Performance Comparison between Coppernose and Native Texas Bluegill Populations

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Abstrtact: Growth, survival, and catchability of non-native coppernose bluegill *(Lepomis macrochirus purpurescens)* were compared to that of common bluegill *(L. macrochirus)* from East (Neches River system) and West (Rio Grande system) Texas populations. The 3 types of bluegills were stocked together (each identifiable by coded-wire tags) into 4 0.25-ha hatchery ponds. Bluegill types were evaluated with and without an established fish community present at age 1 and 2. Coppernose bluegill were larger (i.e., length and weight) than East or West Texas bluegills, regardles of fish community presence. Coppernose bluegill y-o-y survival was higher than East or West Texas bluegills in the presence of a fish community. Survival did not differ among bluegill types regardless of fish community presence in age 2. Catchability was similar among bluegill types, except for lower catchability of age-2 coppernose bluegill without a fish community present. Coppernose bluegill might improve quality of selected fisheries because of their larger sizes. However, any management plan should weigh merits of bluegill type selection before introduction.

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There are at least 2 morphologically distinct subspecies of bluegill *(Lepomis macrochirus)* that inhabit the southeastern United States: common *(L. m. macrochirus)* and coppernose *(L. m. purpurescens)*. Coppernose bluegill have reddish fins and more anal soft rays than common bluegill (Hubbs and Allen 1943, King 1947, Miller and Winn 1951). Electrophoretic data have confirmed that coppernose bluegill are a distinct subspecies, but with considerable intergradation zones with other bluegill subspecies (Alvise and Smith 1974, Felley 1980, Felley and Avise 1980, Kulzer and Greenbaum 1986). Native range of coppernose bluegill includes Atlantic coastal streams from the Carolinas to Florida and the Florida peninsula (Avise and Smith 1974, Hubbs and Lagler 1958). Coppernose bluegill have been suspected to be faster growing, larger, more hardy, and to have better sportfishing qualities compared to common bluegill (Hubbs and Allen 1943, King 1947), which makes them attractive to fisheries managers. However, comparative data supporting these statements are lacking. Age-2 coppernose bluegill stocked into Lake Perris, California, were larger than common bluegill of the same age in other locations in the state (Henry 1980). However, common bluegill were not present in Lake Perris, which prevented comparative evaluation of intersubspecific competition or growth rates. Efforts have been made to evaluate the 2 subspecies stocked together in the same water body, but poor survival prevented study completion (Guest 1984, Nichols 1989). Managers have begun to consider coppernose bluegill for fisheries applications in Texas. Temperature tolerance is similar for common and coppernose bluegill (Sonski et al. 1988) and, therefore, not a factor when considering introductions of coppernose bluegill into Texas waters. Coppernose bluegill have been stocked into large Texas reservoirs and introgression with resident bluegill has been detected. However, coppernose bluegill and its intergrades made such a small percentage of the sample that previous studies were unable to detect growth differences between coppernose and other bluegills (Howells 1987, Betsill 1994).

The objective of this study was to compare growth (size at age), survival, and catchability of coppernose (in an area outside their native range) and native Texas bluegills. Further, because management practices might often involve bluegill introductions into locations where bluegill and other fishes are already present, this study also examined the effect of established fish communities on growth, survival, and catchability. Bluegill in Texas waters frequently exhibit slow growth and become overabundant. Such populations provide poor-quality fisheries to anglers. However, bluegill populations that contain quality-size individuals and have adequate growth rates can provide important sport fisheries. Bluegill rank second only to black basses in percentages of anglers and in time sought in U. S. fresh waters excluding the Great Lakes (U.S. Dep. Int. et al. 1993). If coppernose bluegill can provide enhanced survival, catchability, growth, and size as historically reported (Hubbs and Allen 1943, King 1947), a tool could exist for improving the quality of Texas bluegill fisheries. In addition to performance of coppernose bluegill, considerations of a fish introduction outside its native range warrant review (Li and Moyle 1999).

