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Relating Impoundment Morphometry and Water Quality to Black Crappie, Bluegill, and Largemouth Bass Populations in Iowa

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Abstract.—We evaluated the influence of lake morphometry, water quality, and common carp *Cyprinus carpio* and largemouth bass *Micropterus salmoides* population structure on quality black crappie *Pomoxis nigromaculatus* and bluegill *Lepomis macrochirus* populations for 20 Iowa impoundments. Growth of black crappie was positively related to growth of largemouth bass. Black crappie catch per unit effort (CPUE) was positively associated with watershed size and alkalinity and negatively related to largemouth bass growth. Size structure of bluegill populations was positively influenced by chlorophyll concentrations and largemouth bass catch rates. Total phosphorus and CPUE of stock-to-quality length largemouth bass were also positively related to bluegill growth. Bluegill CPUE was inversely related to largemouth bass growth. Quality largemouth bass populations were allied with turbid (high total suspended solids and low Secchi disk depth) impoundments that had a diverse shoreline and large watersheds. Largemouth bass growth was inversely related to mean depth, and largemouth bass CPUE was inversely related to alkalinity and total suspended solids. Information from this study will be used to classify and rank impoundments in terms of their management priorities. Based on impoundment morphometry and water quality, managers can then target management practices toward species best suited to a particular impoundment.

Introduction

Crappie *Pomoxis* spp. and bluegill *Lepomis macrochirus* support important fisheries in Iowa and made up 46% of the 1994 statewide harvest (Lutz et al. 1995). Popularity of these panfish also ranks high, outranked only by channel catfish *Ictalurus punctatus*, largemouth bass *Micropterus salmoides*, and walleye *Sander vitreus*. Statewide, 20% of licensed Iowa anglers preferred catching bluegill or crappie. Estimated harvest in 1994 was nearly 19 million fish, and panfish constituted about 50% of the harvest in southern Iowa (Lutz et al. 1995). It is common for crappie and bluegill to comprise 85% of the fish harvested by anglers from Iowa's impoundments (Mitzner 1978, 1981).

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The popularity of panfish and dominance of crappie and bluegill in the harvest is largely due to their high abundance in Iowa waters. Some impoundments produce quality angling with very little cost and effort, while others produce fish lacking angler appeal, despite costly application of traditional fisheries management techniques (e.g., whole or partial lake renovations, habitat management, and fish stockings). For example, at Lake Ahquabi, Iowa, traditional fisheries management techniques that focused on lake draw-down, selective or total fish removal, and fish stockings were used in 1965, 1975, and 1981 to restore the quality of the fisheries. These efforts were conducted wholly within the impoundment, targeting management of a fish assemblage dominated by common carp *Cyprinus carpio*, gizzard shad *Dorosoma cepedianum*, and small, slow-growing panfish, typical problems that continue to hinder management (Gardner 1981; Bonneau and Radonski 1983; Crivelli 1983; Drenner et al. 1997; Michaletz and Bonneau 2005). Public dissatisfaction with failed attempts to improve the fishery and continuous deterioration in public use of this historic and once popular state park resulted in renewed thinking to reverse the trend. Improvements to the impoundment's 1,350-ha watershed and lake were initiated in 1993 and were completed in 1997. Improvements included a new lake draw-down structure, repair of the overflow spillway, and modifications to prevent undesirable fish from re-entering the lake during periods of high discharge. Restoration work also included construction of five new sediment-nutrient basins and reconstructing and increasing the size of an existing basin from 6 to 18 ha. These basins were designed as wetlands with structures to allow for water level management. In-lake and watershed enhancements were related to better water quality within the impoundment and an increase in the biomass of sport fishes. This led to improved angler catch and harvest rates, and park use increased substantially (Schultz 2006).

Success stories, like those for Lake Ahquabi, developed from previous water quality and watershed studies conducted in Iowa and elsewhere. Hill (1984) found that mean lake basin slope and adjusted siltation index (an index based on watershed and lake surface area, erosion rate, and percent of the watershed in approved soil conservation practices) were related to the quality and biomass of crappie populations. Buck (1956), Gardner (1981), and Mitzner (1991) also delineated the effect of physical factors on the quality of bluegill and crappie populations, with water level, temperature, turbidity, wind, and substrate having the greatest influence on fish populations.

