Possible Competitive Effects of Two Introduced Planktivores on White Crappie

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Abstract: Field and laboratory experiments were conducted to investigate possible competitive effects of the introduced species inland silversides (*Menidia audens*) and threadfin shad (*Dorosoma petenense*) on the native white crappie (*Pomoxis annularis*) population in Thunderbird Reservoir, Oklahoma. Field collections of zooplankton and stomach analyses were augmented by laboratory feeding experiments with the introduced planktivores and white crappie, alone and in combination. Field samples indicated that silversides, shad, and crappie, showed positive selectivity (Strauss' *L*) for *Daphnia*. Feeding studies in the laboratory corroborated this finding for all species tested individually. However, in feeding experiments, white crappie switched to an indiscriminant diet when in the presence of silversides or threadfin shad. These findings indicate that the introduced planktivores are competing with white crappie and could be a possible contributing factor to the poor growth rates seen in the crappie population of Thunderbird Reservoir.

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Thunderbird Reservoir is a moderately deep (6-m mean depth), turbid (30-cm secchi depth) reservoir that was impounded in 1965 primarily as a water supply for Norman, Oklahoma. The reservoir is moderately fertile, due primarily to urban runoff. Since its impoundment, the reservoir has been monitored and developed into a major sport fishery reservoir in the state. Sport fish species include largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), white crappie (*Pomoxis annularis*), and most recently saugeye (*Stizostedion canadense* x *S. vitreum*).

Recent age and growth analyses of the white crappie population in Thunderbird Reservoir indicated the presence of a slow-growing, if not stunted population (Boxrucker 1986, 1987). Relative weights (Wr) of crappie between 140 and 200 mm TL were poor and stomach content analyses indicated that fish $\leq$ 200 mm TL fed primarily on invertebrates. Fish $>$ 200 mm TL fed largely on gizzard shad (*Dorosoma cepedianum*) and sunfish (*Lepomis* sp.). Because white crappie generally become piscivorous at approximately 150 mm (Hoopes 1960, Neal 1961), the lack of piscivorous crappie between 150 and 200 mm and the large number of fish < 150 mm TL suggests forage-related problems in the population. One hypothesis for the poor growth is that sufficient forage fish of the appropriate size to allow for the conversion to a piscivorous diet is lacking in Thunderbird Reservoir. A second hypothesis is that, because of relatively high numbers of planktivores in Thunderbird Reservoir, competition (both intra- and interspecific) for zooplankton has contributed to poor growth of crappie.

In an attempt to stimulate white crappie growth, inland silversides were introduced into Thunderbird Reservoir in 1978. Subsequent to the silverside introduction, sampling indicated no improvement in growth rates and little usage of silversides by crappie (Boxrucker 1986). Although the lack of prey utilization is unexplained, it is plausible that spatial segregation limits silverside availability. In 1985, threadfin shad (*Dorosoma petenense*), a relatively small pelagic forage species, was introduced to provide a more available forage for white crappie. Data collection is currently underway to determine the impact of threadfin shad introduction on white crappie growth.

Though the introduction of these additional forage fishes into Thunderbird Reservoir has not yielded clear-cut positive effects on crappie growth rates, it has increased the number of planktivores in the reservoir. As a result of non-native introductions, the food web is becoming increasingly affected by planktivores. In this study, we document the food availability and food habits of inland silversides, threadfin shad, and white crappie in Thunderbird Reservoir during 1987. Additionally, tank studies were designed to test for direct competitive interactions among these species.

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Methods

Zooplankton Sampling

Three replicate, vertical zooplankton tows, bottom to surface, were taken at 3 stations (upper, middle, and lower lake areas) in the lake at bimonthly intervals to determine zooplankton species composition and abundances throughout the growing season (March-October). Zooplankton were preserved in a 4%-sucrose-formaldehyde solution. Three 1-ml subsamples were counted using a dissecting microscope from each 40-ml sample (1 vertical tow). Zooplankton were identified to the lowest possible taxonomic level.

