Preservation of Biodiversity: Aurora Trout
Ed J. Smuclos, John M. Gunn, and W. (Bill) Keller

... the worse thing that will probably happen... is not energy depletion, economic collapse, conventional war, or even the expansion of totalitarian governments. As terrible as these catastrophes would be for us, they can be repaired within a few generations. The one process now going on that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly our descendants are least likely to forgive us.

(William 1984)

The habitat alteration and destruction caused by Sudbury's metal extraction and smelting industries have contributed to the global depletion of biological resources (Box 11.1). Damage to local terrestrial vegetation and soils, described in Chapter 2, was striking. Less apparent but more widespread was the damage to aquatic ecosystems. Acidification of lakes from atmospheric deposition of sulfur emissions occurred over an area of 17,000 km² and affected lakes as far as 120 km from the city (Neary et al. 1990). An estimated 134gamete-bearing populations, as well as many populations of less well-studied fish species were extirpated (Matuzzek et al. 1992). The loss of these populations did not endanger entire species, but it did contribute to the loss of unique genetic strains. The losses are part of an alarming global trend to decreasing fish diversity. By region, the percentages of fish species classified as endangered, threatened, or in need of special protection are as follows: South Africa, 63%; Europe, 42%; Sri Lanka, 28%; North America, 51%; Australia, 26%; Iran, 22%; Latin America, 9% (Moxley and Leidy 1992). Within-species genetic diversity is also declining as fish are extirpated from individual lakes and rivers that comprise portions of their native range (Nelsson et al. 1991; Kaufman 1992).

Of the many populations threatened by acidification of lakes in the Sudbury area, only the aurora trout (Etheostoma pumilum) was the subject of extraordinary preservation efforts. It was extirpated from its native habitat and in 1987 was placed on Canada's endangered species list (Table 11.1). This chapter presents the story of the aurora trout restoration program, a combination of personal and agency commitment and perseverance, that saved the fish from extinction and ultimately restored it to its native habitat.
Biological extinction is not a new phenomenon. In fact, it is estimated that more than 90% of all the species that ever existed on earth are now extinct (Simpson 1952). The fossil record indicates that there have been five main periods of mass extinction during the past 600 million years. Although there is some debate over the causes of these extinctions, most authorities seem to agree that each was triggered by a natural catastrophic event in the environment, such as sudden climatic change, drop in sea level, or meteorite impact (Raup 1986).

Averaged over the entire span of life on earth, the rate of extinction amounts to about one species per year. But our current trend far exceeds this rate. Some scientists believe that, on average, several species are disappearing each day, and they estimate that if present trends continue, more than one-quarter of the earth's biodiversity, estimated to be between 3 and 30 million species (May 1990), will be lost in the next 20–30 years (McNeely et al. 1990).

The current period of mass extinction is particularly worrisome in that it is caused largely by human activity. Habitat alteration and destruction, chemical pollution, overharvesting, and the introduction of exotic species that displace or eliminate native biota are among the factors contributing to the modern depletion of biodiversity.

The current accelerated loss of biological diversity should concern us. From an ethical standpoint, some people argue that every species has an inherent right to exist independently of its material benefit to humans. There are also many human-centered utilitarian reasons for preserving biodiversity, not the least of which is that our survival depends both directly and indirectly on diversity at all levels of biological organization. Ecosystems with their variety of habitats and communities provide...
essential ecological services such as the maintenance of air and water quality, soil formation and protection, climate control, and nutrient cycling. The harvesting of natural resources supplies us with food, clothing, and shelter. Wild plants supply the genetic material for selective breeding of domestic crops to increase yields and enhance pest and disease resistance. Many pharmaceuticals, too, are derived from plants. Within-species genetic diversity provides the many varieties of a species that are each suited to different environmental conditions.

Perhaps the greatest long-term benefit of biodiversity is the supply of the raw materials that enable human and nature to respond to changing environments and stresses. Our welfare will largely be determined by how we respond to the current period of accelerated biodiversity loss in which this storehouse of potential solutions to current and future problems is quickly becoming depleted.

Description of the Aurora Trout

The aurora trout and its mother species, the brook trout, are both multihued and spectacularly beautiful, although different in the details of their coloration. Brook trout have a dorsal background color of olive green to dark brown, which is mottled by yellow spots and vermiculations (Fig. 11.1). Along the sides, this coloration pales to a snow-white abdomen that is often tinged with pink. Many red spots surrounded by pale blue halos speckle the sides. Pectoral, pelvic, and anal fins have a leading white edge backed by a black bar and orange or red posterior.

In contrast, the aurora trout’s dorsal coloration fades along the sides to iridescent steel blue and silver, colors mimicking the shimmering brilliance of the fish’s namesake, the aurora borealis, or northern lights. Adult aurora trout do not possess the yellow spots and vermiculations of the brook trout, and there are few, if any, red spots (Figs. 11.2 and 11.3). The coloration of the males intensifies during spawning. The sides and upper abdomen take on a vivid red color, often accented with a band of midnight black along the abdomen.