Biotic factors affecting bluegill and crappie populations often include prey availability and predator density. Control of overabundant panfish populations by stocking predators has been extensively studied by Gabelhouse (1984), Boxrucker (1987), Jahn et al. (1987), and Snow (1988). Mechanical removal of bluegill and crappie to reduce densities and improve growth of remaining fish has been marginally successful, as at least 50% of the population biomass must be removed and results are typically short-lived (Houser and Grinstead 1961; Beyerle and Williams 1972; Rutledge and Barron 1972). Tomcko and Pierce (2001) documented that bluegill length at ages 1–6 was inversely correlated to Secchi and maximum depth in Minnesota lakes. However, the authors suggested that other variables not measured (food resources, species interactions, and exploitation) likely played a large role in bluegill growth. The authors further stressed that a reduction in bluegill recruitment may be the most effective management strategy for improving bluegill population structure. Tomcko and Pierce

(2001) concentrated on relationships between bluegill growth, lake morphometry, and water quality. The authors asserted that Secchi depth, total alkalinity, and maximum depth, although explaining no more than 33% in the variation in bluegill growth through their first 5 years, were easily collected and provide an initial evaluation of bluegill growth. Paukert et al. (2002) explored the relationship of panfish (bluegill and yellow perch Perca flavescens) to Nebraska sandhill lake characteristics and largemouth bass abundance and population structure in these lakes. Quality bluegill populations in these large, shallow lakes were attributed to low exploitation of bluegill, as well as high-density largemouth bass smaller than 30 cm.

We examined the relationship between black crappie *P. nigromaculatus*, bluegill, and largemouth bass population structure and growth, common carp population structure and abundance, lake basin morphometry, water quality conditions, and watershed characteristics. The goal of this study was to provide knowledge necessary to predict the quality of bluegill and black crappie fishing provided by a variety of Iowa impoundments. This information will expand efforts beyond traditional fisheries management activities and help managers address important ecological factors that limit angling opportunity for quality black crappie and bluegill.

Methods

We used information collected by the Iowa Department of Natural Resources (IDNR) biologists for 20 impoundments that contained the following target species: bluegill, black crappie, and largemouth bass. These lakes also contained channel catfish, green sunfish *L. cyanellus*, and black bullhead *Ameiurus melas*. White crappie *P. annularis*, common carp, and grass carp *Ctenopharyngodon idella* were present in several impoundments. Lakes included in this study represented a diversity of ecological conditions common to other Iowa impoundments, and all the lakes represented important fisheries. The physical, chemical, and biological characteristics of each study lake and watershed were examined, particularly relations among fish population structure, growth, lake morphometry, watersheds, and water quality.

Lake Morphometry, Watersheds, and Water Quality

Physical characteristics of the lakes were derived from measurements and calculations made by Bachmann et al. (1994). Characteristics included surface area, maximum and mean depth, shoreline development index (SDI), watershed size, watershed:lake area ratio, and mean basin slope. Water characteristics were measured for the upper 3 m of the water column at each impoundment three times during May through August from 2000 to 2004. Measured parameters included Secchi disk depth, chlorophyll *a*, total suspended solids, total alkalinity, total phosphorous, and total nitrogen, according to the American Public Health Association (APHA 1998) standards.

Fish Populations

Fish size structure and growth were derived from trap nets for bluegill and black crappie during the fall and electrofishing largemouth bass during the spring at all impoundments. Common carp size structure was collected with trap nets during the fall. Size structure was described by proportional size distribution (PSD) and proportional size distribution of preferred-length fish (PSD-P; Guy et al. 2007). Growth was represented using relative growth index (RGI: [Lt/Ls] * 100, where Lt = observed length at age (*t*) and Ls = predicted age-specific standard length; Quist et al. 2003; Jackson et al. 2008] and years required to reach preferred length (Yr-P). Values of RGI greater than 100 indicate relatively fast growth, whereas values less than 100 indicate relatively slow growth. Fisheries data were collected at the study impoundments during one year between 2000 and 2004.

