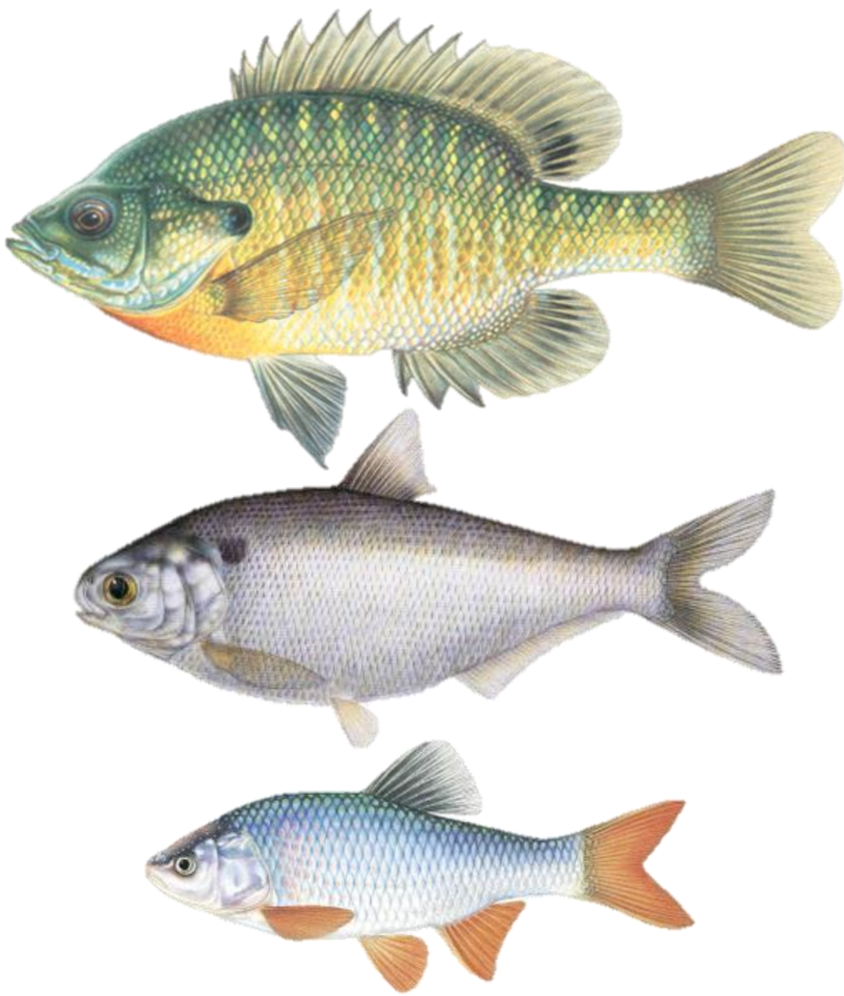
Kansas Department of Wildlife, Parks, and Tourism

Forage Fish Management Plan

April 27, 2016



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Kansas Department of Wildlife, Parks, and Tourism Mission Statement

Fish, wildlife, and outdoor recreation are important to the quality of life for all Kansans and to the Kansas economy. As a public steward of the Kansas natural resources, the mission of the Department of Wildlife, Parks, and Tourism is to:

Conserve and **Enhance** Kansas natural heritage, its wildlife and its habitats--to assure future generations the benefits of the state's diverse, living resources;

Provide the public with opportunities for the use and appreciation of the natural resources of Kansas, consistent with the conservation of those resources;

Inform the public of the status of the natural resources of Kansas to promote understanding and gain assistance in achieving this mission.

Need for a management plan

Fisheries management in Kansas continues to be complicated by multi-use mandates, reservoir aging, climate change, and shifting demographics of the angling base. One component of changing fisheries that is often overlooked is forage fishes. As such, we provide information to further management of forage fishes using the Kansas Department of Wildlife, Parks, and Tourism's Mission Statement as framework.

Conserve and Enhance: Kansas' most popular sport fish populations rely on forage fishes to maintain health. Understanding forage fishes in these waters will provide managers with information needed to conserve and enhance existing angling opportunities in Kansas.

Provide: Understanding the role of forage fishes in comprehensive fisheries management will be vital as Kansas Department of Wildlife, Parks, and Tourism continues to provide constituents with preferred angling opportunities. Additionally, experimental stockings of piscivorous fishes to provide novel opportunities to Kansas anglers will be dependent on understanding how forage fishes contribute to specific ecosystems.

Inform: Fostering a deeper understanding of food web dynamics in Kansas reservoirs will make biologists more informed and better situated to discuss fisheries with constituents. Further, research that identifies mechanisms to increase carrying capacity of popular sport fishes can be relayed to constituents to foster support and trust in managing Kansas' aquatic natural resources.

Introduction

Food web dynamics in lentic systems are complex and reliant on a number of biotic and abiotic factors (Chipps and Graeb 2010). Lower trophic levels in lentic food webs are typically comprised of nutrients (e.g., nitrogen and phosphorus), phytoplankton, zooplankton, and macroinvertebrates. Intermediate trophic levels are characterized by forage fishes, and upper trophic levels by piscivorous fishes. In waters managed by Kansas Department of Wildlife, Parks, and Tourism (KDWPT), food webs vary considerably at lower trophic levels (i.e., many different types of plankton and forage fishes), but gain similarity at intermediate and high trophic levels (i.e., similar predaceous fish communities). Further, piscivorous fishes that occupy upper trophic levels in many Kansas impoundments are sport fish and desired by anglers. The inherent hierarchy of food webs indicates that to properly manage sport fishes in upper trophic levels, forage fishes at intermediate trophic levels must be understood.

