# Historical perspective on the Great Plains fish assemblage

## Introduction

The fish experts described possible biological conditions that might characterize BCG level 1 streams and rivers. The consensus was that level 1 conditions were not currently observable. Landscape changes that include ubiquitous agricultural landscape modifications, resulting and purposeful hydrologic alterations (e.g., low-head dams and artificial ponds [Smith et al. 2002]), climate change effects, atmospheric deposition of pollutants, and urban sprawl. With these anthropogenic alterations of the landscape, it is certain that large natural areas no longer exist in the study area and it is probable that small natural areas are altered due to isolation effects (ecological islands and stream fragmentation [Perkin et al. 2010]).

As a first step in the conceptual description of BCG level 1, the fundamental characteristics of the natural landscape and processes were discussed with both fish and macroinvertebrate experts. The fundamental characteristics were described for the following categories: stream channel, riparian & watershed, hydrologic regime, disturbance regime and resilience, biodiversity, and ecosystem function Appendix \_\_). Through this discussion, it was determined that streams and rivers of the Great Plains are unique in some respects and that the unique aspects warrant recognition in the EPA level 1 narrative.

One overarching concept about the natural BCG level 1 description was that the original EPA narrative was based on a standard of eastern forested landscapes with cool oxygenated streams. Landscapes in the Great Plains are essentially different in topography, soils, geology, climate, native vegetation, and biological composition. For example, streams running through natural grasslands might be flatter and warmer compared to eastern forested streams. Low relief topography and herbaceous riparian vegetation in the plains might be associated with naturally slow velocity, unshaded streams with fine substrates. Natural grasslands are uncommon in the modern Great Plains landscape.

## Historical conditions

The Great Plains landscape has been manipulated to convert tall-grass prairie into agricultural and urban land uses. This conversion began with pioneer settlement in the mid-1800’s and had substantial effects on hydrology and stream characteristics (Wilton 2004, Smith et al. 2014). For smaller streams, the landscape conversion and associated erosion caused cool, deep, and clear streams to become warm, widened, and turbid, with reduced connectivity to wetlands. Longitudinal connectivity was reduced through installations of numerous low-head dams before 1900 (Menzel 1981). The historical landscape was diverse, in that the larger rivers were warm and turbid before intensive agriculture, at least at some times (Matthews 1988).

## Stressor tolerance of fish and macroinvertebrates

Fish diversity in the Great Plains is impressive now and was probably more impressive in the past. Menzel (1981) estimated that there were 139 native fishes in Iowa, though at least 12 species are extirpated. This high diversity might be attributed to the high diversity of stream conditions with many different habitat niches. As noted, steams were historically and naturally cool, deep, and clear and rivers were warm, broad, and turbid. Fish ranges have reduced or expanded depending on the changes in suitable habitat for each species.

From the forested northeast perspective, streams that are warm, slow, and sedimented would be considered stressed and fish suited to those habitat features could indicate habitat degradation. In the Great Plains, however, not only might such habitat conditions be natural now, but the resident fishes might be naturally suited to those conditions. This alignment of fishes and the habitats of the Great Plains streams and rivers confound the assumption that fish samples can indicate habitat degradation. Stream warming, widening, and siltation might be detectable in the resident fish assemblage, but it is not certain that the habitat conditions are due to landscape alteration.

The anthropogenic stressors used in the stressor tolerance analysis included five disturbance variables: the chemistry component of the Index of Watershed Integrity (WCHEM) (Thornbrugh et al. 2018, Johnson et al. 2019), percent row crop (two spatial scales), soil erodibility (Kf) factor of soils on agricultural land, and percent urban land use. Because these stressors might cause only minor additive effects to the naturally harsh conditions, there were many fish that were relatively unresponsive to the anthropogenic stressors and were assigned BCG attributes indicating moderate tolerance (attribute IV) (see the tolerance analysis). Native taxa are somewhat tolerant of the naturally harsh conditions and could occur in both stressed and least disturbed streams.

