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Hybridization Between Black Crappie and White Crappie in Southern Illinois

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ABSTRACT

The black crappie *Pomoxis nigromaculatus* and the white crappie *P. annularis* can hybridize and produce fertile offspring. Although several studies have documented the extent of crappie hybridization in the southern and southeastern United States, no research has focused on the amount of crappie hybridization in other parts of the country. We used allozyme electrophoresis to determine the rate of crappie hybridization in 8 southern Illinois impoundments and the extent of crappie misidentification in these impoundments due to hybridization.

The range of crappie hybridization rates was 0 – 7.9% and most of the hybrid crappie were F_x hybrids. Since hybridization rates were so low, we were able to correctly identify 93.7% of the black crappie and 99.6% of the white crappie by using traditional field methods (coloration, nape length, and dorsal spine count).

INTRODUCTION

Like many members of the family Centrarchidae, fish of the genus *Pomoxis* (black crappie *P. nigromaculatus* and white crappie *P. annularis*) are able to produce hybrid offspring which have unique characteristics when compared to pure crappie. For example, in Weiss Lake, Alabama, larval F_1 crappie swim up earlier and have higher growth rates than the parental larvae (Travnichek et al. 1996a). Consequently, hybrid crappie recruit to the fishery earlier than the parentals (Smith et al. 1994). In Illinois, F_1 hybrid crappie were shown to grow better than the parentals during both their first and second growing seasons (Buck and Hooe 1986; Hooe and Buck 1991) when the fish community was comprised of only *Pomoxis* species and their hybrids. However, when stocked into ponds with established predator and prey communities, the F_1 hybrids had sizes similar to white crappie growing in larger reservoirs (Hooe et al. 1994). Artificially produced F_1 hybrid crappie are able to reproduce, survive well as fry, have egg viability similar to the parentals, and have 1 : 1 sex ratios (Buck and Hooe 1986; Hooe and Buck 1991). In Alabama,

natural F_1 hybrids can also reproduce and have higher survival than the parental species (Smith et al. 1994; Dunham et al. 1994; Travnichek et al. 1996a). However, F_1 hybrids had low recruitment when stocked into an Illinois gravel pit pond (Bennett and Childers 1972) and they had lower recruitment than the parentals when stocked exclusively in experimental ponds (Hooe and Buck 1991). When stocked into ponds with established predator and prey communities, the F_1 hybrid crappie had low survival and recruitment (Hooe et al. 1994).

Second generation hybrid crappie do not seem to be as viable as F_1 hybrids. The F_2 hybrid crappie had low recruitment in an Illinois gravel pit (Bennett and Childers 1972) and had the lowest recruitment when compared to parentals and F_1 hybrids in experimental ponds (Hooe and Buck 1991). The F_2 hybrids also did not grow as well as the F_1 hybrids. In a different experiment conducted in Illinois ponds, F_2 hybrid crappie again had very low levels of reproduction (Epifanio et al. 1999).

Hybrid crappie can backcross with pure crappie, and most studies classify backcrossed fish and higher generation hybrids as F_x hybrids (Bennett and Childers 1972; Smith et al. 1994; Dunham et al. 1994; Travnichek et al. 1996b). First generation hybrids were from 2 – 7 times more abundant than F_x hybrids in Weiss Lake, Alabama (Smith et al. 1994; Dunham et al. 1994) but F_x hybrid crappie were more abundant than F_1 crappie in Douglas Reservoir, Cherokee Reservoir, and Norris Reservoir in Tennessee (Dunham et al. 1994). In experimental ponds, parental crappie mated assortatively such that F_1 hybrid and F_1 by parental backcross offspring occurred less frequently than expected but parental and F_2 hybrid offspring were found more often than expected (Epifanio et al. 1999). In nature, backcrosses are more likely to involve the black crappie as the parental (Smith et al. 1994), probably because the F_1 hybrid crappie superficially resembles the black crappie (Metcalf et al. 1972).