Goal of the forage fish management plan

The definition and role of forage fishes in Kansas reservoirs have not been previously formalized. Typical definitions include small-bodied, pelagic, schooling, and short-lived (Bigford 2014; Rountos 2016). However, these definitions tend to be formed for marine systems and not freshwater lentic systems as found in Kansas.

The goal of the forage fish management plan is to consolidate best available information to promote proper management of forage fishes and increase sport fish angling opportunities and participation in Kansas. To meet this goal, the forage fish committee developed three objectives.

1. Identify current forage fishes in Kansas and their role in fisheries management
2. Identify challenges that face fisheries managers in Kansas as they relate to forage fishes
3. Determine what direction KDWPT should move as it pertains to forage fish management

To address these objectives, the committee developed an eight-question survey that was disseminated to KDWPT district fisheries biologists in January, 2016. Responses were collected through February, 2016, consolidated, and summarized (Appendix A).

Results

Question 1: What species or species groups are currently serving as forage fish in waters you manage? What piscivorous fish in your district rely on forage fishes?

Responses from KDWPT biologists pertaining to available forage fishes varied (16 species and six species groups identified), but Gizzard Shad *Dorosoma cepedianum* and *Lepomis* spp. (typically Bluegill *Lepomis macrochirus* were ubiquitous responses). Other species and taxa that were listed by at least three respondents included *Pomoxis* spp., Cyprinidae, and Golden Shiner *Notemigonus crysoleucas*. Age-0 fishes not commonly referred to as forage, including sport fishes, were identified as forage fishes by several respondents. These responses indicate that forage fishes in Kansas can be broadly defined as schooling fishes that are small-bodied (≤ 6 in) for at least their first two years.

Respondents identified 19 piscivorous fish species and one species group in Kansas waters (Appendix A). All but four of these are defined as sport fish by KDWPT (KDWPT 2016). These results highlight the importance of properly managing forage fishes to maintain, enhance, and promote fisheries for sport fish. Seven species were listed by at least seven respondents. Saugeye (Walleye *Sander vitreus* x Sauger

S. canadensis) were identified by nine respondents, Walleye and White Bass *Morone chrysops* by eight, and Black Crappie *P. nigromaculatus*, White Crappie *P. annularis*, Largemouth Bass *Micropterus salmoides*, and palmetto bass (Striped Bass *M. saxatilis* x White Bass) were identified by seven respondents. It is important to note that two of these piscivores (saugeye and palmetto bass) are hatchery-produced hybrids that do not consistently reproduce in the wild. As such, fisheries for these two species are entirely dependent on hatchery-produced fish. Additionally, many Walleye populations in Kansas are not self-sustaining and supplemental stockings are necessary to maintain fisheries. From 2005 to 2016, an average of 1.8 million Walleye, saugeye, and palmetto bass fingerlings were requested annually from the KDWPT hatchery system. These requests have been stable throughout this period and it is likely that they will persist. It is imperative for KDWPT biologists to understand how these stockings interact with localized food webs and ensure that forage fishes are managed properly to promote fishery health.

Question 2. Are current forage fish populations suitable for your reservoir-specific management goals? If not, what do you think is lacking? What piscivorous fish population metrics (e.g., growth, body condition) do you use to determine forage suitability? What metrics would you like to examine that have not recently been investigated?

The most common forage fish limitation was gizzard shad populations characterized by high abundance of large fish and few smaller fish. Gizzard Shad in small impoundments common to Kansas are problematic for two primary reasons: 1) they are of little value to sport fish populations once their body size exceeds gape width of predatory fish and 2) they directly and indirectly compete for resources with many *Lepomis* spp. and age-0 sport fishes. Gizzard shad in Kansas typically reach 3 to 4 in at formation of first annulus (Willis 1987; Quist et al. 2001). Gosch (2008) noted that few Gizzard Shad ≥ 5 in were consumed by predacious fishes (including Largemouth Bass, palmetto bass, Walleye, and White Bass) in two Nebraska impoundments. Similarly, Wuellner (2009) observed few Gizzard Shad ≥ 4 in were consumed by Smallmouth Bass *M. dolomieu* and Walleye in South Dakota. Largemouth bass are capable of consuming Gizzard Shad up to half of their body length, although Gizzard Shad ≥ 8 in are rarely consumed (see DiCenzo et al. 1996). These examples indicate that Gizzard Shad are suitable prey for most sport fishes in Kansas as age-0 fish, but are no longer available as forage in subsequent years. Many small Kansas impoundments are managed for Bluegill, Channel Catfish *Ictalurus punctatus*, Largemouth Bass fisheries. Introduction of Gizzard Shad into these systems can create competition at lower trophic levels that influences growth and condition of Bluegill and ultimately Largemouth Bass (DeVries and Stein 1990; Welker et al. 1994; Aday et al. 2003).

Additional concerns about forage fish populations included a lack of diversity in prey size throughout the growing season of sport fishes, stunted White Crappie populations feeding heavily and reducing available forage for other species, limited populations of *Lepomis* spp., nutrient-poor systems that don’t support sustaining Gizzard Shad populations, and extreme water fluctuations that result in inconsistent reproduction of forage fishes. These issues were more localized than those concerning overabundant Gizzard Shad and represent unique management challenges.

