Population Characteristics of Black Bullhead (*Ameiurus melas*) in Iowa Natural Lakes

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ABSTRACT

Black bullhead (*Ameiurus melas*) populations in three natural lakes in northwestern Iowa were sampled to describe abundance, size structure, condition, mortality, recruitment variability, and growth in relation to a range of physical and limnological conditions. Six-hundred-and-fifty-three black bullhead were sampled with modified fyke nets during summer 2008 from Silver Lake, Lake Minnewashta, and West Okoboji Lake. Catch-per-unit-effort of black bullhead in Silver Lake (21.9 fish per net-night; fish/NN) was significantly higher than in Lake Minnewashta ($P<0.01$; 10.4 fish/NN) and West Okoboji Lake ($P<0.01$: 5.6 fish/NN). Proportional size distribution (PSD) was similar among populations, but PSD of preferred-length fish in Silver Lake was much greater than in the other lakes. Mean relative weights were generally high across all lakes (90-92) but were highest in Silver Lake. Total annual mortality was highest in Lake Minnewashta (79%) and lowest in Silver Lake (24%). Recruitment variability of black bullhead, measured with the recruitment variability index, was 0.69 in West Okoboji Lake, 0.62 in Lake Minnewashta, and 0.47 in Silver Lake. Black bullhead length at age 3 differed ($P<0.01$) among lakes and was highest in Silver Lake (274 mm) followed by Lake Minnewashta (247 mm) and West Okoboji Lake (228 mm). Silver Lake is considered to have the poorest water quality of the study lakes due to high nutrient concentrations and low water clarity. The influence of black bullhead on water quality conditions is unknown, but our results suggest that these conditions are ideal for black bullhead populations in Iowa lakes.

INRODUCTION

Black bullhead (*Ameiurus melas*) is a widely-distributed and ecologically important species across the midwestern United States, but little is known about its population demographics. Although found in a variety of natural and man-made waterbodies, black bullhead is often highly abundant in systems with low water clarity and high nutrient concentrations (Brown et al. 1999, Hanchin et al. 2002, Phelps et al. 2005) due to its tolerance of poor water quality conditions (Cross and Collins 1995, Pflieger 1997). As such, black bullhead is often associated with depauperate fish assemblages and is frequently the target of removal efforts to improve water quality and fisheries for more desirable fishes (Houser and Grinstead 1961, Hanson et al. 1983, Wydoski and Wiley 1999).

Increasing concerns associated with declining water quality and altered fish assemblages have lead to a number of recent investigations of species associated with degraded habitat, including black bullhead (e.g., Hanchin et al. 2002, Phelps et al. 2005). The effects of black bullhead can be of concern, as populations often reach high biomasses (e.g., 731 kg/ha in Oklahoma ponds, Jenkins [1958]; 931 kg/ha in Iowa common carp [*Cyprinus carpio*], bream [*Abramis brama*]) have been studied to ponds, Carlander and Moorman [1956]). Similarly, other benthivorous species (e.g., determine their effects on water quality (Breukelaar 1994, Lougheed 1998), because understanding

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the ecology of fish species associated with declining water quality is often necessary for the management of aquatic systems.

Fish population characteristics (e.g., abundance, size structure) and dynamics (e.g., growth, mortality) are structured by their interaction with numerous abiotic and biotic factors. Information on these interactions is critical for management of fish populations. In particular, growth information can provide insight on environmental (e.g., habitat and prey availability, water quality) and biotic effects (e.g., predation, competition). Age-structure data allow unique assessment of fish populations (e.g., mortality, recruitment limitations), as well as responses to management actions or environmental changes (Buktenica et al. 2007). Many age and growth studies have focused on ictalurids (Appelget and Smith 1951, Sneed 1951, Mayhew 1969), but there is a paucity of information on the population demographics of black bullhead (Brown et al. 1999, Hanchin et al. 2002, Phelps et al. 2005) despite their potential influence on water quality and fish assemblage characteristics.

The objective of this study was to describe black bullhead population characteristics in natural lakes of Iowa, USA with differing water quality characteristics. Specifically, we sought to evaluate abundance, size structure, condition, mortality, recruitment variability, and growth to provide insight on the relations of population characteristics with water quality conditions.