Since F_1 hybrid crappie resemble the black crappie and F_x hybrids resemble either black crappie or white crappie, hybrids can be difficult to identify in the field. Subtle differences can be detected between the F_1 hybrid and the parental species (Buck and Hooe 1986), but Smith et al. (1995) reported that a combination of nape length (distance from the rear of the eye to the origin of the dorsal fin) and spine count could not discriminate between the white crappie, black crappie, and their F_1 hybrid. Most F_1 fish had a long nape (a white crappie trait) and 7 or more dorsal spines (a black crappie trait), but white crappie, black crappie, and the F_1 hybrid all exhibited overlapping combinations of these characteristics.

Hybrid crappie are best identified using allozyme electrophoresis (Buck and Hooe 1986; Maceina and Greenbaum 1988; Hooe and Buck 1991; Epifanio and Philipp 1993; Smith et al. 1994; Dunham et al. 1994; Smith et al. 1995; Travnichek et al. 1996a; Travnichek et al. 1996b; Epifanio et al. 1999). Analysis of crappie communities using allozyme electrophoresis has shown that hybridization rates (percentage of crappie which are F_1 or F_x hybrids) can vary greatly. In Lake Weiss, Alabama 17% of the age 0 crappie were hybrids (Travnichek et al. 1996a). Observed rates of natural hybridization for other communities ranged from 0% to 55% (Maceina and Greenbaum 1988; Smith et al. 1994; Dunham et al. 1994; Travnichek et al. 1996a; Travnichek et al. 1996b; Travnichek et al. 1997a). Hybrid crappie have even been found in hatcheries (Dunham et al. 1994).

Several factors have been proposed which could influence the rate of hybridization between similar fish species. Hybridization among *Lepomis* species was related to abundance of vegetation, limited spawning areas, high population densities, water level fluctuations, and high turbidity (Hubbs 1955). Turbidity had little effect on *Lepomis* hybridization in Illinois, while crowding and ratio of rare to common species did influence hybridization rate (Dallmier 1992). Smith et al. (1994) suggested that crappie hybridization in Weiss Lake, Alabama was related to turbidity, a short mating season, water fluctuation, and the fact that Weiss Lake lies on the eastern boundary of the historic distribution of white crappie. In Alabama, this boundary is defined by the Coosa River, on which two impoundments had high rates of crappie hybridization but two other impoundments had levels of hybridization similar to other reservoirs in Alabama (Travnichek et al. 1996b). Theoretically, the relative number of F_1 hybrid crappie can influence the amount of F_x hybrid crappie in a community since first generation hybrid crappie can breed with each other and with parental fish to create F_x hybrids. However, the mere presence of F_1 hybrid fish does not guarantee that F_x hybrid fish will be present (Dallmier 1992). Even if hybridization rates are high, survival and recruitment rates of hybrids can be lower than parentals (Bennett and Childers 1972; Hooe and Buck 1991; Hooe et al. 1994).

Naturally occurring crappie hybrids have been found in Illinois (Bailey and Lagler 1938; Buck and Hooe 1986; Hooe and Buck 1991), but no study has measured the rate of hybridization in crappie communities in southern Illinois. Southern Illinois lies within the historical range of both species of crappie (Trautman 1981) and both species have been introduced throughout the state. We sampled several crappie communities to determine the extent of crappie hybridization in southern Illinois and the rate of visual misidentification of crappie due to hybridization.

METHODS

Crappie were obtained from Southern Illinois impoundments which were known to contain both species (Table 1 and Figure 1). Crappie were sampled in the spring and fall of 1996 and the spring of 1997 using vertical throat trap nets (box = 0.91 m by 1.83 m by 0.61 m, lead = 12.8 m, bar mesh = 0.0095 m). All crappie were assigned a putative species identification using traditional methods. Black crappie and white crappie were first separated based on lateral coloration (white crappie have dark vertical bands on their sides) and shape (the nape length is longer than the base of the dorsal fin in white crappie, giving them a more elongate shape than black crappie). For questionable fish, dorsal spines were counted; black crappie were considered to have 7 or greater dorsal spines, white crappie 6 or fewer (Trautman 1981; Smith et al. 1995). Fish with odd coloration or shape were classified as hybrids.