District fisheries biologists with KDWPT used several piscivore metrics to determine forage suitability. Respondents ubiquitously used body condition of piscivorous fish to monitor forage suitability. This is intuitive given the apparent relationship between forage availability and fish plumpness. However, there are exceptions to this relationship. Shoup and Wahl (2009) noted that turbidity limited foraging of Largemouth Bass when forage fish density was consistent. Similarly, Aday et al. (2005) suggested that lower trophic level interactions involving Bluegill and Gizzard Shad influenced body condition of Largemouth Bass. Several respondents indicated that growth of sport fishes was used to discern forage suitability in a given impoundment. Growth of sport fishes has been positively related to abundance of age-0 Gizzard Shad (Michaletz 1997). This is intuitive given that many sport fishes use these as forage. However, recruitment of Bluegill and Largemouth Bass might be reduced when there are high abundances of age-0 Gizzard Shad (Michaletz 1998). Relative abundance, size distribution, and stomach contents of piscivorous fishes were also identified as metrics used to measure forage suitability. Given the complex interactions inherent in aquatic food webs, managers should be cognizant of confounding factors when indirectly assessing forage fish populations by using piscivorous fish as a surrogate (Chipps and Graeb 2010). Directed sampling of forage fishes will likely provide more consistent and useful information when determining management strategies.

Question 3. Do you currently supplement forage fish in any impoundment you manage? Would introduction of additional forage fish (either introduced species or supplemental stockings) help you achieve management goals? If you believe adding forage fish would benefit your management, what would be a proposed stocking schedule (species, number, size, frequency, etc.)?

Current stockings of forage fish are currently limited to *Lepomis* spp. in Kansas, and typically occur when populations are depressed and managers desire both panfish and piscivorous angling opportunities. These stockings generally entail collection of adult Bluegill or Redear Sunfish from established populations and stocking them in waters with limited populations of those species. In some situations, Bluegill and Redear Sunfish are requested through the hatchery system and stocked as fingerlings. When trying to either establish or replenish populations of Bluegill and Redear Sunfish, stockings of either adults or fingerlings can be successful provided suitable numbers are stocked (Swingle 1951; Gabelhouse et al. 2004).

Several respondents indicated interest in stocking Threadfin Shad *D. petenense* to supplement forage. Some suggested stocking Threadfin Shad in waters where there were no Gizzard Shad and others suggested stocking into impoundments when Gizzard Shad were present to supplement the forage base. Threadfin Shad that might be preferred by many managers because they represent a high calorie, soft rayed forage option that does not reach large sizes common to Gizzard Shad (Griffith 1978). However, Threadfin Shad are not coldwater tolerant and typically experience winterkill when water temperature remains under approximately 40°F for an extended period (Parsons and Kimsey 1954; Griffith 1978). Threadfin Shad are stocked in numerous Oklahoma impoundments with varying success. These stockings entail collection of adult fish in March and April and stocking these fish in desired waters to capitalize on age-0 fish production from upcoming spawning. Managers typically expect two to five years survival from these stockings although populations persist indefinitely as far north as Grand Lake

O' the Cherokees, located 14 miles south of the Kansas/Oklahoma border (D. Shoup, Oklahoma State University, pers. comm.). Threadfin Shad populations have successfully overwintered in Kansas (Mosher 1984) but not consistently. Stocking Threadfin Shad would likely have to occur on a cycle (e.g., annually, biennially, etc.) if piscivorous fish were relying on them as a food source. However, periodic stockings might be useful to introduce forage and create the possibility that a population will persist for multiple years before succumbing to winterkill. Stocking rates indicated by respondents were 5 to 10 adults/acre in spring before spawning. Although both Threadfin Shad and Gizzard Shad conduct protracted spawns through summer, Threadfin Shad typically spawn later in the year and their introduction would likely result in more size variation in available forage fishes (Shelton 1972). Despite apparent benefits of supplemental Threadfin Shad stockings, several researchers have noted declines in sportfish populations following Threadfin Shad introduction due to changes in the food web at lower trophic levels (Guest et al. 1990; DeVries et al. 1991). As such, managers should consider all possible repercussions of introducing a new forage fish species.

Question 4. Are there situations in your district where forage fish are creating problems? Please describe these problems, what actions you have considered, and what actions you have undertaken. If you have taken action, how did forage fish and forage fish dependent piscivorous sport fish respond?

Nearly all survey respondents indicated that overabundant Gizzard Shad caused problems in at least one impoundment they managed. Most sought to reduce Gizzard Shad by stocking predacious fishes including Blue Catfish *I. furcatus*, palmetto bass, saugeye, and Striped Bass. However, desired results (i.e., increased growth of sport fishes) were inconsistently evaluated and reported. Some respondents indicated that water level management was helpful in reducing overabundant Gizzard Shad by concentrating prey and creating foraging opportunities for piscivorous fishes. However, water level management isn't typically possible for several reasons (e.g., low inflow, retain water for municipal water supply). Application of rotenone at low doses was used by several respondents at varying rates (7 ppb to 100 ppb) and typically increased recruitment and growth of sport fishes including Bluegill, Black Crappie, Largemouth Bass, and White Crappie. The mechanism driving these changes was attributed to production of a large Gizzard Shad year class the following year by one respondent. Another respondent reported nearly a complete Gizzard Shad eradication following application but has not yet quantified response of Bluegill and Largemouth Bass. Numerous respondents indicated they were willing to try low-dose rotenone to reduce Gizzard Shad abundance but were concerned with impacts it may have the fish community.

Low abundance of sunfishes, particularly Bluegill, was identified by several respondents as a factor limiting sport fish populations. In at least two situations, *Lepomis* spp. abundance decreased to levels that weren't suitable for sustaining Largemouth Bass populations. These declines were qualitatively attributed to increased abundance of Gizzard Shad and changes in water quality, but specific mechanisms were not identified. Supplemental stockings were used to increase abundance of Bluegill and Redear Sunfish in these situations. In another situation, increased abundance of Common Carp *Cyprinus carpio* was attributed to a depressed Bluegill population. A concentrated effort to remove Common Carp was expended, and the Bluegill population recovered to its previous level.

