Goldeye *Hidon alosoides* calorimetry in Red Lake

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Goldeye *Hiodon alosoides* are found across North America and are a relatively unstudied group of fish as they have had no economic value in the past. Ecologically speaking, these fish could have importance to the waters that they inhabit, as they are prey to fishes like Walleyes *Sander vitreus*, Northern Pike *Esox lucius*, and Muskellunge *Esox masquinongy*. These fish could potentially be vital to predatory fishes because of the amount of oil found in these fish, creating gram for gram more energy than compared to other consumable substances. The average energy density for all Goldeye was 6.73 kJ/g (SD = 1.11).

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Introduction

The Goldeye *Hiodon alosoides* is one of two fish in the Hiodontidae family, which are classified by having a saw-toothed keel. Goldeye are found in North America, north and south from the Northern Territories to Louisiana and east and west from Pennsylvania to Montana (Fuller 2018). Although Goldeye are common fish found in Canada and throughout the United States, very few studies have been conducted on this fish and events like spawning activity are unknown (Hatch and Paulson 2002). Goldeye have a very high content of oil compared to other fish species (Fredeen et al. 1972). Fats and oils are very important for all fish species, especially when fish are in the early stages of development (Sargent et al. 1999).

Another oily fish native to North America is the Cisco *Coregonus artedi*, which in Ojibwe means greasy-bodied. When present with Walleyes *Sander vitreus*, the Cisco are very important to the popular game fish found in North America (Kaufman et al. 2007). According to Kaufman et al. (2007), Walleyes of all sizes depended on Ciscoes, however, Ciscos were more important to larger Walleyes. Walleyes did in fact reach larger lengths in lakes in which Ciscoes were present (Kaufman et al. 2007). It is expected that Goldeye will have similar importance in the waters they inhabit as they are very similar to Ciscos, as they are found in the same geological range and are likely to have very similar energy densities (Rand et al. 1998).

When a fish is being consumed, fats and oils are transferred to the predatory fishes. The predatory fishes then use the fats and oils as energy (Barneche and Allen 2018). With fats and oils, there is more carbon atoms per gram. Therefore, gram for gram, have the potential to get more energy than compared to other consumable substances (Bender 2001). It is very important for fish to get energy, as they use it for things like growing, swimming, breathing, and reproducing (Hmelo-Silver 2010). To determine the energetic importance of specific prey in the diet of fishes, it is necessary to know the caloric density of these prey. Alewife *Alosa pseudoharengus* has been found to have an energy density of about 4.6 kJ/g (Rand et al. 1994). Bay Anchovies *Anchoa mitchilli* have an energy density of 2.55 kJ/g, while Steelhead *Oncorhynchus mykiss* have an energy density of kJ/g, 5.70 kJ/g, and Yellow Perch *Perca flavescens* have an energy density of 3.77 kJ/g (Hartman and Brandt 1995). Fish tissue has low energy density in comparison to foods like potato chips (23 kJ/g), chocolate (22 kJ/g), and doughnuts (18 kJ/g). Dairy products vary in energy density, with dry cheeses (17.0 kJ/g) having higher values and yogurt (4.2 kJ/g) and fluid low-fat milk (1.6 kJ/g) having lower values (Drewnowski and Specter 2004).

Goldeye are most important for Northern Pike *Esox lucius*, Walleye and the Sauger *Sander canadensis*, as these predators rely heavily on Goldeye when they are present (Sprules and Kennedy 1967). Goldeye are abundant in Red Lake Minnesota (Smith 1977). However, the importance of the fish as a prey species is not yet known. It is known that Goldeye males reach a higher oil concentration earlier in life as they mature, spawn and have shorter life spans in comparison to females. Females, however, have higher oil concentrations later in life for spawning (Craig et al. 1989). The concentrations of oils in these fish for male or female, or even in general are not yet known. Therefore, the objective of this study was to estimate energy densities of Goldeye.

Methods

Goldeye were obtained from the Minnesota Department of Natural Resources from Red Lake in Minnesota. When obtained, Goldeye were measured for length in millimeters, then measured for weight in grams. Once this was accomplished, sex was also determined by looking at each fish's anal fin. The anal fin on a female Goldeye is straighter, streamlined or sickle shaped; compared to the male Goldeye anal fin which is more of a curved or bowl shape. This holds true for all sizes and ages of Goldeye (Craig et al. 1989).

Goldeye were then put into an oven to dry. Every few days Goldeye were taken out of the oven to weigh. When dry weight was reached, each fish then was homogenized in a blender. Dry weight is when all "fluid" weight has left the fish. After each fish was homogenized, energy density was measured using a Parr 6300 bomb calorimeter. Bomb calorimeters are used to measure the amount of heat that is being released by a reaction. Only one gram from each fish was used in the reaction. When one gram was weighed out from each homogenized fish, they were then pressed into a pellet. Pellets insured that each reaction was completed correctly and that no misfires were registered by the bomb calorimeter. After the pellets were created, they were placed in a crucible and a wick was tied from the wire starter and placed so it was touching the pellet and hexane. Hexane was added to each crucible to ensure that the reaction was completed. The bomb was then put back together and placed in the bucket of water located in the bomb calorimeter. Electrodes where then attached to the top of the bomb and the process began. Once the reaction was completed, the temperature of the water would increase, and this number was recorded. The water for the bomb calorimeter was changed out after each test, and the crucible was cleaned after each test. This was done for all homogenized fish.

