

Mitigating the Effects of Oxygen Depletion On Cape Cod NS Anadromous Fish

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Since 1980, scientific staff at Cape Cod National Seashore and the North Atlantic Regional Office have studied biogeochemical disturbances within the Seashore's Herring River estuary (Soukup & Portnoy 1986), diked and drained for mosquito control since 1908 (Fig. 1). Most recent studies have centered on examining the causes of annual summertime oxygen depletion, and its effects on the survival of migratory herring (both *Alosa pseudoharengus* and *A. aestivalis*). This report outlines an interactive and cooperative process involving elements of scientific research, engineering design, environmental compliance, resource monitoring and construction, which resulted in significant mitigation of juvenile herring mortality during the summer of 1986.

Analysis of the problem

From daily field monitoring of summertime stream conditions (temperature, flow, oxygen demand, dissolved oxygen and carbon dioxide) over several years, we believe anoxia (lack of oxygen) to be caused by the high organic load and low flushing rate of the diked upper estuary. Although seawater flow has been excluded from this system since the turn of the century, organic salt marsh peat, with its high content of reduced iron and sulfur compounds, remains. Warm summer temperatures increase peat decomposition and oxidation of reduced inorganic compounds (e.g. pyrites) and severely tax the stream's oxygen budget. Meanwhile, the dike prevents flushing with tidal salt-water, which is generally saturated with oxygen.

Episodes of total stream anoxia have lasted for up to three weeks and are probably triggered by rainfall and the increased discharge of peat constituents having high oxygen demand. Dissolved oxygen is often undetectable (by Winkler titration) even at midday when photosynthetic oxygen release from aquatic plants is at a maximum; reduction products, such as ammonia gas, are quite evident. Frequently three kilometers of river length are affected, coinciding with the area of diked and drained estuary presently above any tidal reach. Unfortunately, a major component of those juvenile herring hatched in the river's headwater kettle ponds each spring emigrate downstream during midsummer. Migration "pulses" are stimulated by sudden increases in flow following heavy rains. Thus, summer herring migrations tend to coincide with maximum stream organic loads and, often, total stream anoxia. In 1984 and 1985, mortality within the July run was probably complete, affected tens of thousands of fish, and no doubt seriously depressed ultimate recruitment from these year classes.

A short-term solution

Although a long-term goal is to restore native water quality through the partial or total elimination of existing tidal restrictions, the complex hydrological, ecological and socioeconomic effects of reintroducing seawater into this estuary, diked and drained for nearly 80 years, must be studied first.

In the interim, a process of consultation and planning was begun in the spring of 1986 to find a way to avert disastrous fish migrations concurrent with summertime oxygen depletions. Because of the length

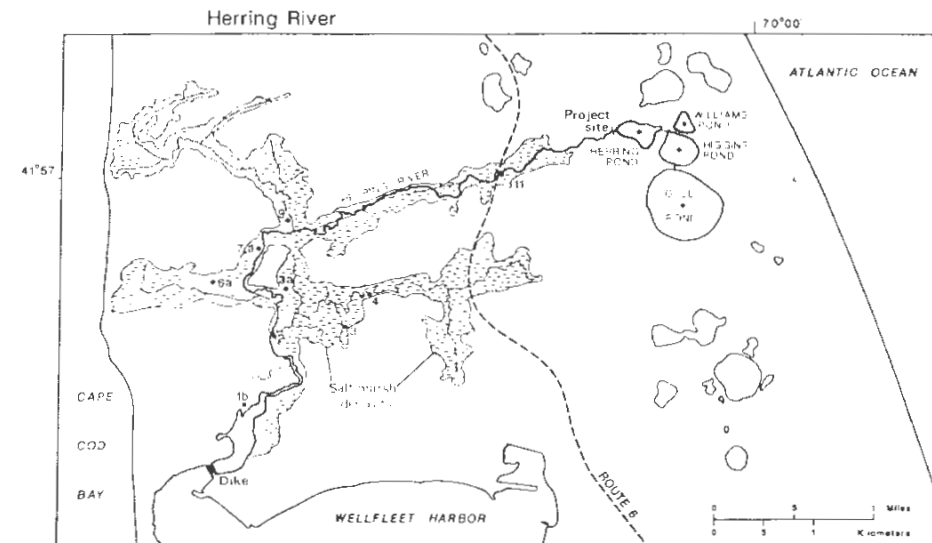


Figure 1. The diked Herring River estuary and herring spawning ponds. A removable fish barrier at the Herring Pond outlet has been used to prevent herring migrations when the lower mainstream is anoxic.