## Shifting Baselines

Experts noted that fish samples from the Iowan Surface (ecoregion 47c) were especially diverse. This ecoregion was recognized as supporting a somewhat unique fish community by the Iowa Department of Natural Resources (Wilton 2004). Some experts were inclined to assign diverse samples to BCG level 2. In the expert panel discussions, some experts also noted that the loss of taxa was probably greater than could be observed in the modern data record. Menzel (1981) estimated that one quarter of the native Iowa fish species were extirpated or in decline at the time of his publication (Table 1). Therefore, some experts were inclined to assign BCG levels reflecting greater departure from natural conditions (level 3) even for the most diverse samples. This difference in perspective on natural diversity due to perceptions of current and historical natural biological potential can be described using the concept of shifting baselines (Pauly 1995). Because of uncertainty in the unobservable potential, shifting baselines are also uncertain, and we can only caution that recent historical natural conditions might not represent pre-settlement natural conditions.

## Fish taxa in decline

A list of endangered and threatened native fish species in Iowa was compiled by the State Preserves Board (Roosa 1977) and approved by the Iowa Conservation Commission (Menzel 1981). According to that 20th century compilation, 34 species were regarded as either extirpated or of undetermined status, which was nearly one-quarter of all native Iowa fishes in the historical records. Of these, 19 are fishes that primarily inhabit interior waters, and at least 4 other inland species seem to merit special concern (Table l). At least a dozen indigenous Upper Mississippi River fishes have substantially declined during the historical period, several to the point of local extirpation. Cross and Moss (1987) reported that the small stream fish community in Kansas declined in complexity in the last quarter of the 19th century and further declines occurred in 1950 – 1980.

Table 1. *Threatened, endangered, extirpated, and depleted fishes of the interior waters of Iowa.* (Menzel 1981)

*Species* Iowa Status Neighboring State Lists

Interior Waters

American brook lamprey Threatened MN, MO

Grass pickerel Threatened

Redside dace Extirpated, NC

Lake chub Endangered, NC IL

Gravel chub Threatened

Pugnose shiner Threatened IL, MN, WI

Ironcolor shiner Extirpated, NC IL

Blackchin shiner depleted, NC IL

Blacknose shiner Endangered IL, MO

Redfin shiner depleted

Topeka shiner Threatened

Ozark minnow depleted WI

Largescale stoneroller depleted

Pearl dace Endangered NE, SD

Lake chubsucker Extirpated, NC MN, MO

River redhorse Extirpated, NC IL, WI

Black redhorse Endangered MN

Starhead topminnow Endangered, NC WI

Plains topminnow Endangered, NC MO, SD

Longear sunfish Endangered, NC WI

Least darter Endangered MN

Orange throat darter Endangered

Gilt darter Extirpated, NC IL,Wl

*Mississippi River*

Chestnut lamprey Threatened

Alabama shad Extirpated, NC IL, MO

Skipjack herring Threatened MN

Pallid shiner depleted IL, MO, WI

Pugnose minnow Undetermined MO

Weed shiner Threatened IL, WI

Pirate perch Undetermined

Crystal darter Undetermined, NC IL, WI

Western sand darter Threatened IL

Mud darter Threatened WI

Bluntnose darter Threatened WI

*Missouri River*

Pallid sturgeon Endangered, NC IL, MO, NE, SD

Sturgeon chub Extirpated, NC MO, SD

Sicklefin chub Endangered, NC IL, MO, SD

Silverband shiner Endangered, NC

*Both Rivers*

Lake sturgeon Endangered IL, MN, MO, NE

Blue sucker depleted MI, WI

depleted = not included on Iowa endangered fishes list but meriting special concern

NC = not collected in Iowa for at least 25 years as of 1981

In Nebraska, losses of native fish species occurred at the same time as increases in introduced species (Smith et al. 2014) (Table 2). Shifts were associated with high levels of human perturbation. Fish taxa groups with the greatest change (all increases) from historical (1939–1940) to modern (2003–2005) surveys included nonnative fishes, piscivores, sport fishes, and lithophilic spawning species. Gido et al. (2004) noted that species invasions in Kansas and Oklahoma were associated with urban populations.

Table 2.—Extirpation and addition of species from a taxonomic assessment of historical (1939–1940) and modern (2003–2005) surveys in Nebraska streams (Smith et al. 2014). Numbers indicate the number of sites where the species was present.

