sucker	FMS	33	24	21	1
Green sunfish	SNF	110	75	62	5
Triploid grass carp	TGC				2
Largemouth bass	LMB	78	55	48	5
Longnose sucker	LNS				1
Northern pike	NPK				2
Plains killifish	PKF	4	2	2	
Rainbow trout	RBT				4
Redside shiner	RSS	14	8	8	1
Roundtail chub	RTC	14	10	7	
Sand shiner	SAH	8	7	7	
Smallmouth bass	SMB	2	2	1	2
Snake River cutthroat trout	SRN				1
Tiger muskellunge	TGM				1
Trout	TRT	9	6	5	
Walleye	WAL				2
White sucker	WHS	66	47	40	3
Western mosquitofish	MSQ	21	15	11	
Yellow perch	YPE	2	2	2	4
Unidentified spp.	Other	9	4	4	
Total Nonnative Occurrences		**612**	**417**	**356**	**49**

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Table 5. **Ponds reclaimed as part of non-native fish control efforts along the Colorado and Gunnison River within or adjacent to critical habitat for endangered fishes (Martinez 2004).**

Treatment to control nonnative fishes	Colorado River	Gunnison River	Total
Chemical only	36	9	45
Chemical + pumping	4	2	6
Chemical + screening	10	2	12
Chemical+ pumping + screening	2		2
Chemical + screening on downstream pond	2		2
Chemical + pumping + screening + rerouting irrigation water	1		1
Chemical + screening + water management	1		1
Screening only	7		7
Screen on downstream pond	8		8
Screening + black plastic	1		1
Water management only	1		1
Total Ponds Controlled	**73**	**13**	**86**

Table 6. **Occurrence of nonnative fish species in the ISA of the Colorado River showing number of ponds that were sampled that contained nonnative fish species and the number that were controlled that contained those nonnative fish species.**

Species	Code	Total Ponds	Ponds Controlled	% Ponds Controlled
Black bullhead	BBH	59	21	35.6
Black crappie	BCR	32	9	28.1
Bluegill	BLG	39	9	23.1
Channel catfish	CCF	17	3	17.7
Common carp	CPP	63	28	44.4
Fathead minnow	FMW	26	13	50.0
Green sunfish	SNF	110	41	37.3
Largemouth bass	LMB	78	24	30.8
Plains killifish	PKF	4	2	50.0
Redside shiner	RSS	14	9	64.3
Sand shiner	SAH	8	5	62.5
Smallmouth bass	SMB	2	1	50.0
Trout	TRT	9	2	22.2
White sucker	WHS	66	17	25.8
Western mosquitofish	MSQ	21	3	14.3
Unidentified spp.	Other	9	6	66.7

Table 7. Summary of requests sent and received for voluntary submission of records for private sector stocking of nonnative, nonsalmonid fishes in Colorado west of the Continental Divide for the years 1998, 1999 and 2000.

Number of written data requests sent	Number of follow-up phone contacts	Number of respondents providing data	No. of respondents indicating that they do not sell non-salmonids	Number of respondents		
				1999	2000	2001
10	9[a]	3	1	3	3	2

[a] One written request delivered in person for a total of ten.

Table 8. Summary of individual nonnative, nonsalmonid fish species stocking events reported in available stocking records. "Statewide" reflects importation permits with non-specific fish destinations, "Inadequate" reflects stocking records that could not be assigned to a location within one-square mile and "Within one-square mile" denotes locations of a stocking site with accuracy sufficient for spatial depiction and analyses.

Year	Stocking destination		
	Statewide	Inadequate	Within one-square mile
1998	138	65	11
1999	171	46	25
2000	100	96	112
2001	~136	44	90
Total	~545	251	238

Table 9. Categories of nonnative fish stocking densities in private waters in western Colorado derived from numbers of individuals of each species reported on stocking permits issued from 1998-2001.

Fish species	Stocking density		
	Low	Medium	High
Triploid grass carp	1-50	51-100	101-300
Channel catfish	1-100	101-500	501-1,000
Largemouth bass, black crappie	1-500	501-1,000	1,001-3,000
Bluegill	1-1,000	1,001-5,000	5,001-7,000
Fathead minnow	1-10,000	10,001-50,000	50,000-250,000

Table 10. Known fish species composition and stocking frequency from stocking records for private waters in western Colorado 1997-2001.

Sp Code	Common Name	Stocking events above 6,500-feet	Events below 6500 ft	Within 100-yr floodplain	Within 50-yr floodplain
BCR	black crappie	7	5	0	0
BLG	Bluegill	9	6	0	0
CCF	Channel catfish	8	6	0	0
FMW	Fathead minnow	20	7	0	0
TGC	Triploid grass carp	89	31	12	11
LMB	Largemouth bass	15	11	0	0

Table 11. Colorado Division of Wildlife stocking of nonnative, nonsalmonid fish species in ponds and reservoirs in western Colorado, 1997-2001. BCR = black crappie, BLG = bluegill, CCF = channel catfish, TGC = triploid grass carp, LMB = largemouth bass, TGM = tiger muskie, WAL = walleye.

All Stocking Events – general study area – west of Continental Divide							
Year	BCR	BLG	CCF	TGC	LMB	TGM	WAL
1997	102,550	18,000	39,925	0	32,473	1,000	0
1998	121,024	48,000	24,870	290	31,532	0	230,000
1999	150,080	35,000	31,965	810	37,000	1,000	70,000
2000	70,042	29,475	10,540	0	37,000	638	262,623
2001	0	70,100	36,040	200	34,350	0	0
Below 6500 ft – regulatory study area							
Year							
1997	0	18,000	10,000	0	4,900	0	0
1998	0	38,000	5,860	290	4,000	0	0
1999	0	30,000	1,040	130	7,000	0	0
2000	52	29,475	3,340	0	7,000	0	0
2001	0	70,100	6,840	200	9,050	0	0
In 100-yr Floodplain - primary study area – critical habitat along Colorado & Gunnison Rivers							
Year							
1997	0	0	0	0	0	0	0
1998	0	0	0	0	2,000	0	0
1999	0	0	0	0	0	0	0
2000	0	3,750	0	0	0	0	0
2001	0	20,000	0	0	2,000	0	0
In 50-yr Floodplain - primary study area – critical habitat along Colorado & Gunnison Rivers							
Year							
1997	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
2001	0	15,000	0	0	0	0	0

Table 12. Summary of importation events from 1998-2000. The numbers do not represent number of fish, but rather number of events of that species being imported to the state.

Species	1998	1999	2000	Grand Total
BLACK BASS	1	1		2
BLACK BULLHEAD	1	1	1	3
BLACK CRAPPIE	11	12	11	34
BLUEGILL	14	16	10	40
BROWN BULLHEAD	1			1
CHANNEL CATFISH	17	19	15	51
CRAYFISH	1	2		3
CREEK CHUB	1	2		3
DIPLOID GRASS CARP	4	1		5
FATHEAD MINNOW	14	18	14	46
GIZZARD SHAD	1	2		3
GOLDEN SHINER	2	2	1	5
GOLDFISH	2	4		6
GREEN SUNFISH	1	2		3
HYBRID BLUEGILL		2	2	4
HYBRID STRIPED BASS	6	9	4	19
KOI CARP	3	4	2	9
LARGEMOUTH BASS	15	14	13	42
MOSQUITOFISH	3	3	3	9
NORTHERN PIKE	2	3		5
SAUGEYE		1	1	2
SMALLMOUTH BASS	9	8	5	22
STRIPED BASS	2	3		5
STRIPED BASS FRY	1	1		2
SUCKER CHUB		1		1
TIGER MUSKELLUNGE		1	1	2
TRIPLOID GRASS CARP	9	19	10	38
WALLEYE	7	11	6	24
WHITE BASS	1	1		2
WHITE CRAPPIE	1			1
WHITE SUCKER	1	2	1	4
YELLOW PERCH	6	6	7	19
Grand Total	137	171	107	415

Table 13. Stocking permits for ponds in western Colorado that were denied or on hold for the years 2000 and 2001, per available records.

Year	Approved?	County	Water body	Application date	Species	Number	Outlet	Screen	Comments/Limitations
2000	NO	Garfield	Ponds 4 miles S of Carbondale	05/03/00	Fathead Minnow	10000	Y	N	Voluntary application withdrawal, screening too much hassle
2000	NO	San Juan	Private pond	06/13/00	Channel Catfish	25	Y		1/4" screens must be installed and maintained for sterile grass carp, largemouth bass, or black crappie. Species not permitted: smallmouth bass, channel catfish, fathead minnow. If trout are stocked, no screening is needed.
2000	NO	Routt	Retention Ponds (3 Ponds)	06/26/00	Canadian Crayfish	1000	Y		Facility is whirling disease neg. Outlet of lower pond must be screened with 1/4 inch mesh screen or smaller. Crayfish not permitted at this time.
2000	NO	San Juan		07/07/00	Fathead Minnow		Y		No Fathead Minnows allowed. 1/4" screen must be installed on outlet if largemouth bass, black crappie or bluegill are stocked. Screen not required for trout stocking.
2000	NO	Gunnison	McLeod Spring #3 Pond	07/20/00	Smallmouth Bass				
2001	HOLD	Delta	Ragged Mountain Enterprises Dam #1	2/14/2001	Channel catfish	10			Waiting for completion of pond
2001	HOLD	Montrose	Private pond	3/28/2001					Waiting for completion of pond

Table 14. Percent composition of selected nonnative, warmwater fish species in backwaters within the ISA of the Colorado River.

Sampling Effort	BBH	BGL	BCR	CCP	FMW	LMB	MSQ	SNF	WHS
Bestgen	1.7	0.1	0.1	1.1	69.9	4.1	7.5	11.1	4.5
Trammel	0.2	0.1		0.3	94.7	0.2	2.1	1.8	0.7
Osmundson	15.5	2.7	0.1	0.4		16.6		53.3	11.4
Average	**5.8**	**0.9**	**0.1**	**0.6**	**54.9**	**6.9**	**3.2**	**22.1**	**5.5**

Table 15. Summary of results of all spatial pattern analyses indicating there was a predominance of no spatial pattern that indicated a relationship between backwater nonnative populations and potential sources from stocking or floodplain pond locations. FMW = fathead minnow, LMB = largemouth bass, SNF = green sunfish.

Visual analyses	**FMW**	**LMB**	**SNF**
1) backwater fish density vs. stocking density	no visible pattern	weak evidence of cluster	n/a
2) backwater fish density vs. treated ponds	no visible pattern	weak evidence of cluster – no reduction observed	no visible pattern
3) backwater fish density vs. pond fish density	no visible pattern	no visible pattern	no visible pattern
4) change in backwater fish density	changes year to year - no reduction observed	changes year to year - no reduction observed	changes year to year - no reduction observed
Proximity analyses	**FMW**	**LMB**	**SNF**
1) "high" backwater density vs. "high" stocking density	no pattern	no pattern	n/a
2) "high" backwater density vs. "high" pond fish density	no pattern	no pattern	no pattern
Geostatistical analyses	**FMW**	**LMB**	**SNF**
1) scattergram			
backwater fish density vs. pond fish density	no pattern	no pattern	no pattern
backwater fish density vs. pond numbers	no pattern	no pattern	no pattern
2) cross-correlogram			
backwater fish density vs. pond fish density	no pattern	no pattern	no pattern
3) semi-variogram backwater fish density	no pattern	no pattern	positive correlation

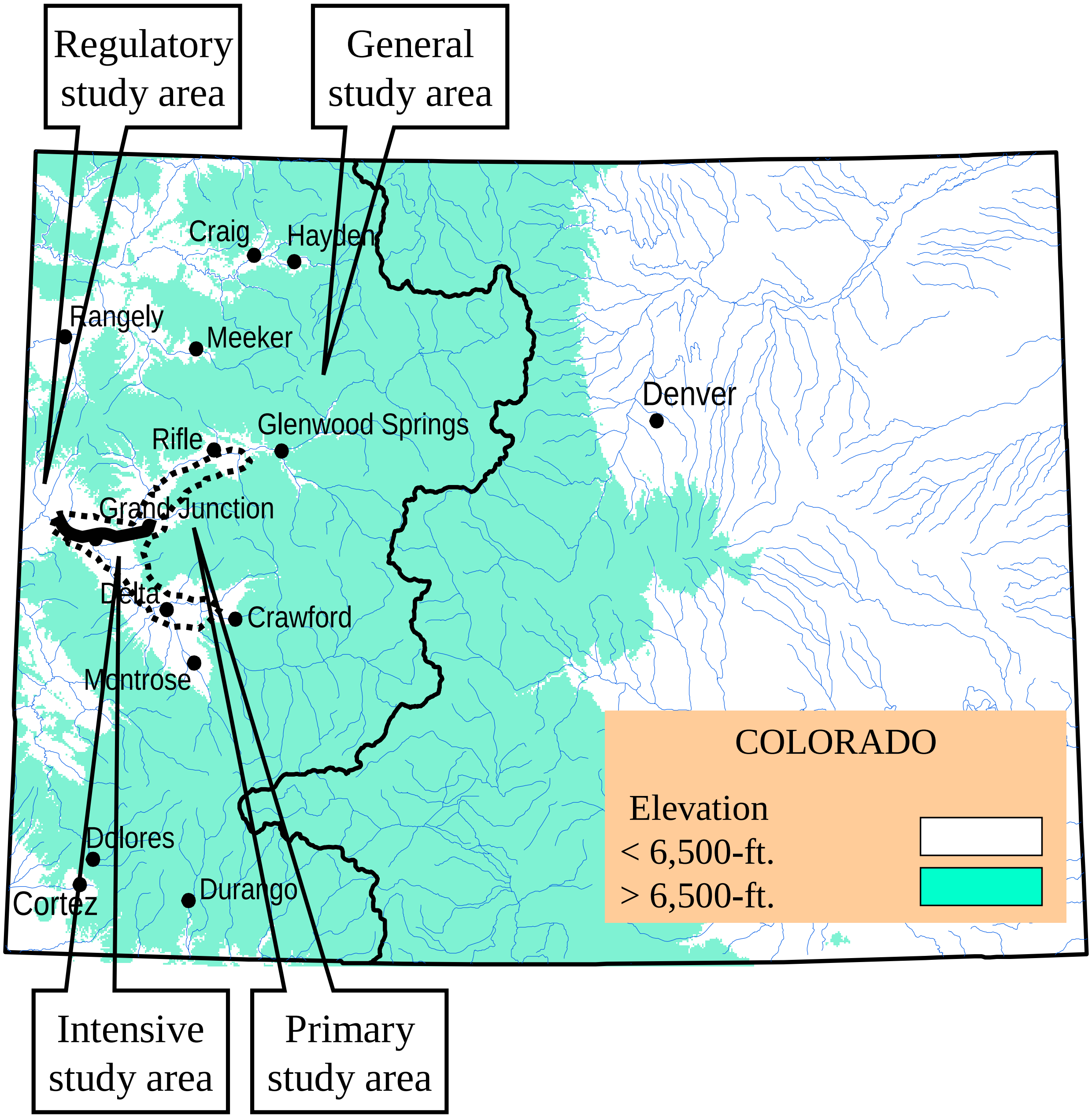


Figure 1. Map of Colorado denoting the general study area west of the Continental Divide, the regulatory study area below 6,500 feet in elevation (excluding the San Juan River basin), the primary study area within and adjacent to critical habitat for endangered fish along the Colorado and Gunnison Rivers, and the intensive study area along the Grand Valley reach of the Colorado River.

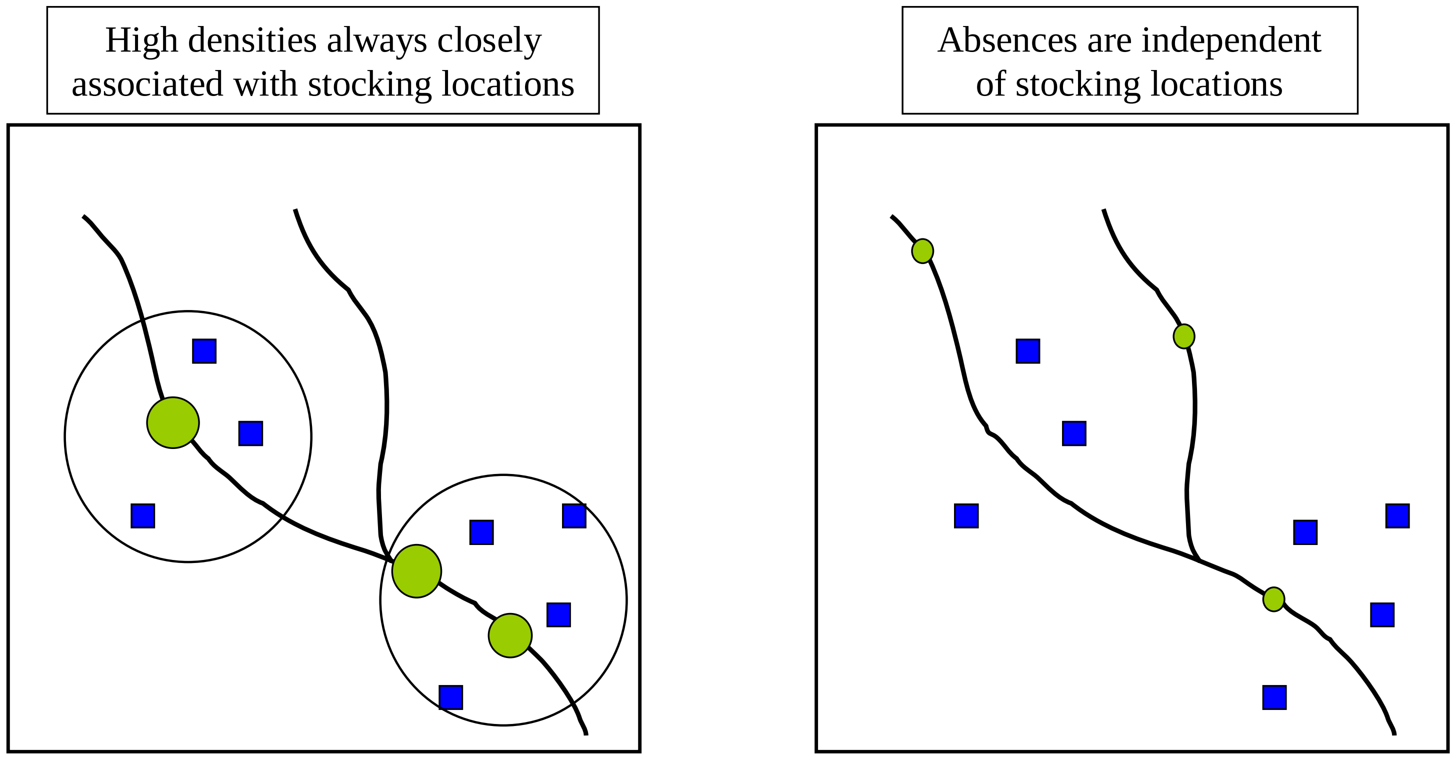


Figure 2. Proximity analysis: if observations of fish density in backwaters are always closer to stocking locations than to locations where the species is absent, the stocked fish may be a source to riverine populations. Circles = backwaters and squares = ponds.

