How much do lake trout and Chinook salmon really eat?

Chinook salmon have been the most important predator in Lake Michigan for decades. With baitfish on the decline, some anglers believe that lake trout are now eating more than salmon.

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The food supply in Lake Michigan is not what it used to be. Invasive species like quagga mussels, nutrient reductions in open waters, and high numbers of predatory fish to feed all play a role in "squeezing" baitfish like alewife. The result can be an imbalance of predators and prey. In other words: too many mouths to feed for the amount of food available in open water.

It takes a lot of food for a lake trout to grow this big, but a Chinook salmon eats much more on an annual basis.

Of course, this is a simplistic way of looking at things. Different species of fish are not the same in terms of the energy they consume and use. They grow at different rates, prefer different water temperatures, and utilize food more or less efficiently.

These factors become important when considering the total number (or biomass) of baitfish being consumed by predatory salmon and trout in Lake Michigan. Many anglers are particularly concerned about the impact of native lake trout versus introduced Chinook salmon. Both species are currently stocked in Lake Michigan, but both species also reproduce naturally.

Chinook salmon are prized gamefish with a very high growth rate and a short lifespan—they typically spawn and die at age 2.5 or 3.5 with a very few surviving to age 4. Lake trout are also a good gamefish, but they do not draw anglers to the lake in the same way that the spectacular fighting ability of the Chinook salmon does. Mid-sized trout are excellent table fare, but large, old lake trout tend to accumulate more contaminants than salmon. Lake trout can also live much longer than salmon (over 20 years), but they grow much more slowly.

Since there is a limited number of baitfish in the lake, there is a limited amount of energy (calories) available to trout and salmon. How does this all play out in terms of the amount and types of prey fish being eaten by lake trout and Chinook salmon? To find out, I relayed some questions on the topic to two people who have been studying Lake Michigan fish for a combined total of over sixty years: Chuck Madenjian (USGS) and Jory Jonas (MDNR).

How would a lake trout and Chinook salmon compare in terms of the energy they consume each year?

C.M.: For the period of time from age 1 through age 12, annual food consumption by a lake trout in Lake Michigan averages 13 lbs. This estimate is based on the assumption that the annual food consumption for age-10 and age-11 lake trout is similar to that for lake trout of ages 7-9. For the period of time from age 0 through age 3.5, annual food consumption by a Chinook salmon in Lake Michigan averages 42.5 lbs. Thus, Chinook salmon in Lake Michigan are feeding at a rate more than three times higher than that of lake trout.

J.J.: I agree with Chuck's summary above, but would also add that Chinook salmon grow faster, inhabit warmer waters than lake trout on average, and are much more active. All of these factors lead to increased demand for energy (food) relative to lake trout.

So, on an annual basis a Chinook salmon eats more than a lake trout of the same size. We know that lake trout live longer than Chinook salmon, though. How much does an average lake trout eat over its entire lifetime as opposed to an average Chinook salmon?

C.M.: The answer to this question partly depends on the definition of an entire lifetime for a lake trout. Based on the bioenergetics modeling by Don Stewart and others, an average lake trout consumes 143.3 lbs. of food between the time of stocking as a yearling into Lake Michigan and age 12. A Chinook salmon consumes 147.7 lbs. of food between the time of stocking as an age-0 fingerling into Lake Michigan and age 3.5, when a Chinook salmon is ready to spawn.

J.J.: Chuck did a nice job of summarizing lifetime consumption of the two species above. When asking a question like this, it is important to consider why it is being asked. Total lifetime consumption of prey does not equate to information valuable in determining sustainability of the system. New year-classes of fish are always being produced and individual species have different life-spans and life-histories. Several generations of alewife and Chinook salmon will have cycled during the life-span of a lake trout. For example, during the lifespan of a lake trout age 12 which consumed 143.3 lbs. of prey there will have been four generations of Chinook salmon each consuming 147.7 lbs. of prey (590.8 total lbs.). Because of fluctuations in births and deaths and the lack of life-span synchrony among species, we typically summarize population levels of predators and prey on an annual basis in order to monitor for changes over time.

Fish are cold-blooded animals, so water temperature must affect how often they eat and how quickly they digest food. Do temperature preferences play a big role when comparing bioenergetics of lake trout and Chinook salmon?

