Burbot Growth Rates in a Northern Mesotrophic Lake

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Burbot *Lota lota* has a circumpolar distribution throughout cold-water areas and is the only freshwater member of the family Gadidae. There are currently very few management techniques applied to Burbot throughout their northern extent. Growth is an indicator of fish health, biomass, and habitat quality; therefore, the objective of this study was to determine the growth rate of Burbot in Lake Bemidji. Burbot (n = 45) were collected along three sites on Lake Bemidji for years 2015-2017. Age was determined from sagittal otoliths, the marginal zones of which were opaque from December to May and translucent from June to November. Mean total lengths for each age group were estimated and a von Bertalanffy growth model was fitted. Burbot grew 186 and 153 mm in their first and second years, respectively. Later, an annual growth increment of 17 mm was exhibited by age-8 fish. Male and female Burbot were both sexually mature by age five with first maturity at age three (male). Burbot in Lake Bemidji demonstrate a comparable growth rate to other fisheries, suggesting there should be no immediate concern about the population.

Faculty Sponsor: Dr. Andrew Hafs

Introduction

Age and growth rate are used by state agencies to determine size structure of fish populations within aquatic systems (Isely and Grabowski 2007; Maceina 2007; Quist et al. 2012). Although mean length at age and growth rate has been established for many game (i.e., Walleye *Sander vitreus*, Northern pike *Esox lucius*) and non-game (e.g., Common carp *Cyprinus carpio*) species, little information is available for Burbot *Lota lota*. Burbot have a circumpolar distribution throughout cold-water regions and is the only freshwater member of the family Gadidae (Hensler et al. 2008). Recent literature has found Burbot attain ages of 20 years and lengths up to one meter (McPhail and Paragamian 2000).

Both age and length are used to estimate growth, which is largely influenced by water temperature (Ferguson 1958). Past studies observed adult Burbot temperature preferendum between 11.1-13.9 °C with 23.3 °C as their upper limit (Ferguson 1958; Hokanson 1977; Hoffman 2002). Since growth is often related to temperature, and temperature is correlated to latitude, Burbot growth rates should vary spatially across their range. McPhail and Paragamian (2000) observed high growth rates of larval Burbot until age three in several systems in Alaska, whereas Hensler et al. (2007) observed relatively consistent growth until age five in Lake Huron and Michigan. However, both observed a decrease in growth after age five when sexual maturity was observed for both sexes. The potential for spatial variability in growth rates demonstrates the need for further research.

Lake Bemidji, MN, is a glacially formed, mesotrophic system approximately 2,669 ha in size with a maximum depth of 23.2 m. The lake is located near the southern edge of the Burbot distribution and is currently managed by the Minnesota Department of Natural Resources (MNDNR). However, Burbot are currently considered a non-game species, and very little effort is put into their management. Therefore, the objective of this study is to determine the growth rate of Burbot in Lake Bemidji.

Methods

Burbot Sampling

Burbot were sampled via hook and line from February 2015 – March 2017. According to Mansfield et al. (1983), age-2 and younger Burbot inhabit near shore shallows from early March into late September. Therefore, 41.9 x 19.1 cm galvanized steel minnow traps with a 0.64 cm mesh and 0.9 x 1.5 m modified Fyke nets with 0.64 cm mesh were set on 4-30 September 2015 and 1-30 September 2016 to target these younger year classes (Figure 1).

Total length (TL; mm), sex, time, and date were recorded upon fish capture. Otoliths were used for age estimation since the small cycloid scales of Burbot lack identifiable markings. A sagittal otolith extraction method developed by Bailey (1972) was used. Through a median incision into the skull, two transect cuts were made, one at the base of the skull, and one directly behind the eyes. Both sections were then pried open and both sagittal otoliths were extracted using forceps. Otoliths were then rinsed off, dried, and placed into scale envelopes to be aged later in the lab.

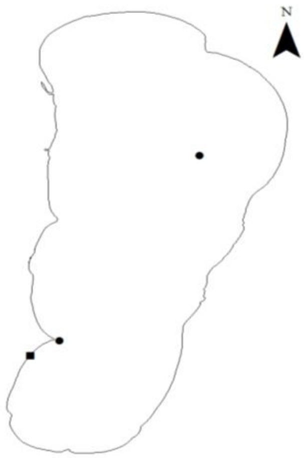

FIGURE 1. Burbot sampling sites for Lake Bemidji, MN; with minnow traps and Fyke nets indicated by square, and hook and line locations indicated by circles.