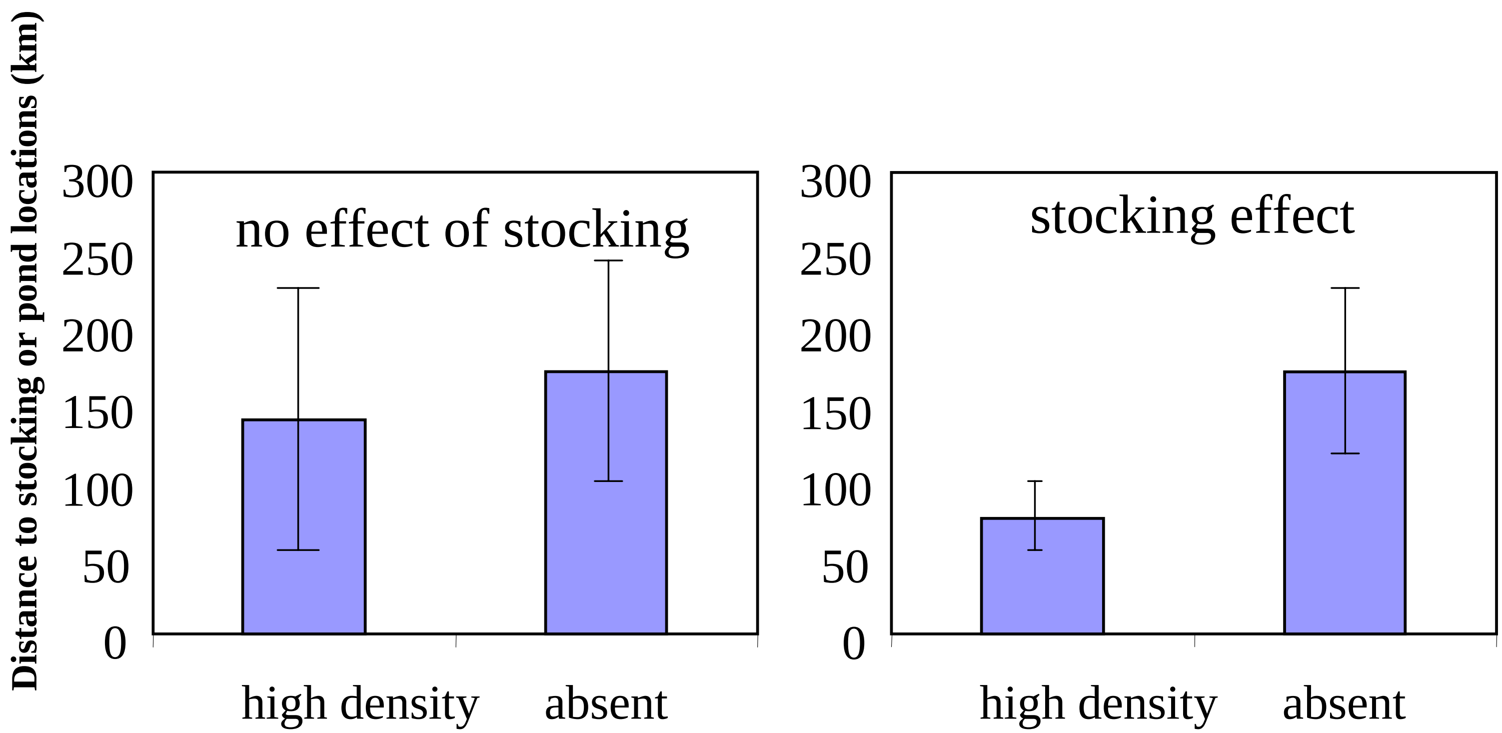


Figure 3. Proximity analysis: If observations of high fish density in backwaters are always closer to stocking locations than to locations where the species is absent, the stocked fish may be a source to riverine populations. A simple t-test can suggest significant difference.

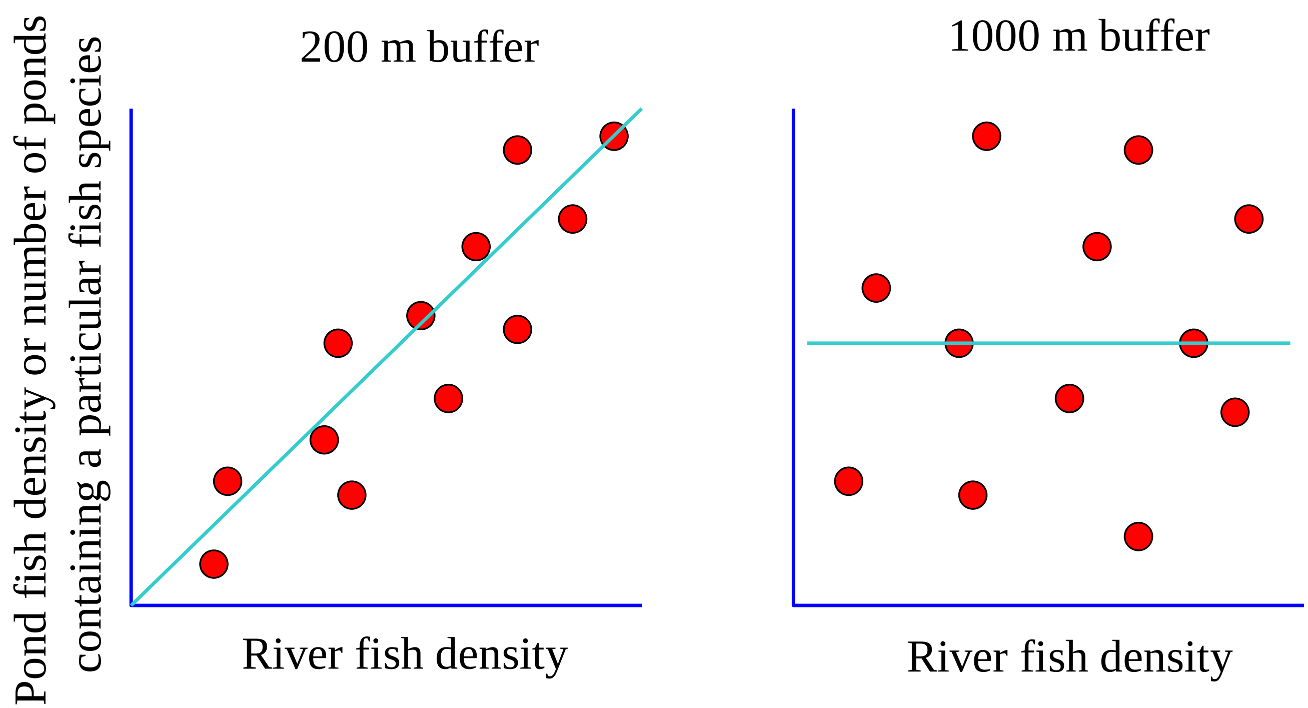


Figure 4. Expected patterns from the modified h-scattergram analysis. Strong relationships at particular scales indicate the potential influence of source populations of nonnative fish species within those distances. In this example we see a strong relationship within 200 m, but no relationship at 1000m.

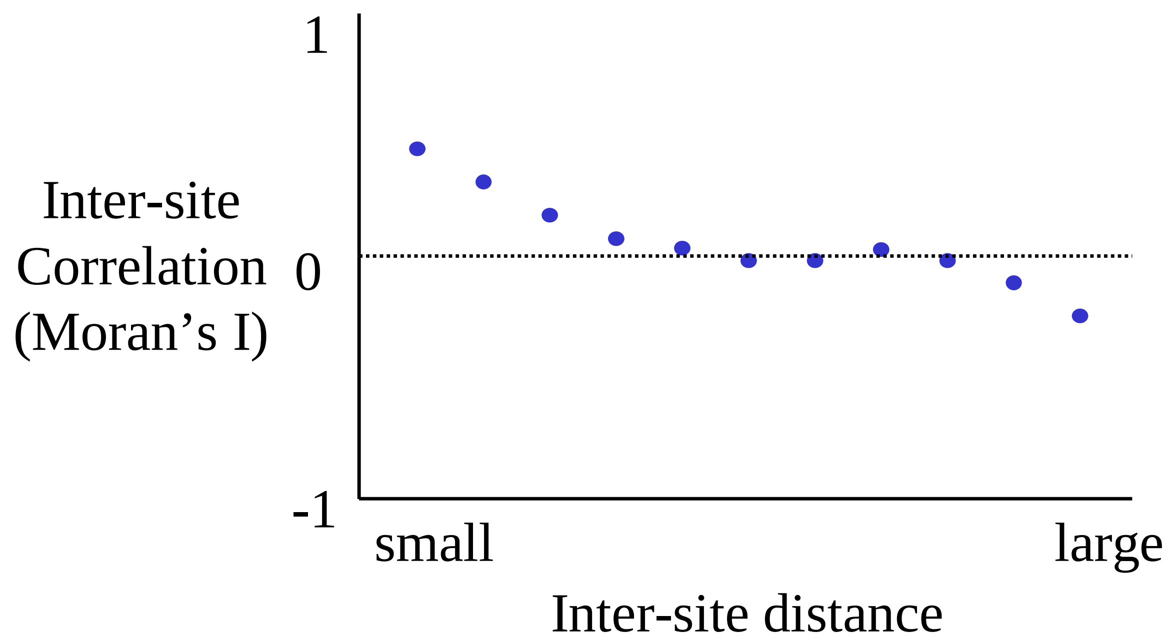


Figure 5. Typical pattern observed in a correlogram. Sites that are close together are often positively correlated, or similar in their densities of fish. As sites become further away, sites are no more likely to be positively or negatively related. On average, there is no relationship. At very large distances, one can sometimes see negative correlations where values of fish density at sites are less related than expected based on distance alone. This might be due to habitat factors, for example.

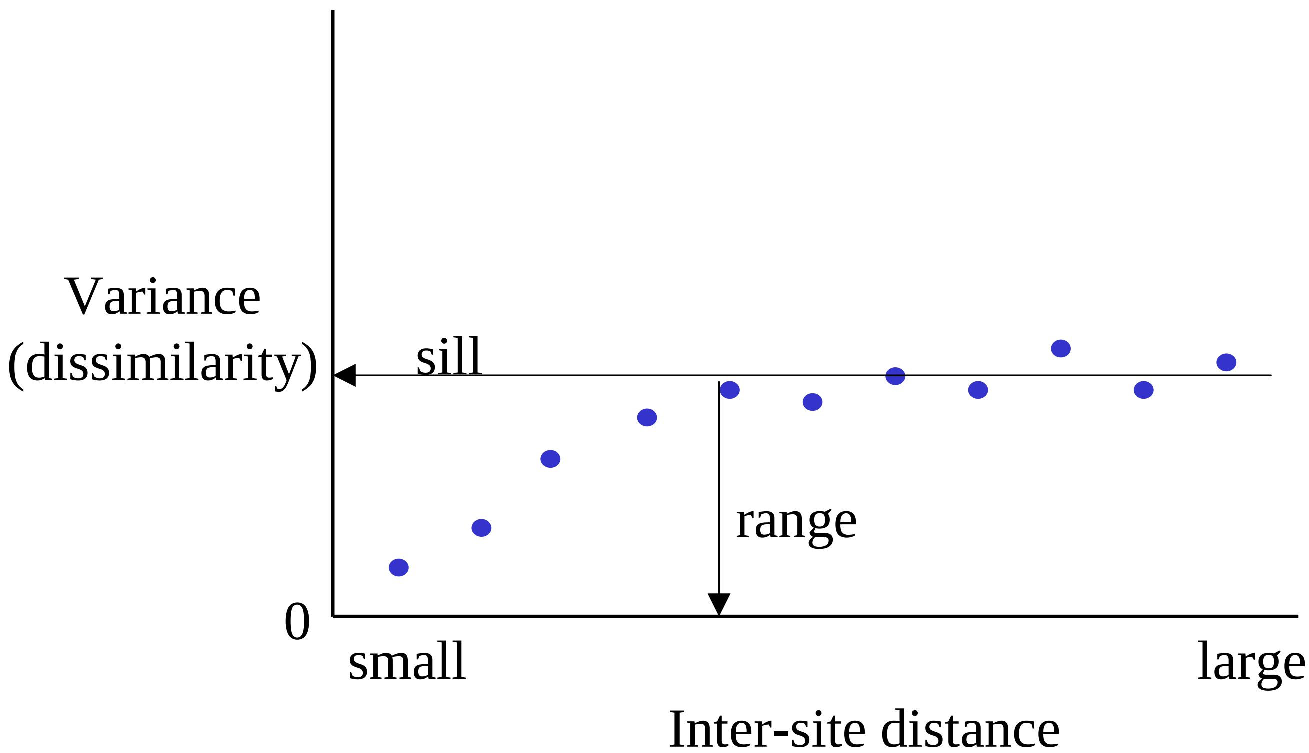


Figure 6. Typical pattern observed in a semivariogram. Sites that are close together are often not dissimilar in their densities of fish. As sites become further away, they are more likely to differ in values. At a certain distance, this difference no longer increases. The variance at which this occurs is referred to as the sill, or maximum spatial correlation. The distance at this point is referred to as the range, or distance to which spatial correlation exists in the data.

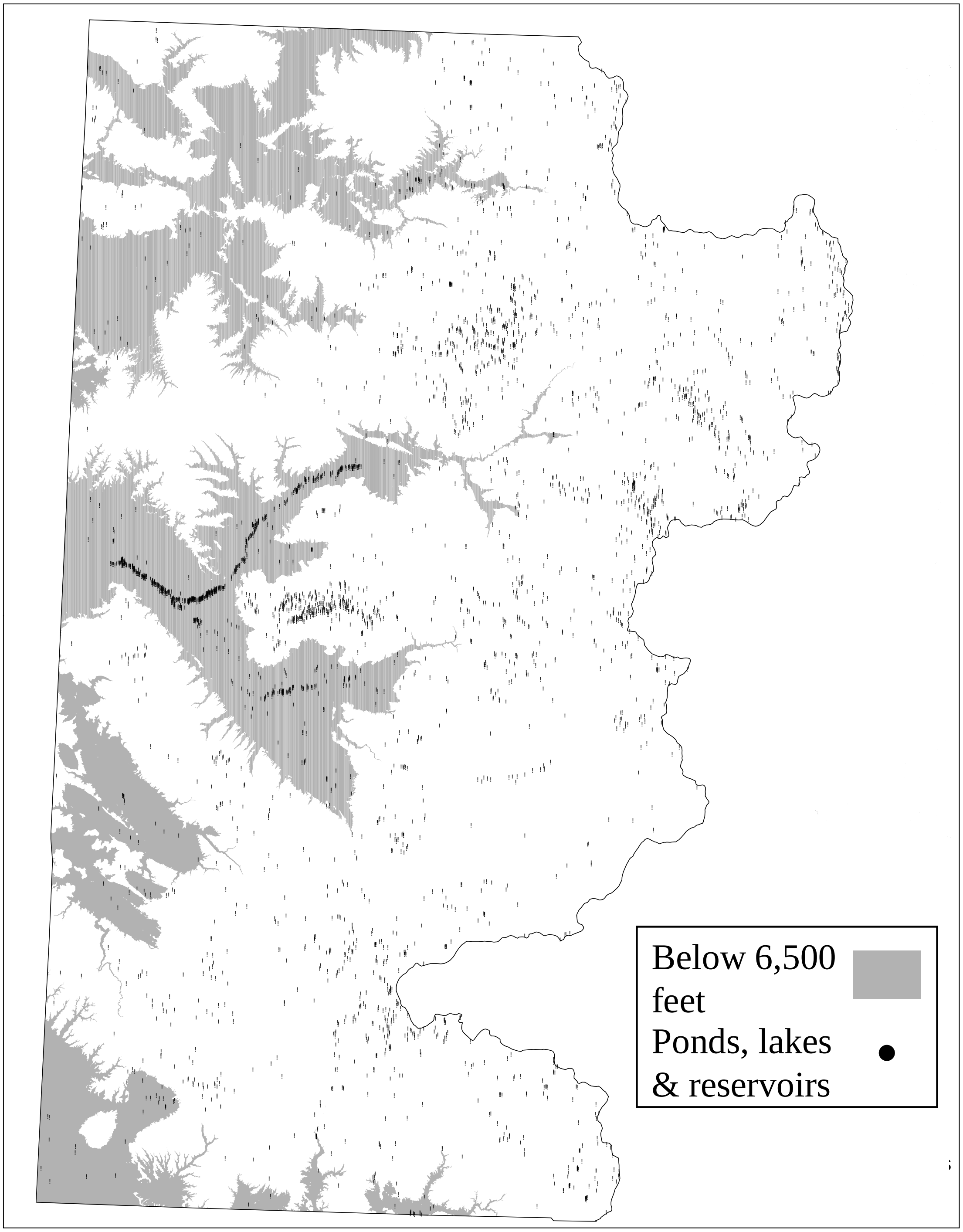


Figure 7. Distribution of ponds, lakes and reservoirs above and below 6,500-feet in elevation west of the Continental Divide in Colorado based on available digital spatial records. Many waters in high-density areas are obscured by the symbol size, but concentrations of standing water habitats remain evident.

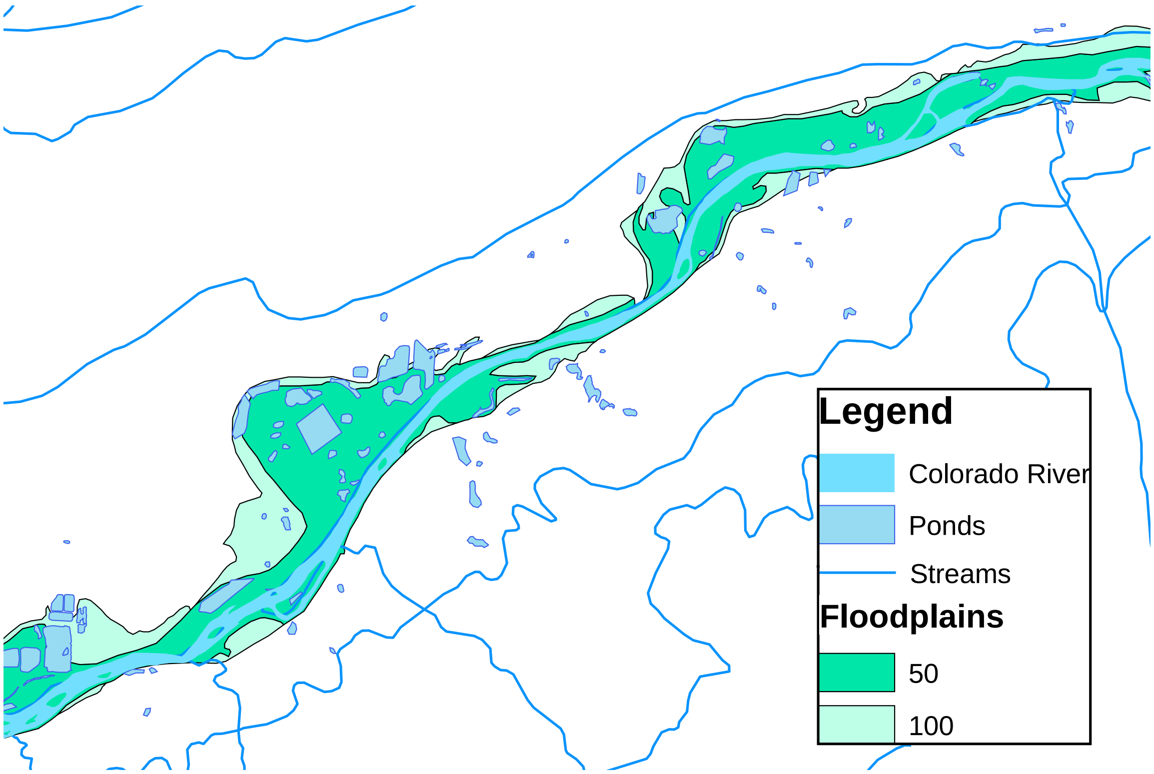


Figure 8. A subset of ponds in the ISA of the Colorado River with respect to the 50-year and 100-year floodplains.

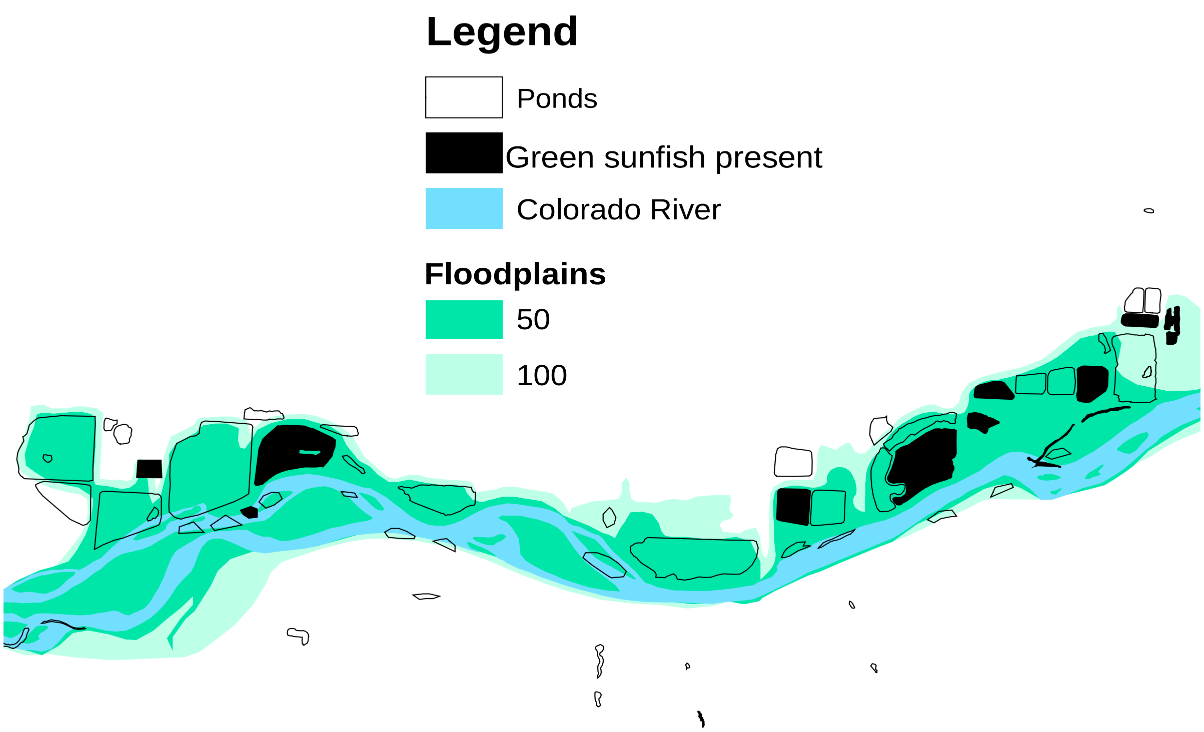


Figure 9. An example of ponds containing green sunfish within the ISA of the Colorado River from river miles 175.5 to 178.8 with respect to the 50-year and 100-year floodplains.

