COMPARISON OF CALCIFIED STRUCTURES TO ESTIMATE AGES OF NORTHERN PIKE *ESOX LUCIUS* IN VARIOUS LAKES

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***Abstract*—Northern pike *Esox lucius* are a dominant predatory fish in many aquatic systems. They can have significant impacts on the ecosystems they inhabit and are also a popular game fish among anglers. However, northern pike are a difficult species to age accurately. This study aimed to compare calcified aging structures to identify trends and determine which structure provides the most accurate age estimates. A total of 119 northern pike were sampled, and multiple structures from each fish were independently aged by two readers. The coefficient of variation (CV) was calculated for each structure to assess precision. Sectioned sagittal otoliths exhibited the lowest CV (4.83), whereas anal fin rays showed the highest CV (7.26). These results indicate that sectioned otoliths are the most reliable structure for aging northern pike.**

INTRODUCTION

Accurate age determination is fundamental to the scientific assessment and management of fish populations. Reliable age estimates provide information on both individual age and the population's age structure, which are essential components of population dynamics (Kerns et al. 2017).

Quantifying age structure enables fisheries managers to characterize cohort strength, evaluate year-class variability, and detect shifts in demographic patterns over time. Accurate age data is essential for estimating key population parameters, including growth rates, total and natural mortality, and age at sexual maturity, and for developing stock assessment models used to estimate spawning stock biomass, recruitment, and sustainable harvest levels (Oele et al. 2015; Campana 1999). Consequently, reliable age estimation is critical for generating the biological reference points and management benchmarks necessary to ensure the long-term productivity and sustainability of fish populations (Quinn and Deriso 1999; Kerns et al. 2017).

Northern pike *Esox lucius* are widely recognized as a challenging species to age accurately. Multiple anatomical structures including scales, cleithra, anal fin rays, and sagittal otoliths have been used for age estimation (Laine et al. 1991; Oele et al. 2015; Blackwell et al. 2016). However, no single structure has been consistently identified as the most precise, and studies often disagree on the preferred method. Among these structures, sagittal otoliths have been shown in some studies to produce lower coefficients of variation (CV) compared to cleithra, scales, and fin rays, suggesting greater precision in age estimates (Blackwell et al. 2016).

Northern pike are an important species to many water bodies and have a large impact on the systems they are present in. In many systems where salmonid species are native or have been introduced, northern pike have made large impacts to salmonid populations and are considered invasive in many areas. Northern pike <600 mm were found to consume 56% of their annual energy consumption on rainbow trout *Oncorhynchus mykiss* in the Pactola Reservoir, a stocked trout lake in South Dakota (Scheibel et al. 2016). Because northern pike are highly piscivorous, their feeding behavior can significantly alter the population structure of prey species and influence broader fish community dynamics, often resulting in declines of native fish populations (Cathcart et al. 2019). This makes it more important for fisheries managers to understand the age structure of the northern pike population in a given system.

With variability in what aging structure should be used to get the most accurate age estimate of northern pike. The objective of this study is to compare three calcified structures of northern pike to determine which gives a more precise age estimate. Structures will be compared to examine aging bias trends with each structure.

METHODS

Northern pike were sampled using gill nets from six lakes in the Bemidji, Minnesota area: Lake Itasca (15001600), Grace Lake (29007100), Big Lake

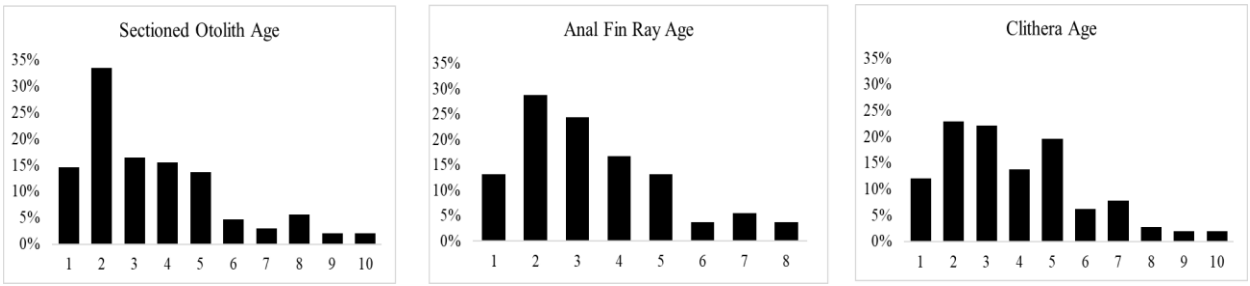

Figure 1. Age frequency based on agreed age estimate of sectioned otoliths, anal fin rays and cleithra for northern pike collected in 6 different lakes in northern Minnesota in 2025.