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Methods

We collected 3 bluegill taxa as broodstock. We obtained coppernose bluegill from a Texas commercial fish farm (Smith County). We collected West Texas bluegill in the Rio Grande drainage (Casa Blanca Reservoir, Webb County) and East Texas bluegill in the Neches River drainage (Alazan Reservoir, Nagadoches County). Bluegill from Rio Grande and Neches Rivers were chosen to represent 2 distinct populations—and potential subspecies—from Texas, as revealed by study of allele frequencies and Identity Coefficient (Nei) dendrogram branching values (G. Garrett, HOH, Ingram, Texas, unpubl. data). We identified 30 individuals of each type collected, to confirm groups as coppernose or native Texas bluegills, by electrophoretic discrimination of 3 liver enzymes: aspartate aminotransferase, 2.6.1.1 (AAT); isocitrate dehydrogenase, 1.1.1.42 (IDH); and phosphoglucomutase, 5.4.2.2 (PGM) (Avise and Smith 1974, Kulzer and Greenbaum 1986). These collected groups of fish became broodstock (each bluegill type maintained in a separate pond) to produce offspring for this study in 1995 and 1997 following pond procedures similar to Warren (1997). We observed timing of spawning activity (nest building and mating) for each bluegill type and sizes of young in brood ponds to determine that equal-sized offspring were available for study-pond stocking.

We injected bluegill offspring (50–70 mm total length [TL]) with coded-wire tags (CWTs, Northwest Mar. Tech. [NMT], Inc. Shaw Island, Wash.) to enable identification of each bluegill type by tag location. We selected 3 tag locations based on ability to distinguish bluegill types, high tag retention, and no evidence of biological effect (Bergman et al. 1968, Elrod and Schneider 1986, Fletcher et al. 1987, Heidinger and Cook 1988, J. Prentice, unpubl. data). We tagged West Texas bluegills in the anterior musculature of the nape region just lateral to the mid-dorsal line, coppernose bluegills in the back musculature just lateral to the 5th or 6th dorsal fin spine, and East Texas bluegills in the caudal peduncle musculature just lateral to the mid-dorsal line. We anesthetized fish with a buffered tricane methanesulfonate solution (7.5 g sodium bicarbonate and 1.5 g MS222 per 20 liters water) before tagging. Tagging was conducted using a Mark IV unit (NMT) with a stationary needle, and an injection-needle guard to allow tag penetration to a depth of 1.5–2.0 mm. We held tagged fish for 3 days in 2,100-liter aquaria with flow-through water supply. During the holding period, we removed unhealthy fish and checked all fish for tag retention before stocking them into hatchery ponds.

We stocked bluegill types into 4 adjacent and similarly-shaped hatchery ponds, about 0.25 ha each, for comparisons. Fill and maintenance water was screened to prevent entry of unknown fishes (Hutson 1990). To better simulate a natural pond setting, natural aquatic vegetation provided habitat in all study ponds. Further, we did not fertilize ponds nor did we feed fishes. In 1995, we stocked study ponds with the 3 bluegill types. In 1997, we removed all fishes and restocked with the 3 bluegill types after establishing a fish community. Species (followed by the mm TL and number added) making up the fish community added to each pond for the study beginning in 1997 were: *Dorosoma cepedianum* (TL = 20–200, N = 100–150), *Lepomis cyanellus* (TL = 50–110, N = 30), *L. microlophus* (TL = 50–110, N = 60), and *Micropterus salmoides* (TL = 100–150, N = 3; TL = 151–230, N = 5; TL = 312–280, N = 4; TL = 281–330, N = 2; TL = 331–360, N = 1). To enable bluegill types to experience identical conditions, equal numbers of tagged young of each type were stocked together into each pond at the beginning of each comparison period (1995 and 1997, Table 1). At the end of each year, ponds were drained and all fishes were collected. Stocked bluegills were separated from other fishes, including y-o-y bluegill. Stocked bluegills were then identified to type using a NMT handheld wand detector and measured to the nearest mm and g. We returned all fishes (except y-o-y bluegills) to the same pond for the second year of comparisons.