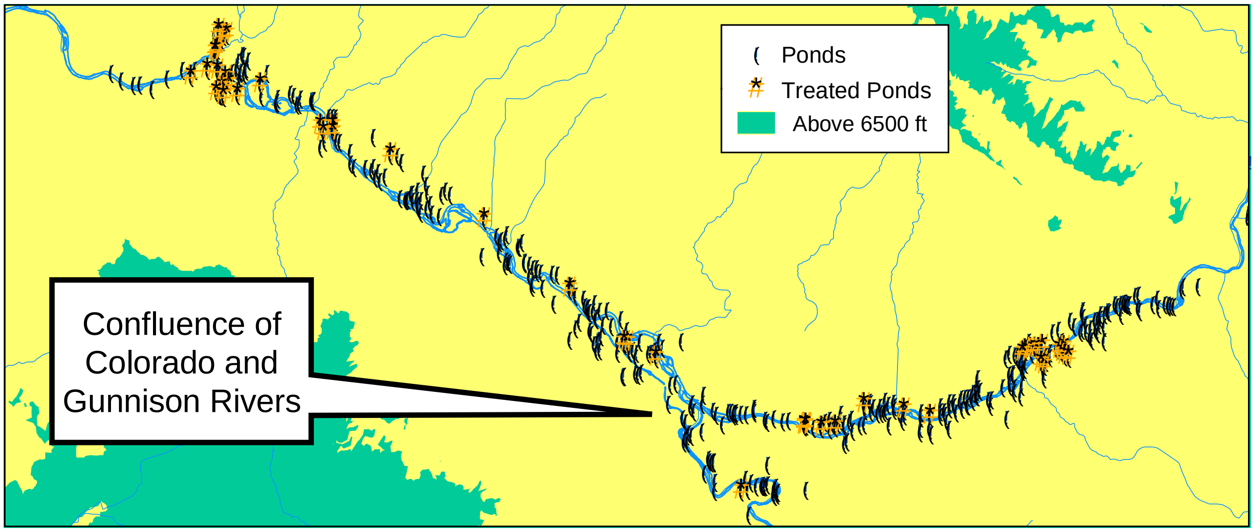


Figure 10. Floodplain and adjacent ponds within the ISA of the Colorado River between river miles 185 to 152 showing the locations of ponds receiving nonnative fish control treatments (Martinez, 2003).

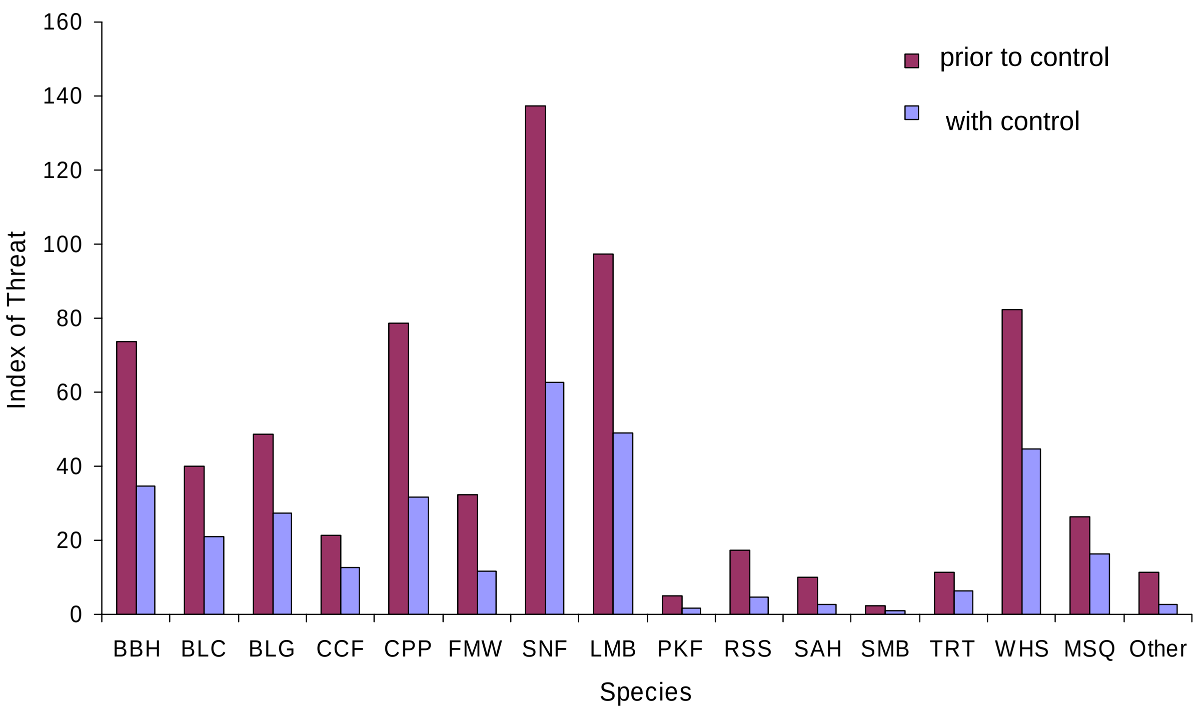


Figure 11. The index of threat gives a relative impression of which nonnative species are prevalent throughout the primary study area, but are also present in many ponds that lack nonnative control measures. The darker bars indicate the threat prior to control measures. In this case, threat equals prevalence. The lighter bars indicate that the index of threat is lowered after control measures have been implemented.

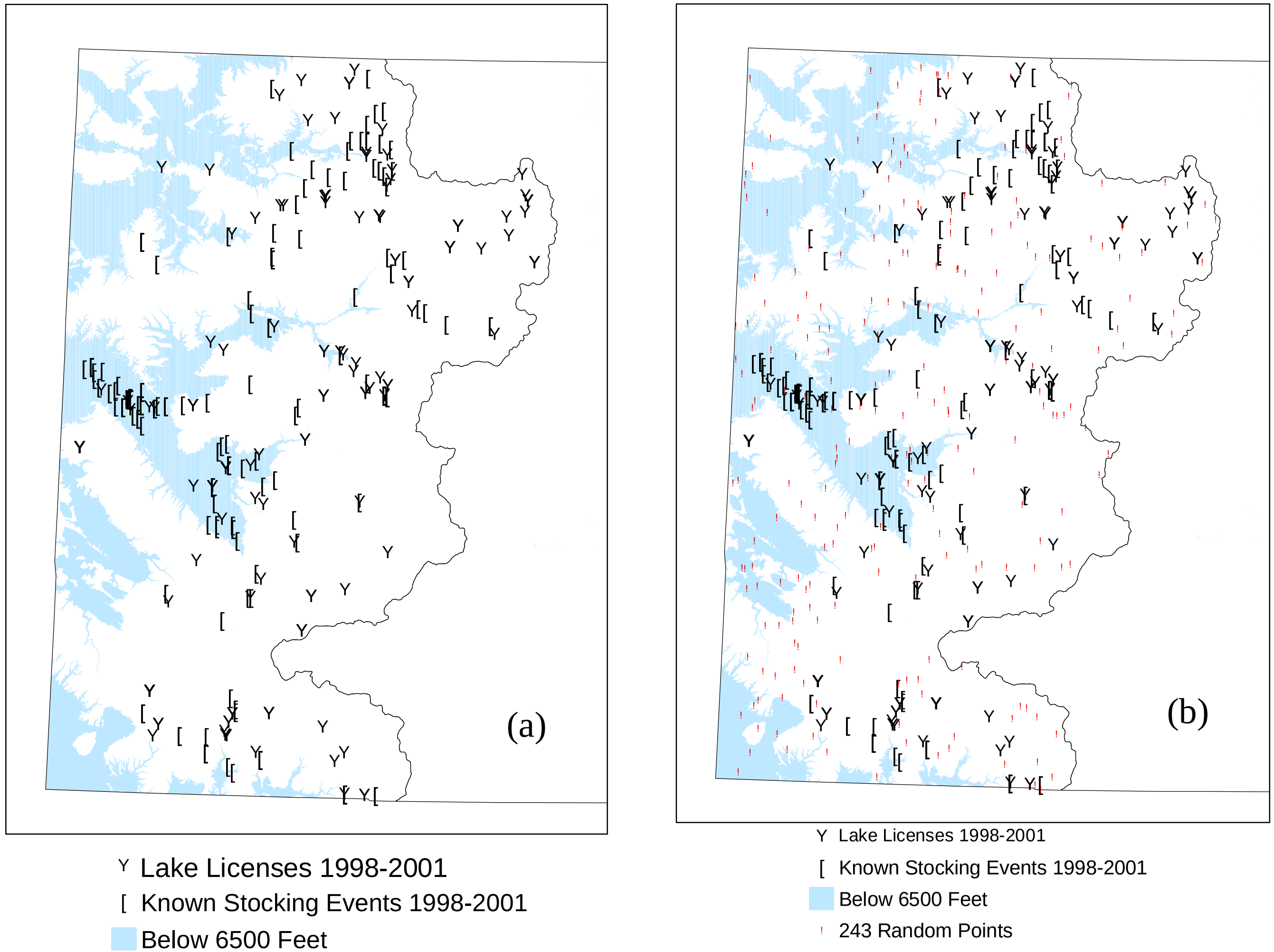


Figure 12. (a) A plot of all known stocking events (336) from 1998-2001 with adequate spatial information to be mapped, compared to the same map with an additional 243 stocking events randomly distributed to illustrate magnitude of information lacking adequate spatial information to be meaningfully mapped (b). The actual distribution of the non-spatial records likely resembles that of the spatially placed records.

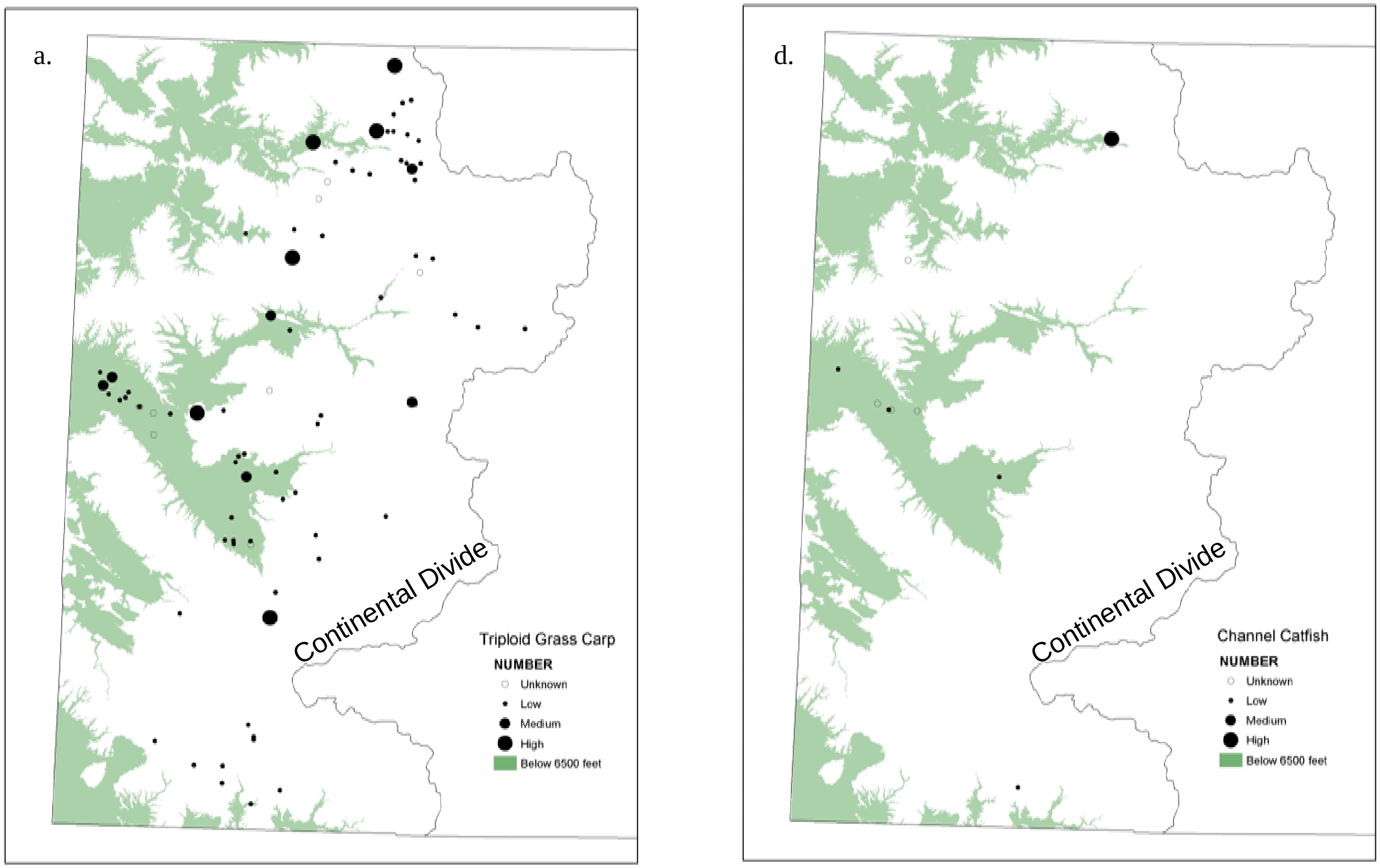


Figure 13. Visual depiction of private stocking densities for (a) triploid grass carp, (b) channel catfish, (c) bluegill, (d) black crappie, (e) largemouth bass, (f) fathead minnow. Maps may show repeated locations due to a single water being licensed for more than one species.

Figure 13, con't. Visual depiction of private stocking densities for (a) triploid grass carp, (b) channel catfish, (c) bluegill, (d) black crappie, (e) largemouth bass, (f) fathead minnow. Maps may show repeated locations due to a single water being licensed for more than one species.

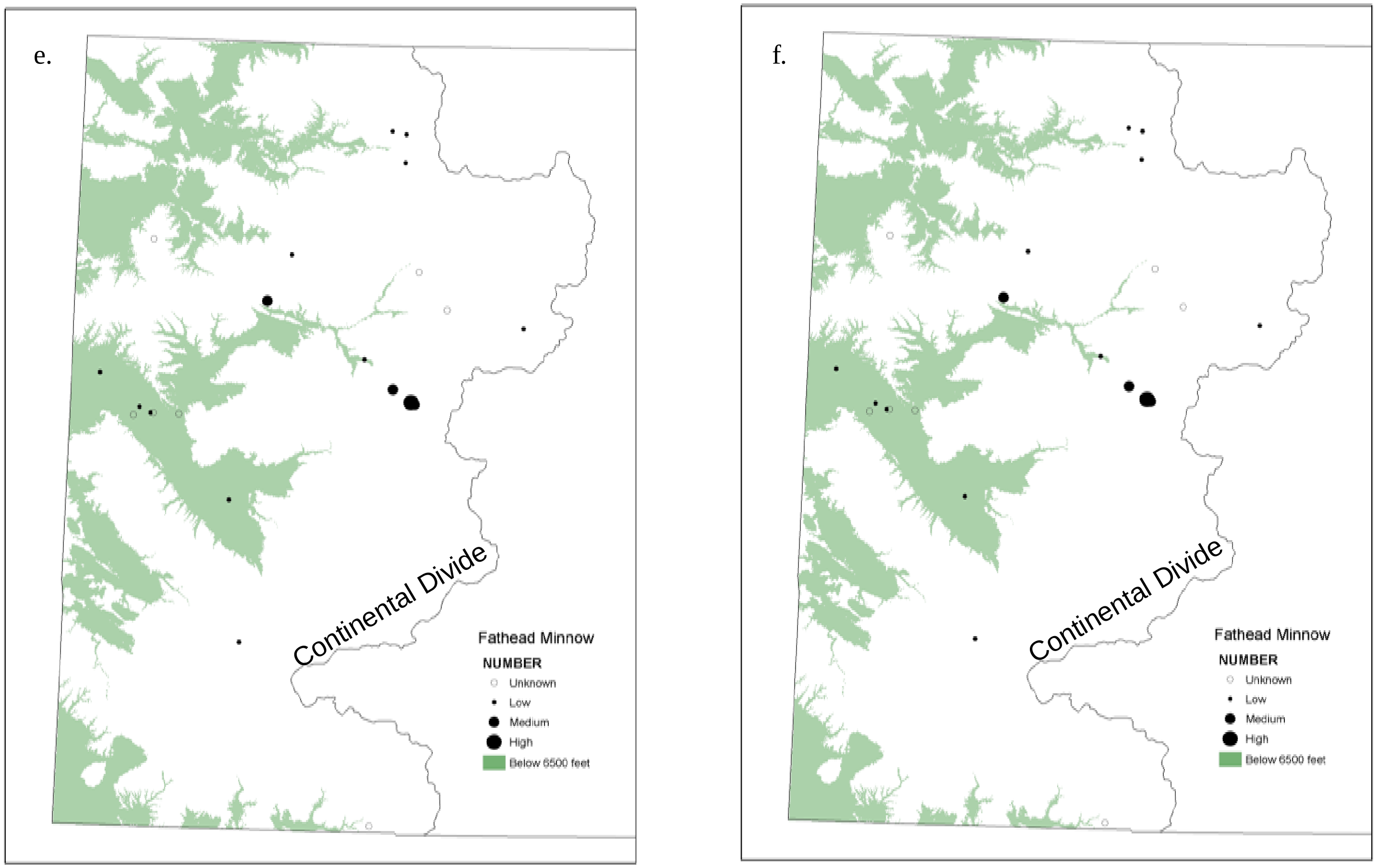


Figure 13, con't. Visual depiction of private stocking densities for (a) triploid grass carp, (b) channel catfish, (c) bluegill, (d) black crappie, (e) largemouth bass, (f) fathead minnow. Maps may show repeated locations due to a single water being licensed for more than one species.

