Results of Concomitant Predator and Prey Stockings as a Management Strategy in Combatting Stunting in an Oklahoma Crappie Population[1]

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Abstract: The objective of this study was to evaluate the effect of an introduced predator (saugeye; *Stizostedion vitreum* X *Stizostedion canadense*) on the density of intermediate-size white crappie (*Pomoxis annularis*) and to provide a prey species (threadfin shad; *Dorosoma petenense*) to facilitate the crappie dietary shift from invertebrates to fish. Concomitant annual stockings of fingerling saugeye and adult threadfin shad were initiated in 1985 and continued through 1991. Although late summer spawns of threadfin shad were documented in 1988 and 1989, trawl samples failed to collect substantial numbers of threadfin shad. Juvenile threadfin densities never exceeded 20% of the maximum gizzard shad (*Dorosoma cepedianum*) densities for a given year. Threadfin shad did not contribute substantially to the diet of crappie. Stomach analysis of adult saugeye indicated that crappie were a primary component of their diet. Catch rates in trap-net samples indicated a decline in the density of intermediate-sized crappie (130–199 mm) and an increase in catch of crappie ≥200 mm. Crappie growth rates improved, but remained below desired levels. Annual angler harvest of crappie from 1989 through 1991 exceeded the estimated harvest in 3 of the previous 4 years. Recommendations were to continue annual stockings of saugeye but discontinue stockings of threadfin shad. A 457-mm minimum length limit on saugeye was proposed to limit angler harvest of saugeye.

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A symposium held in conjunction with the 44th Midwest Fish and Wildlife Conference in 1982 identified the "small crappie syndrome" as a primary crappie management problem (Mitzner 1984). The crappie population at Thunderbird Reservoir has been dominated by sub-harvestable size individuals since the inception of standardized sampling surveys in 1977. Age and growth analysis of white crappie indicated the presence of a slow-growing, if not stunted, population (Boxrucker 1984).

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Gebhard and Summerfelt (1975) stated that for satisfactory growth to occur, both the quantity and quality (appropriate-size) of forage must be available to facilitate dietary shifts to optimize foraging efficiency. Crappie become piscivorous at approximately 150 mm TL (Hoopes 1960). It was deduced that insufficient forage was available for white crappie in Thunderbird Reservoir to effectively switch to a piscivorous diet.

Inland silversides (*Menidia beryllina*) were introduced into Thunderbird Reservoir in 1978 in an attempt to stimulate growth of largemouth bass (*Micropterus salmoides*) and white crappie. Subsequent food habit and age and growth studies on white crappie indicated little use of inland silversides as forage and no improvement in growth rates, even though silversides dominated the littoral forage samples (Boxrucker 1986).

Prey and predator stockings have been used to elicit desired growth responses of target species. DeVries and Stein (1990) reviewed the literature on shad stockings and concluded that whereas increased growth of the target species was documented in some cases, overall benefits to the sport fishery were inconsistent and/or inconclusive. Increasing predator densities has also improved growth rates of targeted prey species (Kempinger and Carline 1978, Gabelhouse 1984).

Saugeye and threadfin shad were introduced into Thunderbird Reservoir in spring 1985 and stocked annually thereafter. This study was initiated to determine if concomitant predator and prey stockings would reduce the density of the overcrowded white crappie population and facilitate the shift to a piscivorous diet consequently improving crappie growth rates. The study was funded through Oklahoma Federal Aid to Fish Restoration Project F-37-R, Job 15.

Methods

Thunderbird Reservoir was impounded on the Little River in 1965 as the municipal water supply for several central-Oklahoma communities. It covers 2,448 ha and has a shoreline development ratio of 7.9, mean depth of 6 m, and maximum depth of 21 m. The lake is moderately turbid (mid-summer secchi disk readings average approximately 60 cm), and urban runoff enhances its fertility. Major forage species include gizzard shad, inland silversides, sunfish (*Lepomis* spp.), and small white crappie. Predator species include largemouth bass, white crappie, white bass (*Morone chrysops*), and saugeye. Dense beds of milfoil (*Myriophyllum* sp.) provide shoreline cover.