White Perch *Morone americana* establishment was identified as deleterious by one respondent. Aggressive stockings of Blue Catfish, palmetto bass, and Walleye have been conducted since their introduction, but there is limited evidence suggesting predation can control White Perch populations (Gosch et al. 2010; Feiner et al. 2013). However, researchers had limited success controlling problematic White Perch populations with low concentrations of rotenone in Pawnee Reservoir, Nebraska (Stewart 2015). Trophic interactions of White Perch in Kansas impoundments should be examined to better understand their niche in systems with piscivorous fishes.

Question 5. Is sampling forage fishes necessary for you to reach district-specific management goals? What metrics do we need to derive from forage fish samples? What is your most effective method of sampling forage fishes?

The necessity of sampling forage fish populations, particularly Bluegill and Gizzard Shad, was acknowledged by all survey respondents. Managers were typically interested in documenting relative abundance and size structure of these two species, and some were also interested in measuring body condition.

Bluegill were sampled predominantly with fall fyke nets as part of KDWPT's standardized fish sampling procedures. Literature pertaining to Bluegill sampling is abundant and fyke nets are typically identified as a suitable gear for monitoring these populations (Schultz and Haines 2005; Miranda and Boxrucker 2009; Pope et al. 2009). However, sufficient effort must be expended to achieve sampling goals regardless of minimum sampling requirements (Koch et al. 2014; Neely et al. 2016).

Gizzard Shad were assessed with summer electrofishing, summer seining, and fall gill netting. Marteney et al. (2010) noted that KDWPT biologists should use electrofishing and seining in summer to document age-0 Gizzard Shad and gill nets in fall to index general population parameters. As such, Gizzard Shad sampling metrics from fall gill nets are used for piscivorous fish stocking score sheets and annual reservoir reports. However, Smith (2015) reported relative efficiency of 7/8-in bar mesh gill net, the smallest mesh in KDWPT's core panel gill nets, is under 0.50 for Gizzard Shad < 5 in. Further, relative efficiency for the same gill net size approaches 0.00 for Gizzard Shad < 4 in. This indicates that gill nets with bar mesh size ≥ 7/8 in do not effectively sample Gizzard Shad < 5 in. This inefficiency coupled with Gizzard Shad growth estimation in Kansas (Willis 1987; Quist et al. 2001) indicate that fall gill nets do not effectively sample age-0 Gizzard Shad in Kansas impoundments. If data from age-0 Gizzard Shad are desired, managers should implement supplemental samples.

Several issues with current forage fish sampling procedures were identified by survey respondents. Most notable was disparity of gears used to monitor Gizzard Shad populations. In itself, this is not necessarily a problem as long as biologists continue to sample forage fishes with the same gear during the same time period from the same reservoir to observe trend data. However, standardized sampling has many benefits and should be used to monitor populations of forage fishes (Bonar et al. 2009). Standardization is further supported by KDWPT's reliance on these data to formulate piscivorous fish stocking plans.

Methodologies for sampling Gizzard Shad, particularly age-0 fish, should be evaluated to better understand benefits and consequences of each method and establish a standardized approach for sampling Kansas impoundments. Similarly, managers should understand what is desired from forage fish samples and expend effort until those data are obtained.

Question 6. Do you think forage fish management will change in the next 5 to 10 years with environmental variability (e.g., drought, climate change, invasive species)? If you foresee a change, what do expect will happen? What are your thoughts on how to quantify and mitigate changes in forage fish populations, and forage fish dependent piscivore populations, associated with these changes?

Survey respondents identified a number of potential scenarios that might introduce forage fish management issues in upcoming years. However, most can be grouped into two categories: introduction of invasive species and environmental change.

Increased distribution of invasive species was deemed problematic by many survey respondents. Of particular mention were Zebra Mussels *Dreissena polymorpha*, Bighead Carp *Hypophthalmichthys nobilis*, and Silver Carp *H. molitrix*. Each of these species is a filter-feeding planktivore with a diet similar to Gizzard Shad and juvenile Bluegill (Horgan and Mills 1997; Raikow 2004; Sampson et al. 2009). If one of these species became established in a reservoir, there would likely be changes in lower trophic levels influencing population parameters of sport fishes. All waters in Kansas are at risk for introduction of these species, although establishment of Bighead Carp and Silver Carp will be limited to stretches of river that are sinuous, turbid, and have rapid water velocity for at least 70 continuous miles and any downstream impoundments (Kocovsky et al. 2012; Deters et al. 2013). One approach for addressing these concerns is to collect baseline information on water quality and forage fish population dynamics in Kansas impoundments that are at most risk for introduction of invasive species. This would provide quantifiable mitigation objectives if invasive species became established.

Environmental change is a persistent threat to aquatic ecosystems and was acknowledged by respondents as something that could alter forage fish management in the future. Concerns included changes in land use in reservoir catchments, inconsistent water levels in impoundments, and changes in fish communities associated with warming water temperatures. Land use changes are frequently associated with accelerated nutrient loading in aquatic ecosystems (Johnes and Heathwaite 1997; Foley et al. 2005). Increased nutrient loading is a symptom of reservoir aging that can deleterious to fish populations (Miranda and Krogman 2015; Pegg et al. 2015). Specifically, increased nutrients and warming water are known to depress dissolved oxygen in aquatic systems (Gabelhouse et al. 2004), and have been associated with blue-green algae biomass (Smith 1986). The end result in both of these scenarios is frequently fish mortality. Another consideration is increased water temperatures associated with climate change (Schneider and Hook 2010; van Vliet et al. 2013). In several systems, increased water temperatures have been associated with introduction and establishment of invasive species that can alter food webs (Rahel and Olden 2008; Kolar et al. 2010). However, increased water temperatures might also support desired introductions of forage fishes (e.g., Threadfin Shad). Environmental change is dynamic both in terms of magnitude and timing and its effect on forage fish populations in Kansas will be difficult to quantify. However, developing baseline parameters of forage fish populations in Kansas reservoirs would be helpful to make robust comparisons in situations where environmental changes are believed to have affected fish communities.