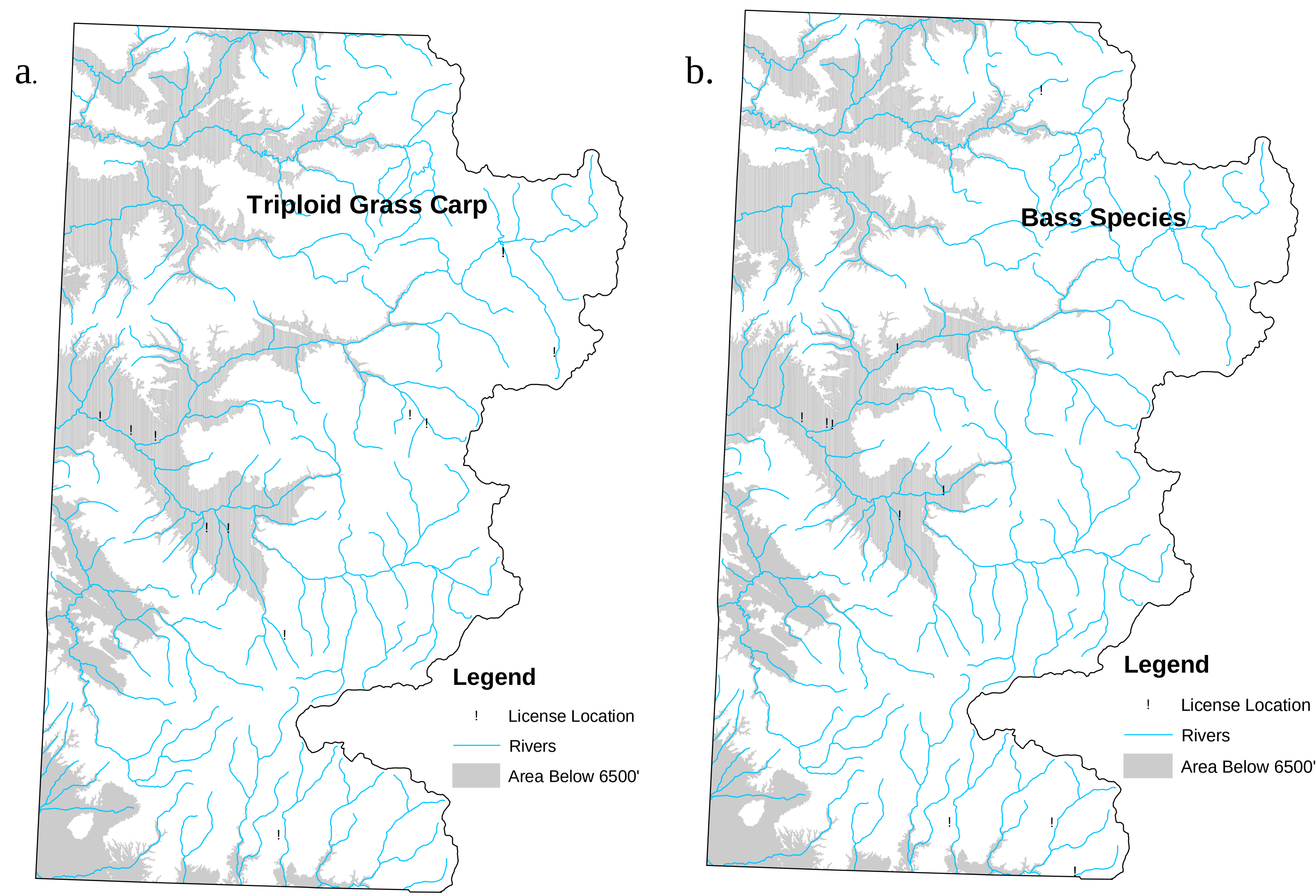
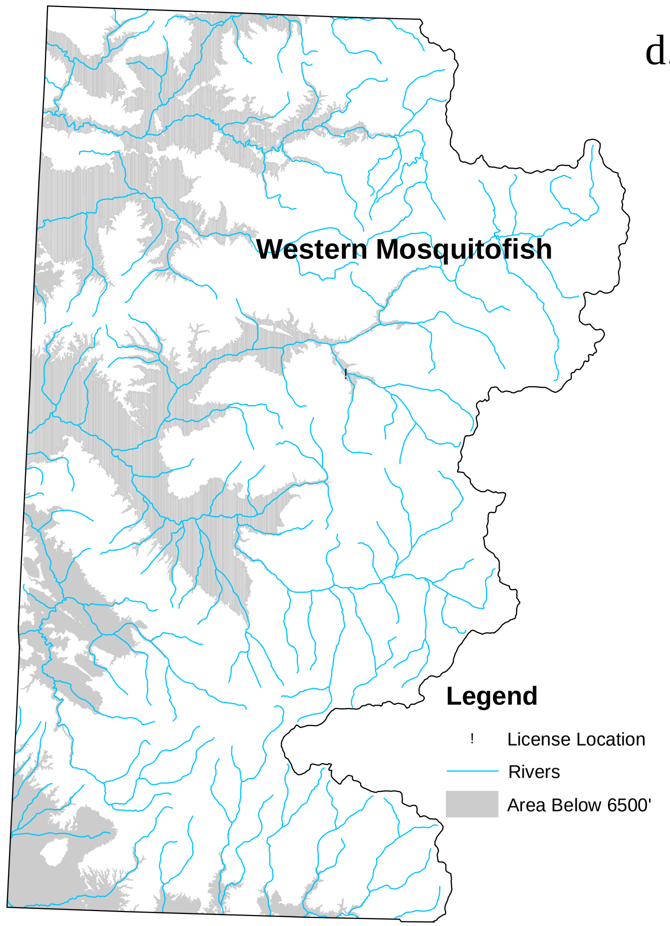


Figure 14. Private lake licenses issued for the years 1997-2001. Maps may show repeated locations due to a single water being licensed for more than one species. a) triploid grass carp; b) bass species; c) western mosquitofish; d) bluegill; e) fathead minnow; and f) channel catfish.

c.



d.

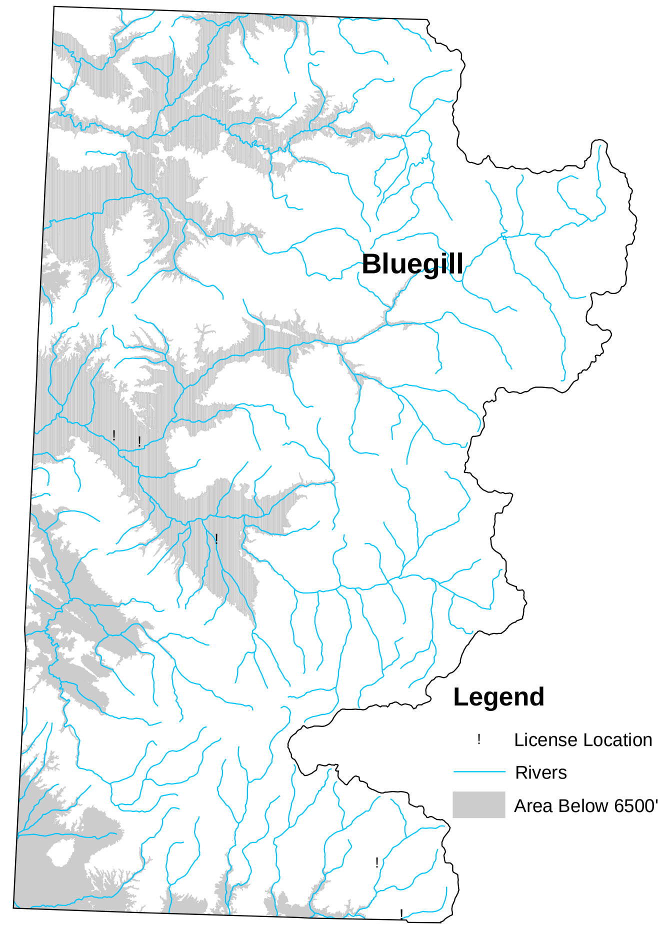


Figure 14 con't. Private lake licenses issued for the years 1997-2001. Maps may show repeated locations due to a single water being licensed for more than one species. a) triploid grass carp; b) bass species; c) western mosquitofish; d) bluegill; e) fathead minnow; and f) channel catfish.

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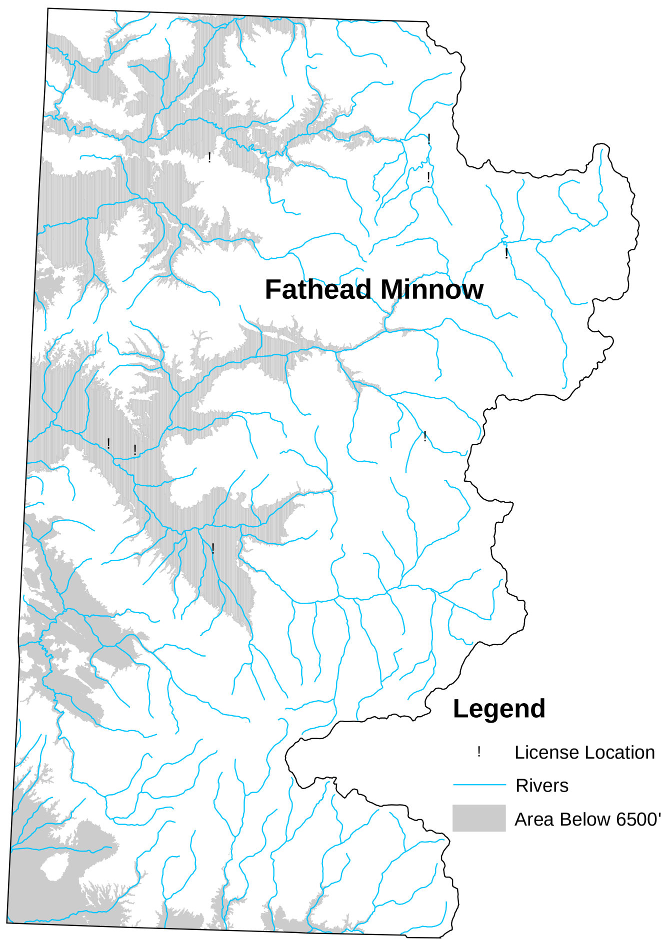

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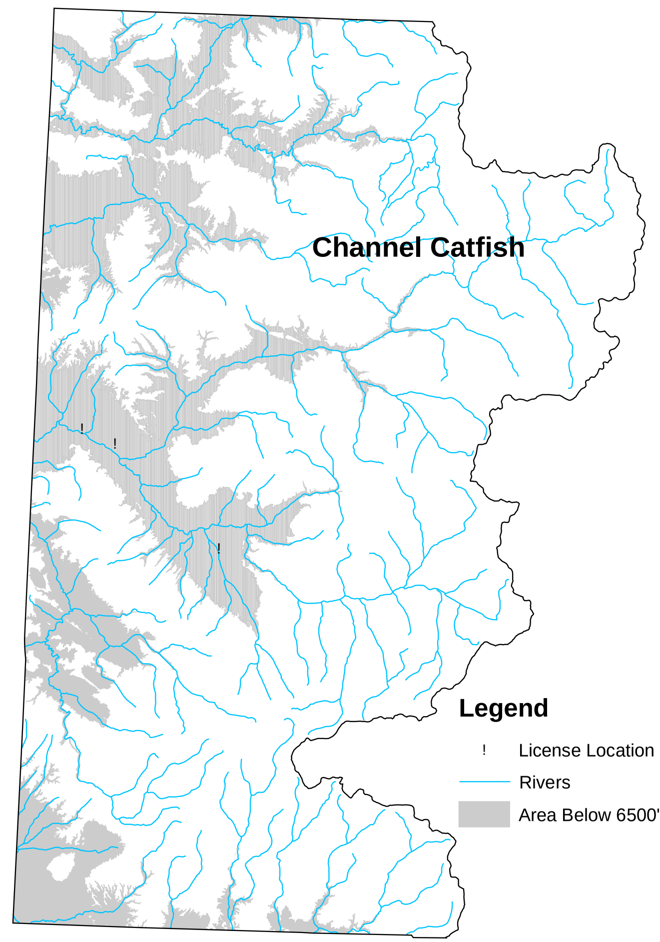

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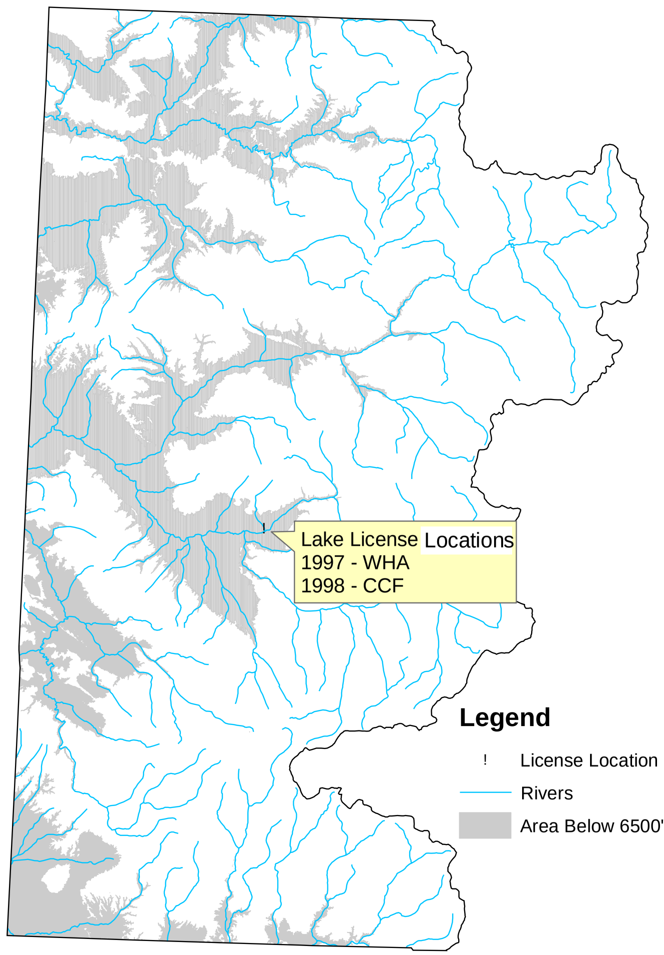

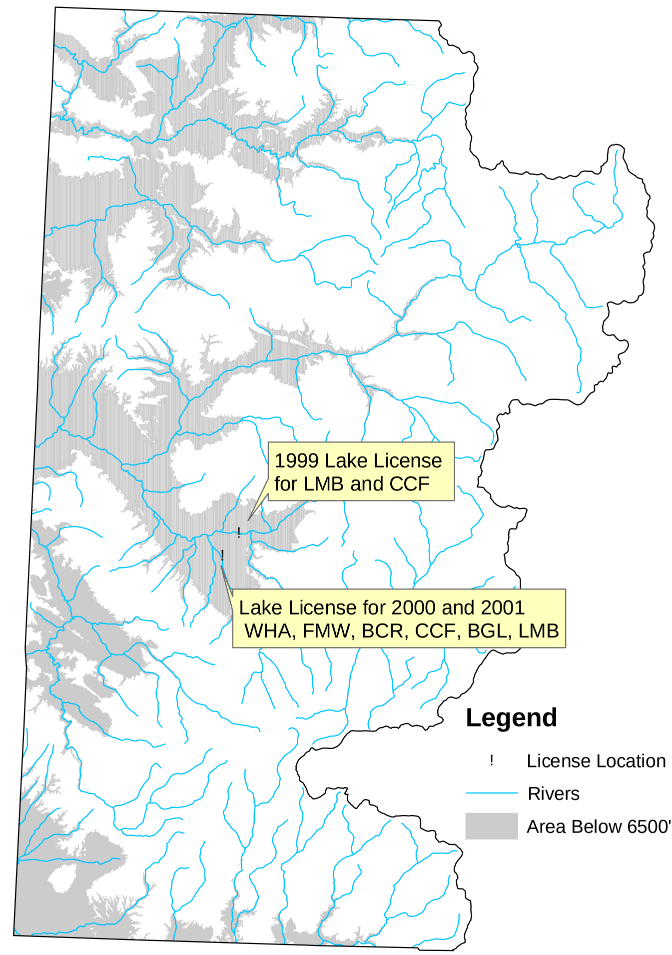

Figure 15. Commercial lake licenses issued for the years 1997-2001.

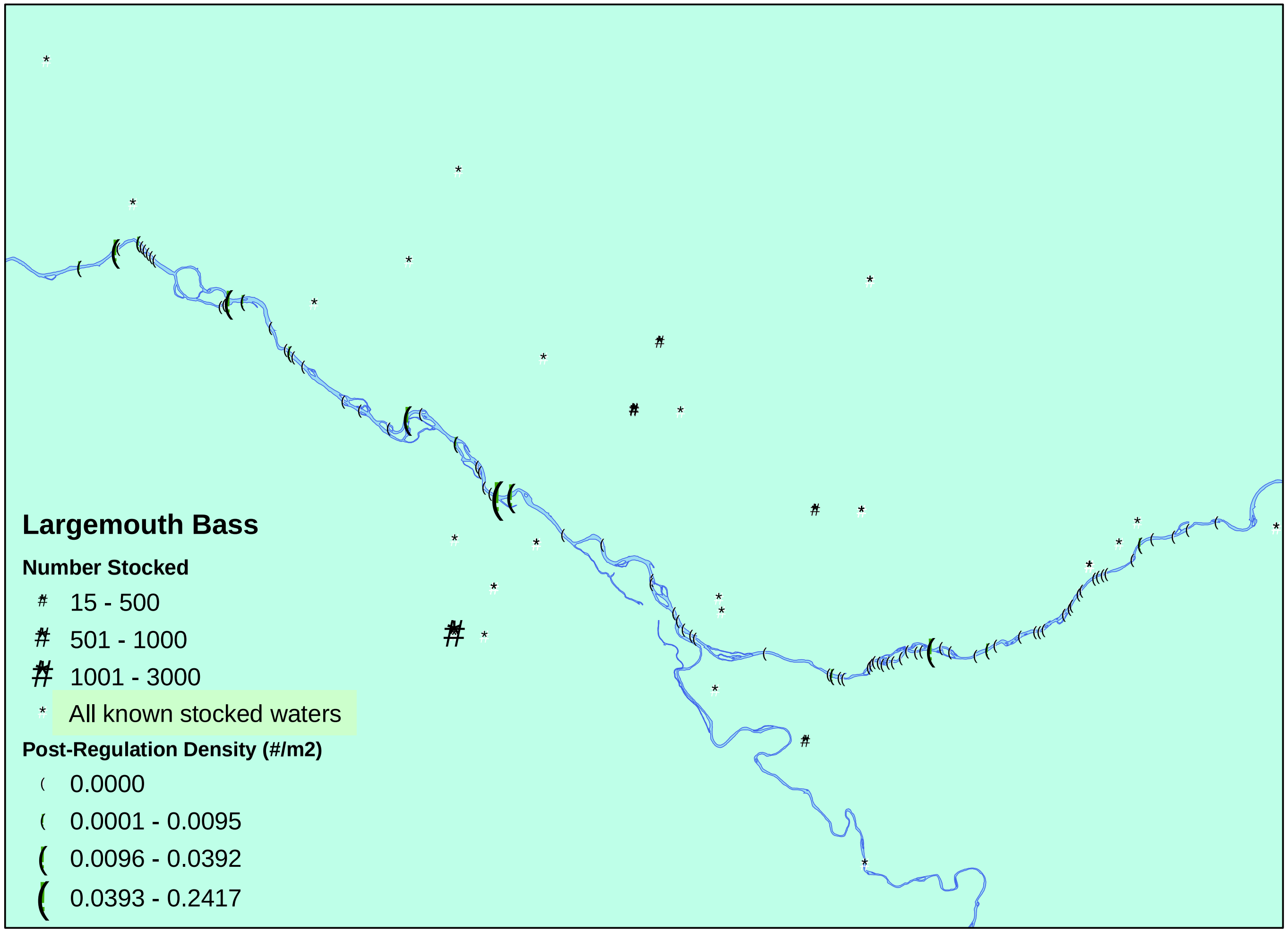

Figure 16. Stocking densities of largemouth bass vs. largemouth bass backwater density in the ISA of the Colorado River.

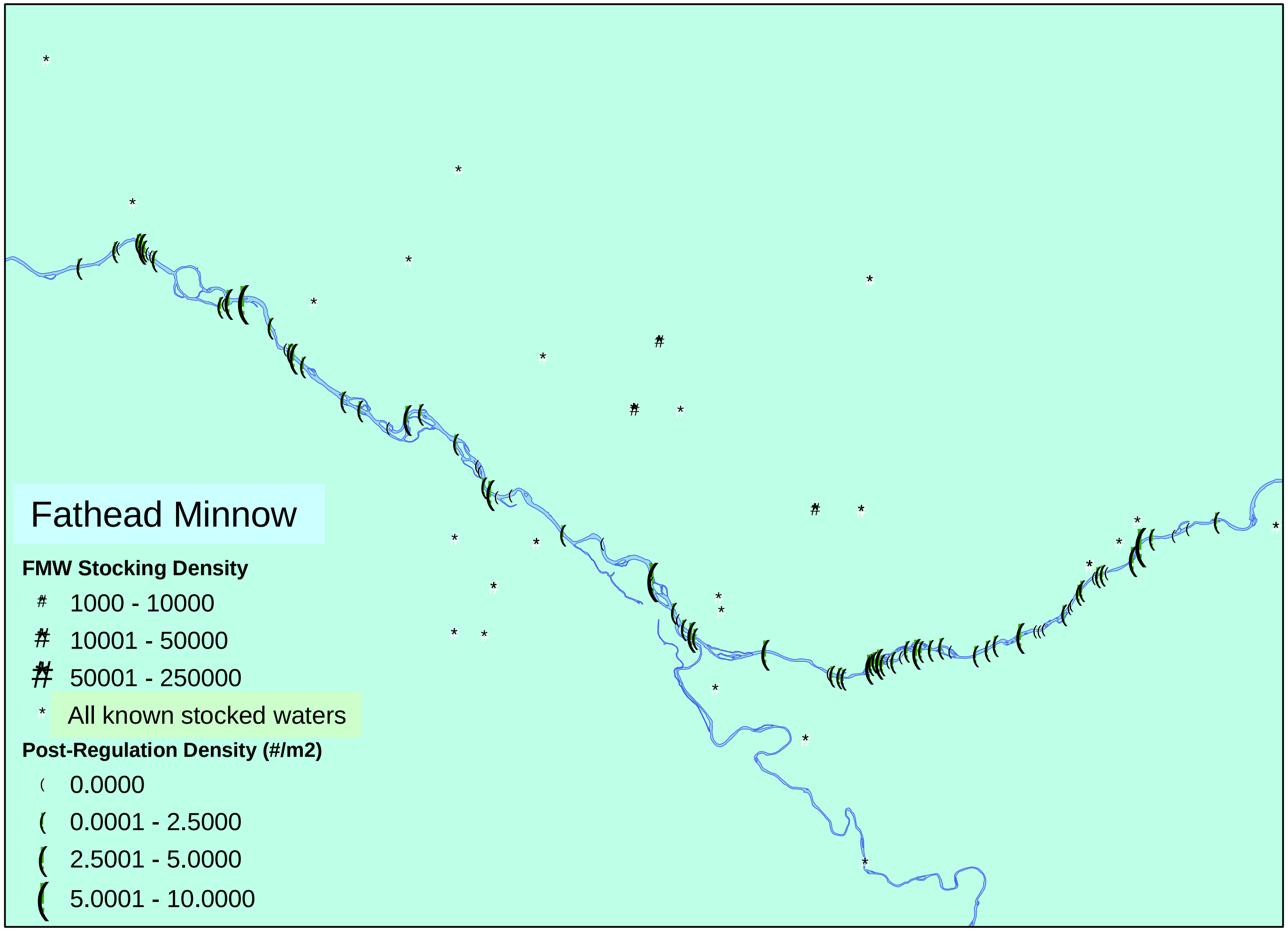

Figure 17. Stocking densities of fathead minnow vs. fathead minnow backwater density.