History of the Aurora Trout

The native range of the aurora trout consists of two small waterbodies: Whitliffig Lake (11-ha surface area) and Whitepine Lake (77-ha surface area), located 110 km north of Sudbury (Fig. 11.4). Each is part of a chain of lakes situated on a ridge in an isolated part of Lady Evelyn Smoothwater Wilderness Park. The surrounding terrain is hilly and rough, topography typical of the Precambrian Shield, and access is gained by canoe or aircraft only. Historically, Whitepine Lake also contained a population of brook trout, and both lakes supported white sucker (Catostomus commersonii) populations.

The aurora trout likely evolved from a population of brook trout isolated some time after continental glaciers receded, about 10,000 years ago. The brook trout were probably trapped as water levels dropped and the land slowly rebounded upward after being freed of the weight of the glaciers. This strain of fish subsequently evolved in isolation and diverged sufficiently to become distinct from other brook trout.

In 1923, a party of anglers from the United States visiting Whitepine Lake caught some of these fish and took one back to the Carnegie Museum in Pittsburgh. The following year, more specimens were collected, and in 1925, a description of the fish was published in the scientific literature. Subsequently, the lakes were often visited by anglers willing to undertake the 4-day journey by canoe and trail to catch this trophy sportfish renowned for its spectacular coloration and superior fighting ability.
### Table 11.1. 1993 Canadian Species at Risk

<table>
<thead>
<tr>
<th>Species</th>
<th>Status</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic Puffin</td>
<td>Endangered</td>
<td>Fratercula arctica</td>
</tr>
<tr>
<td>Black-footed Ferret</td>
<td>Threatened</td>
<td>Mustela nigripes</td>
</tr>
<tr>
<td>Burrowing Owl</td>
<td>Threatened</td>
<td>Bubo virginianus</td>
</tr>
<tr>
<td>Loggerhead Shrike</td>
<td>Threatened</td>
<td>Lanius ludovicianus</td>
</tr>
<tr>
<td>Marsh Harrier</td>
<td>Threatened</td>
<td>Cercotrichas galactotes</td>
</tr>
<tr>
<td>White-tailed Woodpecker</td>
<td>Threatened</td>
<td>Dryocopus leucotos</td>
</tr>
<tr>
<td>Elkhorn</td>
<td>Threatened</td>
<td>Elasmopus elasmopus</td>
</tr>
<tr>
<td>Eastern Osprey</td>
<td>Threatened</td>
<td>Pandion cristatus</td>
</tr>
<tr>
<td>Beach</td>
<td>Threatened</td>
<td></td>
</tr>
</tbody>
</table>
The classification of the aurora trout has been a source of controversy. It was originally classified as a distinct species (Salvelinus taimannensis) (Henn and Rinkenbach 1925) until a closer affiliation with the brook trout subsequently found favor. On the basis of differences in behavior, coloration, and other characteristics, a subspecies classification was proposed (Såke 1967; Quadri 1968; Parker and Brousseau 1988). Recent work suggests that the genetic differences are not sufficient to justify subspecies status and that the aurora
trout is simply a unique strain or race of brook trout (McGlade 1981; Grewe et al. 1990).

The aurora trout lakes lie within the area affected by acid deposition from the Sudbury metal smelters. By the middle of the century, acidification of these lakes was occurring, although it was not recognized at the time. In 1951, the Ontario government began to monitor the aurora trout populations. Angling was no longer permitted on the lakes, but by the late 1950s, the populations had noticeably declined, and by 1967, the aurora trout had disappeared from its home range. The demise of these populations coincided with the acidification of the lakes to near pH 5.0 (Keller 1978), the threshold for brook trout survival (Regees and Gunn 1986).

Fortunately, before the aurora trout completely disappeared, fertilized eggs were collected from both native lakes, and a hatchery brood stock was established (Fig. 11.5). The work of Paul Graf and colleagues at Hills Lake Provincial Hatchery, their efforts at spawn collection, and the discovery in 1958 of a successful artificial rearing method saved the aurora trout from extinction. The lineage of all aurora trout is now maintained in hatchery populations throughout the lake district.

![Figure 11.3. Female aurora trout. (Photo by E. Snucins.)](image)

![Figure 11.4. Aerial view showing the rugged Precambrian shield terrain surrounding the home range of the aurora trout. This rare strain of brook trout likely developed when Whitlipp and Whitepine lakes were isolated from surrounding waterbodies after the last continental glaciers retreated. (Photo by E. Snucins.)](image)
Rehabilitation of the Native Lakes

Given the failure of the many attempts made since the 1950s to establish reproducing populations of aurora trout in non-native lakes, fisheries managers in Ontario decided that the best chance of success would be to reintroduce these fish to their native lakes. However, the water quality in the native lakes was still too acidic to allow for the survival of the aurora trout. Therefore, with Whirligig Lake (pH 4.8) and its headwater Little Whitepine Lake (pH 5.6) were treated with 21 tonnes of powdered lime stone in October 1989; this increased the pH of both lakes to 6.5 (Fig. 11.6). In May 1990, 950 aurora trout hatchery brood stock (aged 2–5 years) were introduced into Whirligig Lake.

