Report on the genetic structure of Credit River steelhead

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PURPOSE

The purpose of this study was to assess genetic differentiation among 1) unclipped Credit River steelhead including individuals of natural and fry stocked (Credit River Anglers Association (CRAA)) origin, both types being progeny of unclipped fish; 2) Ontario Ministry of Natural Resources (OMNR) Normandale hatchery strain used to for OMNR stocking into the Credit River; 3) unclipped, wild Ganaraska River steelhead.

BACKGROUND

Steelhead/rainbow trout were first introduced into the Lake Ontario basin in 1878 (MacCrimmon and Gots 1972). Although early details were poorly documented, accounts suggest that stocking of steelhead into Ontario tributaries occurred at low levels between 1920 and 1940 and resulted in establishment of naturalized populations (MacCrimmon and Gots 1972). Ontario's Normandale and Codrington hatchery stocks were used during these early stockings (MacCrimmon and Gots 1972). McCloud River strain rainbow trout and steelhead likely comprised a large component of the ancestry of these two strains (MacCrimmon and Gots 1972; Dueck 1994), although significant infusion of other strains likely occurred before and during the 1920-1940 period (Dueck 1994; Behnke 2002).

Steelhead have been present in the Credit River for nearly a century but were only found in small numbers until 1970 (Anonymous 1998). The OMNR began stocking large numbers of OMNR Normandale hatchery strain steelhead into the Credit River on a yearly basis during the mid 1970s (Figure 1). The historical Normandale strain (1914-1981) was used by the OMNR until it was destroyed in 1981 (Dueck 1994). A new Normandale strain was developed using wild Ganaraska River steelhead caught during the spring runs of 1983-1985 (Dueck 1994). The Ganaraska River/Normandale Hatchery strain has subsequently been utilized for annual OMNR stocking in the Credit River since 1984. Furthermore, beginning in 1997 CRAA began collecting gametes from unclipped adult steelhead and stocking fry (Figure 1). The proportion of unclipped steelhead in the Credit River (individuals of natural and CRAA fry stocked origin) has been increasing since the 1980s due to the construction of a fish ladder at Streetsville dam, the transfer of unclipped adults into Silver and Black creeks and CRAA fry stocking (Anonymous 1998).

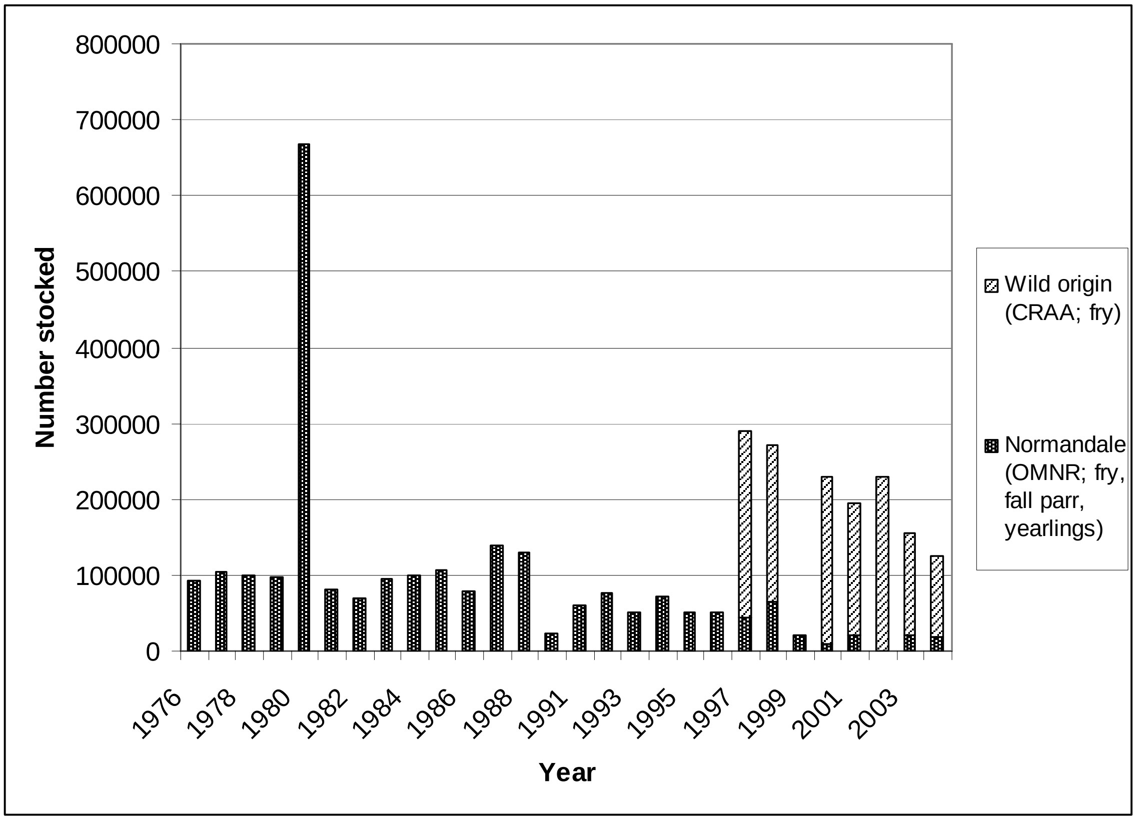

Figure 1. Number of fish stocked into the Credit River (including Port Credit stocking) by the OMNR and CRAA between 1976 and 2005. Note: CRAA stocking utilizes fry, while OMNR stocking has utilized a mix of fry, fall parr and yearlings. Therefore the differences presented are likely not indicative of the number of smolts leaving the Credit River.