Table 1. Number of each of 3 bluegill types stocked into, and retrieved from at draining, 0.25-ha study ponds at Heart of the Hills Research Station, Ingram, Texas with (1997–1999) and without (1995–1997) a fish community present in each pond.

Bluegill type	Year	Pond A			Pond B			Pond C			Pond D		
		N stocked	*N* retrieved	% survival	*N* stocked	*N* retrieved	% survival	*N* stocked	*N* retrieved	% survival	*N* stocked	*N* retrieved	% survival
Bluegill without other fishes present													
Coppernose	1	115	97	84	120	102	85	120	41	34	145	127	88
	2	97	89	92	102	93	91	41	31	76	127	107	84
East	1	115	111	96	120	96	80	120	65	54	145	127	88
	2	111	92	83	96	76	79	65	43	66	127	109	86
West	1	115	100	87	120	104	87	120	64	53	145	123	85
	2	100	91	91	104	87	84	64	48	75	123	90	73
Bluegill with other fishes present													
Coppernose	1	115	85	74	120	75	62	120	85	71	145	102	70
	2	84	77	92	75	72	96	85	70	82	102	89	87
East	1	115	62	54	120	26	22	120	49	41	145	90	62
	2	62	59	95	26	23	88	47	34	72	90	45	50
West	1	115	50	44	120	38	32	120	37	31	145	61	42
	2	50	45	90	38	34	90	37	34	92	61	50	82

After the 2-year growth period in the 4 study ponds without a fish community (1997), 100 bluegills of each type were randomly selected from all study ponds and were stocked together into another 0.5-ha pond without a fish community present to continue growth observations. We drained this pond each year for the next 2 years and all bluegills were identified to type by tag detection and measured to the nearest mm. Because pond space limitations did not allow these older fish to be treated in the same study design as in the first and second years, we used these data to observe growth but did not include them in comparison analyses.

Catchability experiments were conducted in summer and fall of each year. We fished ponds a total of 2 hours (1 hour in morning and 1 hour in afternoon) in 0.5-hour increments each fishing day. All ponds were fished simultaneously by 1 angler per pond during each increment. Each fishing day, anglers were randomly assigned to a pond for the first fishing increment and each angler rotated to a new pond in each succeeding time increment such that each angler fished all ponds. Equal numbers of fishing days were given to all ponds each year. All anglers used identical baits. Use of artificial baits helped reduce deep hooking and associated mortality. Captured fishes were placed in holding tanks at each pond. Upon completion of each increment, we individually identified bluegills in holding tanks to type with a coded-wire detector wand. Numbers of each species caught in each increment were recorded and fishes were returned to their respective ponds before the next fishing increment began. For each angling increment, we recorded how many fish of each type each angler caught.

We developed a 4-factor, partially-nested, repeated measures design for this experiment. Ponds (a random effect) were the primary sampling units. Ponds were nested within the fish community (presence or absence) treatment and repeated measures were taken on ponds at years (ages) 1 and 2. Presence of a fish community, age, and the bluegill types were fixed effects. Growth data were size (mean TL and weight) at age. Survival (*N* collected each fall/*N* stocked) and catch (*N* caught per angling increment/*N* present) data were arcsine of square-root transformed (Snedecor and Cochran 1989) before analyses. We analyzed growth and survival data with a multivariate analysis of variance (ANOVA, SAS Inst. 1987) that incorporated the repeated measures. We were primarily interested in catch at each specific time and were not interested in trends across time. Hence, we analyzed catch data with a univariate ANOVA (SAS Inst. 1987) at each time. We selected error terms for *F*-tests after we derived the Expected Mean Squares (Hicks 1982). We tested for differences among means using the Tukey's studentized range test. Alpha level for all comparisons was $P=0.05$.