Fish sampling

White crappie and inland silversides were collected at least once monthly (May-September) using seining and/or electrofishing techniques. Fish were collected at the zooplankton stations on the same day as zooplankton were collected. Threadfin shad were collected as available (about every other month). Total lengths (mm) and weights (g) for all fish were recorded. Stomach contents from at least 20 individuals of each species were then enumerated. Relative abundances of zooplankton in the diet were compared with concurrent zooplankton samples from the lake using Strauss' (1979) linear index of food selection:

$$L = r_i - p_i,$$

where r is the relative proportion of each zooplankton type (i) found in the fish stomach and p is the relative proportion of each zooplankton type found in the reservoir.

Laboratory Experiments

Feeding experiments were performed for silversides, threadfin shad, and white crappie, alone and in combination in 800-liter plastic tubs. Water (with zooplankton) for these experiments was obtained form Thunderbird Reservoir to control for water chemistry variables as well as density and species composition of zooplankton. All experiments were performed using a cross-classified design (Winer 1971) with three replicates per treatment combination. The number of fish used in each experiment was determined on a biomass basis, with each experiment consisting of 75 g of total fish. Thus, although the number of fish species and sizes of individuals changed between tubs and experiments, the total fish biomass was kept constant throughout. Zooplankton were monitored on days 5 and 10 by placing a 1-liter beaker into the tanks and quickly inverting it. At least 3 fish of each species were collected (and replaced) from each tank on the same day zooplankton samples were taken. Gut contents were analyzed and Strauss' linear selection indices were calculated.

Two feeding experiments were performed. The first experiment involving only silversides and white crappie, was performed in June (hereafter referred to as experiment I). Four treatments were represented in this experiment: 15 silversides (80–100 mm TL) only; 4 white crappie (100–130 mm TL) only; 7 silversides and 3 white crappie (same size ranges as above treatments); and a fishless control.

The second experiment was conducted in July (experiment II) and consisted of threadfin shad and white crappie, both separately and in combination, as well as a fishless control. The treatment with white crappie only was identical to the first experiment. The treatment with only threadfin shad consisted of 5 shad, which ranged from 85 to 125 mm TL. The third treatment consisted of 3 white crappie and 3 threadfin shad (same sizes as above). Statistical tests of differences between observed food selection when fish species were alone versus when fish were in combination were performed using Hotelling's T^2 (Wright and O'Brien 1984).

Results and Discussion

Zooplankton Sampling

Daphnia were the dominant cladoceran during most of the growing season (Fig. 1). *Bosmina* were present in very low densities except in March, when they were more abundant than other cladocerans sampled. Calanoid copepods were the most abundant copepod observed in Thunderbird and cyclopoid copepods were present in moderate densities (Fig. 1). Copepod nauplii reached peak densities in July and October. The observed zooplankton species compositions in 1987 were consistent with the zooplankton patterns in 1985 and 1986 (Boxrucker and Crowl 1988).

Fish Sampling

White crappie (40–200 mm TL) showed positive selectivity (Strauss' *L*) for *Daphnia* during all months except July (Fig. 2). *Bosmina* were generally not found in the diet of crappie. Patterns of preference for copepods in the diet of crappie were inconsistent. As in previous studies, white crappie appeared to select larger zooplankton (Mathur and Robbins 1971, Ellison 1984, O'Brien et al. 1984, Wright and O'Brien 1984).

Threadfin shad generally selected against copepods and, except for July, for *Bosmina* (Fig. 2). Threadfin shad generally selected against *Daphnia* (except in September) in the reservoir.

Silversides (> 80 mm TL) fed primarily on large cladocerans, primarily *Daphnia* (Fig. 2). Silversides were highly selective for *Daphnia*. Few other zooplankton were found in silverside stomachs, but an occasional calanoid copepod and *Bosmina* were found. Strauss' selectivity indices (Fig.2) substantiated this finding, with only *Daphnia* having a positive Electivity.