(04004900), Lake Plantagenet (29015600), Lake Bemidji (04013000), and Pike Bay (11041500). These lakes were selected by the Bemidji Area Fisheries Office as part of their standard lake survey schedule. Fish were collected between 21 July 2025 and 25 August 2025. Gill nets were set and retrieved approximately 24 hours later.

Each gill net measured 1.8 m in height and 76.2 m in length and consisted of five mesh panels, each 15.24 m long. Mesh sizes ranged from 19.05 to 50.8 mm. Northern pike captured in each net were frozen for later processing. Sagittal otoliths, cleithra, and anal fin rays were removed from each fish and assigned unique serial numbers. Total length measurements were recorded after fish were removed from the freezer.

Otoliths were placed in labeled plastic vials and later embedded in two-part quick-setting epoxy for sectioning. Sectioning followed the methods described by Lackmann et al. (2019). Otoliths were embedded in epoxy within plastic trays and allowed to harden. Once set, they were transversely sectioned using a Buehler Isomet low-speed saw. Sections were prepared using the wafer method to ensure that the nucleus of each otolith was included in the final cross-section. Prepared sections were then placed in glycerol and aged independently by two readers using a dissecting microscope with transmitted illumination.

Cleithra were boiled for approximately 30 seconds to remove any remaining tissue. They were then carefully scraped clean and placed in labeled envelopes to air dry prior to aging. Cleithra were aged by viewing annuli under transmitted natural light. Structures were examined with the unaided eye and independently read by two readers to ensure consistency in age estimation.

Anal fin rays were removed from each fish and placed in labeled envelopes for subsequent processing. Rays were sectioned using a Buehler Isomet low-speed saw, with a single transverse cut made perpendicular to the third and fourth fin rays of each specimen. Cut fin rays were then mounted upright, and glycerol reagent was applied to enhance visibility of annuli. Age estimates were obtained by examining the sections under a dissecting microscope with transmitted illumination, viewing directly through the cross-section to identify annuli.

All prepared structures were aged independently by two readers to allow calculation of a coefficient of variation (CV) for each method. Reader experience varied, with most individuals having prior experience aging only whole sagittal otoliths before this project. Prior to recording formal age estimates, all readers completed a practice period to familiarize themselves with each structure and improve consistency in interpretation.

RESULTS

Northern pike ranged from 275 to 959 mm (mean 586 mm). The sample consisted of 88 females, 30 males and one fish that was unidentifed. Cleithra (n = 119), anal fin rays (n = 116), and sectioned sagittal otoliths (n = 111) were aged. Agreed ages ranged from 1 to 10 years. Cleithra and sectioned otoliths produced age estimates ranging from 1 to 10 years, while anal fin rays ranged from 1 to 8 years. Results indicated that sectioned otoliths had the lowest coefficient of variation (CV = 4.83) compared to cleithra (CV = 6.16) and anal fin rays (CV = 7.60). Female fish were generally easier to age, with a lower CV (5.43) than male fish (CV = 7.82). Additionally, 74.75% of agreed age estimates were ≤ age 4, indicating a strong concentration of younger age classes in the sampled population (Figure 1).

Reader 1 and 2 had the greatest agreement on sectioned otoliths and lowest agreement when estimating anal fin rays. Precision was best in sectioned otoliths. Cleithra was the second most precise structure with fin rays being the least precise age estimating structure. Otolith CV values were less than other structures CV (Table 1).

Otoliths produced the highest agreement between readers, with readers 1 and 2 assigning the same age to 77.47% of fish (n = 111). Agreement between otoliths and cleithra was 14% lower, and agreement for fin rays was 20% lower, with fin rays showing the lowest concordance at 57.89%. Patterns in the percentage of

age estimates within one year were similar, although differences among structures were less pronounced. Otolith-derived ages were within one year for 97.29% of fish (n = 111), followed closely by cleithra at 95.80%. Fin rays again showed the lowest performance, with 88.83% of age estimates falling within one year (Table 1).

Table 1. Mean coefficient of variation, percent agreed on initial reading (agree) for two readers, percent within one year (within 1) for two readers, for 3 ageing structures of northern pike collected in 6 different lakes in northern Minnesota in 2025.

Structure	CV	Agree	Within 1
Sectioned Otolith	4.83%	77.47%	97.29%
Clithera	6.16%	63.02%	95.80%
Anal Fin Ray	7.60%	57.89%	88.83%
Male	7.89%	70.00%	92.59%
Female	5.41%	64.84%	84.44%

Estimated ages for otoliths were similar between reader 1 and reader 2. However, reader one tended to age fish under age 5 younger than estimates from reader 1. This trend continued for cleithra and fin rays where reader 1 was consistently aging higher than reader 2 on structures where readers disagreed. The identified trend between reader bias was more largely noticed on younger fish (< age 6) when estimating sectioned otoliths. This trend was seen throughout all ages when estimating cleithra and fin rays (Figure 2).