Question 7. What information about forage fish management is important in your district but not addressed here? Do you have any specific research needs regarding forage fish management in Kansas?

Survey respondents provided many ideas for future research pertaining to forage fish populations. Although ideas varied widely, most can be grouped into four categories: Gizzard Shad sampling methodology, interactions of forage fishes with biotic community, control of overabundant Gizzard Shad populations, and results of stocking Threadfin Shad.

Proper sampling of Gizzard Shad is frequently problematic for KDWPT biologists. Biologists currently monitor age-0 Gizzard Shad with shoreline seining or electrofishing in summer and collect population-level data with fall gill netting. Summer sampling data are typically maintained by the collecting biologist and fall gill netting data are used for KDWPT reporting and fish stocking scoresheets. However, Gizzard Shad < 5 in are not fully recruited to core panel gill nets used in fall (Marteney et al. 2010; Smith 2015). There are many methods for collecting samples of Gizzard Shad populations and each contain biases (Boxrucker et al. 1995; Smith 2015). Given KDWPT's transition to standardized sampling and respondents' concern about effectively sampling age-0 Gizzard Shad, it might be worthwhile to standardize methods for collecting age-0 Gizzard Shad. Potential gears to evaluate include summer seining, summer electrofishing, and fall small-mesh gill nets.

Several respondents indicated knowledge gaps in understanding how forage fishes interacted with the biotic community in managed waters. Of particular interest were interactions of Gizzard Shad and invasive species (e.g., zebra mussels and white perch). Studies that evaluate response of Gizzard Shad to introduction of a non-native species might be necessary to understand the aquatic community. Other respondents were interested in gape width limitations of sport fishes and how those related to Gizzard Shad growth. In at least one situation, Goldeye *Hiodon alosoides*, serves as forage in a popular Blue Catfish fishery. However, little is known about population dynamics and trophic status of Goldeye in Kansas waters. Further work might be necessary to evaluate Goldeye populations and determine their importance in maintaining Blue Catfish fisheries in Kansas. Another concerns from survey respondents was that Gizzard Shad are known to compete with Bluegill for plankton forage in many situations (Welker et al. 1994; Aday et al. 2003). However, it might be worthwhile to assess interactions of Bluegill, Gizzard Shad, and plankton abundance in Kansas impoundments and determine the extent that Gizzard Shad limit Bluegill growth and condition. Regardless, future studies that evaluate interactions of forage fish and the aquatic community will be important to better understand how forage fish impact managed aquatic ecosystems and will provide information necessary for proper management of sport fish populations.

Control of overabundant forage fishes has long been problematic and has been evaluated for many aquatic systems. Removal of undesired fishes typically occurs one of three ways: biological, chemical, or mechanical (Kolar et al. 2010). Biological control typically occurs by stocking a fish species that is expected to prey upon the undesirable fish population. This was indicated as a means of control by several survey respondents. In the case of overabundant Gizzard Shad, pelagic piscivorous fishes including palmetto bass, saugeye, and Walleye were typically introduced to induce biological control of the problematic population. Success in these instances is inconsistent both in Kansas and in published literature, and species introduction can result in unintended consequences (Kolar et al. 2010). Chemical control is a common approach and typically involves application of a piscicide (usually rotenone). These applications are most commonly used when a renovation is planned and all fish are expected to perish. However, species tolerance to rotenone varies and applications at lower doses have been used with success to reduce or eliminate unwanted Gizzard Shad (Stewart 2015). Several respondents indicated a desire to learn more about Gizzard Shad control through low dose application of rotenone. Mechanical control is simply capturing and removing unwanted fish. This approach can be successful when study systems are small, but large-scale eradications are seldom possible. Further, reductions through mechanical removal are typically short-lived (Kolar et al. 2010). Mechanical removal has been successful for removal of rough fish in Kansas although its effectiveness for removal of overabundant forage fish has not been evaluated. Based on survey responses and undesirable populations of Gizzard Shad in small impoundments, research should be conducted by KDWPT to evaluate approaches for reduction or extirpation of unwanted Gizzard Shad populations.

