Distribution, population assessments and annual reproductive cycles of Bermuda's endemic killifishes

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Overview: *Fundulus bermudae* and *Fundulus relictus* are endemic to the islands of Bermuda and are listed as protected species in the Bermuda Protected Species Act 2003. These killifishes were described as abundant and widespread in the wetland communities of Bermuda during the late nineteenth and early twentieth centuries, but are now only found in nine small, isolated ponds. Quantitative assessments of each pond population have been lacking and are limiting conservation efforts for these species. Surveys were undertaken during 2004-2005 to determine the current distribution as well as to make estimates of the size and structure of each *Fundulus* population. This was achieved by performing a census based on mark and recapture sampling while simultaneously gathering size frequency and demographic variance data to assess the condition of each population. In addition to these assessments, the annual reproductive cycle was described from the population inhabiting Mangrove Lake.

Photo by Robin Marirea

Fig.1 Setting the baited minnow traps

Fig.2 Mature male killifish

Photo by Jennifer Gray

Photos by Mark Outerbridge

Fig.3 Mature female killifish with green VIE tag

Introduction: Bermuda's anchianine ponds are isolated, saline, land-locked bodies of water with permanent connections to the ocean. Temperature and salinity are dependent upon the amount of sea water that enters from the ocean and vary from pond to pond, showing predictable seasonal patterns (1). The relative stability and isolation of these ponds has created sanctuaries for the organisms living in them and have enabled species like the killifishes to evolve to the degree of endemism. To date, 433 species of fishes have been recorded in Bermuda, of which eight are currently recognized as valid endemic species (2). Two of these eight endemics belong to the genus *Fundulus*; *Fundulus bermudae* and *Fundulus relictus*. These fishes are believed to be descendants of the *Fundulus heteroclitus - F. grandis* species group, originating from populations on the east coast of North America (3).

Tagging: 44 different areas around Bermuda were surveyed using a combination of direct observation and baited trapping (Fig.1). Where extant populations were found a census was performed based on the Petersen Index methodology of mark and recapture (4) using visible implant elastomer (VIE) tags. These biocompatible tags provided a clearly visible internal mark and were given to fish under full anaesthesia, immediately below the skin (Fig.4). Sex and total length were determined at the time of tagging.

Photo by Anne Glasspool

Fig.4 Injecting *F. bermudae* with red VIE

Results: The surveys confirmed the existence of populations in the following locations only; Lover's Lake, Bartram's Pond, Mangrove Lake, Trott's Pond, Blue Hole Bird Pond, both East and West Walsingham Ponds, Warwick Pond and Evan's Pond (Fig. 5). No additional *Fundulus* populations were discovered. Size ranges, mean lengths, sex ratios and population estimates for 7 populations are displayed in Table 1. Females were significantly larger than males of the same age from Lover's Lake, West Walsingham, and Warwick Pond. Additionally, females outnumbered males in all ponds surveyed, except Trott's Pond where the sexes occurred in equal numbers.

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Table 1. Population assessments for killifishes in Bermuda

Pond	Area (ha)	Size range TL (mm)	Mean Length TL (mm)	Female:Male ratio	Estimated population	Fundulus species
Mangrove Lake	9.89	52 – 126	71.9	1.17:1	11,325 (+/-1,884)	*F. bermudae*
Lover's Lake	0.41	41 – 97	63.0	1.08:1	8,508 (+/-1,347)	*F. relictus*
Trott's Pond	2.88	36 – 100	61.5	1:1	7,926 (+/-1,576)	*F. bermudae*
Blue Hole Bird Pond	0.09	34 – 97	55.0	1.78:1	5,394 (+/-480)	*F. bermudae*
West Walsingham Ponds	0.30	27 - 72	48.3	1.86:1	2,202 (+/-178)	*F. bermudae*
Bartram's Pond	0.28	38 – 92	53.8	2.06:1	1,793 (+/-224)	*F. relictus*
Warwick Pond	1.29	41 – 129	77.1	1.21:1	436 (+/-13)	*F. bermudae*

* Not included are Evan's Pond and the East Walsingham Ponds; fish could not be trapped in these two ponds.

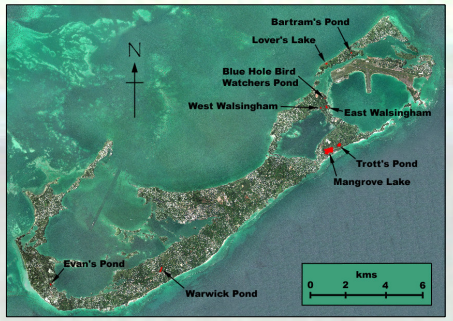

Fig.5 Distribution of killifishes across the islands of Bermuda

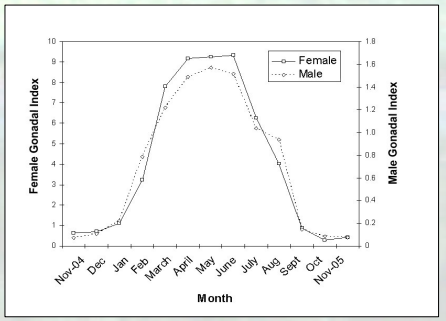

Fig.6 Spawning cycle of killifish from Mangrove Lake

Photo by Mark Outerbridge

Fig.7 Mangrove Lake

Reproductive cycles: Laboratory analysis of gonad development allowed for the description of the annual reproductive cycle of killifish from Mangrove Lake (Fig.7). A distinctive annual pattern was evident, with female and male cycles near synchronous over the 13 month study period. The results indicate that these fish began their spawning season in winter and reached maximum reproductive output in early summer. Gonadal indices abruptly fell after June and continued to fall at a steady rate until September, marking the end of the spawning season. (Fig.6).

Discussion: The present distribution of Bermuda's killifishes is substantially different from their former distribution. Historical records indicate that they were once abundant and widely distributed throughout many of the marshes and ponds of Bermuda, as well as the muddy bays around St. George's and St. David's in the mid 1800s and early 1900s (2,5,6). The survey results of the present investigation indicate that Bermuda's *Fundulus* species have completely disappeared from the coastal mangrove and the inland marsh communities. Human modification to historical killifish habitats is the single greatest reason why distribution is currently limited. Since Bermuda's killifish are now found in a few isolated populations, consideration has to be given to their viability in the short and long term. At least three populations are sufficiently low enough to be deemed vulnerable to extinction. The creation and restoration of wetland habitats, combined with transfer of killifish from the larger populations, is a sensible step forward to ensure the survival of these unique species.

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