EVALUATING THE CONDITION OF AGE-0 BURBOT IN RELATION TO DIET

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***Abstract*—Burbot are becoming more and more popular for angling and aquaculture. However, populations have been declining across the world. Very little information is available about their early life and their interactions in the ecosystem due to challenges in sampling. Condition estimates and diet metrics were used to better understand the status of burbot in Lake Bemidji. Using backpack electrofishing, 45 young of the year burbot were collected. The lengths ranged from 86 to 146 mm and the wet weights ranged from 4.29 to 24.36 g. The stomach contents were removed and stored in ethanol for later analysis. The burbot were then dried in an oven at 60 ℃ and weighed to calculate percent dry weight. R was used to construct an NMDS plot and to calculate both percent dry weight and prey-specific abundance. Amphipods and yellow perch *Perca flavescens* were the most frequently consumed prey. Prey type was not significantly correlated to condition (P = 0.61). Juvenile burbot had an average percent dry weight of 18.1% (SD = 0.87) which appears to be consistent with observations of condition from other systems.**

I. Introduction

Burbot *Lota lota* is the only member of the cod family in freshwater ecosystems. Their range spans the Northern Hemisphere across North America, Asia, and Europe. They inhabit systems with cool water, such as lakes and streams that support trout or deep-water lakes. In North America, burbot spawn under ice from about February to March in water temps from 1 to 4 °C (Stapanian and Madenjian 2013).

Burbot is gaining popularity for angling and aquaculture. Many populations worldwide are in decline, thus, learning the factors that will affect future management and protection is important (Stapanian et al. 2010). Some problems affecting burbot populations are development, overfishing, and lack of monitoring (Stapanian et al. 2010). Many populations in the United States have been affected by dam construction and agriculture, affecting spawning habitats and changing food webs. Burbot have not been considered game fish in many regions, and thus have had limited protections, leading to overfishing. They also do not sample well in standard gill nets, meaning government agencies cannot track trends in their populations.

Few studies have looked at the diet of young of the year or juvenile burbot in the wild. Most past studies looked at adults who consume primarily other fish species and invertebrates such as crawfish and insects. (Rudstam et al. 1995; Schram et al. 2006). Furthermore, the subject of condition and diet has not been explored. The few studies that evaluated the diet of juveniles found they consume primarily the rotifer *Asplanchna* early on and then switch to different copepod species as they age, with prey length being the limiting factor (Ghan and Sprules 1993). Burbot preference for copepods could be concerning due to the risk of their population decreasing in response to increasing pollutants (Di Marzio et al. 2013; Di Lorenzo et al. 2014). To better understand the life history and health of the burbot, this study aims to evaluate the diet of juvenile burbot in Lake Bemidji and compare it to the condition of the fish.

II. Methods

In October 2024 age-0 burbot were sampled using a backpack electrofisher. Rocky habitat was targeted along the western shore of Lake Bemidji. The fish were taken back to the lab, where length and weight measurements were taken. An incision was made down their ventral side, and their stomachs were then removed using scissors and forceps. The stomach contents were flushed into a 7.62 cm PVC pipe with an 80 mm filter on one end using ethanol. The ethanol was allowed to dry, and the filter was weighed. The stomach contents were then preserved in ethanol for later analysis. The fish and empty stomachs were placed in a bag and frozen for later. They were then dried in an oven at 60 °C until the weight remained constant. The invertebrates were identified to the lowest taxonomic unit possible, while fish were identified to species. They were then sorted by species, counted, and dried. Frequency of occurrence and prey specific abundance was calculated for each prey type then plotted against each other. Percent-dry weight (%DW) was used to estimate the condition of the sampled burbot. Percent-dry weight and total length were plotted against each other. To find the frequency of prey occurrence (O_i), the number of fish that ate a specific prey (J_i) was divided by the number of fish with stomach contents (P).

$$O_i = \frac{J_i}{P}$$

To calculate prey abundance (P_i), the total count for a single prey type (S_i) was divided by the abundance of all prey in stomachs that contained that particular prey (S_{ti}).

$$P_i = \frac{S_i}{S_{ti}}$$

A NMDS plot was built by using the metaMDS function in the Vegan package (Oksanen et al. 2020). It was used to organize data to understand the relationships between the prey types and their effect on the condition estimates. An envfit analysis was performed using the NMDS, %DW, and total length data to determine if prey species was affecting the condition estimates.

