

Jaw tags do not impact adult rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792) growth or physiology

Jackson Tyndall, Nathan Huysman and Michael E. Barnes*

South Dakota Department of Game, Fish & Parks, McNenny State Fish Hatchery, 19619 Trout Loop, Spearfish, South Dakota, USA, 57783.

*Corresponding author. Email: mike.barnes@state.sd.us; Tel: 605-642-6920

Copyright © 2025 Tyndall et al. This article remains permanently open access under the terms of the [Creative Commons Attribution License 4.0](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Received 5th November 2025; Accepted 3rd December 2025

ABSTRACT: Metal tags secured to the jaw of fish have long been used in fisheries management to collect data on fish behavior and growth. This study was undertaken to evaluate the possible effects of these jaw tags on relatively large rainbow trout *Oncorhynchus mykiss* growth and physiology. A total of 160 rainbow trout, initial weight 1134 ± 19 g (mean \pm SE) and total length 444 ± 2 mm, were used in this study. Half of the fish ($n = 80$) were tagged, with 20 tagged and 20 untagged fish subsequently co-reared in four compartments for 42 days post-tagging. Length, weight, condition factor, hematocrit, hepatosomatic index (HSI), viscerosomatic index (VSI), and splenosomatic index (SSI) were recorded every seven days. Survival rate was the same in both treatments at 96.3%. Tag retention was 98.8%, with one jaw tag lost in the fourth week during weekly sampling. There were no significant differences in length, weight, hematocrit, HSI, VSI, and SSI between the tagged and untagged groups. Condition factor was significantly different between the groups at the one- and four-week sampling periods. Overall, these results indicate that the effects of jaw tags on adult rainbow trout are relatively benign, at least for the variables measured in this study.

Keywords: Growth, jaw tags, *Oncorhynchus mykiss*, physiology, rainbow trout.

INTRODUCTION

Fish are tagged to collect data on growth, exploitation rates, movement, survival, and behavior (Shetter, 1967). Tags applied externally have been used in fisheries management for over 100 years, with tagging first documented in North American in 1873 (Rounsefell and Kask, 1945). External tags are typically cost-effective, easy to apply, durable, and easy to detect. They can be individually numbered, making them useful for mark-recapture studies as well as for engaging anglers in data collection (Thorsteinsson, 2002).

Jaw tags are a specific type of external tag with a relatively low cost and high retention rate (Shetter, 1967; Zerrenner *et al.* 1997; Newman and Hoff 1998; Vandergoot *et al.*, 2012; Coulter *et al.*, 2022). Made of an overlapped band of metal, these tags are placed around the mandible or maxilla of fish (Smith *et al.*, 1952; Stauffer and Hansen, 1969; Slatick, 1976; Newman and Hoff, 1998; Isermann and Knight, 2005; Vandergoot *et al.*, 2012; Felts

et al., 2021; Coulter *et al.*, 2022). Tags are readily visible to fisheries managers and anglers, and can be used to individually mark fish (Shetter, 1967; Zerrenner *et al.*, 1997; Newman and Hoff, 1998; Vandergoot *et al.*, 2012; Coulter *et al.*, 2022)

For the information obtained from any fish tag to be accurate and useful for fisheries management, the tags must be harmless and have no impact on fish growth, physiology, or behavior. Fisheries managers and researchers must assume that the survival, growth, and behavior of jaw tagged fish do not markedly differ from untagged fish (Slatick, 1976; Schill *et al.*, 2007). Although these beliefs may typically be accepted, there are fish growth and mortality studies challenging these assumptions. Coulter *et al.* (2022) reported lower growth and relative weight in jaw tagged silver carp *Hypophthalmichthys molitrix* (Valenciennes 1844) compared to a control group for two months post tagging.

MacCrimmon and Robbins (1979) observed significantly slower growth rates in jaw-tagged smallmouth bass *Micropterus dolomieu* (Lacepède 1802), suggesting that jaw tags should not be used in studies that require reliable growth data. Similar results have been reported using jaw tags in salmonids.

