THE LIMITING EFFECT OF HYPOXIA ON METABOLIC SCOPE-FOR-ACTIVITY OF JUVENILE LAKE TROUT, *SALVELINUS NAMAYCUSH*

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EXTENDED ABSTRACT ONLY - DO NOT CITE

The objective of this paper is to examine the effect of hypoxia on metabolic scope-for-activity of juvenile lake trout and to propose a new dissolved oxygen criterion for the protection of lake trout habitat in Ontario lakes. Scope-for-activity is defined as the difference between standard (resting, post-absorptive) metabolic rate and the maximum sustained metabolic rate (Fry, 1971). Scope-for-activity represents the metabolic energy that is available for capture of prey, avoidance of predators, migration, spawning and all other types of volitional activity. Juvenile lake trout inhabit and are confined to the hypolimnia of thermally stratified lakes during summer. Direct video observation revealed a strong benthic association of YOY and older juveniles within the hypolimnion. Solitary individuals were consistently observed resting directly on the lake bottom at depths of 15-35m (Davis et al., 1997). During summer stratification juvenile lake trout may be exposed to varying extremes of hypoxia for extended periods of time. Therefore factors that influence oxygen depletion rates in the hypolimnion, such as phosphorus loading, are of considerable relevance to the sustainable management of this species.

Hypoxia limits the transport of dissolved oxygen across the gill membrane and the amount of cellular metabolic activity, which in turn inhibits vital activities of the whole organism, including feeding and growth. The limiting effect of hypoxia on oxygen uptake is well described by monitoring active metabolic rate through the zone of respiratory dependence (Davis, 1975). Active metabolic rate is a measure of aerobic capacity and an effective response criterion because the level of physical activity can be standardized by forced swimming and oxygen uptake is repeatable and easily quantified (Fry, 1971).

Standard and active metabolic rates of yearling lake trout were determined in laboratory trials by Gibson and Fry (1954). Metabolic rates of yearling lake trout were obtained by digitizing their Figure 2 and scope-for-activity was calculated. Metabolic rates at ¼, ½ and ¾ scope-for-activity levels were then determined at temperatures of 4-20 ºC (Fig. 1). The purpose of defining these thresholds of scope-for-activity was to provide a framework for defining dissolved oxygen requirements for various life-support activities. Gibson and Fry (1954) also determined the limiting effect of hypoxia on the active metabolic rate of juvenile lake trout. I have digitized and re-plotted their data for active metabolic rate versus oxygen pressure at 9.5 - 18 °C for yearling lake trout (Fig. 2). On each temperature curve the metabolic rate corresponding to ¼, ½, and ¾ scope-for-activity is indicated, as is the approximate incipient response threshold (RT). The partial pressures of oxygen at which these scope-for-activity thresholds occurred were shifted downward at lower temperatures as metabolic demand declined. Partial pressures were converted to concentrations of dissolved oxygen for each threshold and temperature at the known elevation of the laboratory. At temperatures from 4-16 ºC, ¼, ½, and ¾ scope-for activity of yearling lake trout corresponded to dissolved oxygen concentrations of about 4.5, 6.0, and 7.0 ±0.2 mg L^{-1}, respectively.

Most daily life-support activities of post-larval salmonids can be achieved within the bounds of ¾ scope-for-activity, with the exception of spawning migration, which in sockeye salmon, *Oncorhynchus nerka*, requires almost 80% of the sustained aerobic capacity (Brett and Groves, 1979). The threshold for growth impairment in several species of salmonids, including lake trout, occurs at about 7 mg L^{-1} dissolved oxygen. An environment that provides for ¾ scope-for-activity, i.e. 7 mg L^{-1} of dissolved oxygen, should provide adequate long-term protection and prevent the loss of productive capacity of lake trout habitat. A mean volume-weighted hypolimnetic dissolved oxygen (MVWHDO) concentration of 7 mg L^{-1} (August 15-September 15) is proposed as a criterion for the protection of the summer habitat of lake trout in Ontario lakes. Lakes falling below the threshold during this window would be considered to be at development capacity for phosphorus loading. This criterion would ensure that juvenile habitats on or near the lake bottom at depths of 15-35m would have adequate dissolved oxygen content for short-term survival, usually > 4 mg L^{-1}, which is near the avoidance threshold for free-swimming salmonids (Davis, 1975). The mean MVWHDO measured August 15-September 15 in 174 Ontario lakes that support self-sustaining lake trout populations was 7.1 ±0.35 mg L^{-1} (±95% C.I.). The mean dissolved oxygen in the 1m zone immediately above the

lake bottom at maximum depth (mean 39 ±2.7m) in the same lakes was 4.2 ±0.44 mg L^{-1}. This is near the ¼ scope-for-activity threshold and exceeds the estimated requirement for maintenance feeding, but is within the range of 20-30% growth impairment for salmonids observed in laboratory experiments.

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