A liver tissue sample was removed from each fish, stored at –80 C, and analyzed using both starch gel and cellulose acetate allozyme electrophoresis. Previous studies have documented fixed differences between black and white crappie at several allozyme loci (Buck and Hooe 1986; Maceina and Greenbaum 1988; Dunham et al. 1994). Our study screened crappie using a combination of three to five of the diagnostic loci reported in these studies. The loci initially used were *GPI-A**, *sMDH-B**, *ACP-1**, *FH-1**, and *PGM-1**. Starch gel techniques were similar to those of Travnichek et al. (1996a) using

tris-HCl (pH 7.0) in the buffer and gels (13% starch). In order to ensure compatibility between the starch gel and cellulose acetate techniques, we used both methods to compare allozyme expression at all diagnostic loci for several black crappie, white crappie, and hybrid crappie. Cellulose acetate techniques followed Billington et al. (1996). Detection and electrophoretic mobility of alleles in the cellulose acetate gels was similar to that in the starch gels, but cellulose acetate gels could be scored approximately 45 minutes after obtaining tissue samples, compared to about 6 hours for starch gels.

For each locus, the most common black crappie allele was assigned a value of 100, and all other alleles were assigned a value based upon their mobility relative to the 100 allele. Fish which were heterozygous at all observed loci were considered F_1 hybrids, while those which were heterozygous at only some of the observed loci were considered F_x hybrids. Fish which were homozygous for the black crappie allele at one locus and homozygous for the white crappie allele at another locus were also considered F_x hybrids. Percentage of hybrid crappie was calculated for each lake by summing the total number of F_1 and F_x fish and dividing this number by the total number of fish sampled.

Epifanio and Philipp (1997) and Epifanio et al. (1999) cautioned against using individual genotypes to extrapolate hybrid identities to an entire community, especially when using only a few diagnostic loci. With 3 non-linked diagnostic loci, there exists a 25% chance of misidentifying an F_1 by parental backcross and a 72% chance of misidentifying an F_2 hybrid crappie (from Table 2 of Epifanio and Philipp 1997). In our study we were not concerned with discriminating between F_x and F_2 or higher order hybrids, but we were interested in determining the percentage of crappie which were some form of hybrid. Statistically, 12.5% of the F_1 backcrosses and 3.1% of the F_2 hybrids were expected to be misclassified as parental crappie. Thus, our observed rates of hybridization were conservative. Also, some of the F_x crappie can be heterozygous at all 3 loci and thus might be misidentified as F_1 hybrids, so our observed rate of F_x hybridization was also conservative.

Since hybrids tend to backcross more with black crappie than with white crappie, we determined the direction of introgression by modifying the method of Smith et al. (Smith et al. 1994) for 3 loci. Each F_x hybrid had 6 total alleles at 3 diagnostic loci. The number of white crappie alleles possessed by the F_x hybrid was multiplied by 1/6 (0.167) to obtain an allele score ranging from 0 to 1. A pure black crappie received a score of 0.000 while a pure white crappie received a score of 1.000, and scores for the F_x crappie could range from 0.167 to 0.833 depending upon the number of black crappie and white crappie alleles the hybrid possessed.

RESULTS

We screened 767 crappie from 8 Southern Illinois impoundments and found that hybridization rates between the black crappie and the white crappie were very low. Most of the hybrid crappie were post- F_1 hybrids. The low number of hybrid crappie meant that most crappie were identified correctly; however, of the few hybrid crappie, most were mistaken for parentals.

Hybrid crappie were found in 5 of 8 lakes (Table 2). In lakes which contained hybrids, the percentage of hybrid crappie ranged from 0.6% to 7.9%. Of the 20 hybrid crappie found, 7 were F_1 hybrids and 13 were F_x hybrids. Eleven of the 13 F_x hybrids were heterozygous at the *sMDH-B** locus, 2 were heterozygous at the *PGM-1** locus, 2 were heterozygous at the *GPI-A** locus, and none were heterozygous at the *FH-1** locus (Table 3). Black crappie alleles were more prevalent than white crappie alleles in F_x hybrids (Figure 2.)

Using traditional methods, we correctly identified 93.7% of the black crappie and 99.6% of the white crappie. Both F_1 and F_x hybrids were mistaken for black crappie. One misidentified white crappie was a black crappie, while the other misidentified white crappie was an F_x hybrid. The only putative F_1 hybrid was actually an F_x hybrid (Table 4).