MATERIALS AND METHODS

Lakes sampled were West Okoboji Lake, Lake Minnewashta, and Silver Lake, all located in northwest Iowa. West Okoboji Lake has a surface area of 1,565 ha and a maximum depth of 41 m. Lake Minnewashta, connected by canal to West Okoboji Lake, is 47 ha with a maximum depth of 5 m. Silver Lake has a surface area of 431 ha and is the shallowest of the study lakes with a maximum depth of 3 m. Study lakes were selected based on their close proximity (i.e., similar climatic influences) and varying water quality conditions. A number of physical and chemical water quality characteristics were measured including chlorophyll *a*, total nitrogen, total phosphorus, Secchi depth, and total suspended solids. In addition, Carlson's trophic state index (TSI), based on chlorophyll *a*, total phosphorus, and Secchi depth, was calculated to provide additional insight on the study lakes (Carlson 1977). Water quality data were obtained by Iowa State University personnel three times each summer (May-August) from 2000 to 2007 (Downing et al. 2005). Samples were collected from the epilimnion when a thermocline was present and from the entire water column when a thermocline was absent. Water samples were stored at 4°C and analyzed within 48 hours.

Fish were sampled with modified fyke nets. Fyke nets had a 15.2 m lead, two 0.9 m × 1.8 m frames, and 13-mm bar measure mesh. A total of 10 net-nights was used in Lake Minnewashta and 20 net-nights in Silver Lake and West Okoboji Lake. Nets were deployed in the late afternoon and retrieved the following morning. All lakes were sampled between July 7 and July 13, 2008 to minimize temporal variation among samples. Fish were measured to the nearest millimeter (total length) and weighed to the nearest gram.

Catch-per-unit-effort (CPUE) was calculated as the mean number of fish per net-night (fish/NN). Size structure was estimated using proportional size distribution (PSD; Guy et al. 2007). Proportional size distribution is the proportion of stock-length fish (150 mm) that are quality length (230 mm) or greater (Anderson and Neumann 1996). In addition, PSDs were estimated for preferred- (300 mm), memorable- (380 mm), and trophy-length (460 mm) fish (Gabelhouse 1984, Anderson and Neumann 1996). Body condition of black bullheads was assessed using relative weight (*Wr*; Wege and Anderson 1978, Anderson and Neumamn 1996). Heincke's method was used to estimate total annual mortality for each black bullhead population (Everhart et al. 1953). The recruitment variation index (RVI) was used to calculate variability in recruitment (Guy and Willis 1995). The RVI varies from -1 to 1, with higher values indicating more stable recruitment.

Pectoral spines were removed for age and growth analysis following Sneed (1951). Pectoral spines were removed from ten fish per centimeter-length group (DeVries and Frie 1996). Spines were mounted in centrifuge tubes with epoxy as described by Koch and Quist (2007). Two 0.6-mm cross sections were cut using a Buehler Isomet low-speed saw (Buehler, Lake Bluff, Illinois, USA). Incremental measurements of spine cross-sections were collected with an image analysis system and Image-Pro Plus software (Media Cybernetics, Bethesda, Maryland, USA). All cross-sections were independently aged by three readers. An age consensus for each fish was reached by examining the readers' presumptive ages (Laine 1991). Back-calculated length-at-age was estimated using the Dahl-Lea method (DeVries and Frie 1996). An age-length key was used to assign ages to lengths of non-aged fish using methods detailed by Isermann and Knight (2005). Growth was estimated by fitting von Bertalanffy growth curves to mean back-calculated lengths at age for each population: $L_t = L_\infty(1 - e^{-K(age-t_o)})$, where L_t is the mean length at age t, L_∞ is the theoretical maximum length, K is the growth coefficient, and t_0 is the theoretical age when length equals 0 mm (Isely and Grabowski 2007). Growth models were fit to L_t data using nonlinear regression techniques (Freund and Littell 1991).

Analysis of variance (ANOVA) was used to determine if mean physicochemical habitat characteristics and the mean length at age 3 for each population differed between lakes. All statistical analyses were conducted using SAS 9.1.3 (SAS Institute 2006).