Threadfin Shad provide an important source of forage for many piscivorous fishes in the southern portion of the United States, but their thermal tolerance limits northern distribution (Griffith 1978). Many researchers have experimented with Threadfin Shad introduction outside of their native range as a mechanism to increase available forage in aquatic systems. However, these stockings have had mixed results. Mosher (1984) noted that introduction of Threadfin Shad to a small Kansas impoundment resulted in increased body condition of Black Crappie and White Crappie > 8 in and suggested stocking 5/acre to improve growth of *Pomoxis* spp. Further, it was demonstrated that overwinter survival of Threadfin Shad is possible as far north as 38.78°N. Hale (1996) noted that Threadfin Shad introduced to two Kentucky reservoirs spawned later than Gizzard Shad and created diversity in size of *Dorosoma* spp. throughout summer. However, only White Crappie > 7 in experienced an increase in body condition and growth of age-0 White Crappie was negatively affected. Hale (1996) suggested a stocking rate of 50/acre. Although introduction of Threadfin Shad has potential to benefit piscivorous fish populations, there are also associated risks. Foremost, complete overwinter mortality of Threadfin Shad is expected to occur when water temperature < 40°F for three consecutive days and no thermal refugia is present (Griffith 1978). Water temperatures in nearly all Kansas impoundments meet these criteria annually although presence of thermal refugia is unknown. In addition to overwinter mortality, introduction of Threadfin Shad can have deleterious effects on the existing fish community through competition for food (Guest et al. 1990; DeVries et al. 1991; Hale 1996). As such, future research pertaining to Threadfin Shad should incorporate a design to quantify how introduction influences age-0 sport fishes. Although Kansas water temperatures typically decrease below 40°F in winter, it is possible that impoundments with suitable depth would provide areas of warmer water. Additionally, water warming trends through the last several decades (Schneider and Hook 2010; van Vliet et al. 2013) have resulted in poleward range expansion of several aquatic species (Parmesan and Yhoe 2003; Heino et al. 2008). If this trend of range expansion occurs for Threadfin Shad, it is likely they will be able to more consistently persist through winter in Kansas impoundments. Future research should be directed toward identifying reservoirs that might benefit from introduction of Threadfin Shad and determine whether benefits outweigh both ecological and monetary costs.

Conclusions

Results from this survey were informative and were critical for developing an understanding of forage fishes in Kansas. With provided information, each of the three previously defined objectives of this report were thoroughly addressed. These findings should be considered by fisheries managers and researchers to better understand the current state of forage fish in Kansas and guide future management efforts.

1. **Identify current forage fishes in Kansas and their role in fisheries management**

Survey respondents ubiquitously identified Bluegill and Gizzard Shad as primary forage fishes in Kansas impoundments. Although both species meet previously defined forage fish criteria of being schooling and small bodied, neither have a particularly short lifespan relative to other fishes and Bluegill are not pelagic. Forage fish in Kansas are small-bodied fishes primarily from the family Cyprinidae and several genera including *Dorosoma*, *Lepomis*, and *Pomoxis*. Many of these fishes, including Bluegill and Gizzard Shad, can only be classified as forage fish during their first and second year of life because they quickly outgrow gape limitations of sportfish in Kansas. As such, management of forage fishes in Kansas should be directed at juvenile Bluegill and Gizzard Shad in most situations.

2. **Identify challenges that face fisheries managers in Kansas as they relate to forage fishes**

Challenges associated with forage fish management in Kansas can be grouped into three main categories: aquatic nuisance species, climate change, and reservoir aging. Each of these challenges is addressed in detail above, although their importance to future management of forage fishes in Kansas bears repeating here. Specific mechanisms associated with each challenge differ, but the fundamental consequence of each is altered forage dynamics. These impending challenges highlight the importance of understanding food web dynamics in Kansas impoundments. This will result in biologists having a more thorough understanding of biological and physical interactions in reservoirs and promote more effective holistic management.

3. **Determine what direction we should move as it pertains to forage fish management**

Forage fish dynamics are believed to be impeding sport fish populations in several Kansas reservoirs. Survey respondents identified several ideas where further research is needed to support forage fish management in Kansas. These ideas can be grouped into four categories: sampling methodology, community interactions, control of overabundant Gizzard Shad, and feasibility of Threadfin Shad introduction. These ideas provide a starting point for future research aimed at improving angling in

Kansas through forage fish manipulation. Managers and researchers should consider addressing these issues at various scales to identify solutions and further limitations. Unbiased confrontation of these issues will likely be necessary to ensure that forage fish management in Kansas is sound and promote balanced fisheries.

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Appendix A. Questions and summarized responses of survey sent to Kansas Department of Wildlife, Parks, and Tourism fisheries management biologists, January, 2016.

Question 1. What species or species groups are currently serving as forage fish in waters you manage? What piscivorous fish in your district rely on forage fishes?

Forage fish	Count
Gizzard Shad	12
Bluegill	9
Sunfishes	6
Crappies	4
Cyprinids	4
Green Sunfish	4
Golden Shiner	3
Redear Sunfish	3
Emerald Shiner	2
Longear Sunfish	2
Notropis spp.	2
Red Shiner	2
Age-0 sportfish	1
Centrarchidae	1
Common Carp	1
Fathead Minnow	1
Freshwater Drum	1
Goldeye	1
Orangespotted Sunfish	1
River Carpsucker	1
White Perch	1
Yellow Perch	1

Piscivorous fish	Count
Saugeye	9
Walleye	8
White Bass	8
Black Crappie	7
Largemouth Bass	7
Palmetto Bass	7
White Crappie	7
Channel Catfish	5
Flathead Catfish	5
Blue Catfish	4
Smallmouth Bass	4
Spotted Bass	3
Longnose Gar	2
Striped Bass	2
Black Basses	1
Green Sunfish	1
Sauger	1
Shortnose Gar	1
Spotted Gar	1
White Perch	1

Question 2. Are current forage fish populations suitable for your reservoir-specific management goals? If not, what do you think is lacking? What piscivorous fish population metrics (e.g., growth, body condition) do you use to determine forage suitability? What metrics would you like to examine that have not recently been investigated?

- Too many big Gizzard Shad and not enough small ones.
- Not enough Gizzard Shad for pelagic sport fish.
- Sunfish lacking in some smaller waters.
- Low diversity of prey sizes available to satisfy wide variety of predators with different gape size.
- Too many big Gizzard Shad and not enough small ones.
- Forage limiting in reservoir – Gizzard Shad are growing too quickly to provide forage.
- Too many big Gizzard Shad.