Otolith Measurements

Similar to methods developed by Edwards et al. (2011), whole otoliths were rinsed again and placed concave side up in a blackened dish filled with commercial glycerin (Figure 2). Otoliths were observed under a dissecting microscope at 9 power magnification. Each otolith was photographed and ages were estimated by two independent readers. Otolith lengths were measured by digitizing via the segmented-line measurement option within ImageJ software (Schneider et al. 2012). Each segmented-line measurement was taken from the focus to each annulus.

FIGURE 2. Example of a Burbot placed concave side up in commercial glycerin at 9 power magnification; estimated to be 5 years old.

Data Analysis

Length at age was back calculated using TL and ImageJ pixel measurements between each opaque annulus. Back-calculated lengths at age were used to estimate growth rates in Burbot. Both male and female growth rates were estimated by a fitted von Bertalanffy growth model. The rate of change in length (l_t) was calculated using the formula from von Bertalanffy (1938):

$$l_t = L_\infty \, (1 - e^{-K(t-t_0)})$$

where L_∞ is the asymptotic length at which growth is zero, K is the growth rate, t is time and t_0 is the organisms size at age-0. Average coefficient of variation (ACV) was used to estimate agreement accuracy between readers. According to methods developed by Champagne et al. (2002) and Chang (1982), a threshold ACV was set at < 0.05. All analyses were done in Program R (R Core Team 2013).

Results

Across years, 41 Burbot were sampled via hook and line, 3 in minnow traps, and 1 via modified Fyke nets. Burbot were collected with sizes ranging from 127-692 mm. On average, Burbot grew 186 mm and 153 mm in their first and second years, respectively (Figure 3). Final von Bertalanffy growth parameters are reported in Table 1. Male Burbot exhibited maturation rates with age-1 at 0% maturity, followed by age-2 (38%), age-3 (75%), age-4 (95%), and age-5 (100%). Females exhibited ages 1 and 2 at 0% maturity, followed by 100 % at age-3. Overall, there was an 88.9 (%) agreement between readers with an ACV of 0.001, suggesting high precision in ages between readers (Figure 4).

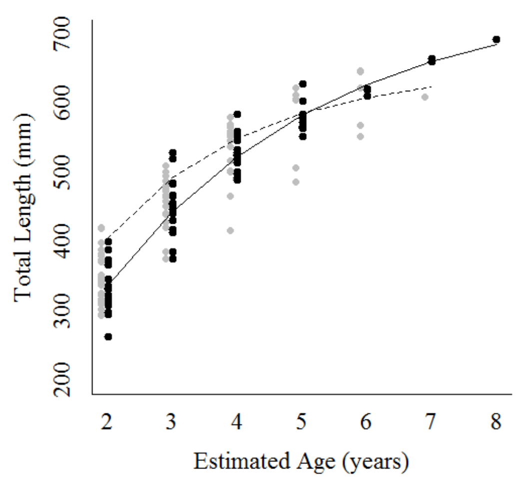

FIGURE 3. Estimated age plotted against length for male (gray, dotted line) and female (black, solid line) Burbot collected from Lake Bemidji, MN between February 2015 – March 2017.

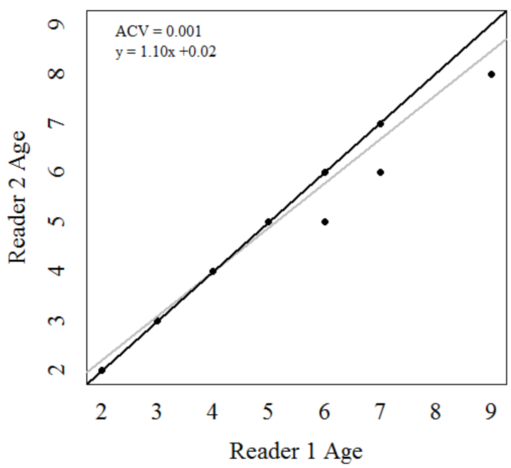

FIGURE 4. Estimated age by reader one plotted against estimated age by reader two with a line of best fit (black) and a 1:1 line (gray) overlaid. Ages were estimated from otoliths extracted from Burbot sampled from Lake Bemidji, MN between February 2015 – March 2017.