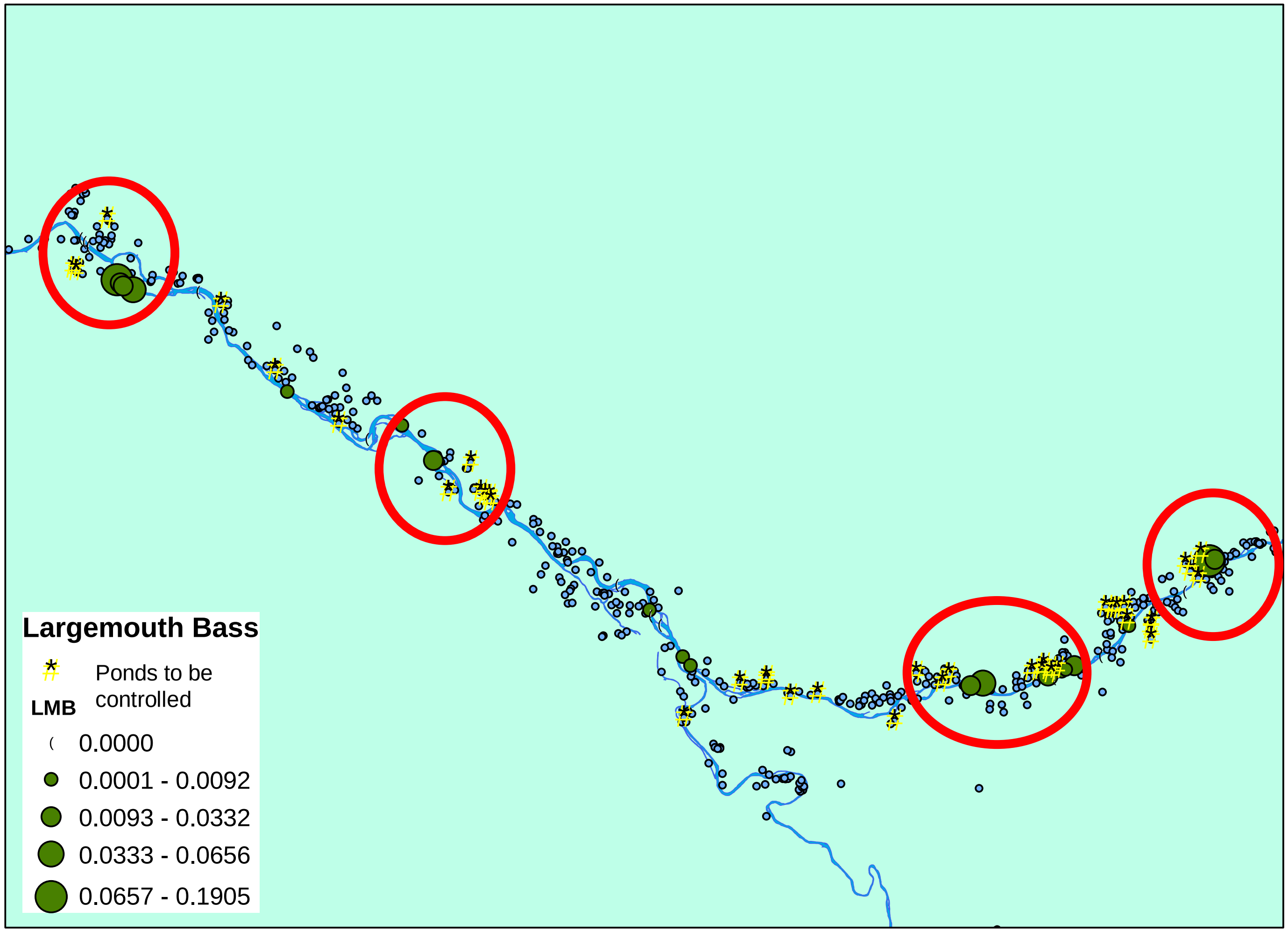

Figure 18. Clusters of high largemouth bass densities appear near several ponds that will eventually be treated to remove/control nonnative fish within the ISA of the Colorado River.

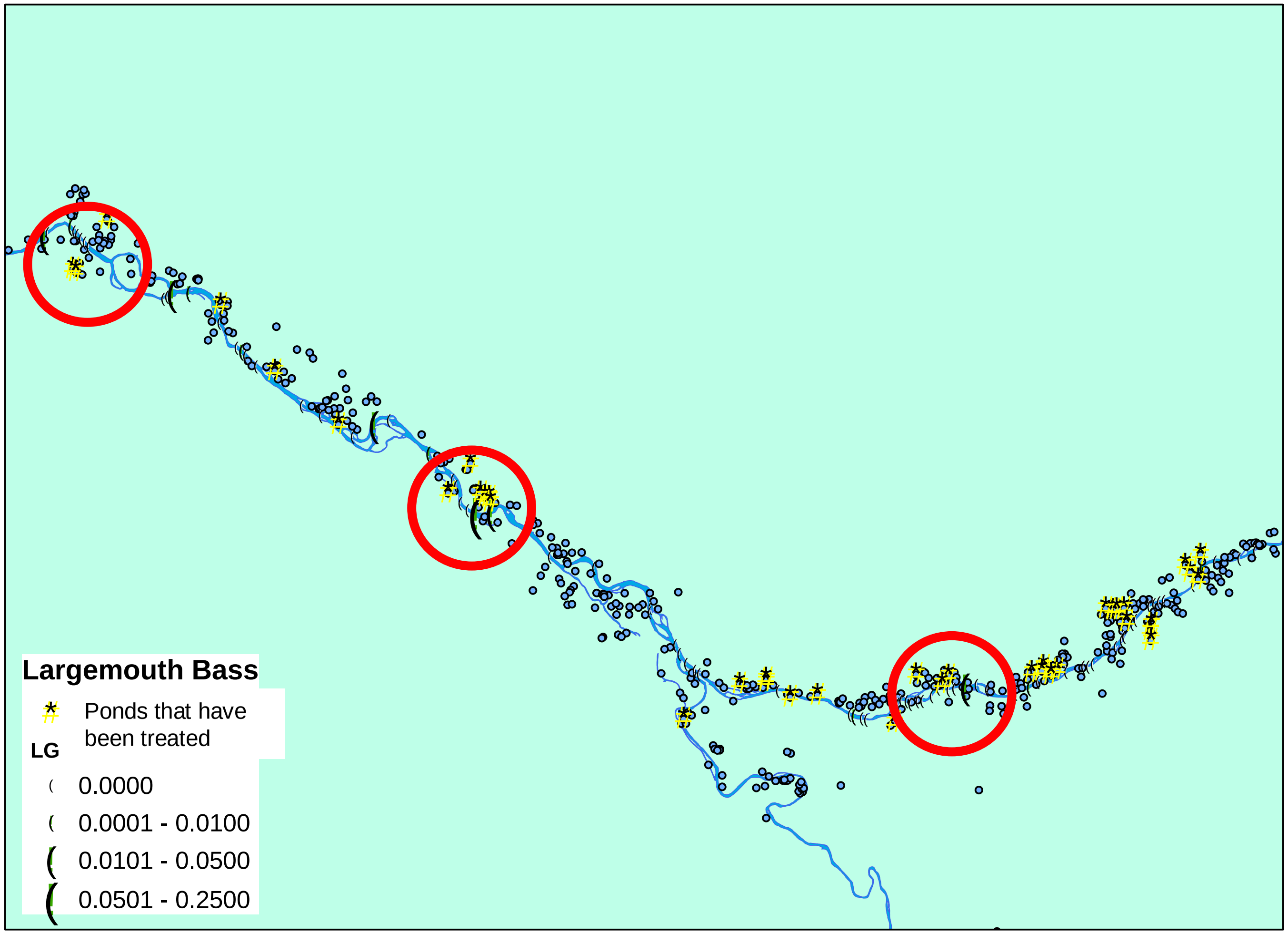

Figure 19. Clusters of high largemouth densities remain near several ponds that have been treated to remove/control nonnative fish within the ISA of the Colorado River.

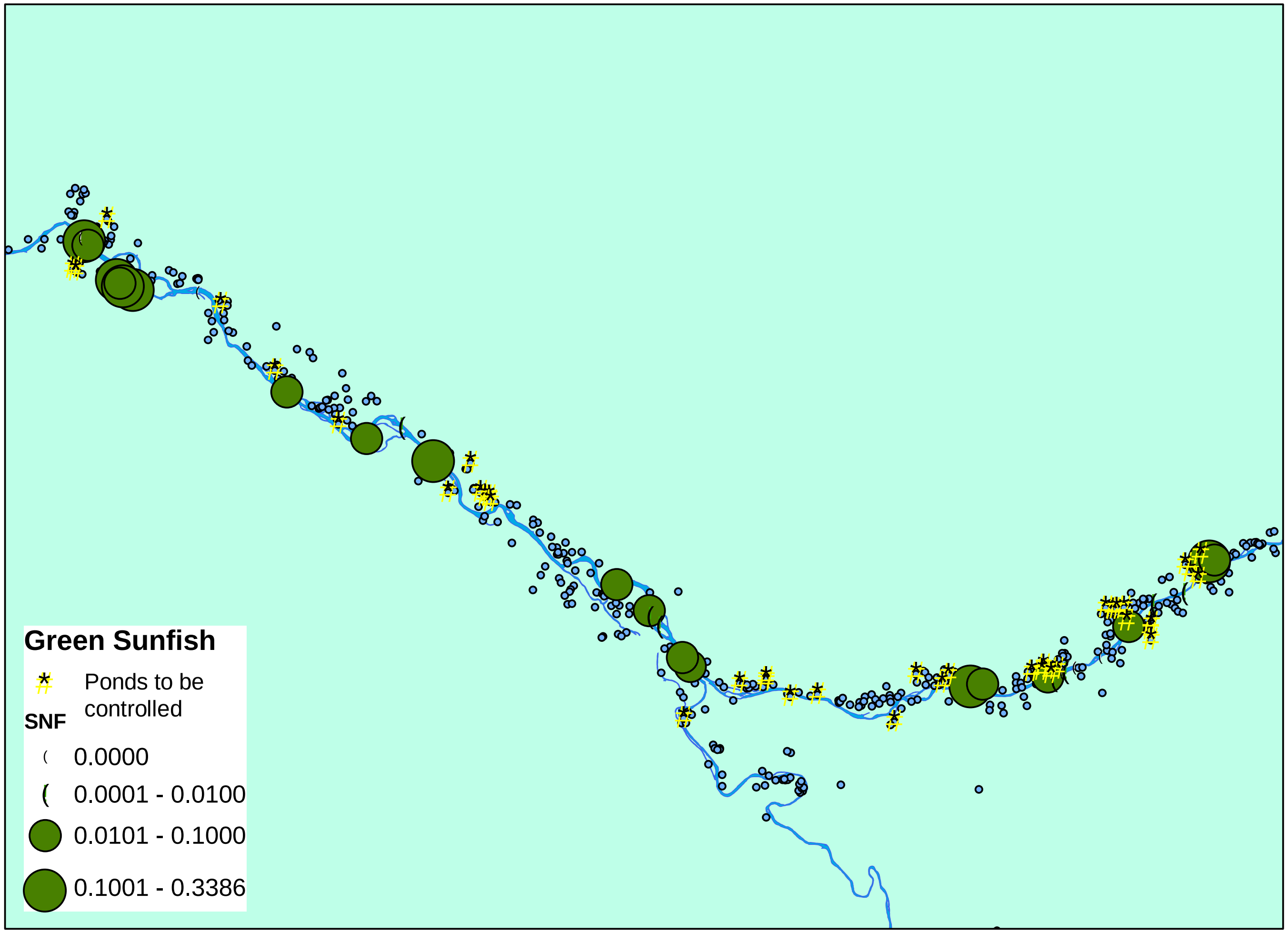

Figure 20. Clusters of high green sunfish densities appear both near and far away from several ponds that will be treated to remove/control nonnative fish within the ISA of the Colorado River.

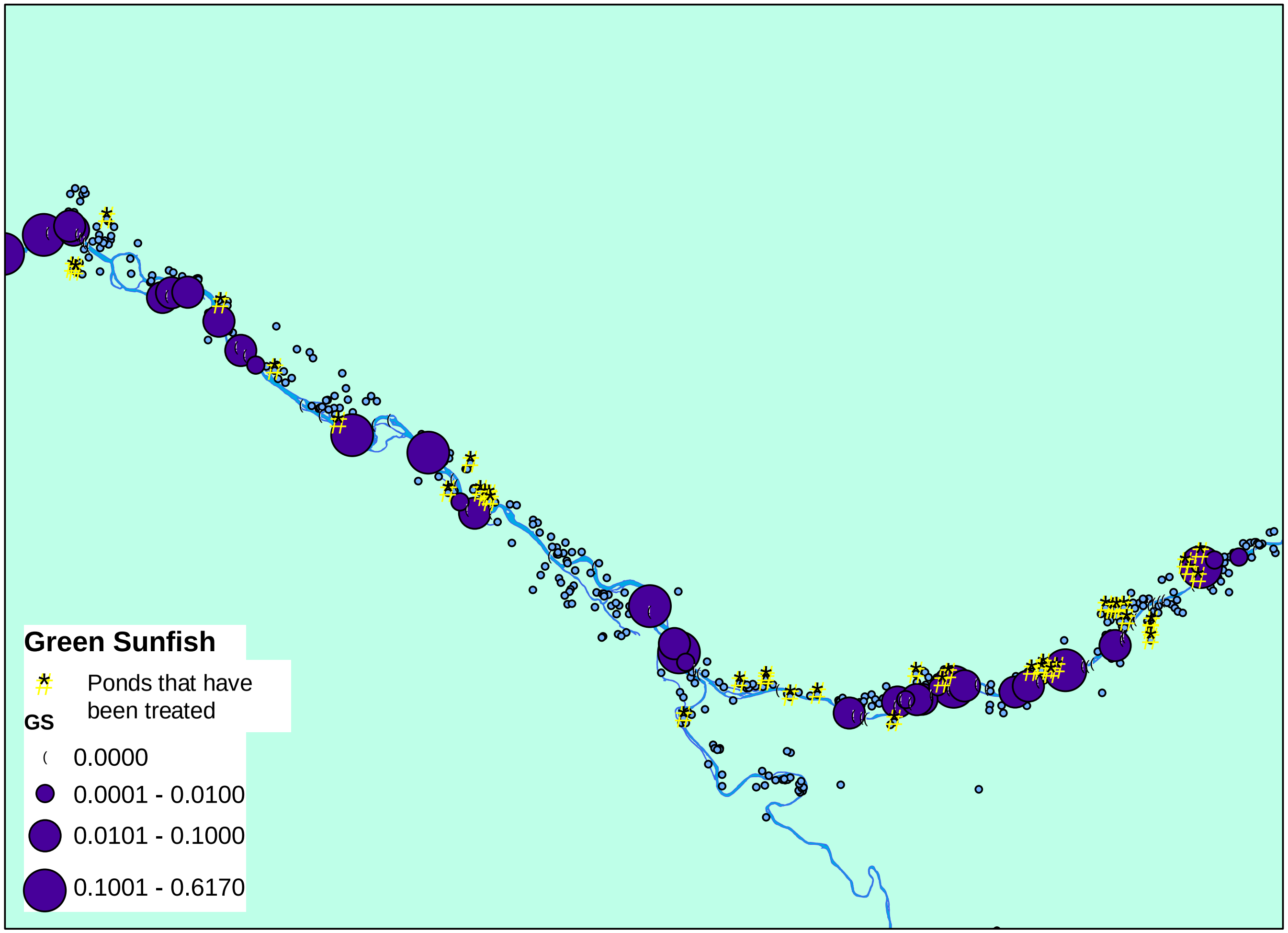

Figure 21. Clusters of high green sunfish densities remain both near and far away from several ponds that have been treated to remove/control nonnative fish within the ISA of the Colorado River.

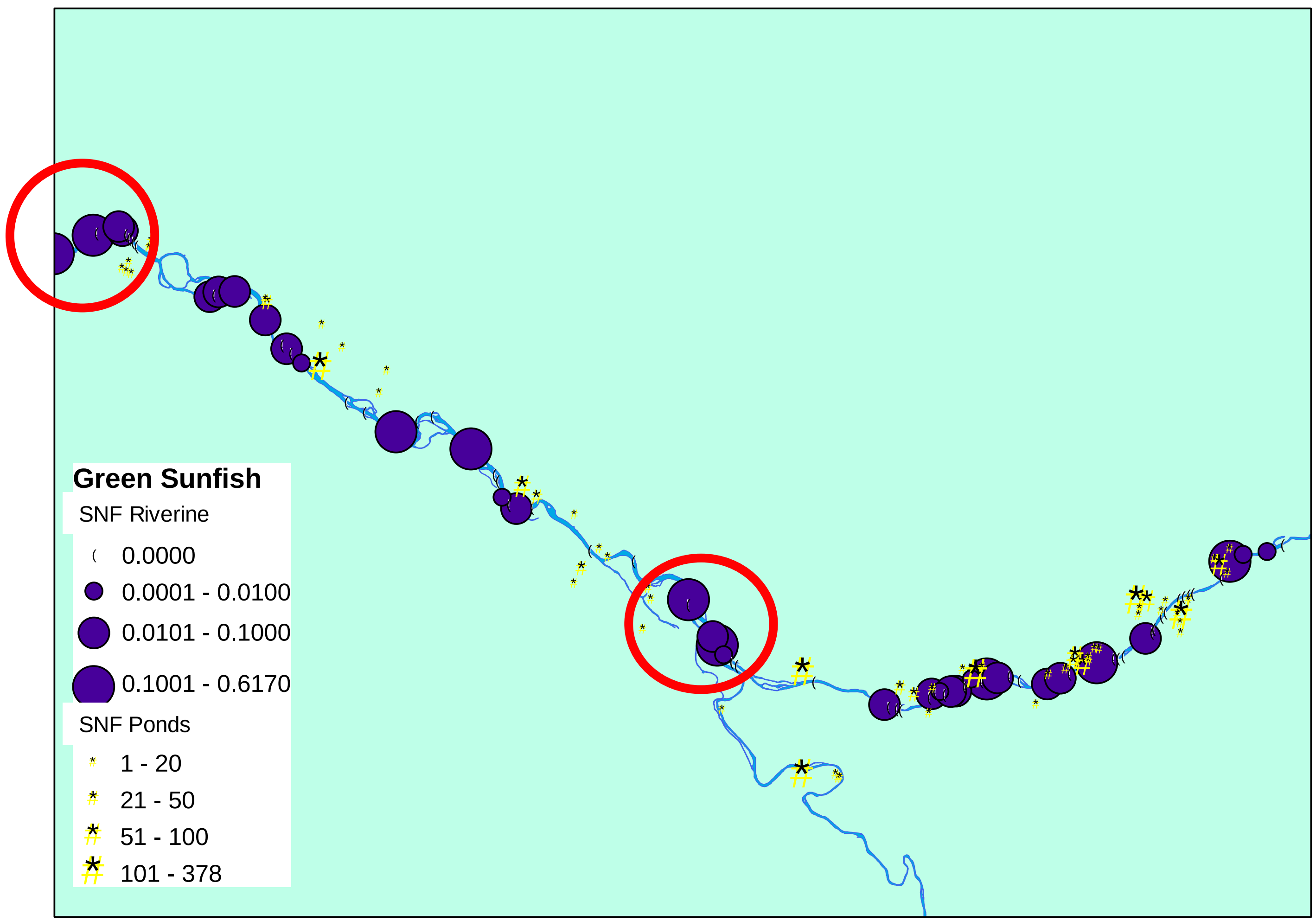

Figure 22. Clusters of high green sunfish densities appear to exist throughout the Colorado River within the ISA, not just near ponds that also have high green sunfish densities.