In the first jaw tagging study conducted on salmonids, Schuck (1942) reported a significantly lower condition factor in jaw-tagged brown trout *Salmo trutta* (Linnaeus 1758) and stated that any growth data after jaw tagging would not be reliable. Shetter (1967) found that juvenile rainbow trout *Oncorhynchus mykiss* with jaw tags experienced 10–21% slower growth than untagged fish. Zerrenner *et al.* (1997) also observed that yearling jaw-tagged brook trout *Salvelinus fontinalis* (Mitchill 1814) grew slower than those not tagged. Lesions induced by jaw tags inhibit feeding and have been hypothesized as the reason for this reduction in growth (Ricker, 1942; Zerrenner *et al.*, 1997). Thus, as healing in such lesions occurs, declines in growth may subside after several months, as has been reported by Welch *et al.* (2007), Ashton *et al.* (2017), and Coulter *et al.* (2022). However, the ability to adapt or heal may be species-specific, as other studies have reported long-term negative effects of jaw tags on growth (DeRoche, 1963; MacCrimmon and Robbins, 1979).

While numerous studies have reported the possible effects of jaw tags on fish growth, there is little data on the possible impact of jaw tagging on fish physiology. In addition, few studies have specifically examined jaw tags in adult rainbow trout that are relatively larger in size. This information is needed to determine the validity of data collected from jaw-tagged fish, as well as to determine the amount of time jaw-tagged fish should be retained in a hatchery prior to release in the wild to maximize post-stocking survival. Thus, the objective of this study was to evaluate the possible impacts of jaw tagging on the growth, hematocrit, hepatosomatic index (HSI), viscerosomatic index (VSI), and splenosomatic index (SSI) of relatively large rainbow trout.

METHODOLOGY

This study occurred at McNenny State Fish Hatchery, Spearfish, South Dakota, USA in an enclosed raceway divided into four 5.6 m × 2.5 m × 0.5 m sections. Each section was separated from the other with perforated metal screens. All sections of the raceway received the same degassed and aerated well water (11°C; total hardness 360 mg/L CaCO₃; alkalinity 210 mg/L CaCO₃; pH 7.6; total dissolved solids 390 mg/L). This study used 160 Troutlodge strain rainbow trout (Bonney Lake, WA) [mean (SE) initial weight 1,134 ± 19 g, total length 444 ± 2 mm, n = 160] divided into two treatments: jaw-tagged and untagged. Initial total lengths and weights for the two groups were not significantly different (Table 1). All four sections of the raceway received 20 jaw-tagged and 20

Table 1. Mean ± SE initial total lengths and weights for rainbow trout that were either jaw-tagged or untagged controls (n = 80).

Parameters	Jaw-tagged	Untagged	p
Length (mm)	446 ± 3	441 ± 3	0.192
Weight (g)	1,102 ± 28	1,166 ± 26	0.101

untagged trout. The experiment lasted for a total of 42 days post-tagging. The fish were fed 4.5 mm extruded feed (Skretting; Tooele, Utah) to satiation daily by hand. On days that data collection took place, feeding did not occur.

Prior to the start of the experiment, six random fish were euthanized with tricaine methane sulfonate (MS-222, Syndel; Ferndale, Washington). Hematocrit, hepatosomatic index (HSI), viscerosomatic index (VSI), and splenosomatic index (SSI) measurements were recorded to obtain basal levels. At the start of the experiment, each fish was anesthetized using 60 mg/L MS-222, measured to the nearest millimeter (TL) and weighed to the nearest gram. Fish receiving jaw tags were selected at random. Each tagged fish had a small incision made beneath the posterior portion of the left mandible that allowed the size 16 jaw tag (0.89 mm thickness, 9.53 mm in height, National Band and Tag Company, Newport, Kentucky) to completely wrap around the mandible. After the curved tag was inserted through the incision, the tag was overlapped and secured using pliers. The fish were then placed into their respective raceway section during recovery.