C.M.: Temperature does play a role when comparing bioenergetics of lake trout and Chinook salmon. However, the main driver of the difference in consumption rates between lake trout and Chinook salmon is the difference in growth rates between the two species. In other words, the main reason for the much higher rate of food consumption by Chinook salmon compared with that by lake trout is that Chinook salmon grow substantially faster than lake trout. Average summer temperatures experienced by lake trout in Lake Michigan range from 46.4 to 50°F, whereas average summer temperature experienced by Chinook salmon in Lake Michigan ranges between 53.6 and 55.4°F. Metabolic costs typically increase with increasing temperature, and so Chinook salmon would be expected to have higher metabolic rates than lake trout. Nonetheless, the primary reason for the higher food consumption rate for Chinook salmon compared with that for lake trout is the higher growth rate by Chinook salmon compared with that for lake trout.

J.J.: Chinook salmon are also more active than lake trout, travelling large distances and generally moving around more. Combine higher activity levels with the factors mentioned by Chuck above, including higher temperature occupancy, and you have a higher demand for calories to support Chinook salmon.

Fish need energy to maintain basic body functions, chase down prey, and reproduce. Additional energy can be used for growth. How do lake trout and Chinook salmon compare in terms of their ability to use food energy for growth?

C.M.: Gross growth efficiency (GGE) is equal to growth (increase in weight) divided by the amount of food consumed to attain that growth. Thus, GGE is a measure of the efficiency with which a fish converts food consumption into its growth. According to the bioenergetics modeling by Don Stewart and others, the GGE for a 3.5-year old Chinook salmon is 13.3%. That is, the 3.5-year old Chinook salmon converted its food into its growth with a 13.3% efficiency. The GGE for a 12-year old lake trout is estimated to be 8.0%. Thus, a Chinook salmon is considerably more efficient at converting food into growth than a lake trout in Lake Michigan.

Large, old lake trout are a common catch in central and southern Lake Michigan. These fish might weigh over twenty pounds and be twenty years old or older. Computer models that calculate how many baitfish are being eaten in Lake Michigan treat a twenty-year old lake trout the same as a six-year old. Does a twenty-year old lake trout really eat only as much as a six-year old?

C.M.: To answer this question, a growth trajectory for lake trout from ages 1 through 20 would be needed. Stewart et al. (1983) estimated mean weight at age for ages 1 through 10 only, so information on mean weight at age for ages 11 through 20 would be needed to answer this question. According to Stewart et al. (1983), annual consumption of food by an average lake trout in Lake Michigan remained relatively constant at a value of about 17.6 lbs. between the ages of 6 and 10. In other words, annual feeding rate of lake trout did not increase as lake trout age increased from 6 to 10. Mean weight at age 6 was 6.6 lbs., and mean weight at age 10 was 10.6 lbs. Thus, even though the weight of an average lake trout increased by 4 lbs. between ages 6 and 10, annual rate of food consumption by lake trout did not increase between ages 6 and 10 (Stewart et al. 1983). Note that annual weight gain by lake trout decreased between ages 6 and 10. If the annual weight gain (annual growth) continued to decrease between ages 10 and 20, a large increase in annual consumption over ages 10-20 would not be expected.

J.J.: It is true that larger fish on average require more energy than smaller fish, all else being equal. As lake trout age, the annual growth rate is much less, reducing energy demands, as mentioned by Chuck above. In more recent catch-at-age modelling efforts in eastern Lake Michigan, the mean weight of a lake trout at age 6 was 5.7 lbs., at age 10 was 9.7 lbs. (a change of 4 lbs. in 4 years) and was 11.2 lbs. at age 15 (an increase of 1.5 lbs in 5 years). By age 7 most Lake Trout are spawning so fish age 7-15 should be experiencing similar energy demands for spawning. Despite this, growth rate (body weight added per year) continues to decline as the fish ages.

Studies on Great Lakes salmon and trout bioenergetics were conducted back in the 1980s. Do they still hold true today with so many invasive species in the food web and changes to the strains of lake trout being stocked?

C.M.: Bioenergetics models for Chinook salmon and lake trout are sufficiently flexible such that they can accommodate changes in the Lake Michigan food web and changes in lake trout strains being stocked. Inputs to the bioenergetics models include growth of the fish (predator), temperature regime experienced by the fish, diet schedule for the fish, energy density of the prey, and energy density of the fish (predator). All of these inputs can be adjusted to more accurately reflect changes in the food web or changes in lake trout strains stocked. Bioenergetics model estimates of food consumption by Chinook salmon and lake trout are especially sensitive to estimates of growth by Chinook salmon and lake trout, so changes in growth over time would need to be taken into account when estimating food consumption by these fishes over decades of time. In the laboratory, the lake trout bioenergetics model performed equally well for both Marquette and Seneca Lake strains of lake trout, so lake trout bioenergetics was very similar among strains of lake trout. The Seneca Lake strain does inhabit slightly cooler water than the Great Lakes strains of lake trout, but this slight difference in temperatures between strains had only a small effect on food consumption. Laboratory performances of both the Chinook salmon bioenergetics and the lake trout bioenergetics model are reasonably good. On average, the model estimates of food consumption are within 5% of observed consumption.