All catch per unit effort (CPUE) data were $\log_{10}$(CPUE + 1)-transformed and proportions were arc sin square root-transformed to better meet the assumptions of normality. We report nontransformed values for clarity. Stepwise multiple regression analysis was used to examine whether the dependent variables of black crappie, bluegill, and largemouth bass PSD and PSD-P, RGI, Yr-P, and CPUE were related to morphometric characteristics and water quality of Iowa impoundments. Additionally, black crappie and bluegill PSD and PSD-P, RGI, Yr-P, and CPUE were tested against largemouth bass PSD and PSD-P, RGI, and CPUE, and common carp PSD, PSD-P, and CPUE. We only used independent variables in the regression analysis when they were highly correlated with dependent variables (i.e., correlation coefficients ≥ 0.30) in the stepwise multiple regression models. An α level of 0.10 was used to define statistically significant relationships.

Results

Although impoundments in Iowa are generally considered eutrophic (Hatch 2003), the study impoundments varied in water quality and lake morphometry (Table 1), as well as sport fish population characteristics (Table 2). Surface area of impoundments varied from 7 to 199 ha, and maximum and mean depths varied from 3.2 to 14.6 m and 1.5 to 4.6 m, respectively. Mean basin slope varied from 2.2 to 12.4, with shoreline diversity indices varying from 1.8 to 4.1. Watershed:lake area ratios varied from 6.1 to 63.2 (Table 1). Water quality parameters varied from 0.2 to 3.2 m for Secchi depth, 4.7 to 137.7 μg/L for chlorophyll-*a* levels, 43.1 to 432.7 μg/L for total phosphorus, and 0.7 to 5.4 mg/L for total nitrogen. Total suspended solids ranged from 5.9 to 88.4 mg/L, and total alkalinity ranged from 86.7 to 207.2 mg/L (Table 1). Black crappie PSD and PSD-P both ranged from 0 to 100 (Table 2). Bluegill size structure was less variable, with PSDs ranging from 0 to 75 and PSD-P from 0 to 50. Largemouth bass PSD ranged from 15 to 83, and PSD-P ranged from 0 to 59. Common carp population characteristics varied greatly. Common carp PSD averaged 29 (SD = 42). Overall catch rate of common carp ranged from 0 to 3.2 fish per trap net. Growth, as depicted by relative growth index was 105 (SD = 13) for black crappie populations, 102 (SD = 13) for bluegill, and 95 (SD = 7) for largemouth bass populations in the study impoundments. Growth was not evaluated for common carp.

Combining Lake Morphometry, Watersheds, Water Quality, and Fish Populations

Black crappie size structure (PSD and PSD-P) was related to morphometry, water quality, and largemouth bass variables (Table 3). For water quality variables, total suspended solids was positively related to black crappie PSD, whereas PSD-P was inversely related to both alkalinity and chlorophyll *a*. Largemouth bass RGI was positively related with black crappie PSD and PSD-P. In addition, black crappie PSD-P was inversely related to catch rates of stock-to-quality length largemouth bass. Black crappie growth (both RGI and Yr-P) was influenced by largemouth bass RGI. Specifically, black crappie RGI was positively related and black crappie Yr-P was inversely related to largemouth bass RGI. Black crappie CPUE was influenced by morphological, water quality, and largemouth bass characteristics (Table 3).

Relationships between bluegill PSD and morphometry, water quality, or largemouth

Table 1. Physical and chemical characteristics of 20 Iowa impoundments used in this study. Physical characteristics were derived from Bachman et al. (1994). Chemical characteristics (SD) were measured three times during May–August for each year, 2000–2004. Total suspended solids is represented by TSS, total phosphorus is TP, and total nitrogen is TN. SDI is shoreline diversity index.