RESULTS

Six-hundred-and-fifty-three black bullheads were sampled from the study lakes. Of these, age and growth were estimated from a subsample of 243 fish. In Lake Minnewashta, 104 black bullheads were sampled and 59 were aged. In West Okoboji, 112 fish were sampled and 88 aged, and 437 were sampled and 96 were aged in Silver Lake. Exact agreement in age estimates was 77% among the three readers and 99% agreement between any two readers. A consensus age was assigned for 100% of the fish.

Black bullhead CPUE differed between lakes ($F_{2,47} = 13.02$, $P<0.01$). Catch-per-unit-effort of black bullhead was higher in Silver Lake (21.9 fish/NN) than Lake Minnewashta (10.4 fish/NN) and West Okoboji Lake (5.6 fish/NN; Fig. 1). Black bullhead CPUE did not differ between Lake Minnewashta and West Okoboji Lake.

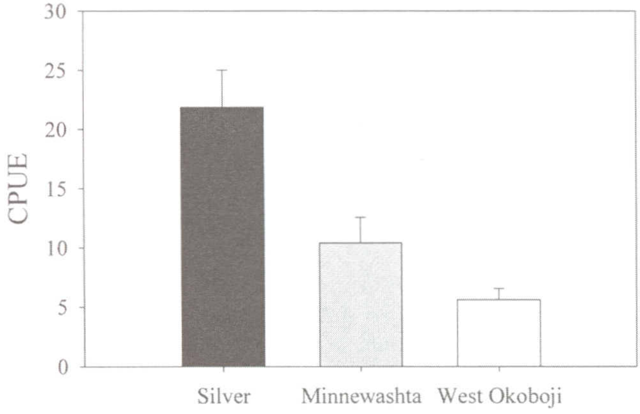

Figure 1. Catch-per-unit-effort (fish per fyke net night) of black bullheads sampled from West Okoboji Lake, Lake Minnewashta, and Silver Lake in Iowa, U.S.A., 2008. Mean CPUE with the same letter did not significantly differ ($P \leq 0.05$).

Size structure was similar among populations (Fig. 2). All fish sampled from Silver Lake were quality length or greater (i.e., PSD = 100), while PSD was 96 in Lake Minnewashta and 91 in West Okoboji Lake. The PSD-P was greater in Silver Lake (PSD-P = 85) compared to Lake Minnewashta (8) and West Okoboji (19). Only one memorable-length and no trophy-length fish were sampled. Relative weights of all fish were similar among populations ($F_{2,644} = 1.73$, P=0.18). Relative weight of quality- to preferred-length black bullhead in Silver Lake was greater than Lake Minnewashta and West Okoboji Lake. Mean *Wr* for all other length categories did not differ among populations. Total annual mortality of black bullheads was 79% in Lake Minnewashta, 35% in West Okoboji Lake, and 24% in Silver Lake (Fig. 3). Recruitment variability was lowest in West Okoboji Lake (RVI = 0.69) followed by Lake Minnewashta (0.62) and Silver Lake (0.47).