Prespawn adult threadfin shad were stocked annually, with the exception of spring 1991, at rates ranging from 0.8–6.2/ha. Numbers stocked depended on availability. Overwinter survival was verified from spring 1986 through spring 1989. No overwinter survival was observed in spring 1990 or 1991. Fingerling saugeye (30 mm TL) were stocked annually from 1985 through 1991 at rates ranging from 30–93/ha.

Monthly food habits samples from 40 white crappie were collected from March through November in the daytime using pulsed DC electrofishing. Lengths (mm) and weights (g) of all fish in the sample were recorded. Crappie were grouped in 3 size classes for diet analysis: small (≤160 mm TL); medium (161–199 mm TL); and large (≥200 mm TL). These size groupings were chosen to correspond to fish on a predominantly zooplankton diet (≤160 mm), fish at a size at which dietary shift from zooplankton to insects to fish occurs (161–199 mm), and fish on a predominantly piscivorous diet (≥200 mm) (Boxrucker 1982). All fish in the diet were identified to lowest possible taxon, and percent occurrence of each taxonomic group was determined. Food habits of saugeye from Thunderbird Reservoir were obtained from Horton and Gilliland (1990).

Shad samples were collected with bow-mounted Tucker trawls (Siler 1983) constructed of 500-micron nitex netting and 3-mm Ace netting. Bimonthly samples were collected from June through September 1988–1991 with each mesh being used once monthly. Three oblique hauls (surface to 7 m and back to surface) were made at night at each of 3 stations on each sampling date. Length of each haul averaged 2 minutes. Catch (N/1,000 m^3), length distribution, and species composition of all shad captured were determined for each haul. All shad ≤20 mm TL were classified as shad sp. Larger shad were speciated by dorsal and anal fin-ray counts.

Mean catch rates (N/hour multiplied by 24 and expressed as net-nights), mean length at age, and relative-weights (Wr; Neumann and Murphy 1991) of the white crappie population were determined from fall trap-net samples collected annually, 1983 through 1991. Catch data were grouped by size (≤130 mm TL, hereafter referred to as age 0; 131–199 mm TL, hereafter referred to as intermediate; and ≥200 mm TL, hereafter referred to as large). The greatest amount of overlap of lengths at age occurred in the "intermediate" size grouping making this the target length for density reduction. The "large" group was the size considered to be the minimal acceptable for harvest by anglers. Crappie were aged using otoliths. Length frequency and catch rates (N/hour) of the saugeye population were calculated from fall night pulsed DC electrofishing samples, 1985 through 1991.

A non-uniform random daylight roving creel survey was conducted from March through November 1985 through 1991. Twenty 10-hour days (13 weekend days and 7 week days) were surveyed each season.

Statistical Analysis

All statistical tests were performed using Statistical Analysis Systems software (1988). The catch, length at age, and Wr data were not normally distributed (Shapiro and Wilk 1965). Log_{10} transformations were performed on all data. Log transformations did not normalize the catch and length data. Therefore, statistical differences in mean trap-net catch rates for crappie and mean length at age among annual samples were compared using a non-parametric Student's t-test. Differences in log transformed mean annual Wr of each 20-mm length group were tested using a Student's t-test. Catch statistics from years prior to saugeye reaching 457 mm TL (1983–1986, hereafter referred to as presaugeye years) and years after saugeye reached 457 mm TL (1987–1991, hereafter referred to as postsaugeye years) were grouped for statistical analysis. That length was chosen because saugeye were utilizing crappie as a significant food source at that size and 457 mm was a reasonable target for a minimum length limit to reduce saugeye harvest.