Impoundment	Area (ha)	Maximum depth (m)	Mean depth (m)	Mean basin slope	SDI	Watershed: lake ratio	Mean Secchi depth (m)	Mean Chlorophyll *a* µg/L	Mean TSS mg/L	Mean TP µg/L	Mean TN mg/L	Mean total alkalinity mg/L
Ahquabi	44	5.3	2.5	2.5	3.27	30.6	1.33	23.33	7.80	85.20	2.00	95.80
							(0.79)	(15.65)	(2.37)	(46.46)	(2.55)	(27.15)
Anita	74	8.5	3.7	5.7	4.05	13.2	1.02	37.05	13.25	70.25	1.22	104.00
							(0.65)	(32.67)	(7.82)	(31.82)	(0.30)	(21.73)
Bob White	36	4.3	1.5	2.7	2.97	38.2	0.27	21.45	38.47	246.07	2.20	86.73
							(0.09)	(19.22)	(22.51)	(139.91)	(1.41)	(30.60)
Green Valley	136	7.3	3	3.4	3.73	12.5	1.13	44.52	12.40	129.80	2.43	112.27
							(0.87)	(57.81)	(7.42)	(93.67)	(1.09)	(47.95)
Hawthorn	70	9.8	3.7	5.4	3.4	19.4	0.92	29.23	12.07	67.40	1.36	112.33
							(0.55)	(22.65)	(6.26)	(44.45)	(0.47)	(47.95)
Iowa	35	9.8	3.7	4.3	2.12	15.5	1.31	30.08	9.67	76.73	1.80	103.80
							(0.82)	(30.84)	(5.39)	(31.10)	(0.83)	(39.90)
Keomah	34	6.7	3	4	2.91	22.1	0.93	40.43	15.53	139.60	1.68	105.67
							(0.68)	(34.59)	(9.91)	(82.43)	(0.63)	(39.56)
Lacey-Keo	9	8.5	3.7	11.3	1.98	34.4	2.11	8.10	13.30	69.80	0.99	122.20
							(0.99)	(6.99)	(26.67)	(63.98)	(0.63)	(56.18)
Miami	55	7.3	3	5.5	3.29	28.9	0.52	48.39	21.87	150.00	1.80	96.47
							(0.20)	(41.66)	(13.62)	(69.09)	(0.86)	(53.42)
Nine Eagles	26	9.8	4.3	7.6	2.3	19	1.67	4.72	6.36	45.21	0.72	102.62
							(0.40)	(4.22)	(2.79)	(45.96)	(0.24)	(31.39)
Pahoja	26	9.1	2.4	2.5	2.98	62.5	1.17	35.90	13.87	132.60	4.00	207.20
							(0.71)	(31.82)	(5.94)	(140.80)	(2.26)	(43.72)
Prairie Rose	89	7.3	3	5.1	3.04	21	0.72	34.05	20.13	104.00	2.04	129.20
							(0.39)	(27.33)	(22.45)	(70.84)	(1.18)	(22.07)

Table 1. Continued.

Impoundment	Area (ha)	Maximum depth (m)	Mean depth (m)	Mean basin slope	SDI	Watershed: lake ratio	Mean Secchi depth (m)	Mean Chlorophyll *a* µg/L	Mean TSS mg/L	Mean TP µg/L	Mean TN mg/L	Mean total alkalinity mg/L
Rock Creek	199	6.1	2.4	–	3.14	53.8	0.99	25.33	13.53	69.47	4.53	135.67
							(0.44)	(9.31)	(7.44)	(23.00)	(2.43)	(17.48)
Slip Bluff	7	7.3	3.7	12.4	2.29	14.4	1.37	4.88	9.87	55.40	0.67	97.93
							(0.57)	(3.58)	(7.88)	(55.61)	(0.17)	(24.88)
Smith	24	3.2	1.5	2.3	1.82	18.6	1.51	29.39	17.13	185.47	5.36	136.00
							(1.13)	(21.19)	(23.02)	(136.63)	(3.78)	(31.98)
Swan	45	4.3	1.8	2.2	1.78	6.1	0.20	137.74	88.40	432.67	2.50	115.80
							(0.08)	(141.17)	(58.87)	(234.16)	(0.87)	(43.22)
Union Grove	43	4.9	2.4	2.3	1.92	63.2	0.63	40.81	22.07	124.20	4.44	135.87
							(0.26)	(24.54)	(10.41)	(68.30)	(3.14)	(25.38)
Viking	55	14.6	4.6	8.6	3.51	15.6	1.05	35.79	11.20	89.47	1.25	113.53
							(0.59)	(17.49)	(5.06)	(48.19)	(0.42)	(21.97)
Williamson Pond	12	5.5	2.4	5.5	2.06	46.8	0.76	22.86	19.67	241.00	2.40	99.42
							(0.82)	(18.49)	(15.26)	(137.28)	(1.41)	(26.87)
Yellow Smoke	16	7.9	3.4	6.2	3.56	39.9	3.16	10.68	5.85	43.08	0.95	163.31
							(0.98)	(8.37)	(3.83)	(25.07)	(0.37)	(27.48)

Table 2. Summary statistics of panfish and largemouth bass populations in 20 Iowa impoundments. Fish were sampled once per impoundment between 2000 and 2004. Growth is represented as the relative growth index (RGI) and years to reach preferred length (Yr-P). Size structure is described by proportional size distribution (PSD) and proportional size distribution of preferred-length fish (PSD-P).