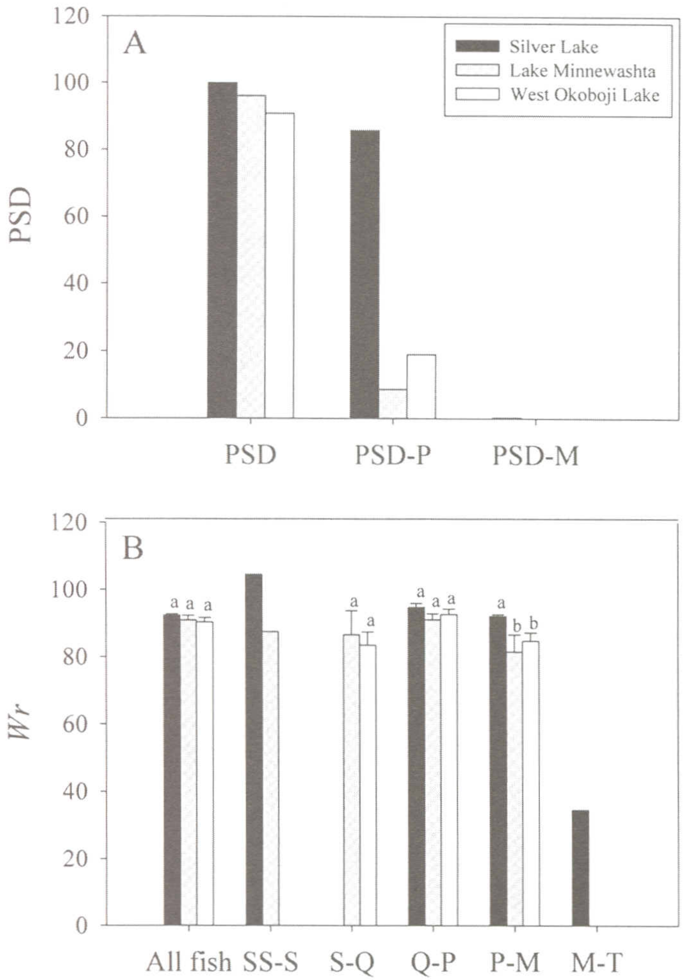

Figure 2. (A) Size structure using proportional size distribution (PSD), PSD of preferred-length fish (PSD-P), and PSD of memorable-length fish (PSD-M); (B) condition using mean relative weight (*Wr*) by length category [length categories are as above and also include substock (SS), stock (S), quality (Q), and trophy (T)] for black bullheads sampled from West Okoboji Lake, Lake Minnewashta, and Silver Lake in Iowa, U.S.A., 2008. Bars represent one standard error. Mean *Wr*s with the same letter did not significantly differ ($P \leq 0.05$).

Mean back-calculated lengths at age 3 differed among lakes and tended to be highest in Silver Lake and lowest in West Okoboji Lake (Table 1). Growth models illustrated similar trends in growth among lakes (Fig. 4). Specifically, *K* was highest in Silver Lake followed by West Okoboji and Lake Minnewashta population parameters.

Water quality characteristics varied across the study lakes. Silver Lake had higher mean inorganic suspended solids, volatile suspended solids, and total nitrogen concentrations than Lake Minnewashta and West Okoboji Lake (Fig. 5). Mean Carlson TSI values using chlorophyll *a* and total phosphorus from West Okoboji Lake were lower than Lake Minnewashta and Silver Lake. Carlson TSI values using Secchi depth differed among all lakes.

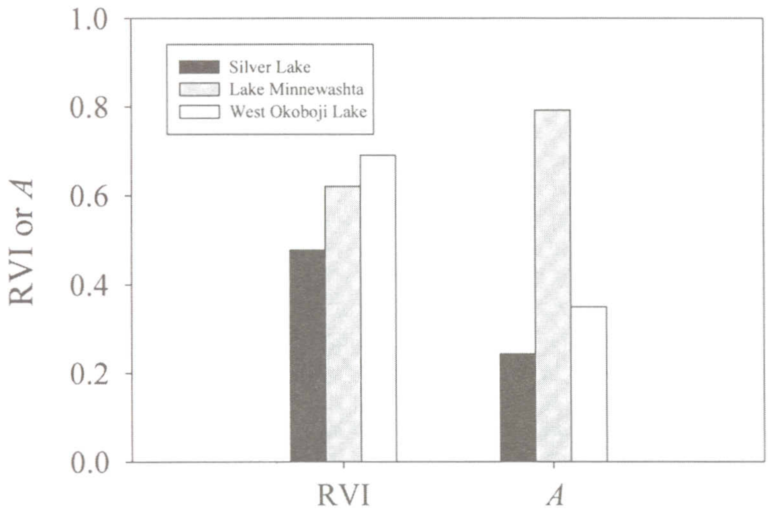

Figure 3. Recruitment variation Index (RVI) and total annual mortality (*A*) for black bullheads sampled from West Okoboji Lake, Lake Minnewashta, and Silver Lake in Iowa, U.S.A., 2008.

Table 1. Mean back-calculated total lengths at age for black bullhead sampled from three natural lakes in Iowa, U.S.A. Values in parentheses are standard errors.