Results

Small and medium crappie fed almost exclusively on zooplankton and insects (Table 1). Sunfish predominated the diet of piscivorous medium crappie (Table 1). No threadfin shad were found in the diet of small and medium crappie during the 7 years of study. Unidentified shad and gizzard shad were the primary forage of piscivorous large crappie. Threadfin shad incidence never exceeded 4% and was absent from the stomach samples in 3 of 7 years. Stomachs of crappie collected in the trawl samples were also examined and no threadfin shad were found in the diet of crappie collected in pelagic areas.

Larval shad densities peaked in late May through mid June, ranging between 2,000 and 3,000 shad/1,000 m^3. Threadfin shad comprised a small proportion (<10%) of these peak densities. Larval threadfin shad densities peaked in late August to early September 1988 and 1989, reaching a maximum density of 98/1,000 m^3 in early September 1989. The bulk of shad <40 mm TL in late summer 1988 and 1989 were comprised of threadfin, yet peak threadfin shad densities never exceeded 20% of the peak gizzard shad densities in a given year. Late summer peaks in larval densities were not observed in 1990 or 1991.

Catch rates (*N*/net-night) of intermediate crappie decreased in postsaugeye years over respective values in presaugeye years ($P < 0.05$), whereas catches of large crappie increased over the same time period ($P < 0.0001$, Fig. 1). The catch of intermediate crappie increased in 1991 over 1990. Recruitment of crappie, as measured by catch of age-0, peaked in 1983 (99/net-night) and again in 1985 (68/net-night, Fig. 2). Recruitment stabilized from 1986 through 1991. W*r*'s of crappie 140–180 mm TL improved in postsaugeye years; however, W*r*'s of crappie 201–260 mm TL declined ($P < 0.0001$, Fig. 3). An increase in mean length of crappie ages 1 through 5 was observed in postsaugeye years ($P < 0.0001$, Fig. 4). However, crappie did not reach 200 mm TL until age 5. Angler harvest of crappie (*N*/ha) peaked in 1986 (11.3 crappie/ha), declined to 4.1/ha in 1988, thereafter increasing steadily to

Table 1. Frequency of occurrence (%) of food items found in stomachs of small (≤160 mm TL), medium (161–199 mm TL), and large (≥200 mm TL) white crappie from Lake Thunderbird, Oklahoma, 1985–1991.

	≤160 mm TL					161–199 mm TL					≥200 mm TL				
Year	ZP[a]	IN	SF	SD	TS	ZP	IN	SF	SD	TS	ZP	IN	SF	SD	TS
1985	72	69	0	0	0	64	56	0	11	0	0	4	6	39	0
1986	91	70	0	0	0	28	42	6	8	0	0	23	0	38	4
1987	82	91	0	0	0	42	77	8	0	0	0	73	19	2	0
1988	68	81	1	0	0	32	74	13	2	0	6	58	4	38	4
1989	63	96	0	0	0	46	87	2	0	0	1	35	0	42	4
1990	72	64	2	0	0	42	87	0	0	0	3	80	11	6	2
1991	27	93	0	0	0	28	86	11	1	0	4	60	21	9	0

[a]ZP = Zooplankton, IN = insects, SF = sunfish, SD = unidentified shad and gizzard shad, TS = threadfin shad.