	Sample years		Black crappie				Bluegill				Largemouth bass			
Impoundment	Fall fyke nets	Spring electrofishing	PSD	PSD-P	RGI	Yr-P	PSD	PSD-P	RGI	Yr-P	PSD	PSD-P	RGI	Yr-P
Ahquabi	2001	2001	0	0	–	–	0	0	102	–	24	3	93	–
Anita	2001	2001	0	0	104	4.1	41	7	108	4.5	74	26	87	5.4
Bob White	2003	2003	100	100	–	–	40	0	86	–	83	59	100	–
Green Valley	2002	2002	59	0	125	3.1	75	50	113	4.6	25	23	105	4.3
Hawthorn	2004	2004	56	0	115	3.5	43	0	108	4.5	39	19	98	4.8
Iowa	2002	2002	94	69	108	4.4	49	2	99	6.9	35	17	97	4.6
Keomah	2003	2003	35	15	107	4.0	53	13	106	6.2	54	11	94	5.6
Lacey-Keo	2003	2003	0	0	–	–	9	9	–	–	42	0	–	–
Miami	2003	2003	29	3	107	5.0	41	5	107	6.7	48	13	91	5.5
Nine Eagles	2001	2001	0	0	111	3.7	50	11	94	6.4	32	0	–	–
Pahoja	2001	2001	49	0	89	8.2	32	0	98	8.6	72	50	–	–
Prairie Rose	2004	2004	47	0	94	–	27	0	102	–	55	22	92	4.7
Rock Creek	2003	2003	42	2	115	3.8	50	0	112	6.5	57	29	99	4.7
Slip Bluff	2001	2001	50	50	–	–	46	0	94	–	15	0	90	–
Smith	2004	2004	33	0	–	–	28	0	100	–	39	0	–	–
Swan	2002	2002	25	0	83	–	43	0	101	–	72	48	–	–
Union Grove	2001	2001	73	0	111	–	39	2	–	4.0	40	17	94	4.8
Viking	2003	2003	37	1	98	–	45	4	112	7.4	50	0	90	5.0
Williamson Pond	2003	2003	9	0	–	–	42	13	102	7.7	57	30	–	–
Yellow Smoke	2001	2001	0	0	–	–	38	0	107	4.8	50	8	95	5.2
Mean			37	12	105	4.6	40	6	102	6.5	48	18	95	5.0
(SD)			(31)	(28)	(13)	(1.5)	(16)	(11)	(13)	(2.3)	(17)	(17)	(7)	(0.4)

Table 3. Stepwise multiple regression models for black crappie, bluegill, largemouth bass, and water quality and impoundment morphometry in 20 Iowa impoundments. Population characteristics are the dependent variables, separated by species. Growth is represented as the relative growth index (RGI) and years to reach preferred length (Yr-P). Size structure is described by proportional size distribution (PSD) and proportional size distribution of preferred-length fish (PSD-P). Catch per unit effort is represented by CPUE, and Secchi refers to Secchi disk depth (m). All relationships are positive unless indicated by (–).