Now we know how much individual trout and salmon eat, but how many baitfish are eaten annually by all predators in Lake Michigan? How did estimated lake trout consumption compare to estimated Chinook salmon consumption on a lakewide basis in 2016?

J.J.: In 2016, lake trout consumed 13.7 kt of prey and Chinook salmon consumed 38.4 kt. Even though numbers of Chinook salmon in 2016 were at all time low levels lake-wide, they consumed nearly 3 times as much forage as lake trout. In 2016, the biomass of Chinook salmon in Lake Michigan was estimated to be 5.0 kt and lake trout 5.9 kt. Just four years' prior, in 2013, Chinook salmon biomass was substantially higher at 15.7 kt and lake trout were 7.0 kt.

Until now we have only been discussing how many baitfish are being eaten, but we know that Chinook salmon depend almost entirely on alewife while lake trout can eat a variety of prey including round gobies. Have lake trout moved away from eating alewife in Lake Michigan?

J.J.: Lake trout tend to be opportunistic feeders and will take advantage of a variety of prey items, whereas Chinook Salmon are more specialized preferring almost exclusively alewife as prey. Since about 2003, lake trout have been taking advantage of a relatively new prey source in Lake Michigan, the round goby. Because of increased public interest in understanding the role of lake trout as predators in Lake Michigan, a variety of new initiatives have begun to better understand this more complex predator. For the last few years, diet collections have been occurring outside of the standard spring assessments which conclude in mid-June, and on broader spatial scales. Preliminary comparisons indicate that there is a seasonal component to lake trout feeding whereby they consume larger numbers of round goby in the spring and increased dependence on alewife as the year progresses. Smelt and bloater have been abundant in the diets of lake trout in the past, but for the recent 5 years over 75% of lake trout diets have been comprised of alewife and round goby. We continue to explore new and more robust methods for keeping up with the changing trends in lake trout consumption. Some of these include evaluation of fatty acid or isotopic signatures which can represent a longer period of lake trout consumption (in the case of isotopes up to one-year). We are seeking funding to conduct broader data collection efforts to better understand changing patterns throughout the lake and in different seasons.

So, we don't yet know exactly what percentage of Lake Michigan lake trout diet is alewife, but what was the realistic range of possible alewife consumption by lake trout in 2016?

J.J.: It's still early, but most of us are comfortable with an average alewife diet proportion of around 50% for lake trout, which we currently use in consumption models. Preliminary investigations indicate that in the spring (April to Mid-June) alewife comprise between 7 to 20% of the diet of lake trout, and from mid-June to August alewife can represent from 50 to 80% of the diet. We continue to pursue improvements to describe feeding patterns of this more complex predator in the Lake Michigan basin.

Thanks Jory and Chuck for providing detailed answers to these questions.

In summary, when anglers point out that lake trout need more food to reach a given weight they are correct. A lake trout needs about 125 pounds of food to reach a weight of ten pounds while a Chinook salmon needs around 75 pounds of food (based on differences in gross growth efficiency). However, the Chinook salmon consumes this amount of food over a very short period of time when compared to a lake trout.

In fact, a typical Chinook salmon consumes roughly three times as much food in a given year as a typical lake trout does. This is critically important because alewife (and other prey fish) reproduce and grow each year. The absolute amount of food consumed by a salmon or trout in its lifetime is therefore less important to maintaining a good predator-prey balance than its annual demand for prey.

Chinook salmon do burn through alewife much more quickly than lake trout, but that does not mean that lake trout consumption is completely insignificant. Science is always improving, and the upcoming study on predator diets is one example of an effort to better understand what lake trout are eating at different times and in different parts of Lake Michigan.

Despite the never-ending quest for better information, fishery managers must make decisions in real time based on the best available scientific information. We know that an individual Chinook salmon consumes more alewife than a lake trout does, but we also know that Chinook salmon are no longer the only important species to consider when looking at predator-prey balance in Lake Michigan. In the future, scientists will be taking a harder look at diet and consumption of other predators like lake trout, coho salmon, and steelhead.