		Mean back-calculated total length (mm) at age						
Lake	N	1	2	3	4	5	6	7
Minnewasta	59	76(3)	162(4)	247(4)	262(9)			
Silver	96	86(3)	192(4)	274(3)	307(4)	331(4)	339(4)	
West Okoboji	88	71(3)	151(4)	228(4)	265(4)	270(7)	291(7)	324(0)

DISCUSSION

The black bullhead population with the highest abundance, largest fish, highest body condition, highest recruitment variability, lowest mortality, and fastest growth was in Silver Lake, where the most eutrophic characteristics were observed. Other studies have found similar correlations between some of the population characteristics evaluated in our study and eutrophic characteristics. For example, abundance and mean length at age 3 of black bullhead have been shown to be positively correlated with increased nutrients in Nebraska and South Dakota lakes (Brown et al. 1999, Hanchin et al. 2002, Phelps et al 2005). Although density-dependent relationships were not apparent in our study lakes, black bullhead in other areas of its distribution may reach high abundances and exhibit density-dependent growth. Phelps et al. (2005) found that densities of black bullhead were inversely related to PSD of black bullhead populations, but not to *Wr* or mean lengths of age-3 fish in Nebraska lakes. In South Dakota, black bullhead abundance was inversely related to size structure (Brown et al. 1999) and growth (Hanchin et al. 2002). The lack of density-dependent relations in our study may be due to substantially higher abundances observed by other studies. For example, Phelps et al. (2005) observed CPUE as high as 564.8 fish/fyke NN in Nebraska, while Brown et al. (1999) observed four lakes in South Dakota with CPUE greater than 200 fish/fyke NN. We observed a maximum mean CPUE of 21.8 Fish/NN in Silver Lake and a minimum mean CPUE of 5.6 Fish/NN in West Okoboji Lake. The modified-fyke nets used in Phelps et al. (2005) and Brown et al. (1999) had similar frame dimensions and bar mesh sizes compared to our nets.

Black bullhead tends to be most abundant in systems with low water clarity and high nutrient concentrations. Additionally, black bullhead abundance is often positively associated with the abundance of common carp (Brown et al. 1999, Hanchin et al. 2002, Phelps et al. 2005). Like black bullhead, common carp is considered a tolerant benthivorous species and has received substantial attention due to its negative influence on aquatic ecosystems. Common carp can increase turbidity and available nutrients through excretion and resuspension of sediment in the water column (Andersson et al. 1978, Breukelaar et al. 1994) and may directly consume or uproot aquatic macrophytes while foraging for invertebrates (Lougheed et al. 1998, Sidorkewicj et al. 1999, Miller and Crowl 2006). This decrease in water quality has negative impacts on less-tolerant native fish species (Bernstien and Olson 2001, Koehn 2004). Although benthivorous fish are often associated with poor water quality, few studies have evaluated the effects of fish other than common carp on water quality conditions. Braig and Johnson (2003) evaluated the effects of black bullhead on turbidity in shallow systems and found that water clarity decreased with increased black bullhead biomass. However, the effect of