- Stunted White Crappie are limiting available forage for other fishes.
- Zebra mussels have decreased abundance of age-0 Gizzard Shad.
- Lack of nutrients to promote forage fish development – Application of liquid fertilizer has been successful in increasing numbers of Gizzard Shad.
- Inconsistent water levels create inconsistent production of Gizzard Shad – water level management might help but isn't a realistic option.

Piscivorous fish population metrics to evaluate forage fish suitability	Count
Body condition (Relative weight)	10
Age estimation	5
Relative abundance (CPUE)	1
Size distribution	1
Stomach contents	1

Question 3. Do you currently supplement forage fish in any impoundment you manage? Would introduction of additional forage fish (either introduced species or supplemental stockings) help you achieve management goals? If you believe adding forage fish would benefit your management, what would be a proposed stocking schedule (species, number, size, frequency, etc.)?

- Stock adult Bluegill to replenish depleted population.
- Stock Bluegill and Redear Sunfish (100/acre) to diversify sunfish forage for Largemouth Bass.
- In certain situations, supplemental stocking would be beneficial to boost the prey base.
- Late April or early May would be a good time to stock forage fish.
- Would consider fertilizing first or supplemental stocking second if Gizzard Shad abundance was too low.
- Periodic stockings have been used to develop sustaining populations and also to present short-term forage opportunities.
- Interest in stocking Threadfin Shad in waters with no Gizzard Shad in spring at 5-10 adults/acre.
- Supplement Bluegill populations by stocking 25 adults/acre biennially.
- Considered Threadfin Shad but unsure of whether the monetary cost is justified by potential results.
- Supplemental stockings of Bluegill and Redear Sunfish because of low abundance and hybridization.
- Want to stock Threadfin Shad in spring at given interval (e.g., once every three years) at rate of 5 adults/acre.
- Stock Redear Sunfish to supplement population.
- Bluegill stocking to increase forage abundance and increase predator fitness.

Question 4. Are there situations in your district where forage fish are creating problems? Please describe these problems, what actions you have considered, and what actions you have undertaken. If you have taken action, how did forage fish and forage fish dependent piscivorous sport fish respond?

- Overabundant Gizzard Shad – Stock predators (Blue Catfish, Wipers, Striped Bass) and enact commercial fishing.
- Overabundant Gizzard Shad – Fall drawdowns, requested saugeye but limited availability, consider low-dose rotenone.
- Overabundant Gizzard Shad in small waters – consider low-dose rotenone.
- Overabundant Gizzard Shad in small waters – Stock saugeye and wiper, successful at changing White Crappie in some situations. Would consider low-dose rotenone in certain situations.
- Overabundant adult Gizzard Shad – Drought fixed problem, would consider low-dose rotenone.
- Too few adult Gizzard Shad /too many small Gizzard Shad not meeting demands of large-gape predators – stock wipers to thin out small Gizzard Shad with minimal improvements. Wiper fry might be more effective than intermediates.
- Inconsistent age-0 production related to water fluctuation – Can only be remedied by proper inflow.
- Emigration of Common Carp depressed Bluegill reproduction and abundance – Concentrated removal of Common Carp was effective to replenish Bluegill population.
- Lack of Bluegill production – Unsure if Gizzard Shad or water quality issues.
- Considered low-dose rotenone but unsure of how it would affect overall fishery.
- Overabundant Gizzard Shad – 3’ drawdown and low-dose rotenone (7.5ppb) knocked them back considerably, possible eradication. Large year classes of Bluegill and Largemouth Bass the following year, but long-term changes in growth and condition have not yet been evaluated. Golden shiner abundance increased substantially but a paucity of data prior to low-dose rotenone application prohibits quantitative evaluation.
- Overabundant Gizzard Shad – Used low-dose rotenone with positive impacts to recruitment and growth of Bluegill, Black Crappie, and Largemouth Bass.
- Overabundant adult Gizzard Shad and desired a big Gizzard Shad year class to provide forage for crappies – low-dose rotenone at 0.1 ppm (100 ppb) resulted in big year class of Gizzard Shad the following year. Crappies benefitted.
- Overabundant forage – Required regular predator stockings (Largemouth Bass, wiper, or Saugeye depending on problematic forage) and time to be successful, but generally favorable results.
- Overabundant Gizzard Shad – Stocked saugeye with no effect. Considered low-dose rotenone.
- Presence of White Perch – Stocked Walleye, wiper, Blue Catfish and maintain restrictive harvest regulations. Evaluation of effectiveness is ongoing.
- Overabundant Gizzard Shad might be outcompeting Bluegill. Largemouth Bass and Channel Catfish populations are doing well so no action is needed at this time.

Question 5. Is sampling forage fishes necessary for you to reach district-specific management goals? What metrics do we need to derive from forage fish samples? What is your most effective method of sampling forage fishes?