(2-3 km) and inaccessibility of affected stream reaches and the high oxygen demand of suspended and dissolved peat constituents, mechanical aeration was ruled out. Meanwhile, Park scientific, resource management, and engineering staff discussed structural options with state anadromous fish experts, knowledgeable in the behavior of juvenile herrings. (The state Division of Marine Fisheries has jurisdiction of anadromous fish runs in Massachusetts but had no funds available to contribute toward any construction.) Through cooperative planning the NPS accepted the lead role in restoration of this herring run.

An idea that emerged early was to simply (it was thought) physically block fish passage at the outlet of the spawning ponds when oxygen downstream within the diked estuary was "contrary to life." However, a basic problem was to maintain normal stream flow, both to sustain those stream biota just below the block and to avoid raising upstream pond levels, without attracting and concentrating migratory fish at the outlet. For example, a filter screen across the outlet — one alternative considered — of sufficient mesh size to avoid fouling would only function as an unintended gill net, trapping juveniles attracted by largely unimpeded direct flow.

State fisheries managers suggested a baffle fishway at the principal headwater pond (Herring Pond) outlet. This structure would block all flow (and fish passage) through the natural outlet, but at the same time would provide normal flow circumventing the block through a flow diversion pipe. Success of the design was dependent on two attributes of juvenile herring: their attraction to the water surface (positive phototropism) and their attraction for downstream flow (positive rheotropism). To avoid drawing surface schooling fish toward the natural outlet, all flow would be dammed at that point. To avoid attracting fish to the flow diversion pipe intake, the pipe would be extended along the pond bottom to reach an intake depth of five feet. It was theorized that flow into the pipe at this depth would be imperceptible to surface schooling young fish (Fig. 2).

Design and construction

Using field measurements of pond outlet and stream bathymetry and estimates of the normal range of flow and hydraulic head, we modified the concrete box baffle design originally suggested by state biologists. To minimize construction impacts on the swampy riparian site, engineering staff designed a light-weight wooden structure (hereafter "fish gate", Fig. 2) which was hand-carried piecemeal along the narrow woodland access path and assembled on site by park rangers. No off-road vehicle use was required.

The structure basically consisted of a removable plywood dam (board) set in slots in vertical members driven into the 10-ft. wide stream bed; a 15-inch diameter flow diversion pipe extending from the pond's five foot contour downstream just through and past the dam; and geotextile stream bed protection both immediately above and below the dam structure. To ensure that all significant flow would travel through the natural stream bed when the dam was open, we added a door to the pipe outlet to stop flow diversion when the lower mainstream contained adequate oxygen. Funding for project materials was provided by Resource Management divisions at both the Park and North Atlantic Region level.

Environmental compliance

Placement of such a structure in a stream bed obviously requires a multi-stepped process of local, state and federal review for compliance with environmental law. Park staff prepared an Environmental Assessment (EA) to analyze several alternatives proposed as short-term solutions to the fish kill problem. The environmental consequences and associated mitigation also were assessed. The EA was made available for public review and comment for a 30-day period in April and May 1986.

Press releases advertised the project and solicited review and comment on the Assessment. The preferred alternative was the above-described fish gate. Supportive comments were received from individuals and state and local agencies for the preferred alterna-

tive as an appropriate interim solution to prevent herring migration during anoxic periods. However, several agencies urged the NPS to pursue long-term management actions to alleviate the basic biogeochemical problems responsible for observed oxygen deficits.

Because the project would involve some ground disturbance within an area containing several prehistoric archeological sites not far from the project location, an "XXX Form" (Assessment of Actions Having an Effect on Cultural Resources) was submitted. NPS cultural resource experts approved the project, concluding that any subsurface artifacts would not be affected by the limited ground disturbance.

Under the Massachusetts Wetlands Protection Act, a Notice of Intent was filed with the Massachusetts Department of Environmental Quality Engineering and local Conservation Commissions. Park staff presented the project at local hearings and obtained the necessary permits. The Order of Conditions from the town Conservation Commission required that as much work as possible be conducted from the stream bed and that a filter screen be deployed during construction to trap suspended sediment. (A geotextile type filter fabric was generously loaned to us by a nearby town's natural resource officer.) In accordance with the federal consistency requirements of the Coastal Zone Management Act, NPS sought and obtained a determination from the state CZM director that the project was in the interests of the CZM Act. Park staff identified the bladderwort *Utricularia fibrosa* occurring along the pond shoreline about 200 ft. upstream of the project. This plant is listed as "endangered" by the State of Massachusetts. The State Natural Heritage program concluded, in concurrence with NPS, that no adverse impacts should be expected; however, NPS was asked to carefully monitor *Utricularia* during all phases of construction. Additional consultations with Natural Heritage indicated no further impact on other endangered species.