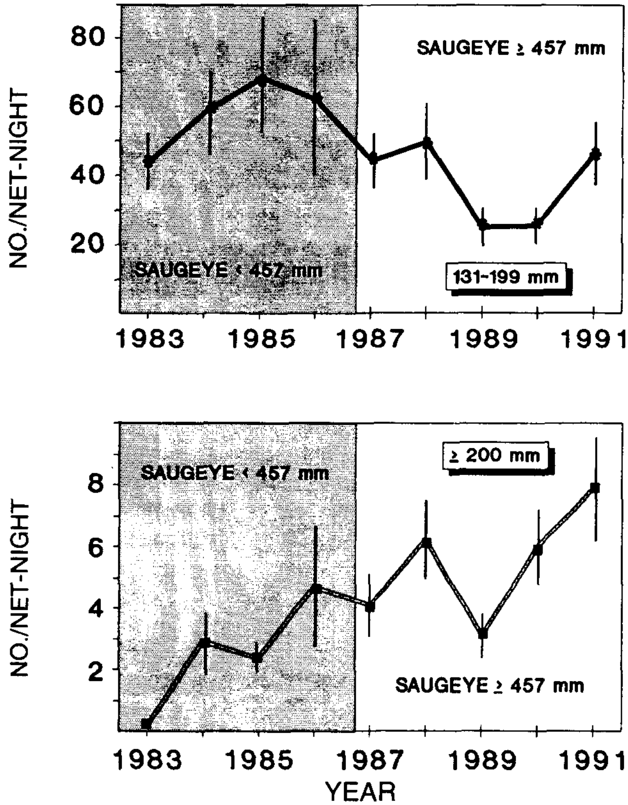

Figure 1. Catch rates (C/f; no./net-night) of white crappie from fall trap-net samples from years prior to saugeye reaching 457 mm TL (1983–1986) and years following saugeye reaching 457 mm TL (1987–1991) from Thunderbird Reservoir, Oklahoma. Vertical bars represent ±1 standard error of the mean.

9.9/ha in 1991. Angler harvest from 1989 through 1991 exceeded the crappie harvest in 3 of the previous 4 years.

Saugeye stocked in 1985 reached 457 mm TL in fall 1987. Electrofishing catch rates (*N*/hour) of saugeye ≥457 mm TL peaked in 1987 at 5.2 and subsequently declined to a low of 0.6 in 1991.

Discussion

The need to improve crappie growth rates in large reservoirs has been the focus of many management efforts. The strategies used typically involved a manipulation of the predator-prey balance. These manipulations are challenging in any large stystem but become even more difficult when dealing with a species such as crappie which begin life as planktivors but switch to a piscivorous diet. A management strategy that favors the planktivorous life stage may have either no effect or interfere with the piscivorous life stage.

The introduction of an additional planktivorous forage species (threadfin shad) in Thunderbird Reservoir should have further restricted the energy flow among the

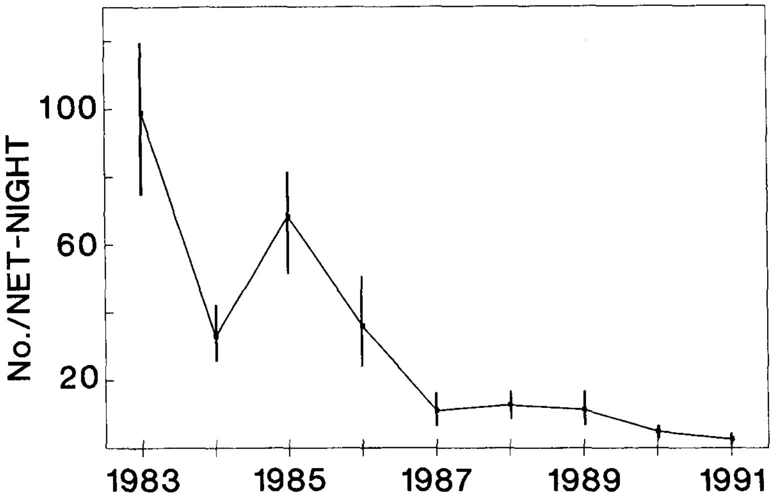

Figure 2. Catch rates (C/f; no./net-night) of white crappie <130 mm TL (age 0) from fall trap-net samples from Thunderbird Reservoir, Oklahoma. Vertical bars represent ±1 standard error of the mean.