Species Historical sampling Modern sampling

(1939–1940) (2003–2005)

Extirpations

Goldfish Carassius auratus e\* 1 0

Common shiner Luxilus cornutus n\* 4 0

Sturgeon chub Macrhybopsis gelida n\* 5 0

Topeka shiner Notropis topeka n\* 2 0

Mountain sucker Catostomus platyrhynchus n\* 1 0

Bigmouth buffalo Ictiobus cyprinellus n\* 3 0

Burbot Lota lota n\* 1 0

Sauger Sander canadensis n\* 2 0

Additions

Pallid sturgeon Scaphirhynchus albus n\* 0 2

Longnose gar Lepisosteus osseus n\* 0 11

Gizzard shad Dorosoma cepedianum n\* 0 16

Grass carp Ctenopharyngodon Idella e\* 0 3

Spotfin shiner Cyprinella spiloptera e\* 0 1

Blue catfish Ictalurus furcatus n\* 0 1

Northern pike Esox Lucius e\* 0 7

Brook silverside Labidesthes sicculus n\* 0 2

Western mosquitofish Gambusia affinis e 0 23

Freshwater drum Aplodinotus grunniens n 0 21

n = native

e = non-native

\* = species that were considered rare (i.e., found at <5% of the sites)

# Conceptual Narrative Level 1 Fish Assemblage Characteristics

After assigning fish attributes and rating several samples, the experts were prompted to describe biological characteristics of a Level 1 fish assemblage. A general narrative to describe Level 1 Biodiversity was crafted during the December 2022 workshop, with input from both fish and macroinvertebrate experts. The descriptions are elaborations of the standard narrative definition stated in U.S. EPA documents (U.S. EPA 2016).

***Workshop Narrative: Level 1 Biodiversity***

*Moderate to high taxa richness characterized by a high number of intolerant species. A diverse mixture of organisms that satisfy various niches and allow for balance within the aquatic environment. Native species are dominant and invasive species are not present. Diversity of instream habitat and depth/flow regime supports abundant niches, which leads to moderate to high fish and macroinvertebrate taxa richness. Aquatic community includes taxa groups tolerant of episodic harsh but naturally occurring conditions (e.g. low flows, high temperatures, low dissolved oxygen), but which are sensitive anthropogenic changes.*

***EPA BCG Framework standard narrative definition of*** ***Level 1, Natural or native condition****—Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability. Level 1 represents biological conditions as they existed (or still exist) in the absence of measurable effects of anthropogenic stressors and provides the basis for comparison to the next five levels. The level 1 biological assemblages that occur in a given biogeophysical setting are the result of adaptive evolutionary processes and biogeography. For this reason, the expected level 1 assemblage of a stream from the arid southwest will be very different from that of a stream in the northern temperate forest. The maintenance of native species populations and the expected natural diversity of species are essential for levels 1 and 2. Non-native taxa (attribute VI) might be present in level 1 if they cause no displacement of native taxa, although the practical uncertainties of this provision are acknowledged. Attributes I and II (i.e., historically documented and highly sensitive taxa respectively) may be useful to help assess the status of native taxa when classifying a site or assessing its condition.*

There were no observable samples identified as Level 1. A set of basic narrative rules were discussed, but no numeric thresholds were proposed. The discussions of level 1 characteristics addressed assemblage characteristics related to taxa richness, non-native fish occurrence, intolerant taxa, and balance of taxa. The overarching description was that the assemblage should be ‘as naturally occurs’. There were discussions about extrapolation of metric patterns seen in Levels 2-6, but these were only theoretical. There should be a logical flow in comparison to Level 2 – such that Level 1 is even more aligned with expectations for natural biological integrity.

**Taxa Richness**

Level 1 is expected to have moderate to high taxa richness, including a variety of families and diversity of species within most families.

**Non-Native Fish Occurrence**

Native fish should predominate at Level I sites. Non-natives should not include invasive exotic species that could displace native taxa. Local biologists with knowledge of native fish taxa would be able to recognize non-native dominance.

The native status of fish is not always clear. For example, undocumented historical introductions (gamefish or baitfish) that have naturalized might appear to be native. Documented native ranges are not always known or might be disputed among experts. Ranges can naturally expand and contract with no or minimal effect on biological integrity.

**Intolerant Taxa**

Attribute I and II taxa are not always expected to occur. In some cases, these taxa will not thrive in naturally harsh environments that can occur in the Great Plains. While Attribute I and II taxa are not expected to occur, the site should be evaluated as a candidate for Level 1 status when they do occur. Attribute III intolerant taxa should occur with abundances that suggest thriving populations in Level 1 sites.

**Balance of Taxa**

A Level 1 assemblage should not be dominated by one or few taxa or taxonomic types. The Shannon-Wiener diversity index is one way of numerically describing the evenness of individuals among taxa. In general, there should be a mix of taxa and taxa groups within a sample. Representation by diverse groups of families, species within families, trophic guilds, reproductive groups, and habitat specialists is also expected in Level 1.