Data Analysis

For relating dry weight to energy densities, a linear regression model was used.

Results

The average energy density for all Goldeye was 6.73 kJ/g (SD = 1.11). Energy densities had a relationship with percent dry weight of y=0.20094x-0.2573 and a R^2=0.3119 (Figure 1). As dry weight increased, the energy density of most fish increased as well (Figure 1). Female energy densities were much more variable compared to that of males, whose where much more closely related (Figure 2). Average energy density for males was 6.78 kJ/g (SD = 1.08) and females were 6.68 kJ/g (SD = 1.13). The length weight relationship is presented in Figure 3.

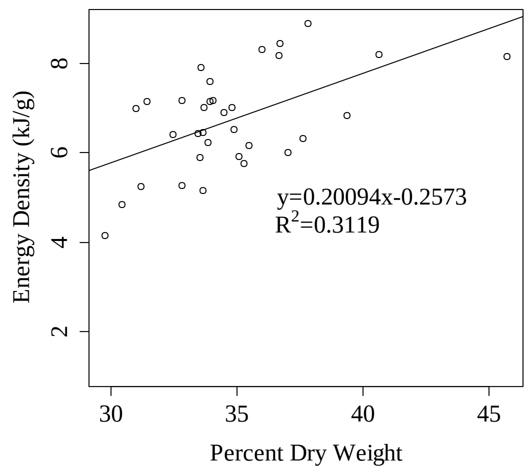

Figure 1. Energy density (kJ/g) percent dry weight relationship for Goldeye.

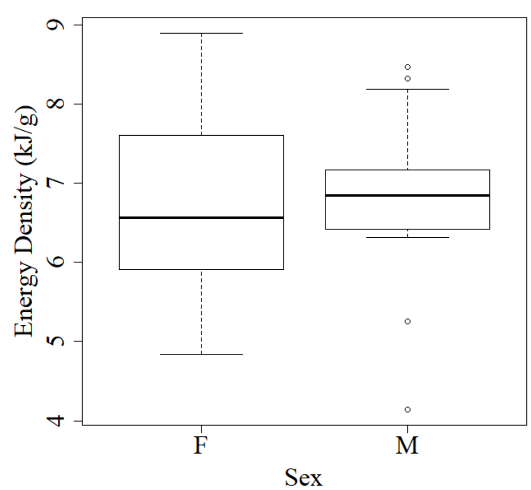

Figure 2. Male and Female Goldeye energy densities.

Discussion

Energy densities increased with increasing dry weight. This could suggest that percent dry weight can directly affect the energy density of Goldeye. This does reflect what has been found in prior studies, as percent dry weight does have an influence on energy densities (Lantry and Ogorman 2007). Perch are known to be very important to Walleyes and Northern Pike (Brennan 2013). Perch are very abundant in Red Lake (Grosslein and Smith 1959). Goldeye on average have higher energy densities than Yellow Perch. Therefore, Goldeye have the potential to be a very important species in Red Lake.

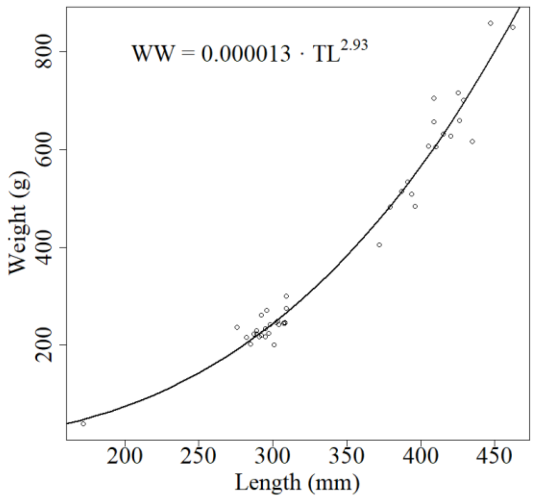

Figure 3. Goldeye length compared to their weight.

Male Goldeye energy densities were much more closely related than that of females. As pointed out earlier by Craig et al. (1989), females will in fact have more fat in their later stages of life compared to when they are younger. Males, on the other hand, do not need to dedicate as much energy in their earlier stages of life for reproduction like females do. This would help explain why male Goldeye energy densities were much more closely related than female Goldeye.

Comparing to other freshwater fish, Goldeye have a relatively high energy density (Hartman and Brandt 1995). This could be very important for predatory fishes in Red Lake. Cisco can have important relationship to predatory fishes explained by Kaufman et al. (2007). Prey is very important to predators, as they usually are the limiting factor for predators in a system (Brennan 2013). If Goldeye could have implications on Red Lake like Cisco's can, it could be worthwhile to have fishing regulations for Goldeye in Red Lake.

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