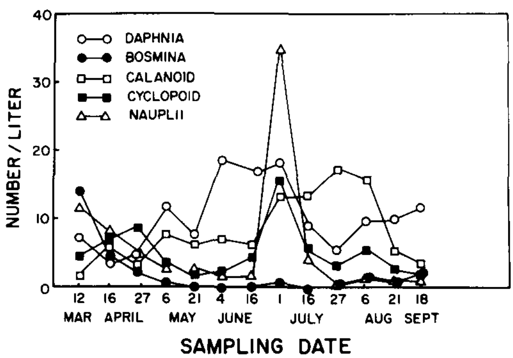

Figure 1. Density (*N*/liter) of zooplankton from Thunderbird Reservoir, 1987.

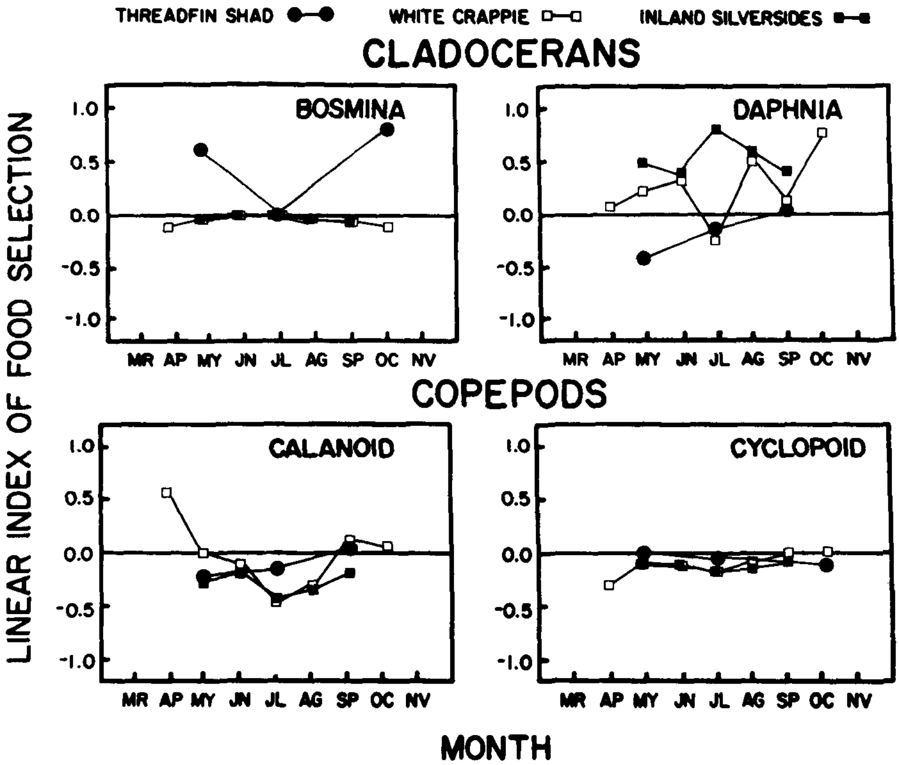

Figure 2. Electivity indices for zooplankton occurring in the diet of white crappie, threadfin shad, and inland silversides from Thunderbird Reservoir, 1987.

Laboratory Experiments—In experiment I (white crappie and silverside), both single-species treatments resulted in positive electivity indices for *Daphnia* (Table 1). When the 2 fish species were combined, silversides continued to selectively feed on *Daphnia* throughout the experiment, while white crappie began feeding selectively on *Daphnia* but then shifted to an indiscriminant diet (Table 1). Hotelling's T^2 revealed that silversides did not shift prey preference when white crappie were present ($F = 1.2$, $P > 0.05$) while white crappie exhibited significant prey preference shifts when silversides were present ($F = 11.4$, $P < 0.001$). When crappie were alone, *Daphnia* was the dominant food item. When silversides were present, *Daphnia* were significantly underrepresented, while cyclopoid and calanoid copepods were significantly overrepresented in the crappie diet.