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# Appendix \_\_.

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| **Fundamental Characteristics** | **Description - From Workshop discussion** |
| **Stream channel** | From workshop summary:  **A diverse mixture of riffles, runs (glides), and/or pools that meander along a highly sinuous channel with increased heterogeneity of habitat such as wood and streamside vegetation with diverse bottom substrates that allow for a wide range of organisms. Water with low turbidity at base flow and moderate turbidities up to bank full conditions.** Highly sinuous, sometimes braided low-gradient stream channel with secondary high flow channels and oxbows formed from abandoned meanders. Oxbows in varying stages of evolving toward wetland/terrestrial habitat, depending on when they were cut off from the main channel. Meandering channels with instream sedimentation predominantly limited to pools. Beaver ponds occurring in frequent intervals in smaller wadeable streams. Gentle to moderately sloping banks with overhanging vegetation and root mats present from trees and vegetative roots. (Add in spring fed segments?) From Don Huggins:  Particularly in the WCBP and CIP, streams geomorphology is characterized by a diverse mixture of riffles, runs (glides), and pools that are sinuous and meander within floodplain environment with increased habitat heterogeneity from wood and streamside vegetation. Bottom substrates of pool/riffle sequence streams are typically diverse where channels flow through regions where surface and subsurface geology provides a gradient of inorganic particle sizes. These diverse bottom substrates occur in an un-embedded matrix that supports a wide range of organisms. Consistent and perhaps higher base flows are common to all streams and rivers within all study ecoregions. Water with low turbidity ... Larger Low-gradient stream and river channels often have secondary high flow channels and oxbows formed from cutoff meanders. Oxbows ... Streams and rivers in the CGP are broad with banks, modest to low sinuosity, and often braided channel flows with vegetated islands. Eastern streams tend to have higher sinuosity values with instream sedimentation predominantly limited to pools. Beaver ponds occurring in frequent intervals in smaller wadeable streams. Gentle ... Large woody debris and log jams were frequent and persistent features of most eastern streams that were resistant to movement during bank flow events. |
| **Riparian & watershed** | From workshop summary:  **A diverse mixture of canopy, understory, and groundcover that allow for temperature control of the stream and provide inputs of instream habitat and food sources for the aquatic organisms**. **Riparian corridor may consist of prairie grasses or trees, or a mix, which allow for the formation of undercut banks. During pre-settlement conditions, woody vegetation in the riparian corridor may have been sparse, tending toward tallgrass prairie species on stream banks, depending on fire interval.** Large woody debris firmly anchored in the benthic substrate and not subject to movement during high flow events. The watershed is free from anthropogenic stressors created by unfavorable land uses. Watersheds consisting of large swaths of unbroken prairie, with trees occurring mostly in valleys or in steep terrain inaccessible to most fires.From Don Huggins:  Riparian areas or ecotones consists of woody forest patches interspersed with grasslands composed of a mixture of prairie wet meadow species. A mixture of native woody canopy and understory species provided for some temperature control of the stream and a source of instream habitat materials. For the most part, woody riparian areas are primarily absent from intermittent stream swales and shallow channels, especially in the drier western and southern regions of CIP and CGP. . Woody riparian patches or segments vary in length, width, and interspersion distances due in part to undefined micro-environment conditions and external forces such as fire. Allochthonous organic inputs are derived from both woody and non-woody riparian patches. A quality watershed that is free from non-native biota and anthropogenic stressors created by unfavorable land uses. Upland woody vegetation was sparse and savannah-like within the WCBP and CIP but were virtually absent in the CGP. Woody riparian segments and patches became less frequent in occurrence and size from east to west being replaced by midgrass and tallgrass prairie species along stream banks. depending on fire, Indian wood harvests and winter bison foraging on cottonwood bark and saplings.. Watersheds, especially in the CGP, consisted of large swaths of unbroken prairie, with trees occurring mostly in stream and river valleys and in steep terrain where sufficient surface and groundwater facilitated their establishment. Watersheds with highly sandy soils in the western and southern portions the CIP and CGP are characterized but few, thinly populated, woody riparian areas due, in part, to frequent dry soil conditions. Cottonwood and willow species are common woody riparian species found throughout the three ecoregions. Overall watershed drainage densities were moderate with many first-order channels being formed due to post-settlement alterations. |