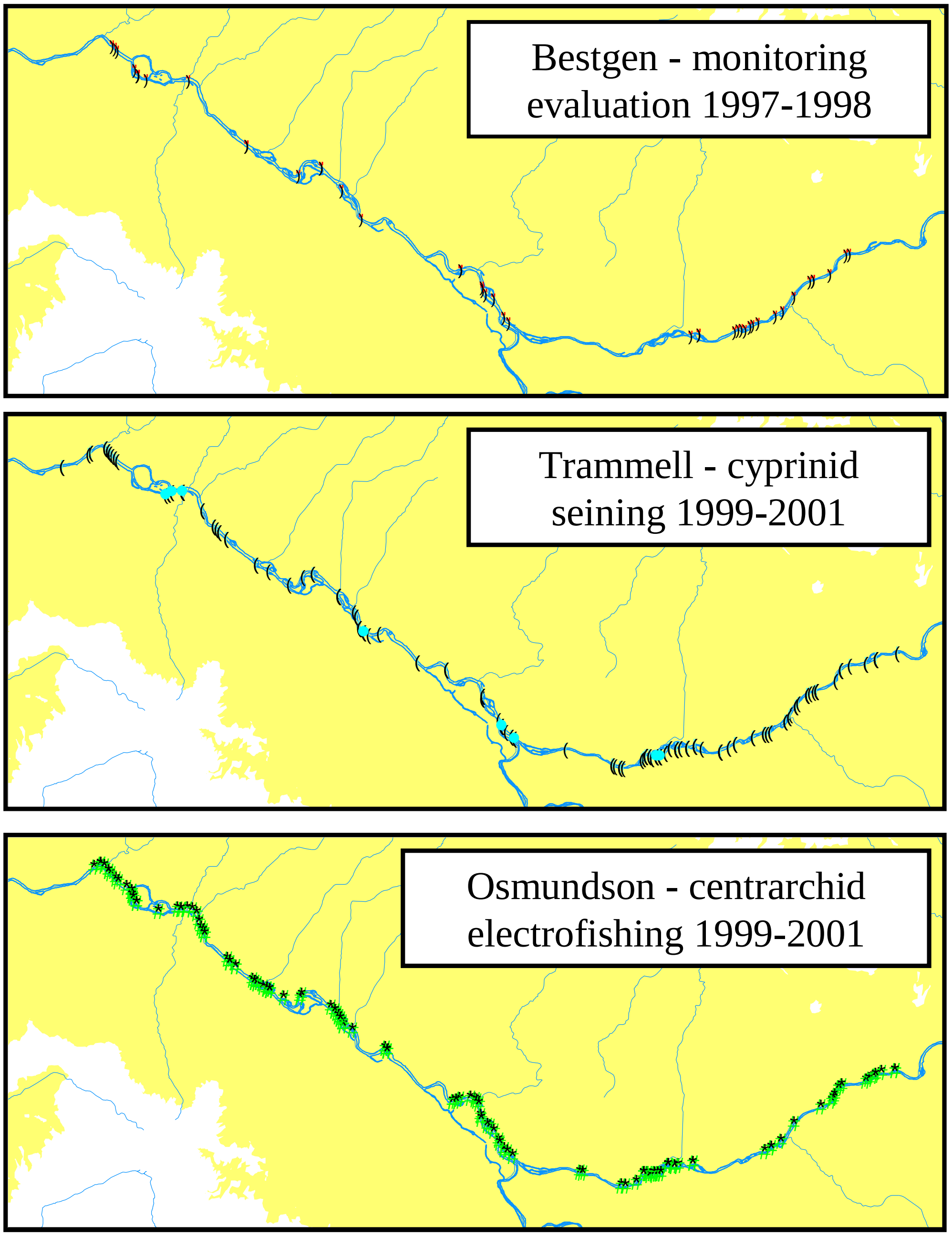

Figure 23. Backwaters sampled as part of three intensive nonnative fish sampling or removal efforts in the Grand Valley reach of the Colorado River from 1997 to 2001: the Interagency Standardized Monitoring sampling protocol in 1997-1998 (Bundy and Bestgen); a cyprinid removal effort by seining in 1999-2001 (Trammell et al. 2002); and a centrarchid removal effort by electrofishing in 1999-2001 (Osmundson 2003).

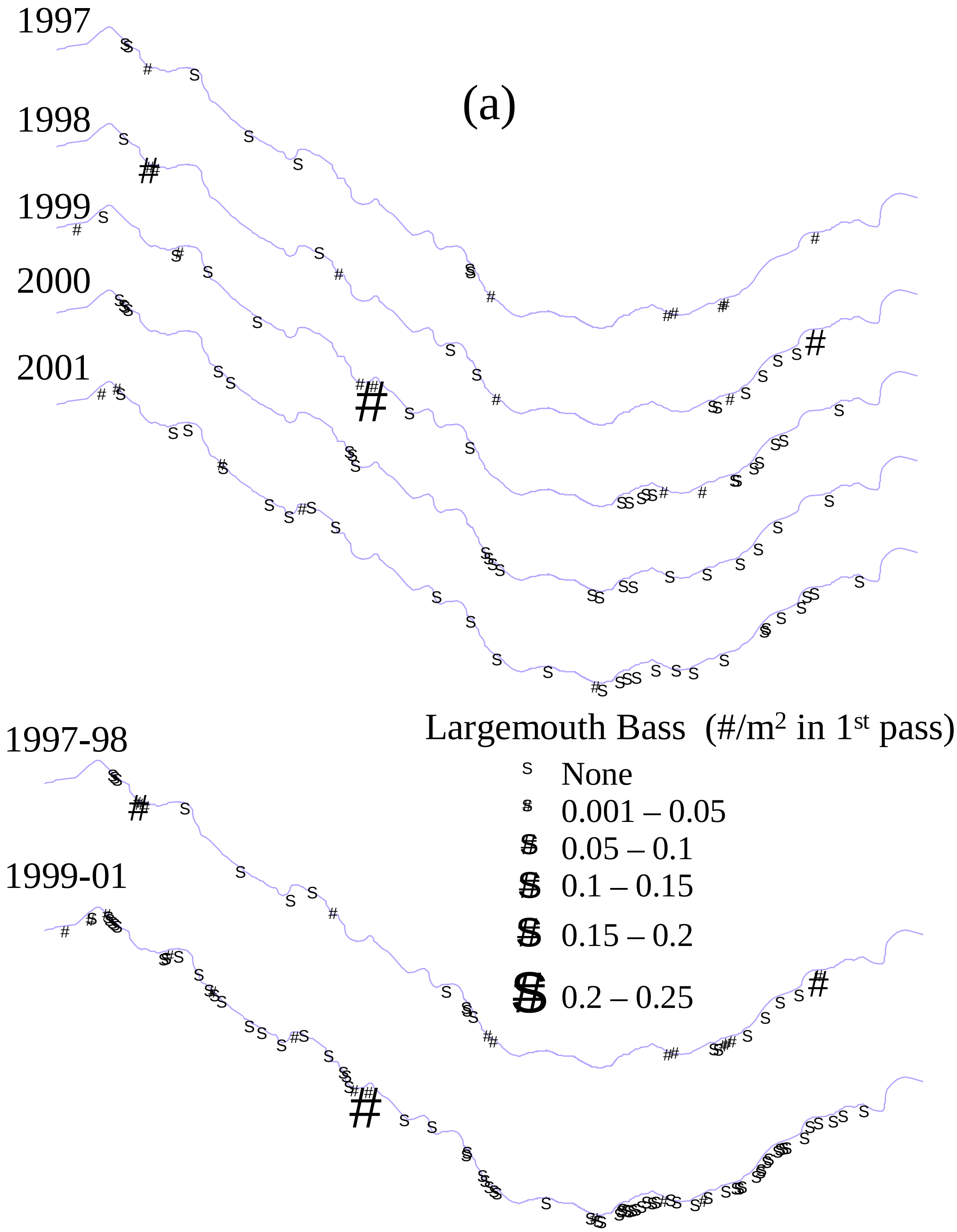

Figure 24. Densities of selected nonnative fish sampled in riverine backwaters from 1997-2001, and also shown for combined years 1997-1998 and 1999-2001: a) largemouth bass; b) green sunfish; c) fathead minnow; d) bluegill; and e) black crappie.

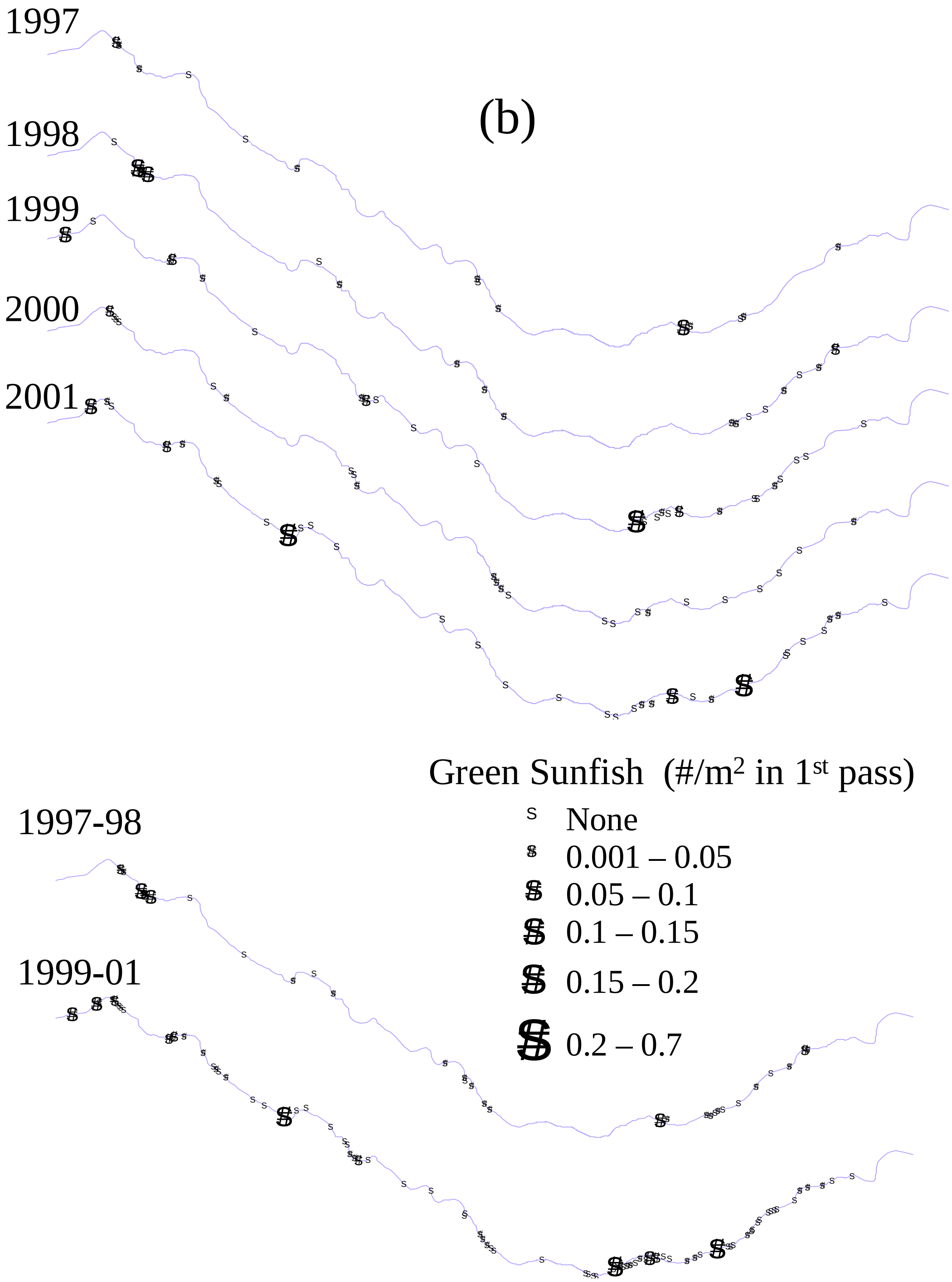

Figure 24 con't. Densities of selected nonnative fish sampled in riverine backwaters from 1997-2001, and also shown for combined years 1997-1998 and 1999-2001: a) largemouth bass; b) green sunfish; c) fathead minnow; d) bluegill; and e) black crappie.

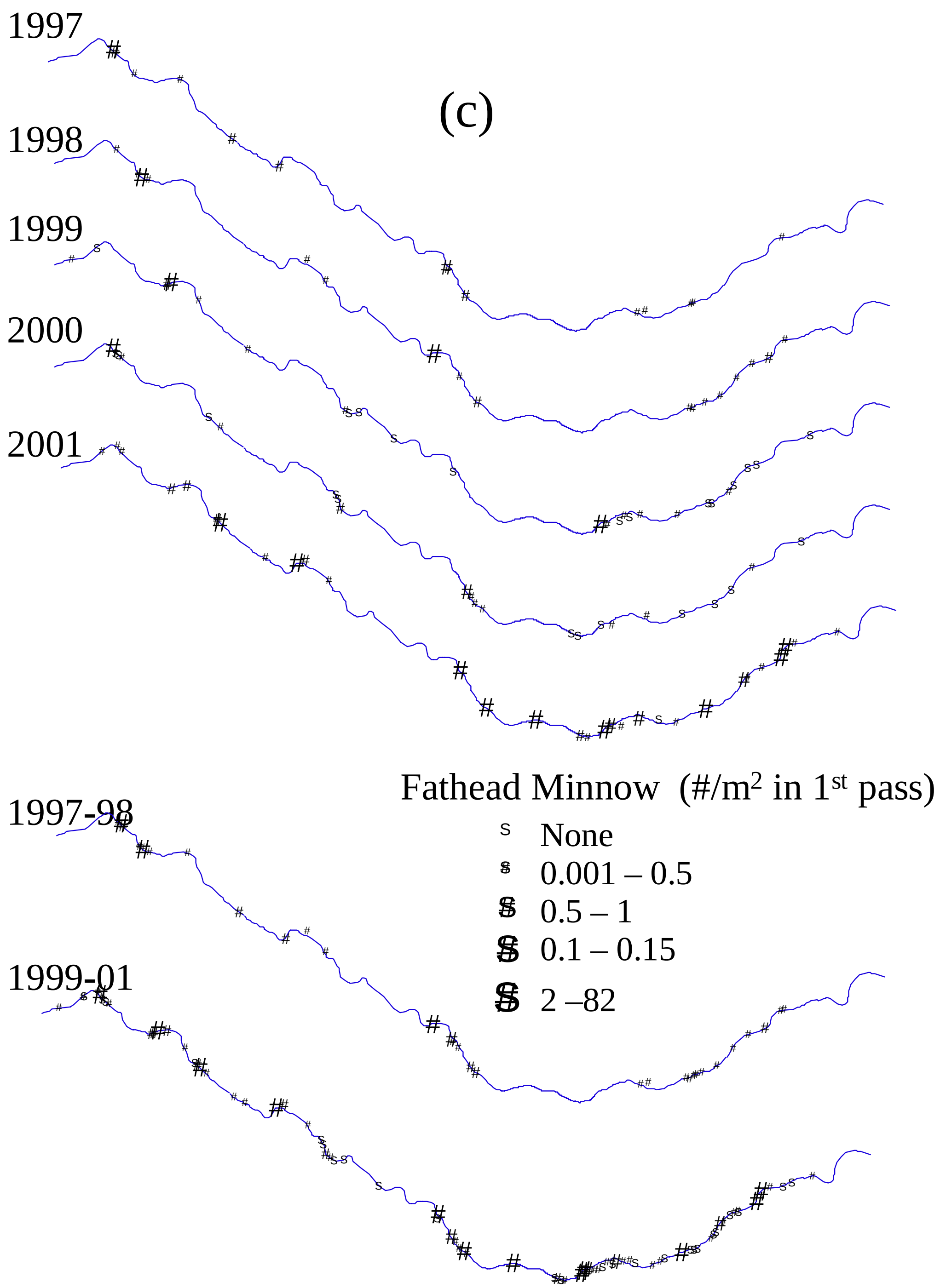

Figure 24 con't. Densities of selected nonnative fish sampled in riverine backwaters from 1997-2001, and also shown for combined years 1997-1998 and 1999-2001: a) largemouth bass; b) green sunfish; c) fathead minnow; d) bluegill; and e) black crappie.

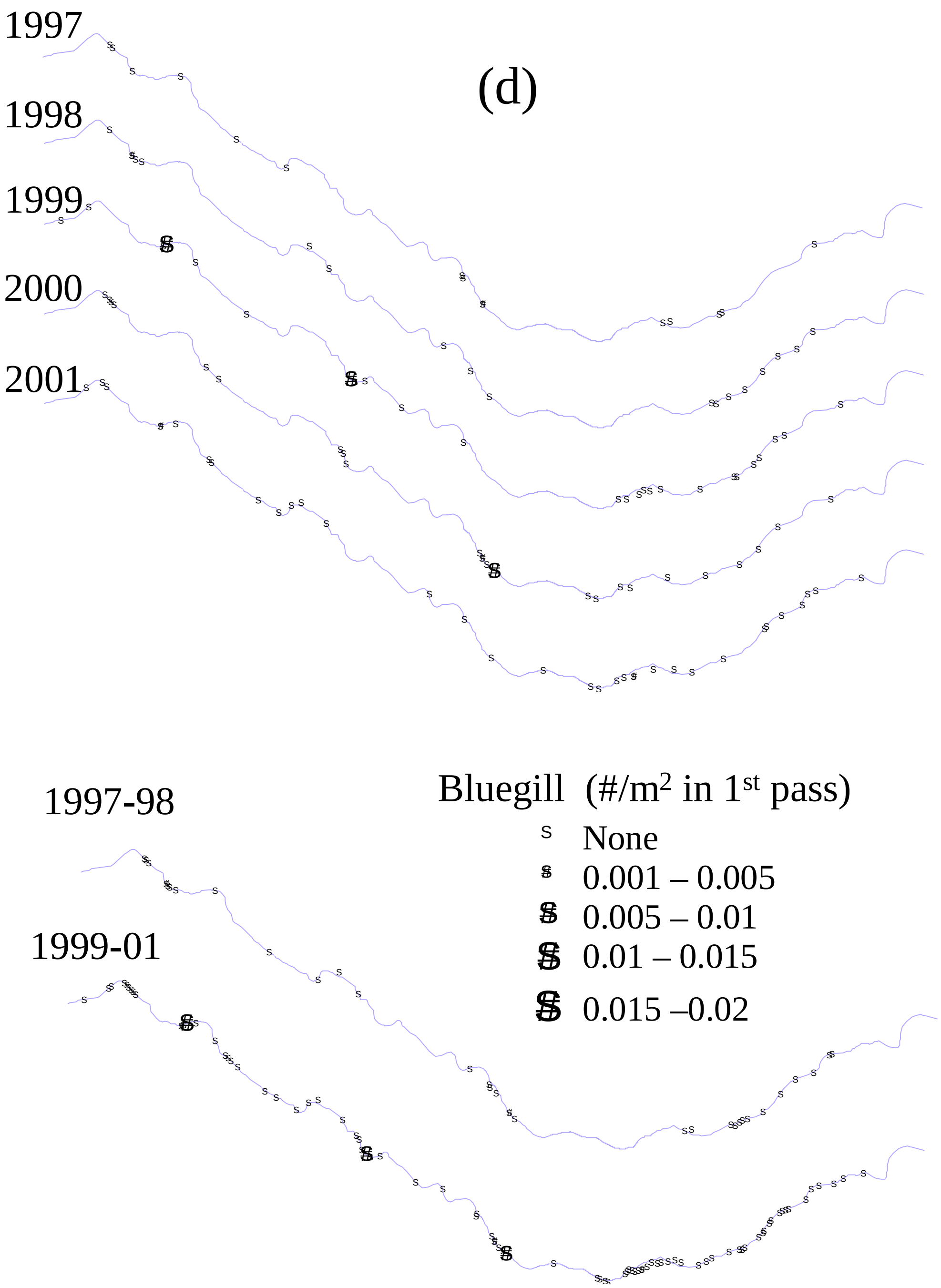

Figure 24 con't. Densities of selected nonnative fish sampled in riverine backwaters from 1997-2001, and also shown for combined years 1997-1998 and 1999-2001: a) largemouth bass; b) green sunfish; c) fathead minnow; d) bluegill; and e) black crappie.