Discussion

It appears growth rates are similar across the Burbot distribution. A study in southwestern Lake Superior found growth rates of 145 mm and 109 mm in their first and second years, respectively (Bailey 1972). Polacek (2006) observed an average growth of 61 mm between years 3-5, which is similar to results from this study in Lake Bemidji (Table 2).

TABLE 1. von Bertalanffy growth equation parameters for Burbot captured in Lake Bemidji, MN between February 2015 – March 2017.

Sex	L-inf	K	t0
Male	592.3745	0.2138	-1.4129
Female	659.4272	0.2307	-0.5084

Although past studies provide an essential baseline dataset on Burbot growth metrics, there is still a small range of studies that have been completed throughout their range. Although our data indicated little concern is warranted for the current Burbot population in Lake Bemidji, future environmental stressors may influence growth rates and the population should continue to be monitored.

All freshwater fishes are exotherms, meaning they cannot actively regulate their body temperature (Ficke et al. 2007). Although fish are

TABLE 2. Mean total length (mm) at age for Burbot populations sampled by Chen (1969; Yukon Tanana Rivers), Bailey (1972; Southwestern Lake Superior), Polacek et al. (2006; Lake Erie), and the current study in Lake Bemidji.

	Mean Total Length (mm)				
Age	Yukon River	Southwestern Lake Superior	Lake Erie	Lake Bemidji	Tanana River
1	109	254	210	176	110
2	174	301	323	345	175
3	239	339	377	460	236
4	300	378	424	539	294
5	355	412	492	592	352
6	408	438	540	692	405
7	450	497	558	654	457
8	497	505	579	671	507
9	537	555	591		546
10	575	596	616		585
11	614	640			
12	643	710			
13	678				
14	712				
15	750				
16	814				
17	834				
18	868				
19	931				

species-specific to thermal regimes, they are still constrained to the range of temperature available in their environment (Regier and Meisner 1990). Coldwater stenotherms, including Burbot and Cisco *Coregonus artedi*, have a lower set thermal regime than warm water species (Carl 1995). In fact, Burbot and Cisco exhibit similar temperature and oxygen tolerances (Jacobson et al. 2008; Zakhartsev et al. 2003). The large number of Burbot (n = 233) and Cisco (n = 648) lakes in Minnesota combined with sensitivity of these fish to warm temperatures make them excellent indicator species. However, while extensive research regarding thermal tolerance has already been carried out for Cisco, Burbot are still poorly documented. Therefore, monitoring growth metrics and thermal tolerances for Burbot may provide us with early signs of ecological stressors on cold-water refuge, such as extended stratification, eutrophication, and climate change (Dillan and Rigler 1974; Carl 1995).

Routine lake surveys may effectively monitor Burbot growth metrics and population dynamics. These quantifications allow fisheries professionals to determine future steps in assessing suitable cold-water habitat refuge. According to methods developed by Bernard et al. (1991), baited hoop traps provide an increased catch rate of Burbot and is a method that can be easily implemented into routine lake surveys. This provides a necessary means to collect the data needed for effective lake management. Most management plans also exhibit a no-bag limit on Burbot. Since Burbot are an indicator species, establishing a bag limit is necessary to reduce the risk of local extinction from human impact. However, climate change may increase the frequency of warm summers, therefore increasing littoral temperatures, resulting in mortality events of larval Burbot inhabiting nearshore shallows. Although McPhail and Paragamian (2000) found larval Burbot have slightly higher tolerances to temperature than adults, consecutive warm summers will harm entire larval age classes, affecting whole populations. Lakes with deep, well-oxygenated hypolimnia, including Lake Bemidji, may provide important refuges for coldwater stenotherms. By measuring baseline information of Burbot, managers will be able to better identify suitable thermal habitat to better protect them from future environmental stressors.

Acknowledgements

I want to thank Eric Katzenmeyer and Douglas Zentner for age estimation and comments. I also want to thank Adam Lorentz, Andrew Schmeig, Benjamin Erb, Cole Kranz, and Zane Den Ouden, for data collection and angling.

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