| **Hydrologic regime** | From workshop summary:  **A natural hydrologic regime free of dams, channelization, and other anthropogenic impacts that would prohibit the waterbody from flowing freely and meandering.** Natural hydrologic regime, free of channel modifications (e.g. channelization, dredging) or watershed alterations (e.g. mainstem reservoirs, upland Public Law 566 impoundments or “farm ponds,” drainage tiles).Consistent surface and subsurface base flow with some segments fully subsurface (intermittant streams). Stream discharge during summer low flow periods supplemented by water retained in prairie sod.From Don Huggins: ... free of dams, dikes, levees, tiling, water diversions, channelization, and other anthropogenic impacts that would alter natural water quality and quantity regimes. Normal, reoccurring Flood hydrographs are characterized by long lag times, slow rising limbs and long falling limbs, modest flood peaks and extended throughflows that enhance baseflows. Stream bases flows stable and higher due to high watershed infiltration rates and physical flow retention associated with instream structures and longer throughput water periods from flood events. |
| **Disturbance regime and resilience** | From workshop summary:  **A robust system that is highly resilient and can recover rapidly from either natural or anthropogenic disturbances such as fire, drought, flood, and other stressors that are introduced into the landscape.** Spring and early summer bank full and over bank flood events serve as channel maintenance flows, transporting sediment and recruiting large woody debris from the riparian corridor. However, robust bank vegetation and riparian corridor prevent excessive bank sloughing, and presence of complex stream bottom heterogeneity prevents scouring. Undercut banks and presence of well-anchored woody debris provide velocity refugia, which help to foster a resilient biological community.  From Don Huggins:  Ecosystems that are both highly resistant and resilient and can recover rapidly from disturbances such as fire, drought and flood that are a part the natural landscape. Climatic variability along with episodic extreme events result in highly variable stream flows with dry-ups and floods creating high ratio of intermittent streams. Spring .... Robust .... Undercut ..., while isolated pools and hyporheic zones help to foster resistant biological communities. |
| **Biodiversity** | From workshop summary:  **High taxa richness and a high number of intolerant species. A diverse mixture of organisms that satisfy various niches and allow for balance within the aquatic environment. Native species are dominant and invasive species are not present.** Diversity of instream habitat and depth/flow regime supports abundant niches, which leads to high fish and macroinvertebrate taxa richness. Aquatic community includes not only taxa groups tolerant of harsh conditions (e.g. low flows, high temperatures, low dissolved oxygen) but also taxa intolerant of organic pollutants and those requiring a high-DO environment.  From Don Huggins:  **Moderate to high taxa richness** .... **moderate to high** fish and macroinvertebrate taxa richness. Aquatic community includes taxa groups tolerant of episodic harsh but naturally occurring conditions (e.g. low flows, high temperatures, low dissolved oxygen), **but which are sensitive anthropogenic changes**.From EPA BCG Narrative:Level 1, Natural or native condition—Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability. Level 1 represents biological conditions as they existed (or still exist) in the absence of measurable effects of anthropogenic stressors and provides the basis for comparison to the next five levels. The level 1 biological assemblages that occur in a given biogeophysical setting are the result of adaptive evolutionary processes and biogeography. For this reason, the expected level 1 assemblage of a stream from the arid southwest will be very different from that of a stream in the northern temperate forest. The maintenance of native species populations and the expected natural diversity of species are essential for levels 1 and 2. Non-native taxa (attribute VI) might be present in level 1 if they cause no displacement of native taxa, although the practical uncertainties of this provision are acknowledged. Attributes I and II (i.e., historically documented and highly sensitive taxa respectively) may be useful to help assess the status of native taxa when classifying a site or assessing its condition. |
| **Ecosystem function** | From workshop summary:  **The stream fully supports the watershed’s full range of ecological processes and functions essential to maintaining high biodiversity provided by a minimally disturbed ecosystem.** Food web, nutrient and energy flow linkages between aquatic and terrestrial environments fully supported.   From Don Huggins:  ... Vertebrate and invertebrate omnivores are an essential component of the functional system with prey species showing slow recovery from disturbances. Microbes form the basis of the food chain as in other system and quickly recovery from stressors. High nitrogen retention is a common attribute of native prairie streams. Ecosystem processes are fully restored before and after any type of landscape disturbances that may take place within the watershed. |