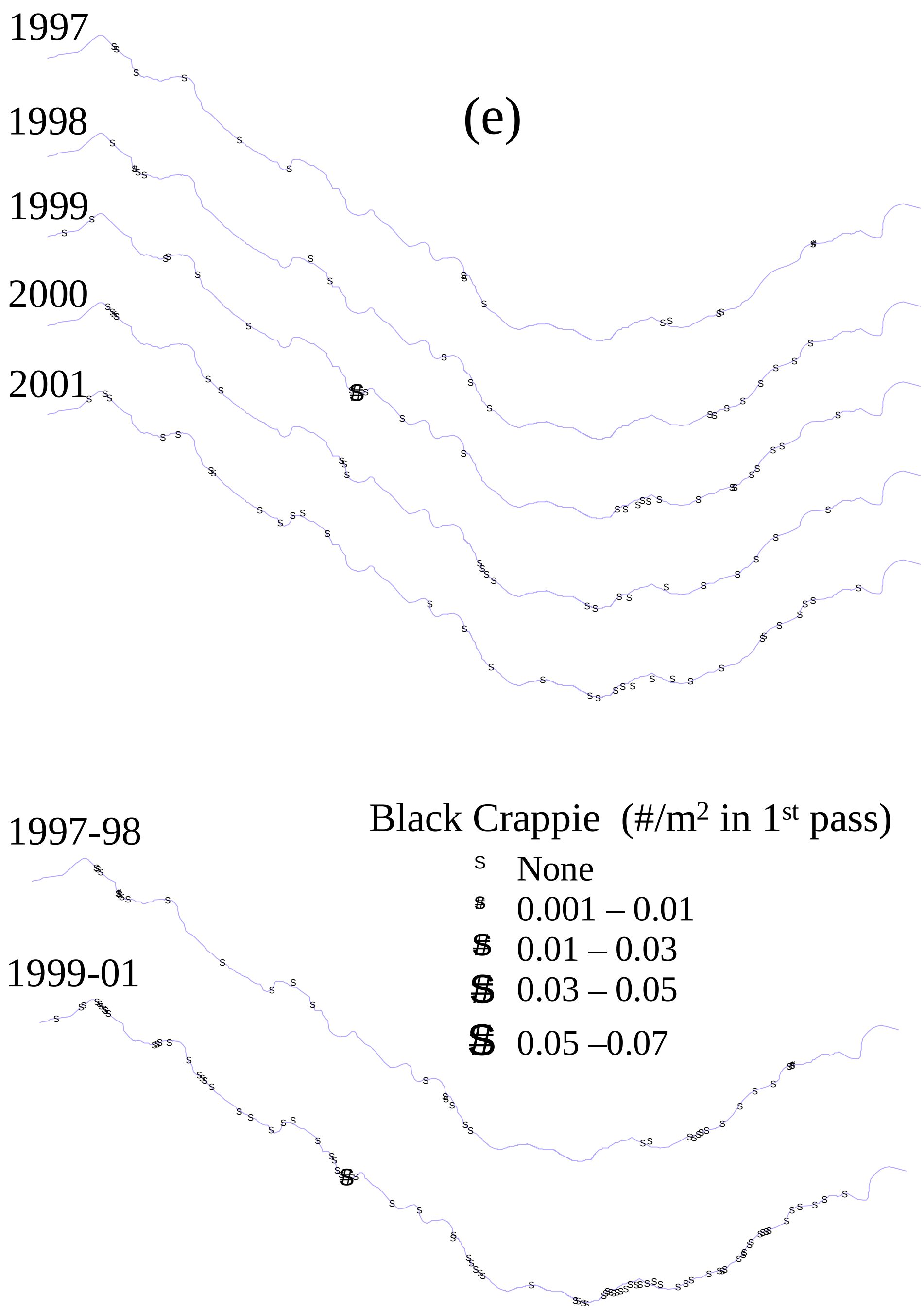

Figure 24 con't. Densities of selected nonnative fish sampled in riverine backwaters from 1997-2001, and also shown for combined years 1997-1998 and 1999-2001: a) largemouth bass; b) green sunfish; c) fathead minnow; d) bluegill; and e) black crappie.

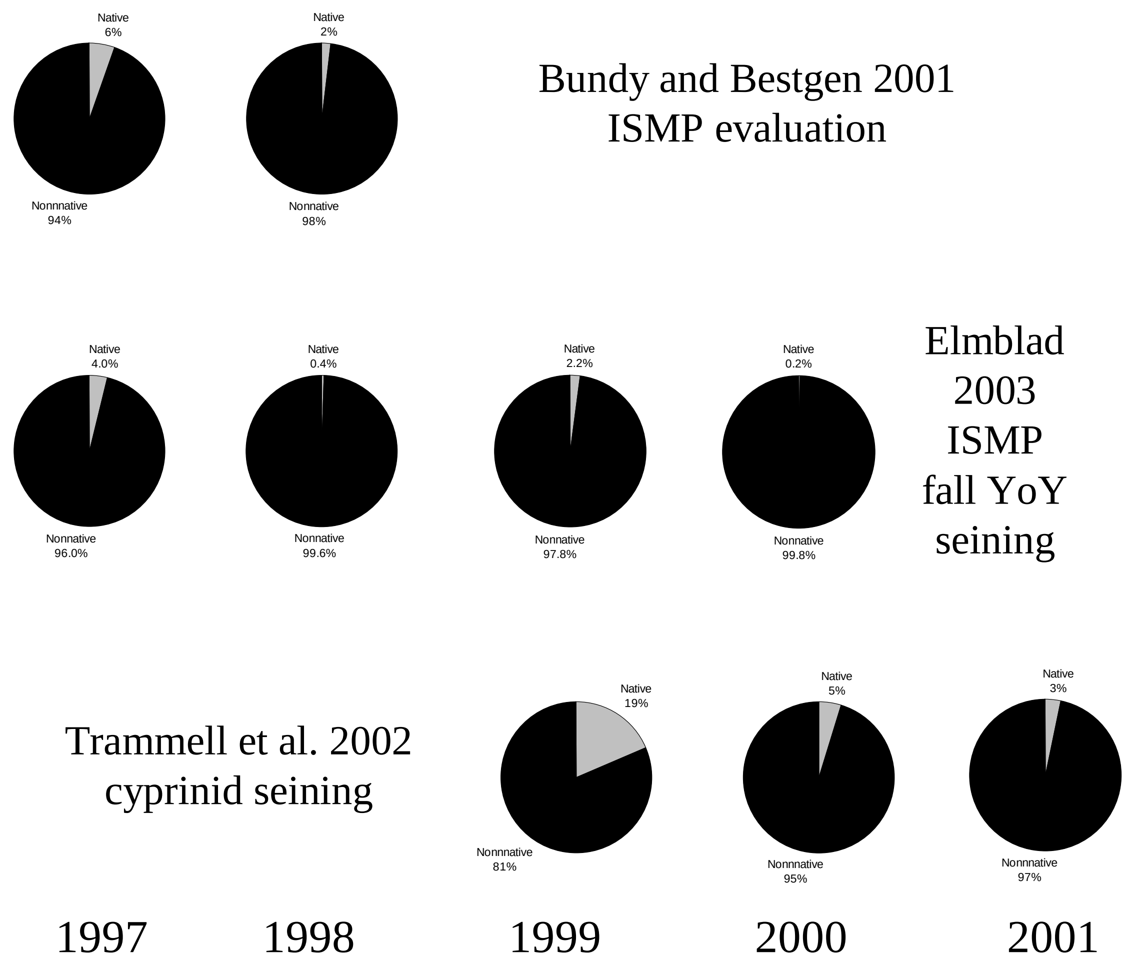

Figure 25. Proportion of native and nonnative fish species in riverine backwaters of the Grand Valley reach of the Colorado River between 1997 and 2001.

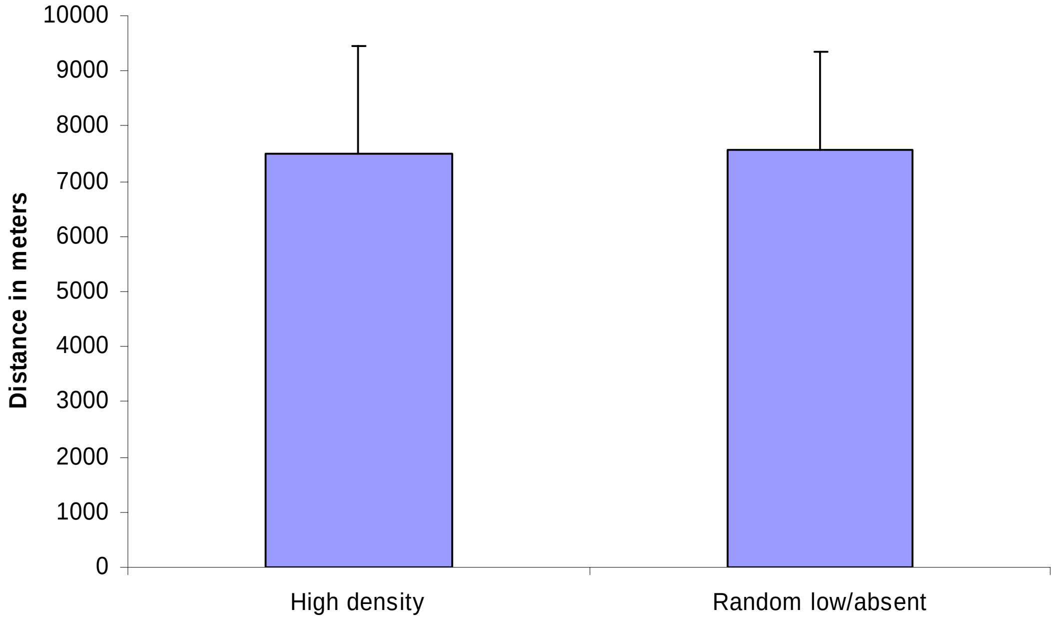

Figure 26. Proximity analysis relating high density backwater sites for largemouth bass to ponds stocked with largemouth bass. There is no difference between high density and random low or absent backwater locations vs. stocking sites. This analysis used backwater sampling data from Trammell et al. (2002). The error bars represent one standard error.

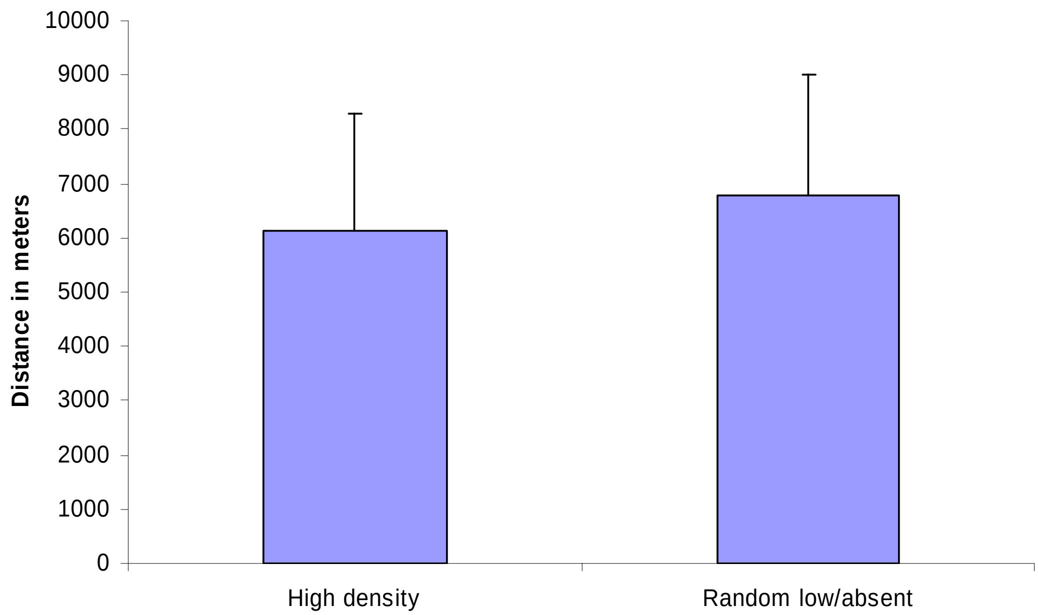

Figure 27. Proximity analysis relating high density backwater sites for largemouth bass to ponds that also had high densities of largemouth bass. There is no difference between high density and random low or absent backwater locations vs. pond sites. This analysis used backwater sampling data from Trammell et al. (2002). The error bars represent one standard error.

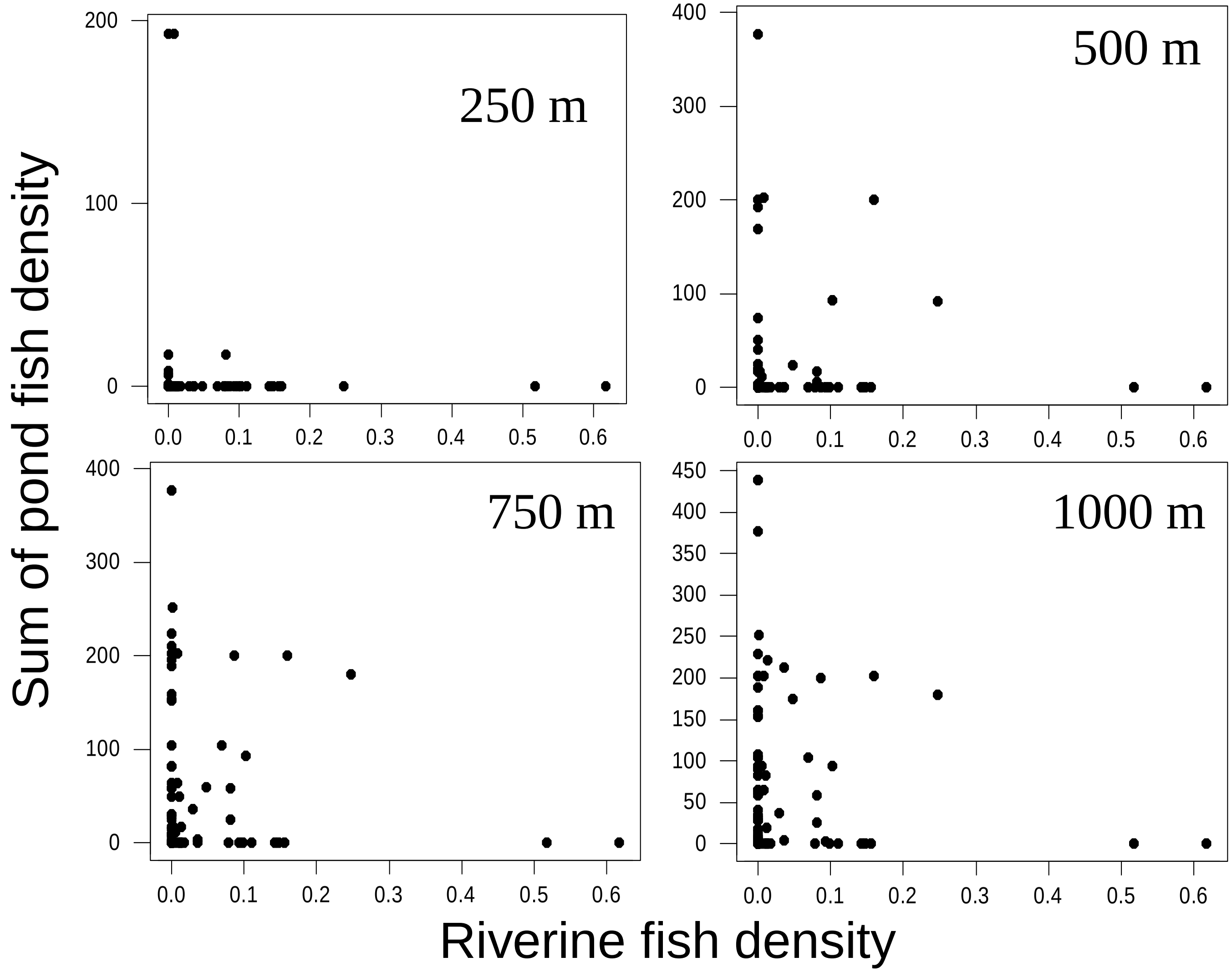

Figure 28. Scattergram results for green sunfish. There is no relationship between density in ponds and density in riverine sites at any of the distances indicated.

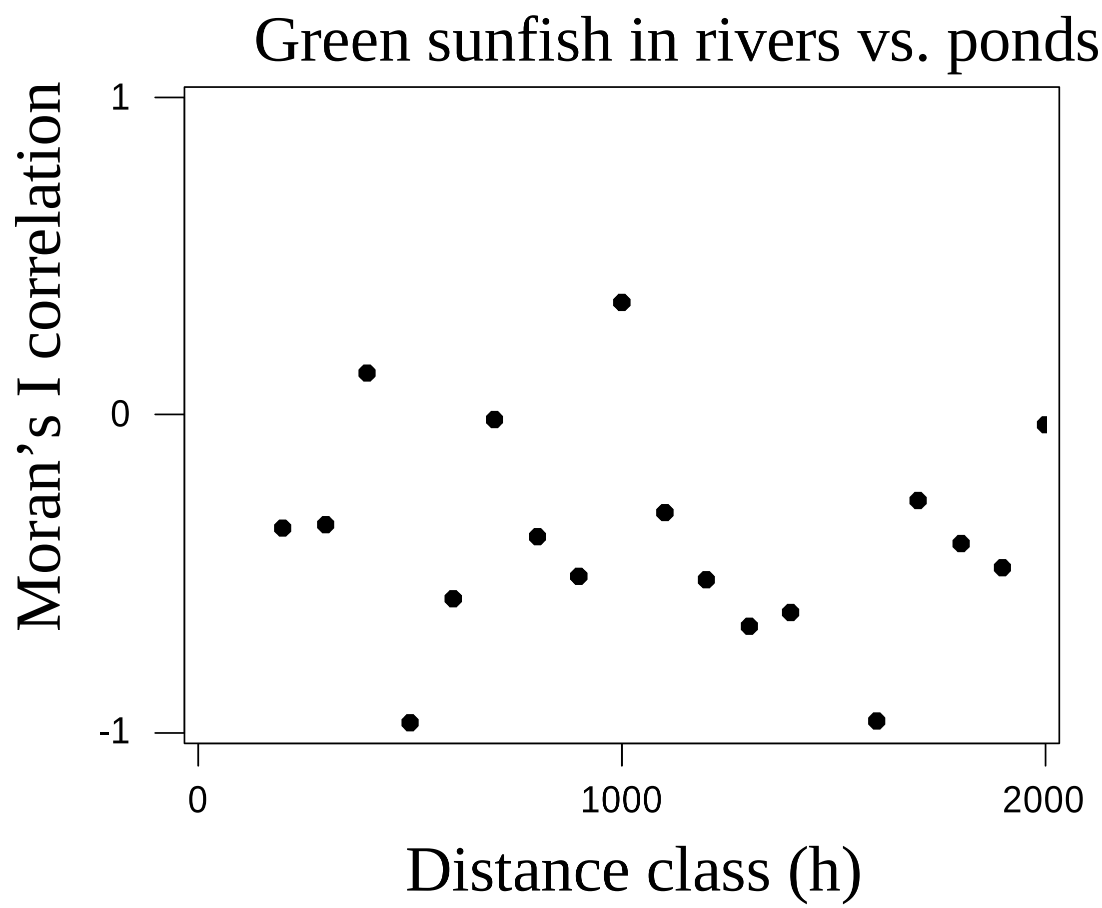

Figure 29. Cross-correlogram results for green sunfish. There is no discernable pattern of correlation between density in riverine sites and ponds based on distance between locations. Distance is in meters.

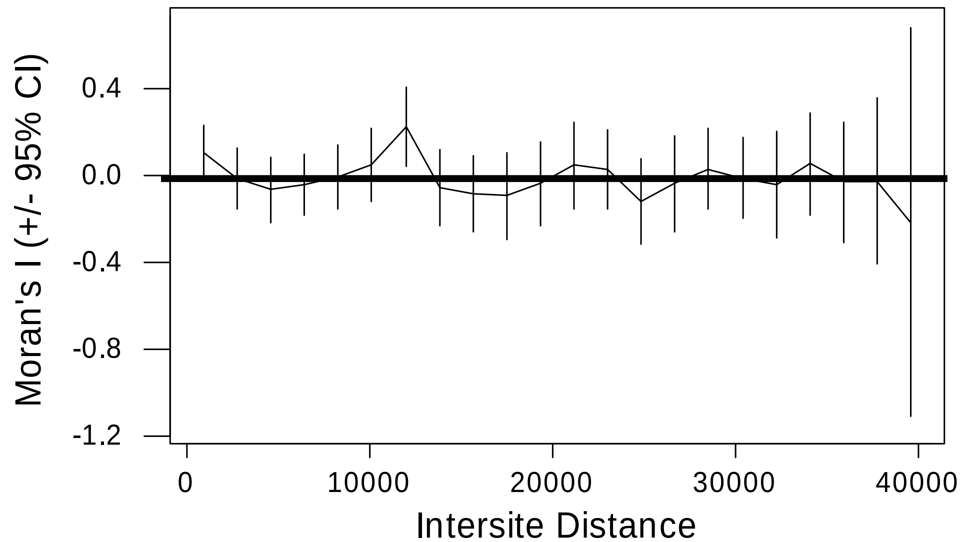

Figure 30. Correlogram results for green sunfish in riverine backwater locations. The correlogram indicates that there may be slight positive correlations between sites that are very close together and sites that are about 12,000 m apart.