Past genetic analysis of Lake Ontario steelhead populations (Dueck 1994; Dueck and Danzmann 1996; O'Connell et al 1997) suggests some hierarchical (multiple levels) genetic structuring. Large scale genetic differences between naturalized populations from Ontario and stocked populations of New York were identified using both mitochondrial and microsatellite DNA (Dueck 1994; Dueck and Danzmann 1996; O'Connell et al. 1997). O'Connell et al. (1997) identified limited smaller scale genetic heterogeneity among tributary populations within Ontario.

METHODS

DNA was extracted from samples of unclipped Credit River steelhead (N=94), Ganaraska River/Normandale Hatchery steelhead (N=79) and wild Ganaraska River steelhead (N=27) collected during 2006-2007. Eleven highly polymorphic microsatellite loci were amplified for each individual. The program GENEPOP version 3.4 (Raymond and Rousset 1995) was used to test each locus for deviation from Hardy-Weinberg equilibrium (HWE) expectations. Two loci deviated from HWE expectation and were subsequently removed from all subsequent analysis. GENEPOP was used to test for pairwise population-based genic differentiation and estimate pairwise population-based F_{ST}. The program STRUCTURE (version 2.2, Pritchard et al. 2000) was used to assess genetic population structure based on individual genotypes.

RESULTS and IMPLICATIONS

Population-based F_{ST} estimates of divergence suggest that unclipped steelhead of the Credit River have not diverged significantly from wild steelhead of the Ganaraska River. In contrast, the individual from the Credit River have diverged from the Ganaraska River/Normandale hatchery strain (Table 1). This suggests that gene-flow between the Normadale hatchery strain and the unclipped Credit population has been insufficient to cause homogenization of the magnitude recorded on the New York side of Lake Ontario (Dueck 1994; Dueck and Danzmann 1996) and in Lake Michigan (Bartron and Scribner 2004).

Table 1. Estimates of pairwise F_{ST} among unclipped Credit River steelhead, wild Ganaraska steelhead and Normandale hatchery strain steelhead.

	Credit	Normandale	Ganaraska
Credit	---		
Normandale	0.0163	---	
Ganaraska	0.0036	0.0071	---

In contrast to the population population-based analysis, the individual-based analysis performed using STRUCTURE showed that fish of the Credit are indistinguishable from wild Ganaraska River and Normandale steelhead at the individual level (Figure 2). If individuals of the Credit River, Ganaraska River and Normandale strains were highly distinct, we would expect the bars representing individuals of each population to be largely made up of one colour, however all individuals generally assigned equally to each of the three groups. This result is consistent with the findings of Dueck and Danzmann (1996) who found that genetic diversity was generally evenly distributed across steelhead populations in Ontario tributaries of Lake Ontario. Furthermore, individual assignment programs such as STRUCTURE generally underestimate the number of populations present when differentiation among populations is low, such as population differentiation reported here based on F_{ST} (Waples and Gaggiotti 2006).

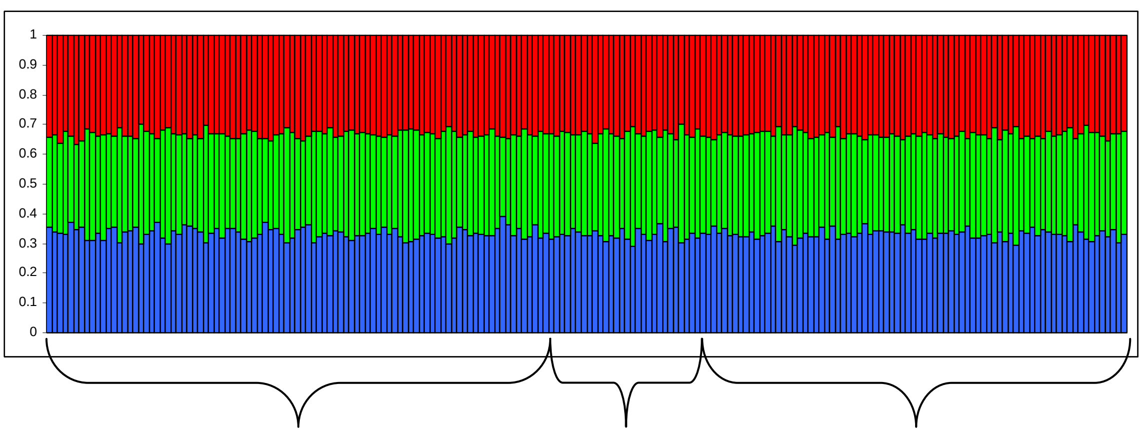

Figure 2. STRUCTURE (version 2.2) output showing no individual-based differentiation among the three groups. Each vertical bars shows the fractional membership coefficients for walleye calculated using STRUCTURE.

In conjunction, these results suggest that limited differentiation of tributary steelhead populations has taken place along the Ontario shoreline of Lake Ontario. The process of differentiation occurs over time when populations are isolated. Gene flow, both natural through straying and artificial through stocking, has the ability to reduce the rate of divergence or to homogenize any existing divergence (for example see Bartron and Scribner 2004). The markers used in this study are neutral pieces of DNA that are thought not to be under any natural selection. Since phenotypic traits such as life history and mophometry can be exposed to strong selective pressures, causing populations to diverge more quickly at these traits than at the microsatellite loci used here (for a review see Merila and Crnokrak 2001). Therefore, pertinent adaptive differences can arise at a faster than the microsatellite differences, suggesting that low levels of divergence can be associated with local adaptation. Based on these findings we suggest that in cases where locally adapted, self-sustaining steelhead populations are desired, limiting stocking (artificial gene-flow) and transfers among populations will provide the greatest opportunity for local adaptation and future production. In cases where put-grow-take fisheries in the absence of locally adapted naturalized populations are desired we suggest continued stocking of the Ganaraska River/Normandale hatchery strain.

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