Allele mobilities were similar to other studies (Table 5 and Table 6). Two alleles were found for the *ACP-1**, *FH-1**, and *GPI-A** loci and 3 alleles were found for the *sMDH-B** and *PGM-1** loci. A rare allele was found in Goodman Lake white crappie for the *sMDH-B** locus; this allele was called the **180* allele based on its mobility, and it could be the same allele as the **147* allele found in Dunham et al. (1994). We also found a unique allele at the *PGM-1** locus which we called the **135* allele.

Some uncertainty exists which *FH** locus is useful to diagnose between the black crappie and the white crappie. Some authors report using the *FH-1** locus (Epifanio and Philipp 1993; Smith et al. 1994; Travnichek et al. 1997a) while others have used the *FH-2** locus (Dunham et al. 1994; Travnichek et al. 1996a; Travnichek et al. 1996b; Travnichek et al. 1997b). Epifanio and Philipp (1994) reported that *FH-1** was diagnostic between the black crappie and white crappie but *FH-2** (from muscle tissue) was not diagnostic. The mobilities of *FH** alleles in our study were similar to the mobilities reported for both *FH-1** (Epifanio and Philipp 1993; Epifanio and Philipp 1994) and *FH-2** (Travnichek et al. 1996b). Since we are unsure which *FH** locus we looked at, and since the *FH-1** locus is linked to the *PGM-1** locus (Epifanio and Philipp 1993), we did not use the *FH** locus to identify hybrid crappie.

DISCUSSION

In the Southern Illinois impoundments we studied, the F_x hybrid crappie outnumbered the F_1 hybrids. Although first generation hybrids were consistently more numerous than F_x hybrids in Weiss Lake, Alabama (Dunham et al. 1994; Smith et al. 1994; Travnichek et al. 1997a; Travnichek et al. 1997b), higher order hybrids were more prevalent than F_1 hybrids in several Tennessee reservoirs (Dunham et al. 1994). Nine of the 13 F_x hybrids found in our study were identified as F_x hybrids based solely on their heterozygous phenotype at the *sMDH-B** locus (Table 3). Eight of these fish were found in Crab Orchard Lake and the remaining fish was found in nearby Goodman Lake. It is possible that introgression of the white crappie allele for this locus occurred at some point in the history of the Crab Orchard crappie community and that the *sMDH –B** locus is not useful as a diagnostic locus there. Disregarding the *sMDH –B** locus as a diagnostic locus reduces the percent hybrid crappie in Crab Orchard Lake from 7.9% to 3.0% and reduces the percentage of hybrids in Goodman Lake from 4.1% to 3.1%. According to the owner of Goodman Lake, Crab Orchard Lake was connected to Goodman Lake by a very small

overflow stream on at least one occasion. The rare *PGM-1** allele we found in Crab Orchard Lake was also found in Goodman Lake, suggesting that these two crappie communities have some limited genetic exchange.

The low number of hybrids found kept us from determining which factors promote hybridization in Southern Illinois; however, we can speculate which factors could result in F_x hybrids outnumbering F_1 hybrids as was observed in our study communities. Dallmier (1992) suggested that conditions which influence hybridization can fluctuate from year to year. If conditions favored hybridization in 1 year, a single year class of F_1 hybrids would be produced which could then reproduce over several seasons, resulting in several year classes of F_x hybrid crappie. As the F_x hybrids reproduced with each other and backcrossed with the parentals, a large number of F_x hybrids would be produced from just a single season of interspecific hybridization. Another possibility is that the single F_1 hybrid year class could mate assortatively and create a large year class of F_2 hybrids, as demonstrated by Epifanio et al. (1999). Thus, a single breeding season which favored the (rare) hybridization between black and white crappie could lead to several year classes of F_x crappie. Although hybrid crappie were not aged in this study, future studies should include age analysis to understand the dynamics behind hybridization.