Population characteristic	df	Predictor	R^2	*P*
		Black crappie		
PSD	13	Total suspended solids	0.36	0.024
		Shoreline diversity index (–)	0.22	0.036
		Largemouth bass RGI	0.21	0.012
		Maximum depth	0.16	0.001
PSD-P	13	Alkalinity (–)	0.32	0.036
		Shoreline diversity index (–)	0.17	0.083
		Largemouth bass PSD S-Q (–)	0.15	0.068
		Chlorophyll *a* (–)	0.15	0.031
		Largemouth bass RGI	0.13	0.008
RGI	9	Largemouth bass RGI	0.68	0.004
Yr-P	6	Largemouth bass RGI (–)	0.52	0.067
CPUE	13	Watershed area	0.33	0.032
		Largemouth bass RGI (–)	0.20	0.051
		Alkalinity	0.13	0.080
		Secchi (–)	0.10	0.081
		Bluegill		
PSD	13	No significant relationships		
PSD-P	14	Chlorophyll *a*	0.27	0.057
		Largemouth bass CPUE	0.18	0.086
RGI	12	Shoreline diversity index	0.37	0.029
		Mean depth	0.19	0.067
		Watershed area	0.27	0.005
		CPUE of PSD S-Q length largemouth bass (–)	0.11	0.007
Yr-P	10	Mean basin slope	0.29	0.088
		Total Phosphorus	0.24	0.082
CPUE	13	Largemouth bass RGI (–)	0.25	0.067
		Largemouth bass		
PSD	19	Total suspended solids	0.34	0.007
		Shoreline diversity index	0.14	0.052
		Watershed:Lake ratio	0.12	0.042
PSD-P	19	Secchi (–)	0.40	0.003
		Alkalinity	0.14	0.037
RGI	13	Mean depth (–)	0.21	0.099
Yr-P	11	No significant relationships		
CPUE	19	Alkalinity (–)	0.44	0.001
		Total suspended solids (–)	0.18	0.011

bass population structure and growth were not significant (Table 3). Bluegill PSD-P was positively related to chlorophyll *a* and CPUE of largemouth bass. Bluegill RGI was positively related to shoreline complexity and CPUE of stock-to-quality length largemouth bass. Bluegill Yr-P was positively related to basin slope and total phosphorus concentrations. Bluegill CPUE was inversely related to largemouth bass RGI (Table 3).

Largemouth bass PSD was directly related to shoreline development index values, watershed:lake area, and total suspended solids (Table 3). In contrast, largemouth bass PSD-P was inversely related to Secchi depth and positively related to alkalinity. Largemouth bass RGI was inversely related to mean depth, and largemouth bass Yr-P was not related to either impoundment morphometry or water quality. Largemouth bass CPUE was inversely related to alkalinity and total suspended solids (Table 3).

Discussion

Fishing opportunities associated with southern Iowa are composed of small impoundments. Although impoundments used in this study were spatially constrained, they varied greatly in morphometry and water quality despite being classified as eutrophic (Hatch 2003). Previous studies have linked fish production and yield to phosphorus (Hanson and Leggett 1982) and chlorophyll-*a* levels (Jones and Hoyer 1982). Maceina et al. (1996) documented that crappie and largemouth bass size structure and growth are often positively related to trophic state. Recent studies have concentrated on panfish relationships to lake morphometry and water quality (Tomcko and Pierce 2001; Paukert et al. 2002; Tomcko and Pierce 2005).

Our results suggest that panfish populations in Iowa impoundments are influenced by lake morphometry, water quality, and largemouth bass population structure. Gabelhouse (1984) and Boxrucker (1987) detailed relationships between largemouth bass and crappies in small Midwestern and Oklahoma impoundments. Both authors suggested that the development of quality crappie populations in small impoundments is dependent on the ability to produce and sustain dense largemouth bass populations. Both authors also reported that the PSD of black crappie populations was inversely related to PSD of largemouth bass populations. Our study did not reveal similar patterns. Rather, we found that black crappie PSD-P was inversely related to the abundance of stock-to-quality length largemouth bass. The mechanism for this relationship in Iowa impoundments is unknown since it is unlikely that 20–30-cm largemouth bass have a direct effect on black crappie greater than or equal to 25 cm (i.e., preferred length). Additionally, we found that largemouth bass RGI was influential in producing quality (both PSD and PSD-P) black crappie populations. Our results showed that black crappie and largemouth bass RGI were positively correlated. However, black crappie years to preferred length was inversely related to largemouth bass RGI. Slower growth in largemouth bass populations in Iowa impoundments may create an abundance of slow-growing largemouth bass, which has been shown to have a positive influence on black crappie size structure (Gabelhouse 1984). Black crappie CPUE in small Iowa impoundments was positively related to watershed size and alkalinity but inversely related to largemouth bass RGI and Secchi disk depth.

