HYBRIDIZATION BETWEEN *DOROSOMA CEPEDIANUM* AND *D. PETENENSE* IN LAKE TEXOMA, OKLAHOMA[1]

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ABSTRACT

The level of natural hybridization in Lake Texoma between *Dorosoma cepedianum* and *D. petenense* for the years 1962-63 and 1968-69 was determined to be 2.5 and 1.7% respectively. The two species have been sympatric in that reservoir since 1957. Male and female hybrids with well developed gonads were collected. Eggs from a hybrid were fertilized experimentally with milt of *D. petenense* and produced viable larvae. Hybrid fry were produced in the laboratory by crosses between *D. cepedianum* males and *D. petenense* females but not the reciprocal. Spawning of the two species is discussed in relation to the possible means of natural hybridization.

Natural hybridization between the clupeid species *Dorosoma cepedianum* and *D. petenense* was reported by Minckley and Krumholz (1960). They cited as the probable cause, the less abundant *D. petenense* joining groups of spawning *D. cepedianum*. Hybrids were first identified in Lake Texoma in 1960 by C. D. Riggs and G. A. Moore (personal communication). *Dorosoma petenense* was first collected from the lake in 1957, when the young-of-the-year were already more abundant than those of *D. cepedianum* (Riggs and Moore, 1958). The population of *D. petenense* expanded rapidly and soon surpassed that of *D.* cepedianum. At present, both species are abundant.

This study was conducted to determine factors responsible for hybridization and if the relative abundance of hybrids changed over several years. Specimens were collected with experimental gill nets (19-, 25-, 31-, 38-, and 51-millimeters bar-mesh) and hybrids were identified from fresh material. Characteristics described by Minckley and Krumholz (1960) were easily recognizable. In general, hybrids had a snout shape similar to that of *D. cepedianum* but with the yellow pigmentation characteristic of the fins of *D. petenense*. It is assumed that these were probably f1 hybrids and is not known if subsequent filial groups could have been recognized. Gill nets were selective for the larger specimens and *D. petenense* were regularly collected only in the 19 mm mesh. This is reflected in the small number of *D. petenense* collected (Table 1) which would tend to increase the apparent level of hybridization. But since the method of collection was uniform throughout the study, the error would tend to be relatively constant.

The level of hybridization during the initial year of introduction (1957) was not established but was estimated at roughly 5-year intervals thereafter. The percentage of hybrids collected appears to have changed only slightly during the study period (Table 1). Five years following the initial appearance of *D.* petenense, the level of hybridization was estimated to be 2.5%, after 10 years it had decreased slightly to 1.7%.

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Table 1. Number of *Dorosoma* collected with gill nets in Lake Texoma during 1962-63 and 1968-69.

year	*D. cepedianum*	*D. petenense*	hybrids	% hybrids
1962-63	927	420	35	2.5
1968-69	1,047	993	36	1.7

Bennett (1962) stated that in natural populations, the hybridization level usually does not exceed 1 to 2 percent. Although the level of hybridization during 1962-63 was higher than the estimate for 1968-69, they are of the same order of magnitude and probably do not indicate more than a random departure. It appears that the two species populations might have come to an equilibrium, producing a low but continuous number of hybrids. It is significant to note that the scarcity of neither parental type has been a factor in the production of hybrids in this reservoir. Both species have maintained a large population over the years.

Most of the mature hybrids collected were larger than *D. petenense*, i.e. greater than 150 mm total length. Thus the catch was probably more nearly indicative of the actual level of the population. Hybrids of both sexes were collected but the number of specimens was inadequate to judge if the sex ratio was balanced. Hybrids were not sexed during 1962-63 but during 1968-69, 17 male, 9 female, and 10 immature specimens were collected. Hybrids had well developed gonads, many with free-flowing sex products.

Laboratory fertilization was attempted on several occasions to determine if viable gametes were produced. Larvae were produced from back-crosses of male *D. petenense* and hybrid females (Table 2) indicating at least some fertility. Cross fertilization between the two species was also attempted. Hybrids were produced in the laboratory between *D. cepedianum* and *D. petenense* females (Table 2). This combination resulted in a total of 450 viable yolk-sac larvae. The reciprocal cross, however, repeatedly failed with the embryos rarely developing beyond gastrulation. Other possible combinations were not attempted since parental types in a ripe condition were not available simultaneously.

Table 2. Artificially produced hybrids and parental types.

males		females	number of larvae produced	crosses attempted
D. cepedianum	X	*D. petenense*	450	4
D. petenense	X	*D. cepedianum*	0	15
D. petenense	X	hybrid	45	5

Developmental periods for *D. petenense*, *D. cepedianum*, and hybrid embryos were discussed by Shelton (1972). He reported developmental periods for hybrid embryos as intermediate between the embryos of the parental types (Table 3). Hybrids developed pigment in the eye prior to hatching except in one series incubated at 18.5°C. Development of eye pigment is more precocious at higher temperatures (Smith, 1957). At hatching, the yolk of the fry was spherical and pectoral fin buds were developed. These characteristics are typical of *D. petenense* larvae at hatching. Developmental period of embryos from the hybrid

females and male *D. petenense* crosses was similar to that observed for f1 hybrids and no undue mortality was apparent. At hatching, these larvae had eye pigment, globular yolk, and pectoral fin buds, thus also resembling the larvae of *D. petenense*. *D. cepedianum* larvae at hatching have unpigmented eyes, lack fin buds, and the yolk is oval.

Table 3. Developmental period at various temperatures for hybrids between *D. cepedianum* males and *D. petenense* females.