We correctly identified crappie 97% of the time using traditional methods, a rate which agreed well with the 96% success rate given by Buck and Hooe (1986) for Illinois crappie. Smith et al. (1995) correctly identified 57 – 89% of Alabama crappie; however, they relied solely on nape length and dorsal spine count while we used coloration as well. Hybrid crappie were often mistaken for parental species (Dunham et al. 1994 and Table 4) and rarely can be identified in the field. We agree with Buck and Hooe (1986) that differences between the hybrids and parentals are subtle and difficult to characterize. Our experience with lab-reared hybrid crappie has indicated that hybrid crappie often appear to have a shape intermediate to the two parental species. For example, the nape of the white crappie is longer than that of the black crappie, making the white crappie appear more elongate. The F_1 hybrid appears have a nape length intermediate to the two parentals, giving it a more “rounded” shape which distinguishes it from the white crappie but which seems slightly distinct from the black crappie as well. Data we obtained from laboratory-spawned crappie indicated that mean ratio of nape length to dorsal fin length was 0.92 for black crappie, 1.00 for F_1 hybrids, and 1.14 for white crappie; however, much overlap occurred among the groups, and this measurement was not taken on crappie sampled from the wild. Our observations also indicate that the hybrid crappie has a more “spotted” coloration similar to the black crappie, but the spots of the hybrid appear larger and more irregular than the black crappie. Although the presence of hybrid crappie in Southern Illinois impoundments provides the opportunity for misidentification of crappie taken from these lakes, the low number of hybrids actually present suggests that misidentification would not be a significant problem.

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Table 1. Surface area and mean depth of Southern Illinois impoundments from which crappie were sampled for hybridization analysis.

Location	Surface Area (ha)	Mean Depth (m)
Aldridge Lake	4	1.0[a]
Carlyle Lake	10, 522	3.4
Crab Orchard Lake	2, 819	2.7
Goodman Lake	1[a]	1. 0[a]
Kinkaid Lake	972	7.6
Lake Sara	586	6.7
Lake Shelbyville	4, 492	5.8
Rend Lake	7, 649	3.0

[a]Estimated values

Table 2. Number of black crappie, white crappie, F_1 hybrid crappie, F_x hybrid crappie, and rate of crappie hybridization in 8 Southern Illinois impoundments.

Location	Black crappie	White crappie	F_1	F_x[a]	Pct. hybrids
Aldridge Lake	1	70	0	0	0.0%
Carlyle Lake	58	119	0	1	0.6%
Crab Orchard Lake	108	44	3	10	7.9%
Goodman Lake	73	21	3	1	4.1%
Kinkaid Lake	1	33	0	1	2.9%
Rend Lake	26	63	1	0	1.1%
Lake Sara	2	9	0	0	0.0%
Lake Shelbyville	1	118	0	0	0.0%

[a]Indicates post-F_1 hybrids (any cross in which at least one parent was a hybrid).

Table 3. Phenotypes of F_x hybrid crappie at 4 diagnostic allozyme loci.[a]

Location	*sMDH-B**	*PGM-1**	*GPI-A**	*FH-1**
Carlyle Lake	100/129	73/73	100/109	56/56
Crab Orchard Lake	100/129	100/100	100/100	100/100
Crab Orchard Lake	100/129	100/100	100/100	100/100
Crab Orchard Lake	100/129	100/100	100/100	100/100
Crab Orchard Lake	100/129	100/100	100/100	100/100
Crab Orchard Lake	100/129	100/100	100/100	
Crab Orchard Lake	100/129	100/100	100/100	100/100
Crab Orchard Lake	100/129	100/100	100/100	100/100
Crab Orchard Lake	100/129	100/100	100/109	100/100
Crab Orchard Lake	100/129	100/135	100/100	
Crab Orchard Lake	100/100	100/73	100/100	100/100
Goodman Lake	100/129	100/100	100/100	
Kinkaid Lake	100/100	100/73	100/100	

[a] Black crappie alleles are designated as 100 or 135. All other alleles are white crappie alleles and are labeled according to their mobility relative to the most common black crappie allele (100).

Table 4. Percentage of misidentified crappie as determined by allozyme electrophoresis.