III. Results

The average length of the burbot sampled was 118 mm (SD = 15.97). The average wet weight was 11.91 g (SD = 5.07), and average percent dry weight was 18.10% (SD = 0.87; Figure 1). Empty stomachs were present in 15 of the 45 burbot sampled. A total of 387 prey items were identified (Table 1) the most abundant prey type were amphipods (27%) and perch (2%). Six of the burbot consumed sand or gravel. Amphipods were consumed most often across all the sampled burbot followed by perch and chironomids (Figure 2). The *envfit* analysis returned P-values of 0.61 for percent dry weight and 0.84 for total length.

TABLE 1. TOTAL COUNTS, FREQUENCY OF OCCURRENCE (O_i), AND PREY SPECIFIC ABUNDANCE (P_i) OF PREY TAXA. PREY WERE COLLECTED FROM STOMACH CONTENTS OF LAKE BEMIDJI BURBOT SAMPLED IN OCTOBER 2024.

Prey Species	Count	(O_i)	(P_i)
Amphipods	102	56.25	69.86
Hirudinea	4	9.38	21.05
Annelids	4	12.50	9.76
Chironomidae	10	21.88	22.73
Unidentifiable Fish	2	6.25	66.67
Perca flavescens	9	21.88	6.16
Copepod	2	6.25	10.53
Decapoda	1	3.13	3.45
Gastropod	3	9.38	14.29
Bivalvia	1	3.13	50.00
Ephemeridae	1	3.13	11.11
Ephemeroptera	3	3.13	30.00
Rocks/sand	39	15.63	61.90
Ostracoda	1	3.13	50.00
Unidentified Invert	5	15.63	17.24
Tipulidae	1	3.13	4.55
Dreissena polymorpha	1	3.13	4.55

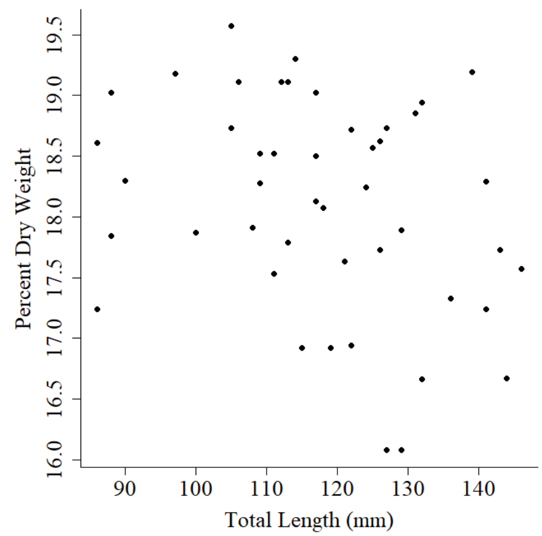

Fig. 1. Relationship between percent dry weight and total length (mm) of burbot *Lota lota* sampled from Lake Bemidji in October 2024.

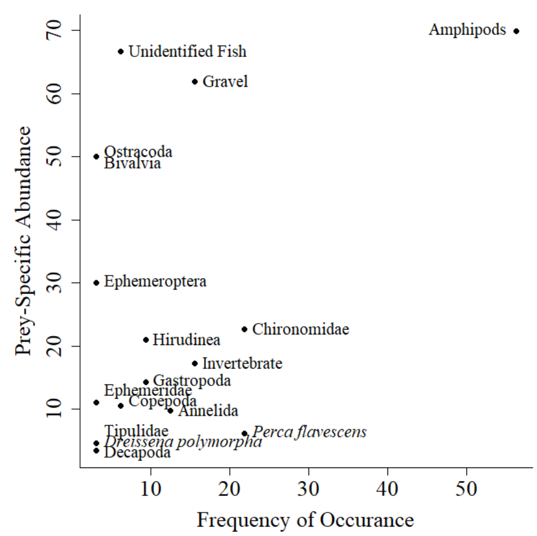

Fig. 2. The relationship between frequency of occurrence and prey-specific abundance of identified burbot prey items. Prey items are sorted to the lowest taxonomic unit that was identified. Prey was collected from burbot sampled from Lake Bemidji in October 2024.

IV. Discussion

There was not a significant relationship between prey type and %DW or total length of age-0 burbot in Lake Bemidji. Studies indicate that prey and forage habitat is dependent on the size of the individual (Ghan and Sprules 1993; Fischer 2004). Where the larger individuals control better forage sites and can consume larger prey. With better forage and a wider range of available prey, growth and condition would likely be affected. However, that is not what this study observed with the p-values of the envit analysis being insignificant. It is known that juvenile fish increase in length more than weight (Bacon et al. 2005). This combined with lethal studies providing a limited temporal view into the diet of fishes could help explain these results.