Results and Discussion

Spawning activity of brooders began at the same time for all bluegill types (last week of February 1995–first week of March1997) which provided the same size young for tagging at the same time each year (mid–April). Offspring production numbers among bluegill types appeared similar although counts were not made. Further study on spawning strength and y-o-y survival of coppernose compared to

Table 2. *Mean (±SE) total length (mm) and weight (g) of bluegill types collected at study pond draining when fishes were at ages 1 and 2 growing with and without a fish community present, Heart of the Hills Research Station, Ingram, Texas. Mean values without a letter in common across a row are significantly different between bluegill types,* $P \leq 0.05$.

		Bluegill type		
Year	Parameter	Coppernose	East	West
Bluegill without other fishes present				
1	Total length	151.1 ±4.27 A	141.6± 5.34 B	135.1±4.40 C
	Weight	63.5 ±8.11 A	54.4± 8.36 b	45.8±6.18 C
	N	4	4	4
2	Total length	167.6 ±2.57 A	154.4± 2.90 B	149.1±2.85 C
	Weight	91.25±5.54 A	73.4± 5.28 B	65.1±4.77 C
	N	4	4	4
Bluegill with other fishes present				
1	Total length	156.5 ±3.38 A	144.2± 5.04 B	142.0±5.07 B
	Weight	73.8 ±8.80 A	58.9±11.22 B	56.7±9.87 B
	N	4	4	4
2	Total Length	183.0 ±2.56 A	163.8± 3.22 B	165.3±3.55 B
	Weight	113.1 ±7.00 A	79.6± 6.87 B	87.1±7.55 B
	N	4	4	4

common bluegill could help explain other population performance differences and aid fisheries management.

Coppernose bluegill were significantly larger than the 2 Texas types in all scenarios tested. Significant differences were also observed between the 2 Texas types (Tables 2, 3) in cases where no fish community was present. All bluegill types attained slightly larger mean sizes when growing in the presence of a fish community. Several factors could produce larger bluegill sizes in the presence of a fish community such as decreased bluegill population densities caused by predation or selective predation of smaller fish. If bluegill density reduction is increasing bluegill size, there is the suggestion that food may have been limiting. Therefore, both attained sizes and size differences between bluegill types observed could be conservative. Additional study comparing bluegill types in the presence of ample food could establish maximal attainable size and differences. Although coppernose bluegill were always larger, East and West types varied in performance depending on age and presence of a fish community (Tables 2, 3). Despite efforts to diminish their study influence, it is not possible to totally isolate extrinsic (year differences caused by climate, ponds, or both) and intrinsic (genetic differences of bluegills stocked) influences from the experimental treatment. Faster growth and larger size of coppernose compared to common bluegill has been suspected (Hubbs and Allen 1943, Henry 1980), but not confirmed due to high mortality rates in past studies (Guest 1984, Nichols 1989). The largest mean size difference observed between coppernose and Texas bluegills was 19.2 mm TL and 33.5 g weight over 2 years in ponds with fish communities present (Table 2). In a field study, sampling effort required to detect this difference may surpass what can typically be done (Betsill 1994). All bluegill types grew to quality

Table 3. Summary of analyses of variance of growth (total length and weight at age) and growth factors of bluegill types (coppernose, East Texas and West Texas) in ponds at Heart of the Hills Research Station, Ingram, Texas, with and without a fish community present.