		Actual identification				
Initial identification	Observed	Black	White	F_1	F_x	Pct. correct
Black crappie	287	269	0	7	11	93.7 %
White crappie	479	1	477	0	1	99.6 %
F_1	1	0	0	0	1	0.0 %
F_x	--	--	--	--	--	--

Table 5. Allele frequencies of 5 diagnostic allozyme loci for black crappie, white crappie, and their hybrids from 8 Southern Illinois impoundments.

		*ACP-1**			*FH-1**			*GPI-A**			*sMDH-B**				*PGM-1**		
		allele			allele			allele			allele				allele		
Lake	N[a]	*78	*100	N	*56	*100	N	*100	*109	N	*100	*129	*180	N	*73	*100	*135
Aldridge Lake																	
Black							1	1.00		1	1.00			1		1.00	
White							70		1.00	70		1.00		70	1.00		
F_1																	
F_x																	
Carlyle Lake																	
Black	4		1.00	21		1.00	52	1.00		58	1.00			57		1.00	
White	55	1.00		62	1.00		94		1.00	119		1.00		113	1.00		
F_1																	
F_x				1	1.00		1	0.50	0.50	1	0.50	0.50		1	1.00		
Crab Orchard Lake																	
Black				99		1.00	105	1.00		108	1.00			97		0.93	0.07
White	5	1.00		39	1.00		32		1.00	44		1.00		44	1.00		
F_1				2	0.50	0.50	3	0.50	0.50	3	0.50	0.50		3	0.50	0.50	
F_x				8		1.00	10	0.95	0.05	10	0.55	0.45		10	0.05	0.90	0.05
Goodman Lake																	
Black	2		1.00				73	1.00		73	1.00			73		0.95	0.05
White							20		1.00	21		0.95	0.05	21	1.00		
F_1							3	0.50	0.50	3	0.50	0.50		3	0.50	0.33	0.17
F_x							1	1.00		1	0.50	0.50		1		1.00	

[a]Sample size (N) indicates the number of fish of each species or hybrid which were screened at that locus.

Table 5. continued.

		*ACP-1**			*FH-1**			*GPI-A**			*sMDH-B**				*PGM-1**		
		allele			allele			allele			allele				allele		
Lake	N[a]	*78	*100	N	*56	*100	N	*100	*109	N	*100	*129	*180	N	*73	*100	*135
Kincade Lake																	
Black							1	1.00		1	1.00			1		1.00	
White				33	1.00		29		1.00	33		1.00		30	1.00		
F_1																	
F_x							1	1.00		1	1.00			1	0.50	0.50	
Rend Lake																	
Black				26		1.00	26	1.00		26	1.00			26		1.00	
White				55	1.00		31		1.00	63		1.00		63	1.00		
F_1				1	0.50	0.50	1	0.50	0.50	1	0.50	0.50		1	0.50	0.50	
F_x																	
Lake Sara																	
Black	2		1.00							2	1.00			2		1.00	
White	9	1.00								9		1.00		9	1.00		
F_1																	
F_x																	
Lake Shelbyville																	
Black										1	1.00						
White	113	1.00					91		1.00	118		1.00		117	1.00		
F_1																	
F_x																	

[a]Sample size (N) indicates the number of fish of each species or hybrid which were screened at that locus.

Table 6. Allelic mobility at 5 allozyme loci of crappie sampled in our study compared to allelic mobility of crappie sampled in other studies.[a]

	*ACP-1**		*FH-1**		*GPI-A**		*sMDH-B**		*PGM-1**	
Study	Black	White	Black	White	Black	White	Black	White	Black	White
Our study	*100	*78	*100	*56	*100	*109	*100	*129	*100	*73
								*180	*135	
Maceina and Greenbaum (1988)							*100	*120[b]	*100	*85[c]
Epifanio and Philipp (1993)			*100	*70[d]						
Dunham et al. (1994)	*100	*77	*100	*66	*100	*108	*100	*120		
								*147		
								*117		

[a]All mobilities are based upon liver tissue samples. Buffers varied between studies.
[b]Reported as *MDH – B**
[c]Reported as *PGM – A**
[d]Reported as *FH-1**

Figure 1. Location of Southern Illinois impoundments from which crappie were sampled for hybridization analysis (SB = Lake Shelbyville, SA = Lake Sara, RN = Rend Lake, GM = Goodman Lake, AL = Aldridge Lake, CO = Crab Orchard Lake, KN = Kinkaid Lake, and CA = Carlyle Lake).