Temperature (C)	developmental period (hr).	range (hr).	number of larvae hatched
18.5	83	81-87	331
21.0	72	69-75	18
22.0	56	56-71	76
24.0	41	39-59	25

The spawning biology of *D. petenense* and *D. cepedianum* was compared by Shelton (1972) and is summarized in Table 4. The spawning of the two species overlapped spatially, diurnally, and behaviorally. However, sufficient separation apparently exists to maintain the species sympatrically. Hybridization occurs when isolating mechanisms are not totally effective. Mayr (1968) discussed isolating mechanism and various degrees of breakdown.

Spatial difference in spawning was suggested in two modes, horizontally and vertically. *D. petenense* seemed to spawn less in backwater areas and not at all upstream in small tributaries. There was an apparent stratified spatial difference in mutual spawning areas. *D. petenense* appeared to spawn heaviest in very shallow water and at the surface, whereas *D. cepedianum* oriented more to the bottom and in somewhat deeper water. But, again there was an overlap.

The temporal aspect of segregation was evident seasonally as *D. cepedianum* spawned earlier, but the peaks of both species overlapped. Also, there was a separation in diurnal spawning. *D. cepedianum* was most active at night, but their activity tapered into the peak spawning period of *D. petenense* which spawned in the post-dawn to mid-morning hours.

Behavioral separation was evident from the difference in habitat preference so far described but the basic mechanistic stimuli of the spawning act seemed very similar and potentially capable of breakdown. This is perhaps exemplified by the "miscues" between male *Dorosomoa* and other genera of fishes. Male *D. cepedianum* were observed pursuing *Morone chrysops* that swam through the spawning area and *D. petenense* males were seen following *Menidia audens*.

It seems that there are at least two feasible means by which hybrids have been produced in Lake Texoma. Accidental union of eggs and sperm is highly probable as both species spawn in overlapping conditions. Both species have been observed spawning at the same site simultaneously. In addition, on several occasions there appeared to be mixed species participation. A single *D. cepedianum* among a spawning group of *D. petenense* was observed several times. Behaviorally, these were judged to be males and this was confirmed once when a ripe male was collected. It is suggested that the latter condition is the most plausible means of hybrid production. Small *D. cepedianum* males have been observed participating in *D. petenense* spawning, they are most com-

parable in size to large *D. petenense* males, and the fertilization experiments indicate a possible inviability in the reciprocal cross.

Isolating mechanisms, although adequate to maintain species sympatrically, do break down. The level of hybridization depends somewhat on the degree of overlap in the biology of the species involved. In *Dorosoma*, several overlapping areas seemed to exist in the reproductive biology, permitting a low but continuous level of hybrid production.

Table 4. Comparative summary of *Dorosoma cepedianum* and *D. petenense* spawning in Lake Texoma, Okla.

	D. cepedianum	*D. petenense*
Temperature:	> 16 - 17°C	> 19 - 20°C
Seasonal:	Late March to mid-May (ca. 6-8 wks.)	Mid-April to mid-June (some in July) (ca. 8-11 wks.)
Diel:	Entire 24 hrs. (max. -2000-0800)	Post-dawn-1200 (max. -0600-0900)
Sites:		
Lake	Variety of substrate. Edge to deeper water. Bottom oriented.	Variety of substrate. Shallow water and on floating objects. Surface oriented.
Tributary	Ascends small tributaries, congregates in pools. Spawns in riffles.	Mouth only of small tributaries
Sex Ratios:	2-4 males: 1 female	5-15: 1 female
Habits:	Smaller aggregations. Probably little movement parallel to shore. Inshore movement along bottom; abruptly turning in shallow water. Less surface agitation	Large aggregations moving parallel to shore near surface. Shoreward movement in smaller groups. Much surface agitation.
Maximum Spawn Density: (Lake)	1800 eggs per sq. ft. (0.1 sq. m) or less	96,000 eggs per sq. ft. (0.1 sq. m). Often completely covering submerged objects to thickness of nearly 25 mm.
Spawn Density: Tributary	Higher concentration. May approach *D. petenense* density.	None
"Miscues"	Males observed following *Morone chrysops* and *D. petenense*	Males observed following *Menidia audens*.

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GROWTH OF FIVE SPECIES OF GAME FISHES BEFORE AND AFTER INTRODUCTION OF THREADFIN SHAD INTO DALE HOLLOW RESERVOIR[1]

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ABSTRACT

The possible effect of threadfin shad stocking in Dale Hollow Reservoir on the growth of five predatory species was measured by analysis of scale samples taken before and after threadfin stocking. There was no significant change in growth rate of largemouth bass, *Micropterus salmoides*; smallmouth bass, *Micropterus dolomieui*; and spotted bass, *Micropterus punctulatus*. There was a significant increase in growth rate of walleye, *Stizostedion vitreum* and white crappie, *Pomoxis annularis*.

INTRODUCTION

Threadfin shad, *Dorosoma petenense*, have been widely introduced into warm-water reservoirs as forage for piscivorous game fishes. The objective of this study was to determine if the introduction of this shad into Dale Hollow Reservoir was followed by significant length increase in five species of game fishes: largemouth bass, *Micropterus salmoides*; smallmouth bass, *Micropterus* dolomieu; spotted bass, *Micropterus punctulatus*; white carppie, *Pomoxis annularis*; and walleye, *Stizostedion vitreum*.

The first known stocking of about 400 shad into Dale Hollow occurred in the spring of 1954. That stocking, as well as a subsequent stocking of about 7,000 shad in 1961, failed to produce a sustaining threadfin population. In April, 1965, several stocking totaling about 25,000 shad were made and in subsequent years a continuing population of threadfin shad has existed.

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