During late October of the same year, biologists assessed spawning behavior of introduced fish in the limed lake. A group of about 40 fish was observed congregating at a near-shore groundwater upwelling site. The fish were sexually mature and in good condition, having experienced a threefold increase in weight during the 5 months that they had resided in the lake. However, no spawning was observed and a search for young fish during the spring of 1991 was unsuccessful. It seemed no reproduction had occurred.
Biologists believed that the failure to spawn may have been due to a low water table in 1990 and the consequent absence of high-quality groundwater upwelling sites, the typical spawning area of brook trout. Therefore, in 1991, two artificial upwellings were constructed at the location where the fish had congregated the previous October. Water from a small inlet stream was piped to two wooden boxes, each filled with limestone and granite gravel, and lined with perforated pipe along the bottom. Water percolated up through the gravel, simulating a groundwater upwelling. During October, 13 adults were captured and injected with salmon pituitary extract to induce spawning. Again, despite these extraordinary efforts, no spawning was observed.

The results were disappointing to those working on the restoration project, and doubts arose over the reproductive ability of the introduced fish. Perhaps after many generations in the hatchery, the aurora trout was no longer able to reproduce in the wild. Much time, effort, and money had been spent, possibly to no avail. But worries quickly vanished the following year when two young aurora trout were observed by a diver swimming along the shoreline (Fig. 11.7).

**Figure 11.6.** Ontario government helicopter slings powdered limestone into a northeastern Ontario lake. Lime treatment was used to raise the pH levels of lakes as the home range of the aurora trout so that the extirpated aurora trout population could be re-established in the wild. (Photo by E. Smucins.)

**Figure 11.7.** After nearly 2 years of searching, biologists discovered the offspring of aurora trout in Whitchitak Lake in 1992, positive proof that the re-introduced species can reproduce in the wild. (Photo by E. Smucins.)
Two near-shore nests, or redds, were found in 1992, but it was not until 1993 that the primary spawning sites were discovered. Most redds were constructed at depths of 3–4 m, and the lake's tea-colored water had hidden this deep spawning habitat from surface observation. The age distribution of juvenile fish in the population indicated that successful spawning had occurred every year since the fish were re-introduced.

The discovery that the aurora trout was still capable of reproducing in the wild was very encouraging, but the realization that the lake was re-acidifying and would soon be too acidic for fish survival was soon to follow. During 1992, the pH of Whirligig Lake fell to 3.4 (Fig. 11.8). Much of the acidic input seemed to be coming from a nearby wetland. During September 1992, 32 tonnes of agricultural limestone was applied to the wetland in an attempt to improve the lake's water quality, but this treatment was not immediately effective and it was necessary to raise the lake itself in September 1993. This succeeded in raising the lake pH to 6.8.

Because Whitepine Lake, the second native lake of the aurora trout, receives the runoff from Whirligig Lake, its water may also have benefited from the liming. The pH of Whitepine Lake rose from 4.9 in 1990 to 5.1 in 1993. In response to these improved conditions, aurora trout were re-introduced to Whitepine Lake in the spring of 1994 as the next step in the restoration plan.

**Summary**

Our observations of good reproduction indicate that the return of the aurora trout to its native waters has, at least initially, been successful, but the long-term viability of the re-introduced population remains unknown. It is possible that the fitness of the stock for life in the wild has been reduced through inadvertent selection in the hatchery or because genes critical for survival were lost during the genetic bottleneck. However, if the original genetic material was not critically altered, the prospects for long-term persistence of the population in Whirligig Lake are probably good.

The continued survival of the aurora trout in Whirligig Lake depends on maintaining good water quality. Metal smelter emission reductions that began in 1994 will help reduce acid loading and may prolong the time to re-acidification. Water quality monitoring will need to continue, and if current pollution controls are not sufficient to prevent re-acidification, the lake will need to be relined.

The genetic diversity represented by individual fish stocks uniquely adapted to local condi-
The Convention on Biological Diversity was signed at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil (June 3–14, 1992). Under the convention, steps will be taken to protect endangered species and their habitats. All signatory nations agreed to adopt regulations to conserve biological resources, including establishing a system of protected areas. Most of the world's biological diversity exists in the tropical developing countries. To promote conservation in these economically impoverished areas, the developed countries will help supply the required financial resources and technical expertise. Also, to more equitably distribute the financial benefits of genetic resources and thus encourage their preservation the convention promotes biological diversity as a financial asset that can generate income for the country of origin, in particular the local indigenous peoples.

References