Source of variation	df	Sum of squares	Mean square	*F*-ratio	*P* (>*F*)
Total length, between pond effects					
Community	1	554.45	554.45	2.87	0.1411
Community (pond)	6	1,158.27	193.05	35.76	<0.0001
Bluegill type	2	1,538.36	769.18	30.30	0.0320
Community X bluegill type	2	50.78	25.39	4.70	0.0310
Error	12	64.78	5.40		
Within pond effects					
Age	2	125,059.85	62,529.93	815.79	<0.0001
Age X community	2	742.71	371.36	4.84	0.0290
Age X community (pond)	12	919.85	76.65	47.61	<0.0001
Age X bluegill type	4	1,038.40	259.60	161.06	<0.0001
Age X community X type	4	26.61	6.65	4.13	0.0027
Error	24	38.68	1.61		
Weight, between pond effects					
Community	1	1,261.69	1,261.69	7.71	0.2385
Community (pond)	6	4,420.16	736.69	41.29	<0.0001
Bluegill type	2	2,929.25	1,464.63	13.76	0.0678
Community X bluegill type	2	212.89	106.45	5.97	0.0159
Error	12	214.11	17.84		
Within pond effects					
Age	2	82,533.25	41,266.63	5,691.95	<0.0001
Age X community	2	850.37	425.19	1.41	0.2817
Age X community (pond)	12	3,617.14	301.43	41.58	<0.0001
Age X bluegill type	4	1,896.69	474.17	11.15	0.0192
Age X community X type	4	170.11	42.53	5.87	0.0027
Error	24	174.00	7.25		

size (≥150 mm TL) within 2 years (Table 2), indicating good potential of any of the bluegill types for Texas fishery management goals. Bluegill growth in this study was particularly favorable for fishery management goals compared to more northern locations. Legler (1977) determined that rapid bluegill growth at early age in Missouri was necessary to reach harvestable size, and that a satisfactory growth rate was ≥145 mm TL reached by age 4.

Although aspects of maximum or trophy size were not addressed, observations of the 100 bluegill of each type that were reared for 2 additional years indicated all bluegill types can attain quality sizes (Anderson and Neumann 1996). Mean TL (mm±SE) for coppernose, East, and West Texas bluegill types were 196±1.1, 180±2.7, and 172±1.1 for year 3 and 214±1.0, 190±2.3, and 184±1.5 for year 4, respectively. Larger size of coppernose over the Texas bluegills was observed, but mean growth increments for each bluegill type each year indicated similar growth rates after year 1.

We determined that y-o-y coppernose bluegill had significantly higher survival in the presence of a fish community than did y-o-y East or West Texas bluegills (Tables 1, 4). By age 2, however, all bluegill types had similar survival (Table 1). Considering the previous discussion on coppernose bluegill growing larger, y-o-y survival may

Table 4. Summary of analyses of variance of survival and survival factors of bluegill types (coppernose, East Texas and West Texas) in ponds, Heart of the Hills Research Station, Ingram, Texas, with and without a fish community present.

Source of variation	df	Sum of squares	Mean square	*F*-ratio	*P* (>*F*)
Between pond effects					
Community	1	610.7	610.7	2.24	0.1851
Community (pond)	6	1,635.9	272.6	13.99	<0.0001
Bluegill type	2	341.7	170.9	1.31	0.4696
Community X bluegill type	2	302.6	151.3	7.76	0.0069
Error (between)	12	233.8	19.5		
Within pond effect					
Age	1	1,956.7	1,956.7	52.91	<0.0001
Age X community	1	1,225.5	1,225.5	33.14	0.0240
Age X community (pond)	6	816.9	136.2	3.68	0.0261
Age X bluegill type	2	128.4	64.2	1.74	0.7120
Age X community X bluegill type	2	317.4	158.7	4.29	0.0393
Error (within)	12	443.8	37.0		

have been enhanced by faster growth and better ability to avoid predation. Bluegill survival in this study was relatively high (Table 1) compared to other studies (Guest 1984, Nichols 1989). For management purposes, higher y-o-y survival performance suggests an advantage in establishment of coppernose bluegill as result of a stocking program. However, efforts to introduce coppernose bluegill in some large Texas reservoirs have met with low success (Howells 1987, Betsill 1994). The advantage in coppernose bluegill survival in this study may be greatly different than the survival in a typical stocking scenario. In this study, equal numbers of young of each bluegill type were introduced. In "real world" scenarios, the number of stocked fish could

Table 5. Mean catch rate (*N* fish caught in each angling increment / *N* of those fish present in that pond×100; (±SE) and N fishing events of bluegill types in 0.25-ha study ponds, Heart of the Hills Research Station, Ingram, Texas, when bluegill types were with and without a fish community present in each pond. Mean values without a letter in common across a row are significantly different between bluegill types, $P \leq 0.05$.