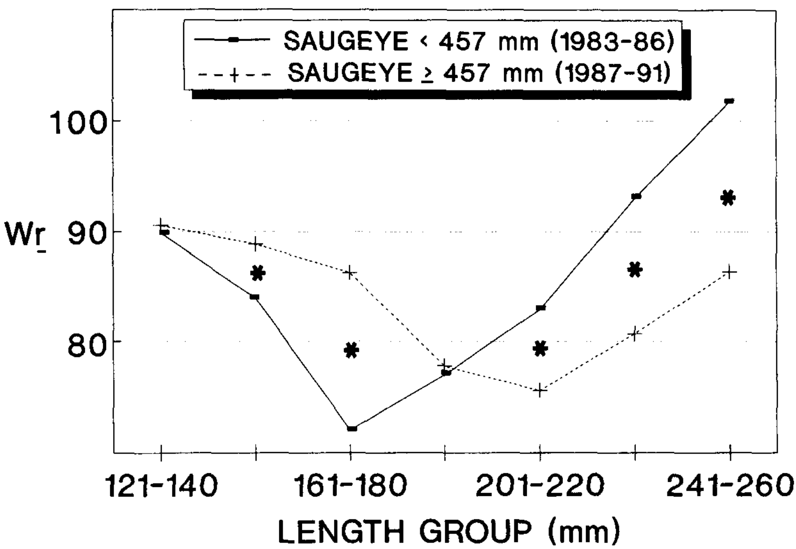

Figure 3. Relative weight (W*r*) of white crappie from years prior to saugeye reaching 457 mm TL (1983–1986) and years following saugeye reaching 457 mm TL (1987–1991) from Thunderbird Reservoir, Oklahoma. * denotes statistically significant differences.

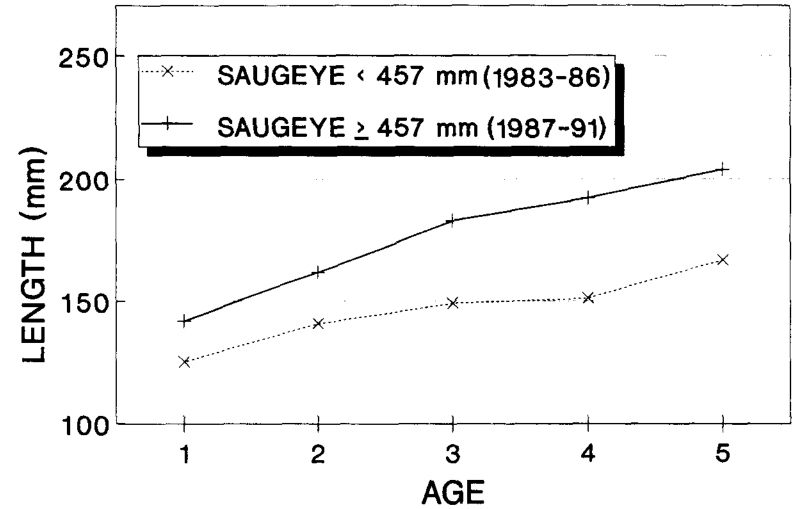

Figure 4. Mean length at age of white crappie from years prior to saugeye reaching 457 mm TL (1983–1986) and years following saugeye reaching 457 mm TL (1987–1991) from Thunderbird Reservoir, Oklahoma. * denotes statistically significant differences.

planktivorous white crappie. Li et al. (1976) found a decrease in growth of planktivorous sizes of crappie in Clear Lake, California, following the introduction of inland silversides. Crowl and Boxrucker (1988) found that, in the laboratory, inland silversides and threadfin shad were able to outcompete white crappie for the more desired large cladocerans and force crappie to feed on less desired copepods. However, zooplankton densities increased in Thunderbird following the threadfin shad introductions (Boxrucker 1991), thereby lessening the potential for interspecific competition. High water in fall 1984 caused high turbidity that continued through 1985. Increasing water clarity and subsequent increasing euphotic zone likely resulted in increased zooplankton densities. The threadfin population never reached densities (maximum density estimated was 98/1,000 m^3) that would have significantly impacted the zooplankton community structure.