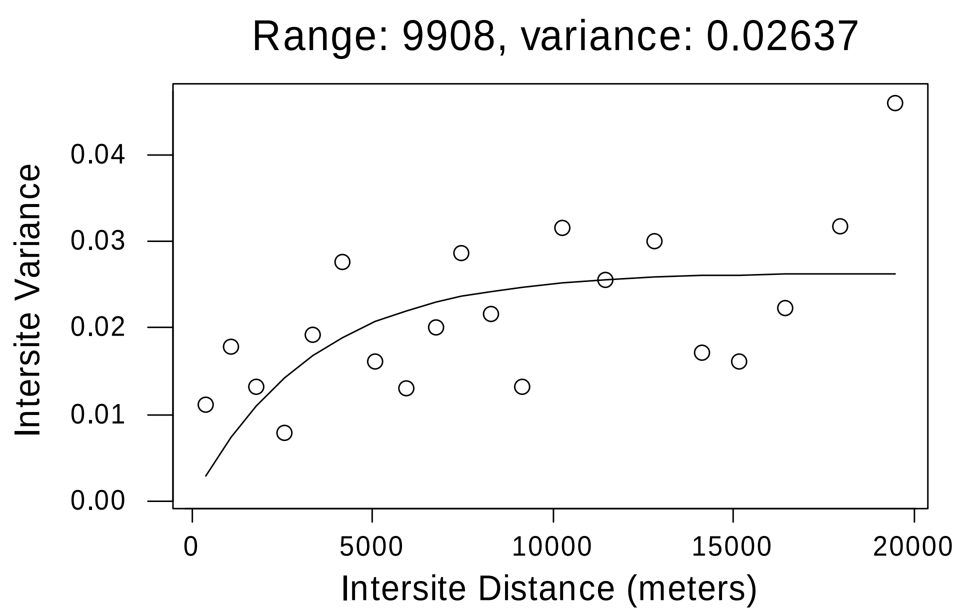

Figure 31. Semivariogram results for green sunfish densities of Trammell et al. (2002). The semivariogram confirms that sites are more similar when they are closer together and the range of correlation (after which density is independent of distance) is almost 10,000 m.

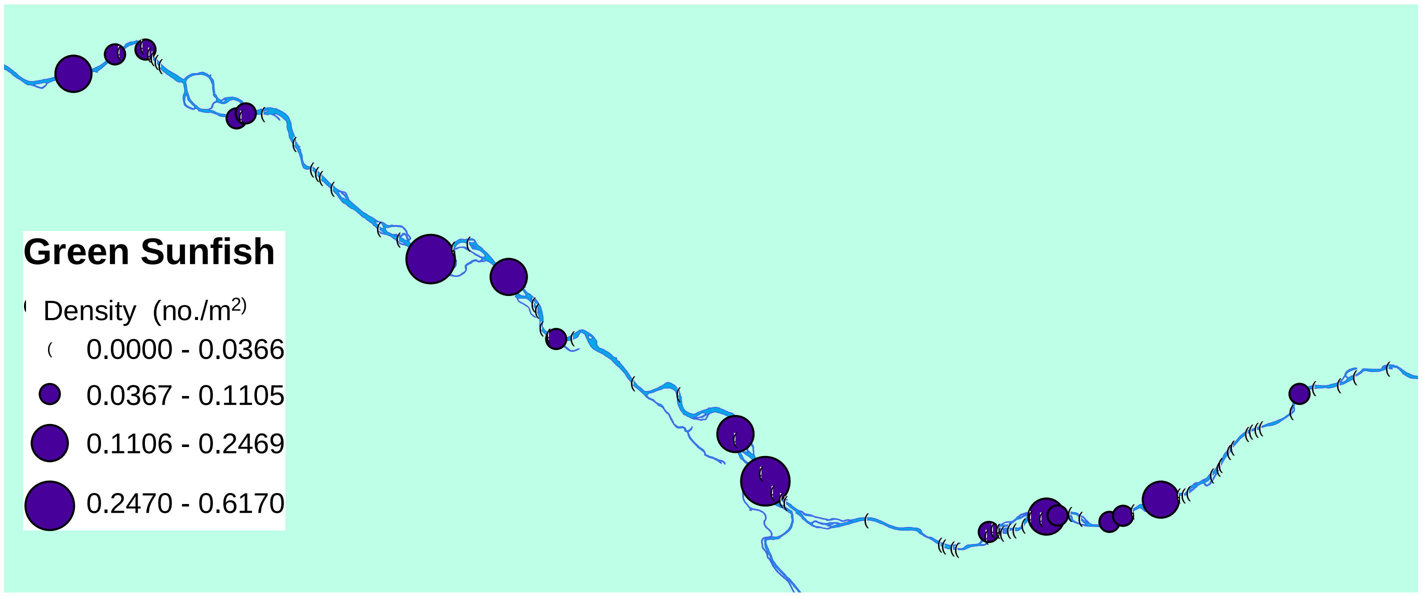

Figure 32. High density locations for green sunfish are 10-12 km apart, just greater than the "range" of spatial correlation indicated by the semivariogram model.

Appendix I. **Common and scientific names of fish species mentioned in this report including the Colorado Division of Wildlife's fish species code which is used in some of this report's tables and figures.**

Scientific Name	Common Name	Code
Family:Clupidae		
Dorsoma cepedianum	Gizzard Shad	GSD
Family:Salmonidae		
NA	Trout	TRT
Oncorhyncus clarki ssp	Cutthroat Trout	SNR
Oncorhyncus mykiss	Rainbow Trout	RBT
Salmo trutta	Brown Trout	LOC
Family:Esocidae		
Esox lucias	Northern Pike	NPK
Esox lucias x Esox masquinongy	Tiger Muskellunge	TGM
Family:Cyprinidae		
Carassius auratus	Goldfish	GDF
Carassius auratus	Koi Carp	GDF
Ctenopharyngodon idella	Grass Carp (triploid)	WHA
Ctenopharyngodon idella	Grass Carp (diploid)	TGC
Ctenopharyngodon idella X *Cyprinus* ssp.	Hybrid Grass Carp	HGC
Cyprinus carpio	Common Carp	CPP
Gila robusta	Roundtail Chub	RTC
N/A	Sucker Chub	None
Notemigonus crysoleucas	Golden Shiner	GSH
Notropis stramineus	Sand Shiner	SAH
Pimphales promelas	Fathead Minnow	FMW
Richardsonius belteatus	Redside Shiner	RSS
Semotilus atromaculatus	Creek Chub	CRC
Family:Catostomidae		
Catostomus catostomus	Longnose Sucker	LNS
Catostomus commersoni	White Sucker	WHS
Catostomus discobolus	Bluehead Sucker	BHS
Catostomus latipinnis	Flannelmouth Sucker	FMS
Family:Ictaluridae		
Ictaluris melas	Black Bullhead	BBH
Ictaluris nebulosus	Brown Bullhead	BRH
Ictaluris punctatus	Channel Catfish	CCF
Family:Cyprinodontidae		
Fundulus zebranus	Plains Killifish	PKF
Family:Poeciliidae		
Gambusia affinis	Western Mosquitofish	MSQ
Family:Percichyidae		
Morone chrysops	White Bass	WBA
Morone saxatillis	Striped Bass	SBS
Morone saxatillis X *Morone ssp.*	Hybrid Striped Bass	SXW
Morone saxatillis.	Striped Bass Fry	SBS
Family:Centrachidae		
Lepomis cyanellus	Green Sunfish	SNF

Lepomis macrochirus	Bluegill	BGL
Lepomis macrochirus X *Lepomis ssp.*	Bluegill Hybrid	HBG
Micropterus dolomieui	Smallmouth Bass	SMB
Micropterus salmoides	Largemouth Bass	LMB
N/A	Black Bass	None
Poxomis annularis	White Crappie	WCR
Poxomis nigromaculatus	Black Crappie	BCR
Family:Percidae		
Perca flavescens	Yellow Perch	YPE
Stizostedion canadense X *Stizostedion ssp.*	Saugeye	None
Stizostedion vitrium	Walleye	WAL
Misc.	Crayfish	CFI

Appendix II. **Summary of GIS layers used and developed as part of this study and CD #s for those layers and data sets that were archived for distribution upon request.**

Use of data layers in a GIS project

There are essentially three purposes for which spatial data layers are needed in any GIS project. The first is simply for visualization and/or orientation. Many layers are useful for simply understanding how things are oriented in space, and how they relate to each other. These layers are also often critical for making final maps as well. Some layers that often meet these criteria may be roads, streams, political boundaries, and cities. The second purpose for GIS layers is that of providing reference for finding specific locations, often for creating new data layers. For example, one may use a township, range, section layer to locate points where animals were observed. Or, one may use stream names and elevations to location fish sampling sites. Finally, the third purpose of a GIS layer is for displaying new data or performing analyses. Often these are layers that are created specifically for a specific project. In the case of this work, these are the fish sampling data, stocking data, floodzone data, and others identified below. The tables below identify the layers that were used for this project, and what purpose they served. Also, for created layers, a dataset name is given that matches the name of the ArcGIS shapefile (spatial data layer) stored on the project CD.

Base layers (available)

Data	Use	Source(s)
DEM – Digital Elevation Model National Elevation Dataset (NED) delineate 6500’ contour (bio-political boundary below which stocking regulations were imposed in 1999)	Visualization/ Reference	USGS
Roads - 1:100K and better aid in finding stocking locations	Visualization/ Reference	Tiger Lines Mesa County
State and County boundaries, Towns	Visualization/ Reference	ESRI
1:24K BLM digital quad maps (DRGs) aid in finding stocking locations aid georeferencing of aerial photos	Reference	USGS
Orthophoto quarter quads aid in locating waters aid in georeferencing aerial photos	Reference	CO BLM

Mesa County aerial photos location/digitization of waters	Reference	Mesa County GIS
USFWS aerial photos location/digitization of waters	Reference	USFWS (F. Pfeifer)
Topographic Index Map location of maps/photos	Reference	USGS
Hydrography - (Lakes and Streams, 1:100K) link to fish stocking and sampling data	Visualization/ Reference	CDOW GIS

Base layers (created)

Because hydrography was only available 1:100K when this project began, we immediately had to add to and improve aquatic features. High quality data for hydrographic features was essential for this project, in particular for the Intensive Study Area (ISA) because they were needed to identify stocking and sampling locations for nonnative fish species and their relationship to critical habitat and/or floodplain position. What follows is a list of GIS data layers that were created for this project, brief methods, and what their utility was.

River miles were needed to link to riverine fish data. We could not simply use GIS to calculate distances because a set of "standardized" river miles are used by the Recovery Implementation Program (RIP).

Flood plain designations were needed to evaluate where aquatic resources existed, and what species resided or were stocked in these areas.

Data	**Source(s)**	**Name of shapefile on CD**
1:24K River	Digitized from 1:24K quads (digital files)	CoGunRiver
River miles (tenths) – standardized as adopted by RIP (1987)	Digitized from 1:24K quads (paper maps)	RiverMiles
1:24K Floodplain designations	Digitized from 1:24K quads (CWCB paper maps)	Colo_Flood Gunn_Flood White_Flood Yamp_Flood
High Quality Pond Layers (ISA)	Topo maps (A. Martinez), Co_Lakes (CDOW GIS), digitized from aerial photos (USFWS, Mesa County)	ISA_Ponds

Ponds, lakes and reservoir database	Multiple sources	co_lakes3

Fish data layers (created)

All of the fish data (stocking and sampled in ponds, backwaters, and rivers) had to be spatially referenced and made into a GIS layer to facilitate mapping and spatial pattern analyses. What follows is a list of these layers, source information, and name of the shapefile on the project CD.

Data	**Source(s)**	**Name of shapefile on CD**
Private nonnative stocking	Vendor Records Stocking Permits (Martin)	Stock_All
CDOW stocking	Area Fishery Biologists	DOW_Stock
Private lake licenses	Konishi	Priv_Lic
Commercial lake licenses	Konishi	Comm_Lic
Pond fish data	Martinez (2004)	Pond_Fish
Backwater fish data	Trammel et al. (2002) Bundy & Bestgen (2001) Osmundson (2003)	Tram_Fish Best_Fish Osmd_Fish

Appendix III. **Number of instances of permitted stocking, importation, lake licenses (commercial – "C" and private – "P") and vendor records for nonnative, nonsalmonid fish species stocked west of the Continental Divide in Colorado in 1998, 1999, 2000, and 2001. "Statewide" indicates that the destination(s) of the fish were listed on the permit/report as "statewide" and therefore actual locations are unknown. "Inadequate" indicates that a location was determined to be on the west slope, but could not be pin-pointed to within at least one square mile accuracy with the information given. If the record did have enough information to establish a location, it is listed as "W/in square mile". The "W/in square mile" indicates that we were provided with a geographic coordinate, address, township, range, section, or other designation that allowed us to establish a stocking location within one square mile of the actual location.**

1998			Destination		
		Species	Non-Spatial		Spatial
Records	Species	Code	Statewide	Inadequate	W/in square mile
Importation	BLACK BASS		1		
	BLACK BULLHEAD	BBH	1		
	BLACK CRAPPIE	BCR	11		
	BLUEGILL	BGL	14		
	BROWN BULLHEAD		1		
	CHANNEL CATFISH	CCF	17		
	CRAYFISH		1		
	CREEK CHUB		1		
	DIPLOID GRASS CARP		4		
	FATHEAD MINNOW	FMW	14		
	GIZZARD SHAD		1		
	GOLDEN SHINER		2		
	GOLDFISH		2		
	GREEN SUNFISH	SNF	1		
	HYBRID STRIPED BASS		6		
	KOI CARP		3		
	LARGEMOUTH BASS	LMB	15		
	MOSQUITOFISH	MSQ	3		
	NORTHERN PIKE	NPK	2		
	SMALLMOUTH BASS	SMB	9		
	STRIPED BASS		3		
	TRIPLOID GRASS CARP	TGC	9		
	WALLEYE	WAL	7		
	WHITE BASS		1		
	WHITE CRAPPIE		1		
	WHITE SUCKER	WHS	1		
	YELLOW PERCH	YPE	6		
Lake Licenses-C	CHANNEL CATFISH	CCF			1
Lake Licenses-P	BLACK CRAPPIE	BCR			1

	LARGEMOUTH BASS	LMB			1
Stocking Permits	No information				
Vendor Records	BLUEGILL	BGL			2
	CHANNEL CATFISH	CCF			3
	FATHEAD MINNOW	FMW		8	2
	WHITE SUCKER	WHS		9	1
	TRIPLOID GRASS CARP	TGC		48	
TOTALS	**ALL SPECIES**		**138**	**65**	**11**
1999			**Destination**		
		Species	**Non-Spatial**		**Spatial**
Records	**Species**	**Code**	**Statewide**	**Inadequate**	**W/in square mile**
Importation	BLACK BASS		1		
	BLACK BULLHEAD	BBH	1		
	BLACK CRAPPIE	BCR	12		
	BLUEGILL	BGL	16		
	CHANNEL CATFISH	CCF	19		
	CRAYFISH		2		
	CREEK CHUB		2		
	DIPLOID GRASS CARP		1		
	FATHEAD MINNOW	FMW	18		
	GIZZARD SHAD		2		
	GOLDEN SHINER		2		
	GOLDFISH		4		
	GREEN SUNFISH	SNF	2		
	HYBRID BLUEGILL		2		
	HYBRID STRIPED BASS		9		
	KOI CARP		4		
	LARGEMOUTH BASS	LMB	14		
	MOSQUITOFISH	MSQ	3		
	NORTHERN PIKE	NPK	3		
	SAUGEYE		1		
	SMALLMOUTH BASS	SMB	8		
	STRIPED BASS		4		
	SUCKER CHUB		1		
	TIGER MUSKELLUNGE	TGM	1		
	TRIPLOID GRASS CARP	TGC	19		
	WALLEYE	WAL	11		
	WHITE BASS		1		
	WHITE SUCKER	WHS	2		
	YELLOW PERCH	YPE	6		
Lake Licenses-C	CHANNEL CATFISH	CCF			1
	LARGEMOUTH BASS	LMB			1
Lake Licenses-P	LARGEMOUTH BASS	LMB			1
Stocking Permits	BLACK CRAPPIE	BCR			2
	BLUEGILL	BGL			1
	CHANNEL CATFISH	CCF			1
	FATHEAD MINNOW	FMW			2
	LARGEMOUTH BASS	LMB			5

	TRIPLOID GRASS CARP	TGC			2
Vendor Records	BLUEGILL	BGL			3
	FATHEAD MINNOW	FMW		14	3
	LARGEMOUTH BASS	LMB			3
	WHITE SUCKER	WHS		8	
	TRIPLOID GRASS CARP	TGC		24	
TOTALS	**ALL SPECIES**		**171**	**46**	**25**
2000			**Destination**		
		Species	**Non-Spatial**		**Spatial**
Records	**Species**	**Code**	**Statewide**	**Inadequate**	**W/in square mile**
Importation	BLACK BULLHEAD	BBH	1		
	BLACK CRAPPIE	BCR	10	1	
	BLUEGILL	BGL	10		
	CHANNEL CATFISH	CCF	14	1	
	FATHEAD MINNOW	FMW	13	1	
	GOLDEN SHINER		1		
	HYBRID BLUEGILL		2		
	HYBRID STRIPED BASS		4		
	KOI CARP		2		
	LARGEMOUTH BASS	LMB	12	1	
	MOSQUITOFISH	MSQ	3		
	SAUGEYE			1	
	SMALLMOUTH BASS	SMB	5		
	TIGER MUSKELLUNGE	TGM	1		
	TRIPLOID GRASS CARP	TGC	9		
	WALLEYE	WAL	6		
	WHITE SUCKER	WHS	1		
	YELLOW PERCH	YPE	6	1	
Lake Licenses-C	BLACK CRAPPIE	BCR		1	
	BLUGILL	BGL		1	
	CHANNEL CATFISH	CCF		1	
	FATHEAD MINNOW	FMW		1	
	LARGEMOUTH BASS	LMB		1	
	TIRPLOID GRASS CARP	TGC		1	
Lake Licenses-P	BLACK CRAPPIE	BCR			3
	BLUEGILL	BGL			4
	CHANNEL CATFISH	CCF			1
	FATHEAD MINNOW	FMW			8
	LARGEMOUTH BASS	LMB			5
	TRIPLOID GRASS CARP	TGC			9
Stocking Permits	BLACK CRAPPIE	BCR		1	4
	BLUEGILL	BGL		3	4
	CHANNEL CATFISH	CCF		1	6
		CFI			1
	FATHEAD MINNOW	FMW		6	14
	LARGEMOUTH BASS	LMB		4	5
	SAMLLMOUTH BASS	SMB		1	
	TRIPLOID GRASS CARP	TGC		13	32

Vendor Records	BLUEGILL	BGL			4
	CHANNEL CATFISH	CCF			1
	FATHEAD MINNOW	FMW		1	4
	LARGEMOUTH BASS	LMB		1	3
	WHITE SUCKER	WHS		2	4
	TRIPLOID GRASS CARP	TGC		50	
TOTALS	**ALL SPECIES**		**100**	**96**	**112**

2001			**Destination**		
		Species	**Non-Spatial**		**Spatial**
Records	**Species**	**Code**	**Statewide**	**Inadequate**	**W/in square mile**
Importation	No information				
Lake Licenses-C	BLACK CRAPPIE	BCR		1	
	BLUGILL	BGL		1	
	CHANNEL CATFISH	CCF		1	
	FATHEAD MINNOW	FMW		1	
	LARGEMOUTH BASS	LMB		1	
	TIRPLOID GRASS CARP	TGC		1	
Lake Licenses-P	BLUEGILL	BGL			2
	CHANNEL CATFISH	CCF			3
	FATHEAD MINNOW	FMW			2
	LARGEMOUTH BASS	LMB			2
	MOSQUITOFISH	MSQ		1	
	SMALLMOUTH BASS	SMB			1
	TRIPLOID GRASS CARP	TGC			4
Stocking Permits	BLACK CRAPPIE	BCR			1
	BLUEGILL	BGL		4	4
	CHANNEL CATFISH	CCF			2
	FATHEAD MINNOW	FMW		7	6
		GDF		1	
	LARGEMOUTH BASS	LMB		6	5
	GREEN SUNFISH	SNF			1
	TRIPLOID GRASS CARP	TGC		19	57
Vendor Records	No information				
TOTALS	**ALL SPECIES**		**0**	**44**	**90**