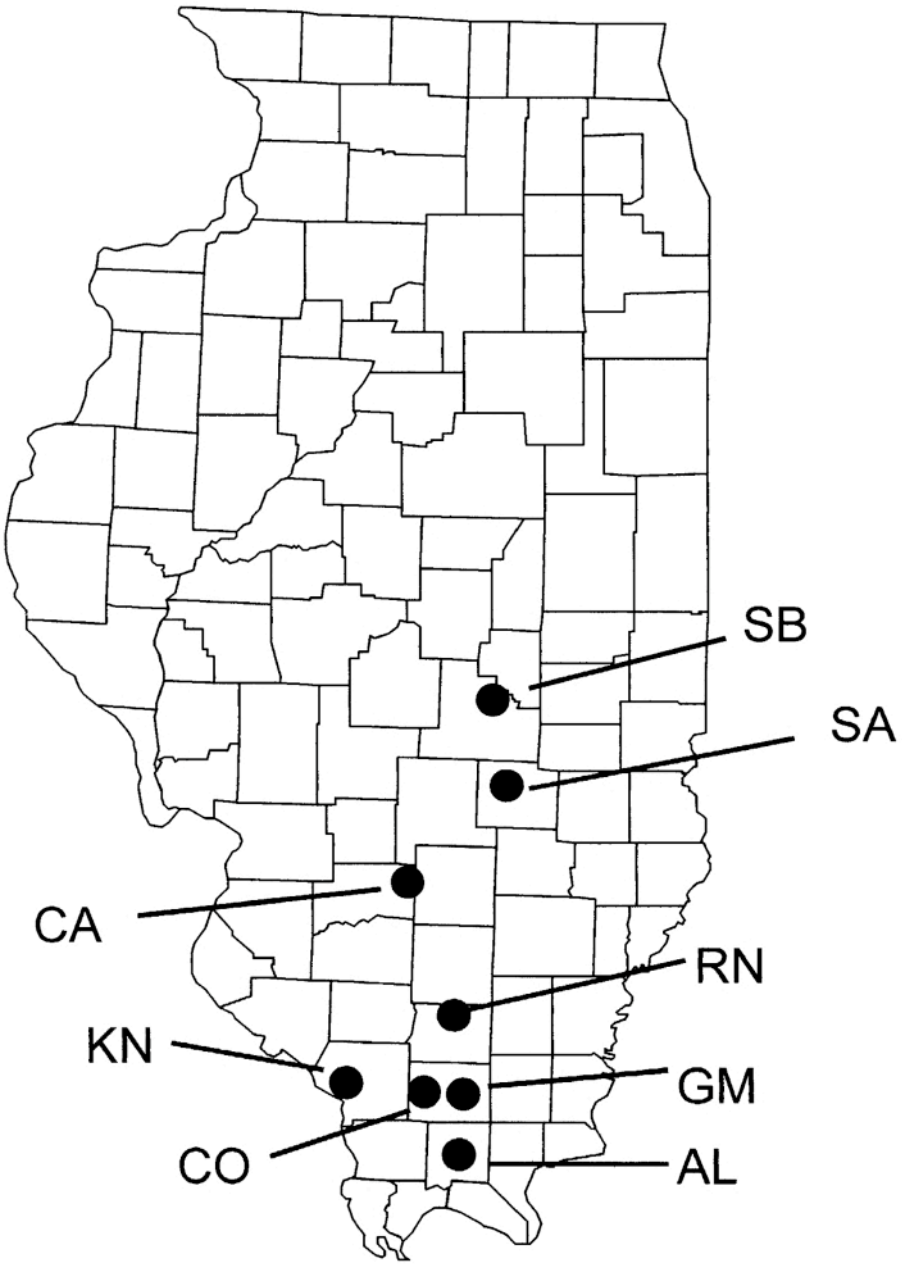

Figure 2. Direction of introgression indicated by a frequency distribution of allele scores of F_x hybrid crappie (N = 13). A score of 0.000 would indicate a phenotypic black crappie while a score of 1.000 would indicate a phenotypic white crappie.