Studies detailing the relationship between crappie population structure and lake morphometry and water quality variables are less prevalent in the literature. Relationships between water quality and black crappie population characteristics, growth, and catch rates illustrated the influence of water clarity, nutrient concentrations, and alkalinity on black crappie populations in Iowa's small impoundments. Hill (1984) linked fish population characteristics of interest to anglers to increased water levels and low sediment input. We found that similar relationships in the maximum depth were positively correlated to black crappie PSD. In our study impoundments, however, black crappie PSD was positively related to TSS, which may be due to the fact that our water samples were collected during spring when runoff and sediment transport were likely high. Low SDI was important to both black crappie PSD and PSD-P. Low SDI equates to less littoral area. Further research is warranted on the biotic and abiotic factors that affect crappie in small impoundments, especially in light of the popularity of crappie to anglers (Lutz et al. 1995).

Bluegill population dynamics are influenced by abiotic factors in lentic systems. For instance, Tomcko and Pierce (2005) found that growth, recruitment, and population structure were strongly interrelated rather than being related to predator, lake morphometry, or physical and chemical lake characteristics. Our study did not emphasize intraspecific bluegill relationships; rather, this study was designed to explore impoundment morphometry and water-quality relationships to quality panfish populations, as studies with this focus are not particularly common in the literature. We found no relationship between limnological characteristics and bluegill PSD, but bluegill PSD-P was positively correlated with chlorophyll and largemouth bass CPUE. Theiling (1990) found that macrophyte density, zooplankton size, and profundal benthos biomass explained 60% of the variation in bluegill growth rates. In contrast to Theiling (1990) who found no relationship between bluegill growth and water quality or lake morphometry, bluegill growth in the present study was associated with both water quality and impoundment morphometry. Bluegill relative growth indices were above 100 in most cases and positively correlated with SDI, mean depth, mean basin slope, and larger watersheds. Tomcko and Pierce (2001) also found SDI to be an important factor associated with bluegill growth. Nutrients (total phosphorus) also influenced growth of bluegill in Iowa impoundments. Faster growth and greater numbers of largemouth bass have been positively linked to quality bluegill size structure in other studies (Novinger and Legler 1978; Gabelhouse 1984; Guy and Willis 1990). Bluegill population structure, growth, and CPUE were unrelated to common carp population structure and CPUE, although the low catch rate and high variability of common carp may have obscured any bluegill–common carp relationships.

Largemouth bass size structure was influenced by water quality and morphometry variables. Total suspended solids and alkalinity were positively associated with largemouth bass size structure, whereas Secchi disk depth was inversely related. This inverse relationship details that productivity and size structure may be linked. Largemouth bass size structure was also related to larger watershed:lake ratios with more diverse shorelines. Maceina et al. (1996) also related eutrophic reservoirs in Alabama with increased abundance of memorable-length and mean weight of angler-caught largemouth bass and increased largemouth bass growth and condition. The significance of this finding for small Iowa impoundments is that impoundments deemed inappropriate for impoundment or watershed renovation (due to large watershed:lake ratios, cost of renovation, uncooperative landowners, etc.) can still provide quality fishing for largemouth bass. However, panfish population structure and growth may be undesirable in these systems.

Many impoundments in Iowa were constructed with little regard for the factors that ultimately influence fish production and yield. The influence of factors occurring in the watershed and impoundment morphometry on water quality and resultant fish populations have only recently been considered prior to impoundment construction in Iowa (Hill 1984). Impoundments that have already been constructed can benefit from lake deepening and reducing soil and nutrient erosion in the watershed (Schultz 2006). Technology is available to predict the reduction in sediment and nutrient loading from watershed erosion control efforts and implementation of best management practices in the watershed. These benefits should be compared to the cost required to implement these practices and modify the impoundment. Depending on impoundment size, morphoedaphic factors, and management goals, physical and chemical factors can only be altered with great cost and effort after an impoundment is constructed. These costs and associated benefits should then be considered during prioritization of impoundment improvement efforts and for new impoundment construction. Fisheries benefits, in terms of reduction in sediment and nutrient loading through best management practices in the watershed, should be compared to the cost required to implement these practices to benefit water quality and fisheries. Likewise, impoundments containing undesirable panfish populations should be examined to determine the potential for improvement. Even if lakes are not candidates for rehabilitation, the condition of fish populations can be assessed relative to physical characteristics of the impoundment and its watershed. Impoundments containing undesirable panfish populations should be examined to determine potential for improvement. Fish management efforts can then target those species best adapted to the morphometry and water quality occurring in a particular impoundment.

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