In experiment II (white crappie and threadfin shad), the results were similar to the first experiment when each species was alone. Threadfin shad were highly selective for large cladocerans (primarily *Daphnia*; Table 2). The white crappie exhibited a response similar to the previous experiment in that they selectively fed on *Daphnia*

Table 1. Proportions of organisms in the diet, water samples, and Strauss' linear index of food selection (*L*) for silversides and white crappie in experiment I. Results are the average of samples taken on days 5 and 10. The values outside parentheses represent results when fish were alone; those inside parentheses represent results from the "both-fish-present" treatment.

	Bosmina	*Daphnia*	Calanoids	Cyclopoids	Nauplii
			Silversides		
Diet	0(0)	98(97)	2(3)	0(0)	0(0)
Water	2(3)	55(56)	23(22)	13(12)	6(7)
L	−0.02(−0.03)	0.43(0.41)	−0.21(−0.19)	−0.13(−0.12)	−0.07(−0.07)
			White crappie		
Diet	0(1)	86(58)	9(29)	5(12)	0(0)
Water	2(1)	54(56)	24(26)	12(11)	8(6)
L	−0.02(0)	0.32(0.02)	−0.15(0.03)	−0.07(0.01)	−0.08(−0.06)

when alone, but shifted to a less discriminant diet in the presence of threadfin shad (Table 2). As in the first experiment, Hotelling's T^2 showed that threadfin shad exhibited no change in prey preference when crappie were present ($F = 1.9$, $P > 0.05$, while white crappie significantly altered their diet choice when threadfin shad were present ($F =$ $P < 0.01$). As with silversides, crappie shifted from primarily *Daphnia* when alone, to a diet of significantly fewer *Daphnia*, and significantly more cyclopoid and calanoid copepods in the diet when threadfin shad were present.

Both field and laboratory feeding preference data obtained in this study suggested that white crappie, inland silversides, and threadfin shad overlapped in zooplankton prey selection. Interspecific competitive interactions among these species cannot be rejected as a possible mechanism contributing to the poor growth and

Table 2. Proportions of organisms in the diet, water samples, and Strauss' linear index of food selection (*L* for threadfin shad and white crappie in experiment II. Results are the average of samples taken on days 5 and 10. The values outside parentheses represent results when fish were alone; those inside parentheses represent results from the "both-fish-present" treatment.

	Bosmina	*Daphnia*	Calanoids	Cyclopoids	Nauplii
			Threadfin shad		
Diet	0(0)	78(75)	19(22)	3(3)	0(0)
Water	1(1)	23(25)	43(41)	17(16)	16(17)
L	−0.01(−0.01)	0.55(0.50)	−0.24(−0.19)	−0.14(−0.13)	−0.16(−0.17)
			White crappie		
Diet	0(0)	83(51)	12(38)	5(10)	0(1)
Water	0(1)	25(24)	43(42)	15(14)	17(19)
L	0(−0.01)	0.58(0.27)	−0.31(−0.04)	−0.10(−0.04)	−0.17(−0.18)

population structure of white crappie in Thunderbird Reservoir (Boxrucker 1987). All 3 species showed strong preference for the large cladoceran, *Daphnia*. If *Daphnia* abundances are annually or even seasonally low, strong competitive effects of threadfin shad and inland silversides may result in white crappie shifting their diets to a less discriminant diet.

Prey species such as threadfin shad, are often introduced to enhance growth and production of game fish (Gerdes and McConnell 1963, von Geldern and Mitchell 1975). Because most introduced prey species are primarily zooplanktivorous, zooplankton populations are often overutilized. Our results corroborate previously reported findings that have shown adverse competitive effects on both other prey species and sport fish species with the introduction of planktivorous forage fish (Jenkins 1957, Smith 1959, Miller 1967, McComas and Drenner 1982, Ali and Bayne 1985, Kirk and Davies 1985, Mallin et al. 1985). Field sampling as well as additional laboratory studies are currently underway to further our understanding of the Thunderbird Reservoir foodweb.

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