The %DW estimates of the burbot were consistent with those of a typical population. Previous studies have found that burbot have energy densities between 3350 and 5000 J/g (Rudstam et al. 1995; Schram et al. 2006). Energy densities are correlated to %DW in fish (Hartman and Brandt 1995). Using that relationship burbot %DW can range between 18% and 23%. The burbot in this study were between 16.0% and 19.5%, slightly below the expected range. It has also been shown that juvenile fish have a lower lipid content than adult fish (Martin et al. 2017). More research needs to be done on the bioenergetics of burbot, however, these results seem to be consistent with what others have found.

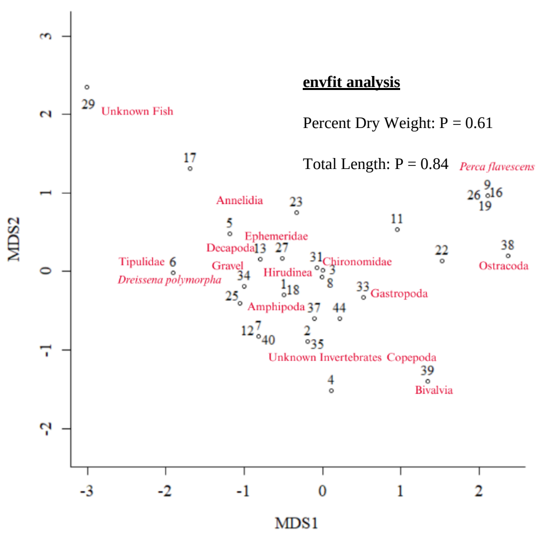

Fig. 3. NMDS (nonparametric multi-dimensional scaling) of sampled burbot and prey taxa. Individual fish are represented by their fish id number. Fish and prey located closely together are correlated to each other. Burbot were sampled from Lake Bemidji in October 2024.

Amphipods and yellow perch (*Perca flavescens*) are important prey species for juvenile burbot in Lake Bemidji. While both taxa were commonly consumed, individual fish typically consumed only one of the two. The abundance of amphipods is consistent with other studies (Ryder and Pesendorfer 1992; Blabolil et al. 2018). Blabolil et al. (2018) also found that fish were not frequent prey of juvenile burbot. Yellow perch and amphipods are both abundant food sources in Lake Bemidji and that is reflected in the stomach contents. The isolation between these two prey species can be explained by the size differences. The yellow perch that were consumed were smaller than the burbot, but occupied most of the available stomach volume. Implying that individuals were consuming perch or amphipods when the other was not available.

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Appendix A

TABLE 2. TOTAL LENGTH (TL), WET WEIGHT (WW), AND PERCENT DRY WIGHT (%DW) FOR BURBOT SAMPLED FROM LAKE BEMIDJI IN OCTOBER 2024.

Fish_ID	TL (mm)	WW (g)	%DW
1	146	24.36	17.57
2	144	21.13	16.67
3	121	13.00	17.63
4	143	21.60	17.73
5	124	14.50	18.24
6	132	16.55	16.66
7	126	15.41	17.73
8	108	9.29	17.91
9	139	20.63	19.19
10	129	13.77	17.89
11	113	9.38	17.79
12	114	8.97	19.30
13	111	8.32	18.52
14	122	11.61	18.72
15	117	10.66	18.13
16	119	12.16	16.92
17	141	18.91	18.29
18	115	10.83	16.92
19	127	15.87	16.08
20	117	10.72	19.02
21	132	16.65	18.94
22	141	20.67	17.24
23	111	9.05	17.53
24	109	8.52	18.28
25	122	11.84	16.94
26	113	9.17	19.11
27	105	9.11	18.73
28	117	9.79	18.50
29	109	8.29	18.52
30	100	6.34	17.87
31	86	4.29	17.24
32	88	5.18	19.02
33	86	4.57	18.61
34	88	5.09	17.84
35	125	13.48	18.57
36	136	18.94	17.33
37	131	13.67	18.85
38	129	15.92	16.08
39	118	9.83	18.07
40	126	12.68	18.62
41	105	7.33	19.57
42	106	8.37	19.11
43	112	8.65	19.11
44	97	5.64	19.18
45	127	12.37	18.73
46	90	4.67	18.30