A bit of irony

An Army Corps of Engineers permit was waived because of the small size of the affected stream and because no dredged material would be deposited in the waterway. Interestingly, a Waterways License was required, pursuant to the state Chapter 91, Tidelands Regulations, not because the project site was tidal, but because state funds had been previously spent

on "improving" the river. Ironically, the improvement was a 1974 repair of the Herring River tidal dike – the same structure responsible for blocking tidal flushing and depressing stream oxygenation. As expected in this context, both reviewing officials and the public saw the fish gate project as purely mitigative: approval was quickly received.

Importantly, the flow diversion design addressed provisions of Section 2(d) of Executive Order 11988, Flood Plain Management, and in particular, the maintenance of natural stream functions. Even with the barrier in place, the structure would only obstruct fish passage, with normal stream flow bypassing the dam through the flow diversion pipe.

A Record of Decision (ROD). Finding of No Significant Impact (FONSI) was prepared on June 1, 1986, recording the management alternatives selected by the NPS after discussions with the State Division of Marine Fisheries, a 30-day public comment period, and careful consideration of legislative mandates, applicable regulations, the Conservation Commission's Order of Conditions and NPS policies and research findings. All compliance was completed by mid-June 1986. The State Commissioner of the Department of Environmental Quality Engineering issued emergency authorization of the Waterways Permit, allowing us to complete the structure before anticipated oxygen problems in early July.

Operation

As midsummer approached, field rangers began daily monitoring of stream dissolved oxygen (DO) conditions (always at midday to control for diel fluctuation). We modified a commercially available portable DO kit to increase precision and accuracy of field measurements and calibrated the field method against laboratory Winkler titrations at least weekly.

The fish gate was completed around July 6, 1986, just as stream DO declined to lethal levels. For this reason, the removable door was immediately dropped in place, blocking downstream fish passage. By July 8, DO was not detectable in the lower Herring River mainstream. Anoxia continued until about July 20.

During this period, no juvenile alewives were seen to exit Herring Pond through the flow diversion pipe, the only egress remaining with the drop gate in place. Also, no juveniles were seen dead or alive in lower stream reaches. We feel it's reasonable to assume that if significant numbers of fish did emigrate, they, or rather their corpses as in previous years, would have been conspicuous in the anoxic lower mainstream. Schools of tens of thousands of 5 - 8 cm alewives continued to circle in the shallows of Herring Pond while the fish gate was closed. But fish were not especially attracted to the outlet, presumably because of the absence of surface flow.

Finally, by July 25, midday DO had increased to 3 ppm; the fish gate was opened; and, stimulated by increased flow with rain on the 27th, juveniles emigrated en masse. No mortality was observed downstream. A second hypoxic episode occurred in August: again the fish gate was closed and mortality was prevented. Alewife passage from herring Pond was blocked in this way for a total of three weeks in 1986.

Looking ahead

Obviously, such extreme measures to sustain a particularly vulnerable group of animals, anadromous alosids, do nothing to benefit all other stream organisms dependent upon adequate DO. We hope that our understanding and management of the Herring River ecosystem will continue to improve to a point where severe systemic disturbances, like those re-

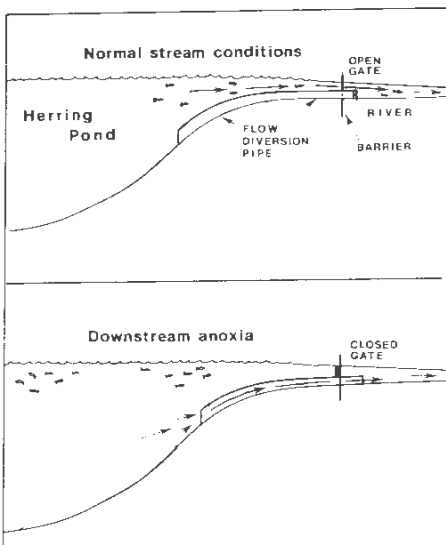


Figure 2. Fish gate operation under normal and anoxic stream conditions.

sponsible for total oxygen depletion, can be resolved.

Restored tidal flushing is a primary long-term management goal piloted by ongoing ecological and hydrological studies. However, until a major reintroduction of tidal flow is possible, we can expect periodic oxygen problems. The current program of DO monitoring and "fish gate management" will therefore continue – we hope with the success encountered during the July 1986 run.

Acknowledgements

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The three authors, all Cape Cod NP employees, are Portnoy, research biologist; Samora, resource management specialist; and Phipps, chief of maintenance.

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