Even though the introduction of threadfin into Thunderbird improved the quality of forage for crappie in 1988 and 1989 as the result of an influx of juvenile shad in late August, this late summer pulse of threadfin was not seen in 1990 nor 1991, nor did the threadfin stockings substantially augment overall shad densities. Apparently there are mechanisms operating in Thunderbird which limit shad spp. production relative to other Oklahoma reservoirs. Late summer juvenile shad spp. densities at Thunderbird were <10% of the respective shad spp. densities at Arbuckle and Kaw Reservoirs from 1989–1991 (Boxrucker 1992).

Trap-net data indicated that the population structure of crappie improved over the course of the study. Recruitment was higher in the presaugeye years, mostly due to 2 strong year classes in 1983 and 1985. However, based on growth rates, it should have taken up to 5 years for a given year class to reach 200 mm. If recruitment alone were influencing the catch of intermediate crappie, then the 1983 and 1985 year classes should have caused the catch of intermediate crappie to remain high. The catch of intermediate crappie continued to decline despite stable recruitment from 1986 through 1991.

It appeared that the improvement in crappie population structure was the result of a density-dependent growth response resulting from predation on crappie by adult saugeye. Horton and Gilliland (1990) found that saugeye upon reaching 350 mm TL began feeding on crappie and that crappie comprised more than 60% of the diet of saugeye ≥525 mm TL in summer. Declines in density of intermediate crappie were observed after saugeye reached a length (457 mm) that they became significant predators on small crappie. Crappie growth rates improved and as a result of increased growth, the density of large crappie increased. However, crappie growth rates remained below desired levels and continued improvements are necessary for the Thunderbird crappie population to sustain a quality fishery.

The changes observed in W*r* as a result of the changes in density of the 2 size groups of crappie are indicative of what occurs when predator density changes relative to its food supply. With the decrease in density of intermediate crappie, the W*r* of crappie from 141–180 mm TL increased (Fig. 4). At the same time, the W*r* of large crappie decreased with a corresponding increase in density. The failure of threadfin shad to increase forage availability commensurate with the increasing numbers of large crappie resulted in an imbalance in the prey-predator ratio. In the event available prey for large crappie can not be augmented, angler harvest must be increased to balance the increasing numbers of larger crappie with their limited prey resources.

The decreasing electrofishing catch rates of large saugeye was cause for concern. Variable year-class strength of stocked saugeye coupled with an increasing trend in the creel for high harvest of saugeye <457 mm TL were likely manifested in decreasing densities of large saugeye. The increase in catch rate of intermediate crappie in 1991 was likely due to a decrease in predation by an ever decreasing density of large saugeye. This trend must be reversed in order to maintain the improvements in crappie population structure observed to date.

Management Implications

In systems with higher shad densities (those in which crappie would not be a significant component of the forage base) saugeye may not utilize crappie as forage as extensively as was the case in Thunderbird. Under this scenario, saugeye may not have similar impacts on crappie density as was evidenced in this study.

A better understanding of the factors limiting shad production in Thunderbird Reservoir is needed prior to further attempts to augment forage densities. As a result, threadfin shad stockings have been discontinued. A 457-mm minimum length limit was proposed to limit angler harvest of saugeye. Research was initiated to improve our knowledge of factors controlling saugeye fingerling survival. These efforts were undertaken with the goal of increasing electrofishing C/f of saugeye ≥457 mm TL to 10/hour. Angler harvest of crappie will be promoted through public education and addition of fish attractors to keep the numbers of large crappie commensurate with their food supply. Approximately 30% of the annual angler harvest of crappie were fish <200 mm. Consequently, anglers appear to be a viable tool to balancing the crappie-prey ratios in Thunderbird Reservoir.

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