DISCUSSION

The study aimed to recommend an aging structure when estimating ages of northern pike. After collecting and reading three aging structures from 119 northern pike, a difference in precision has been observed. Sectioned sagittal otoliths, cleithra, and anal fin rays were used to estimate ages. These structures have been previously examined, and in studies where otoliths were used, they have been the recommended structure for gathering age estimates (Oele et al. 2015; Blackwell et al. 2016). In this case otoliths, cleithra, and anal fin rays all provided age estimates that were precise and likely to be accurate. Variability in precision likely coming from age of fish, sex, and reader experience.

A coefficient of variation (CV) of 5% is recommended for species with moderate lifespans (Campana 2001). In this study, overall precision across structures was high, with sectioned otoliths meeting the 5% CV threshold and, therefore, considered the most precise. Cleithra and anal fin rays produced CV values close to this benchmark, indicating that both structures also provided reasonably precise age estimates. These findings differ from previous studies, which reported whole cleithra CV values ranging from 12–18% (Oele et al. 2015; Blackwell et al. 2016). This discrepancy may be attributed to differences in reader experience or

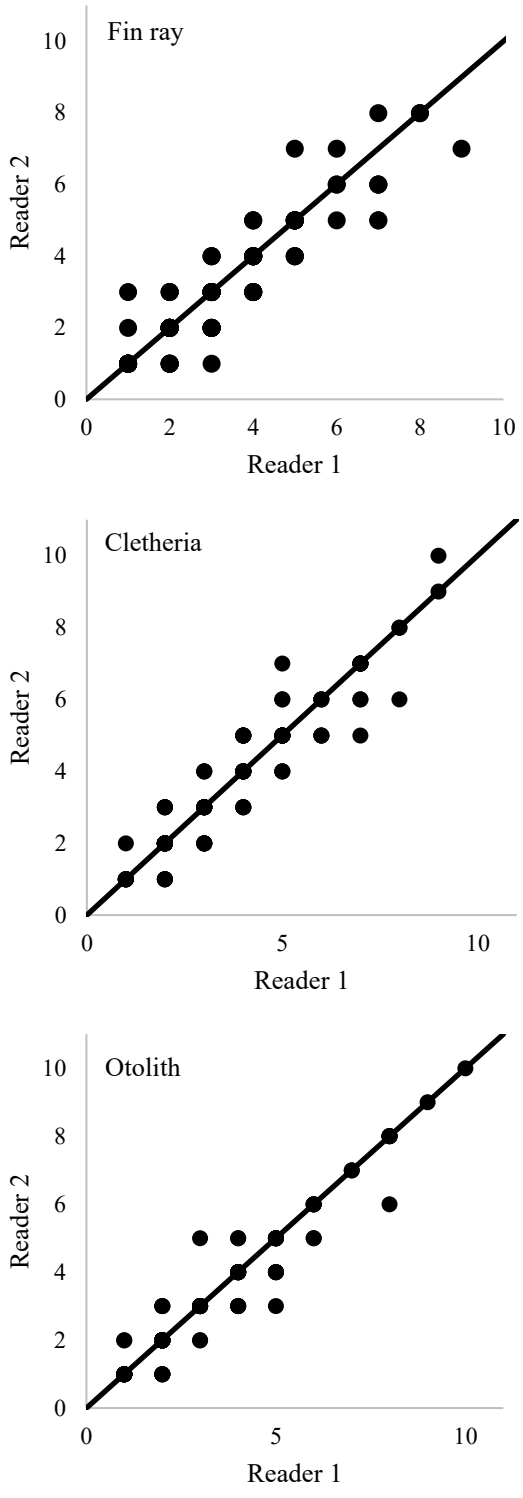

Figure 2. Age-reader bias plots for age estimates of northern pike obtained by two independent readers. Three calcified structures from each fish (n=111-116) were sampled from 6 Bemidji MN area lakes. Trend lines indicate agreeance between readers.

sample composition, as approximately 75% of the fish in this study were female.

Sex-based differences in growth may also explain variation in precision. Dimorphic growth patterns have been documented in muskellunge *Esox masquinongy*, particularly after age 3 (Hermus et al. 2020). Because northern pike and muskellunge both belong to the genus *Esox*, similar growth patterns are likely. Female fish typically grow faster than males, resulting in more widely spaced and distinguishable annuli on aging structures. In contrast, annuli in slower-growing fish (presumably males) tend to be more tightly packed, making accurate age estimation more difficult.

The findings suggest that sectioned sagittal otoliths be used when gathering age estimate of northern pike. However, cleithra and anal fin rays present good secondary options. The disadvantage with sectioned otoliths and cleithra is that fish must be sacrificed to collect these aging structures. Another disadvantage to using otoliths is there is a lot of time required to prepare this structure for aging. Along with this, specialized equipment is required for sectioning of otoliths and cutting anal fin rays. Compared to cleithra where they can be viewed whole with very little preparation. More research with known age fish is needed to test the accuracy of these structures.

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