		Bluegill type		
Year	Parameter	Coppernose	East	West
Bluegill without other fishes present				
1	Mean catch	4.3±1.86 A	2.7±0.72 A	2.9±0.59 A
	N	16	16	16
2	Mean catch	0.5±0.21 A	1.1±0.28 B	1.6±0.42 B
	N	48	48	48
Bluegill with other fishes present				
1	Mean catch	0.4±0.13 A	0.4±0.12 A	0.3±0.13 A
	N	80	80	80
2	Mean catch	1.1±0.24 A	0.9±0.23 A	0.7±0.23 A
	N	64	64	64

easily be a small fraction of total bluegill in the system stocked. Therefore, even with a coppernose bluegill competitive advantage in survival, their overall contribution to the total bluegill population would be minor. Also, in typical stocking scenarios, stocked bluegill would be competing with resident bluegill which may have a competitive advantage to that environment over any stocked variety. Therefore, again, contributions of stocked coppernose bluegill to the community could be minor compared to that of resident bluegill.

Without a fish community present, age 2 coppernose were significantly harder to catch than the 2 Texas bluegill types (Table 5). All other comparisons suggested equal angling vulnerability across bluegill types. Guest (1984) indicated coppernose bluegill were not as vulnerable to angling, although his results were inconclusive due to apparent mortality and low sample size.

Management Implications

Sunfishes, particularly bluegills, are popular sport fishes in Texas (Ditton et al. 1991) with fisheries objectives centering on high catch rates and harvest (Novinger and Legler 1978). However, bluegill populations often require management to prevent over-population and slow growth rates (Kruse 1991). Although coppernose bluegill in this study grew to larger sizes than the Texas types, all bluegill types demonstrated the ability to rapidly create a fishery with quality-size individuals. When considering common management objectives, coppernose bluegill appear to have some advantage, occurring during or resulting from the first year of life.

Efforts to create bluegill fisheries should center first on establishment of management objectives for quality bluegill populations (Guy and Willis 1990, Kruse 1991). Second, selection of a native or non-native bluegill type for management should follow established guidelines for introduction (Li and Moyle 1999). In Texas, selection of a bluegill type should involve consideration of whether the water body is a closed system (i.e., a created "farm" pond) where native bluegill do not occur and do not have natural access, or an open system, where native bluegill are present or have access through a natural watershed. For establishment of bluegill in Texas closed water systems without bluegill, native or coppernose bluegill could be considered for stocking and the larger size of coppernose bluegill could enhance the fishery. There would be a necessary cost for stocking that is near equal for either native or coppernose bluegill. In open systems, bluegill are generally already present and do not require stocking, but rather management. Establishment of coppernose bluegill in Texas water systems with native bluegills present, or open systems where influx of resident bluegill can occur, may be difficult and will lead to intergradation with resident bluegill subspecies (Avise and Smith 1974, Howells 1987, Sonski et al. 1988, Betsill 1994). Advantages of coppernose bluegill growth performance might be enhanced or diluted as intergradation with native fish occurs, which might lead to required restocking for coppernose bluegill maintenance. Efforts to manage bluegill fisheries based on coppernose bluegill introductions would be increased due to recurring stocking efforts and costs. Control of bluegill numbers in a population, or even elimination of year classes, through predation, a major accepted management tool to maintain fast-growing bluegills (Beard 1971, Kruse 1991), would also be counter-productive in the presence of a bluegill introduction activity. Therefore, for water bodies with resident bluegill present, management activities with resident bluegills are recommended.

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