- Summer seining for age-0 Gizzard Shad.
- Fall gill nets for adult Gizzard Shad.
- Summer shoreline electrofishing for age-0 Gizzard Shad.
- Relative abundance, size distribution, and body condition of Gizzard Shad sampled in fall gill nets and summer seine hauls.
- Shoreline seining because high conductivity prevents effective electrofishing.
- Electrofishing.
- Important to monitor year class production of Gizzard Shad in large impoundments and when prey density is a suspected problem. Measure relative abundance, size structure, and seasonal growth.
- Late summer electrofishing and sometimes shoreline seining if enough bank is free of obstructions.
- Electrofishing and summer seining with 1/8” 50’ bag seine. Prefer seining if bank is free of obstructions.
- Fall trap nets to index Centrarchidae forage.
- Sample Gizzard Shad in fall gill nets and sunfishes in fall trap nets.
- Spring electrofishing (Gizzard Shad and Bluegill), fall trap nets (Bluegill), and fall gill nets (Gizzard Shad).
- Summer electrofishing when age-0 Gizzard Shad samples are needed.
- Bag seines in reservoirs with clear banks, electrofishing elsewhere. Target the second week of August.
- CPUE, length frequency, and condition of Gizzard Shad from electrofishing.
- Prefer results from seining for broad community monitoring, but obstruction-free shoreline availability limits gear deployment in many situations.
- Fall trap nets for Centrarchidae sampling.
- Electrofishing for sunfish and age-0 Gizzard Shad, gill nets and trap nets for White Perch and adult Gizzard Shad.

Question 6. Do you think forage fish management will change in the next 5 to 10 years with environmental variability (e.g., drought, climate change, invasive species)? If you foresee a change, what do expect will happen? What are your thoughts on how to quantify and mitigate changes in forage fish populations, and forage fish dependent piscivore populations, associated with these changes?

- Change in forage fish management due to increased pressures to provide large sport fish. This will require focusing on providing large forage as well as small.
- Bighead Carp and Silver Carp could be a detriment to Gizzard Shad populations.
- Competition between age-0 Gizzard Shad and age-0 Walleye might increase.

- More sampling than standard would be required to quantify any changes in forage fish populations.
- Creel surveys would be necessary to monitor piscivore responses to changes in forage fish populations.
- Changes in land use accelerating eutrophication – Concerned with increased prevalence of blue-green algae and summer fish kills.
- Be wary of stocking more biomass into reservoirs as they age – decrease piscivore richness to maintain suitable forage fish populations.
- Prolonged drought could cause issues with forage fish population persistence. However, most forage fishes are quick to rebound when reservoirs refill.
- Maintain open mind to technological advances in sampling and control methods for forage fish.
- Extreme water fluctuations will force management of ephemeral forage populations rather than perennial populations.
- Establishment of invasive species might require changing harvest regulations, implementing forage fish stocking plan, and water level manipulation to maintain forage base suitable for maintaining sport fish populations.
- Difficulty with long-term management because of drought.
- Warming water temperatures might allow alternative forage (e.g., Threadfin Shad) to be effectively used for supplemental forage in reservoirs where lack of small Gizzard Shad are limiting growth of sport fishes.
- Should expend extensive forage fish sampling in reservoirs with a greater likelihood of getting aquatic nuisance species to measure how fish communities respond to establishment.
- Drought will promote dynamic forage fish and sport fish populations (boom-bust cycle). More short term management might be needed rather than the traditional long-term sustainable approach currently being implemented.
- Invasive species might limit what is available for forage fishes and depress growth and abundance of forage fishes.

Question 7. What information about forage fish management is important in your district but not addressed here? Do you have any specific research needs regarding forage fish management in Kansas?

- Age and growth study on Gizzard Shad.
- Statewide evaluation of Gizzard Shad response to zebra mussel colonization.
- Habitat use, reproduction, diet, and growth of Goldeye in Milford Reservoir with particular emphasis on their trophic status and influence on Blue Catfish.
- Proper way to sample age-0 Gizzard Shad sampling in fall.
- Continue to refine forage sampling methods in reservoirs.
- Evaluate the possibility of the hatchery system providing more and larger piscivorous for stocking to control overabundant forage fishes.
- Measure Gizzard Shad and Striped Bass interactions when density of the two species varies.

- Quantify the effects of Gizzard Shad predation by early-spawn Largemouth Bass.
- Determine if gape size of sport fish is limiting efficient utilization of forage fishes.
- Response of sportfish to Threadfin Shad introduction.
- Evaluate effects of Piscivore species richness on abundance and size structure of forage fishes and growth and condition of piscivorous fishes.
- Evaluate how Gizzard Shad populations respond to alum treatment.
- Increase understanding of low-dose rotenone to manipulate fish communities.
- Measure fish population responses to supplemental stockings of forage fish.
- Quantify population and community level responses to low-dose rotenone.
- Determine feasibility of staggering prey to create diverse sizes throughout year to match gape size demands of predators.
- Identify specific interactions between invasive species and forage fishes. Identify trophic-level and niche changes if invasive species establish.
- Identify how characteristics of Gizzard Shad, plankton community and abundance, and water quality interact to affect Bluegill growth.
- Identify suitable sample metrics for forage fish populations. For example, is 10 GZS/nn suitable? Is CPE=20/nn and PSD=30-50 suitable for a ‘good’ bluegill forage population?
- Evaluate small mesh gill net to sample age-0 Gizzard Shad in fall.
- Begin proactive monitoring on forage fishes in ‘high-priority’ ANS waters to measure effects if ANS become established.
- Evaluate competition between forage fishes and young sport fishes. Find the balance to promote growth of sport fishes at small sizes, but also have forage available at larger sizes.
- Evaluate effects of Threadfin Shad stocking on food webs, water quality, and growth of sport fishes.
- Conduct broad scale low-dose rotenone evaluation and monitor water quality throughout.
- Alter ADAS to reflect different methods for sampling forage fishes.
- Compare how contributions of golden shiner and Gizzard Shad to largemouth bass populations differ.
- Increase knowledge of how to manipulate forage populations. What stocking options are available?

Question 8. Please provide any additional thoughts on forage fish management here.

- Should we consider stocking alternate prey in some situations? Crayfish might be useful to stock to bolster Smallmouth Bass populations. Would need to determine stocking rates.