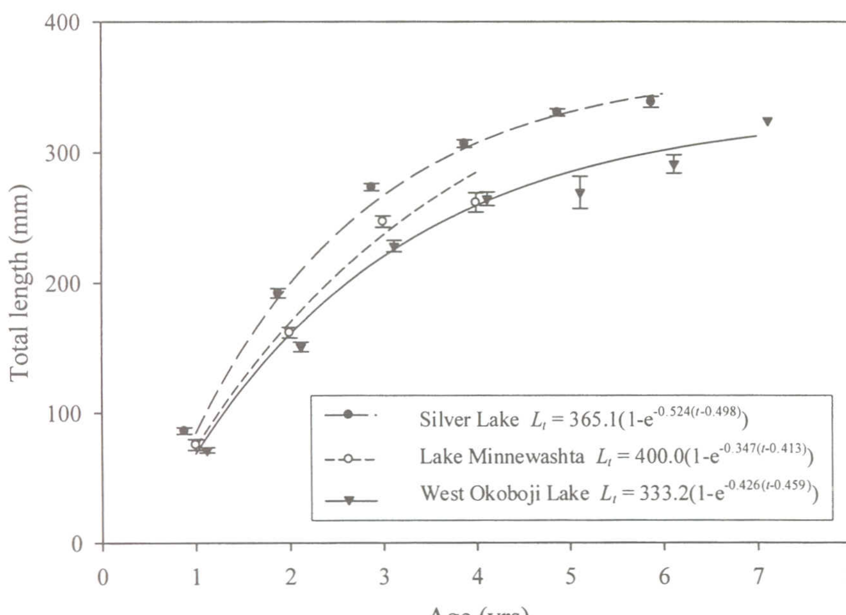

Figure 4. Mean back-calculated lengths-at-age for black bullhead populations sampled from West Okoboji Lake, Lake Minnewashta, and Silver Lake in Iowa, U.S.A., 2008. Bars represent one standard error. The line represents the best-fit von Bertalanffy growth model for each population.

black bullhead was less than the effect of wind resuspension of sediment. The results of our study demonstrated higher growth, abundance, and *Wr* of black bullhead populations from the most eutrophic lake. While black bullhead may have caused these conditions, it may also be the beneficiary of reduced competition from species intolerant of degraded water quality conditions. However, the mechanisms driving these relationships remain unknown and further investigations are needed to evaluate the potential influence of black bullhead on water quality conditions.

Although the scope of this study was limited to three populations, our results provide important information on the characteristics of black bullhead populations from lakes with differing water quality. Our results also provide fisheries managers with information regarding population characteristics and habitat influences on black bullhead growth, condition, and size structure. A noticeably high abundance of black bullhead can provide insight on chemical and physical characteristics of a system. Moreover, the status of other fish species and management decisions can be evaluated by observing the abundance of black bullhead in a given waterbody. For example, the population

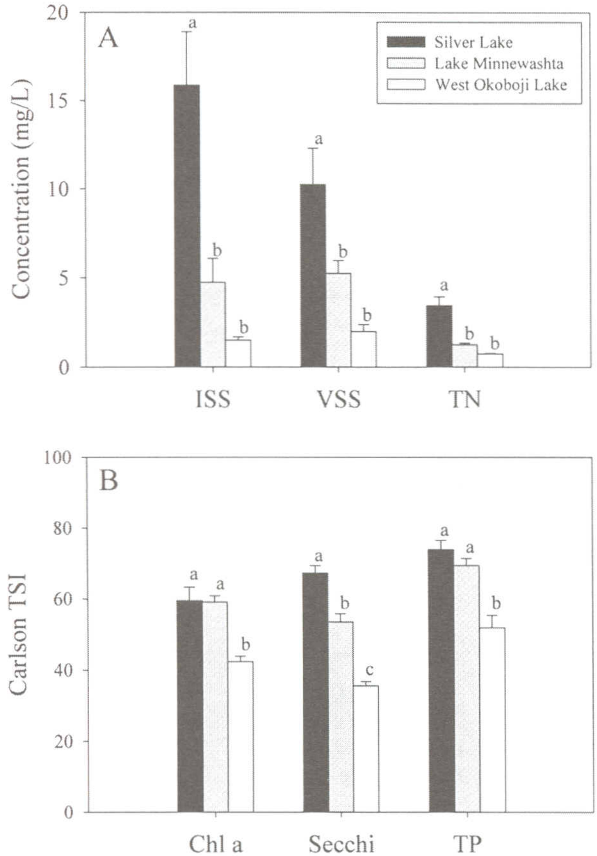

Figure 5. (A) Mean inorganic suspended solids (ISS; mg/L), volatile suspended solids (VSS; mg/L), and total nitrogen (TN; mg/L) concentrations; (B) Carlson Trophic Status Index (TSI) for chlorophyll *a* (Chl *a*), Secchi depth, and total phosphorus (TP) sampled from West Okoboji Lake, Lake Minnewashta, and Silver Lake in Iowa, U.S.A., 2000-2007. Bars represent one standard error. Mean water quality characteristics with the same letter did not differ significantly ($P \leq 0.05$).

characteristics of black bullhead in a system may indicate condition or abundance of less tolerant species of interest and may be used as a potential bioindicator of habitat and water quality characteristics. In turn, shallow, highly productive systems that tend to revert back to a eutrophic status upon management action may be suitable areas to manage or allow the existence of more tolerant fish species such as black bullhead.

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