In weeks 1, 2, 3, 4, and 6, every fish in each section was anesthetized, measured to the nearest millimeter (TL), and weighed to the nearest gram. In addition, one jaw-tagged and one untagged fish from each section were randomly selected and euthanized. From these fish, hematocrit was obtained by severing the caudal fin and collecting blood in a heparinized microhematocrit capillary tube (Fisher Scientific; Pittsburg, Pennsylvania), sealed with Critoseal (McCormick Scientific; Berkeley, Missouri). The tube was centrifuged for 10 minutes at 11,500 rpm. After centrifugation, calipers were used to measure the amount of total blood cells and red blood cells. Liver, viscera, and spleen were extracted from each euthanized trout and weighed to the nearest 1.0 mg. The following formulas were used:

$$\text{Hematocrit (\%)} = [\text{red/whole blood}] \times 100$$

$$\text{Hepatosomatic Index (HSI)} = [\text{liver weight (mg)} / \text{total weight (mg)}] \times 100$$

$$\text{Viscerosomatic Index (VSI)} = [\text{viscera weight (mg)} / \text{total weight (mg)}] \times 100$$

$$\text{Splenosomatic Index (SSI)} = [\text{spleen weight (mg)} / \text{total weight (mg)}] \times 100$$

$$\text{Condition Factor (K)} = 10^5 \times [\text{total weight (g)} / \text{total length (mm)}]^3$$

Data collected were analyzed using the SPSS (24.0) statistical analysis program (IBM, Armonk, New York, USA) with significance predetermined at $P < 0.05$. A t-test was used to compare initial weights and lengths between treatments and to compare survival between treatment groups. A repeated measures ANOVA was used to determine if differences between the treatments in weight, length, condition factor, hematocrit, HSI, VSI, and SSI occurred over the course of the study for. A Greenhouse-Geisser correction was used if sphericity was violated according to Mauchly's Sphericity Test.

RESULTS

Survival rates for both treatments were identical at 96.3%. Tag retention was 98.8%, with one jaw tag lost in the mesh net during the fourth weekly sampling.

Total length (Figure 1, $F_{4.6, 550.2} = 0.301$, $P = 0.9$) and weight (Figure 2, $F_{5, 600} = 0.499$, $P = 0.78$) were not significantly different between the treatments over the course of the experiment. However, condition factor was significantly different between the treatments over the course of the experiment (Figure 3, $F_{5, 30} = 3.30$, $P = 0.017$), with significant differences between the treatments also occurring at week 1 ($P = 0.035$) and week 4 ($P = 0.02$).

Hematocrit was highly variable and was not significantly different between the untagged and tagged groups (Figure 4, $F_{5, 30} = 0.394$, $P = 0.85$). The untagged group hematocrit never fell below 40% while the tagged group dropped below 40% in weeks 1 and 3. There was no significant difference between the treatments in HSI (Figure 5, $F_{5, 30} = 0.995$, $P = 0.44$), VSI (Figure 6, $F_{5, 30} = 1.151$, $P = 0.356$), or SSI (Figure 7, $F_{5, 30} = 1.385$, $P = 0.258$). While HSI and VSI dropped in both treatments after initial handling (and tagging in the tagged group), values returned to near-basal levels by week 4 for both treatments. SSI never stabilized for the tagged treatment. The untagged treatment was less variable and returned to basal by week 3.

DISCUSSION

The 96.3% survival rate observed in this study agrees with the 96.0–97.5% survival rates reported for jaw-tagged rainbow and brown trout after 4–6 months (Nelson, 1961; Stauffer and Hansen, 1969). The jaw tag retention rate of 98.8% also supports the 99% retention rate reported by Zerrenner *et al.* (1997) in brook trout after 251 days and the 95% retention rate reported by Stauffer and Hansen (1969) in rainbow trout after 2 years. Jaw tag retention may be dependent on the size of jaw tag relative to the size of the fish. For example, over the course of two years in adult rainbow trout, No. 10 jaw tags had higher retention rates (95%) compared to the smaller No. 8 (85% retention) and No. 3 (79% retention) tags (Stauffer and Hansen, 1969).

Jaw-tagged rainbow trout grew larger in this study compared to prior research. Zerrenner *et al.* (1997)

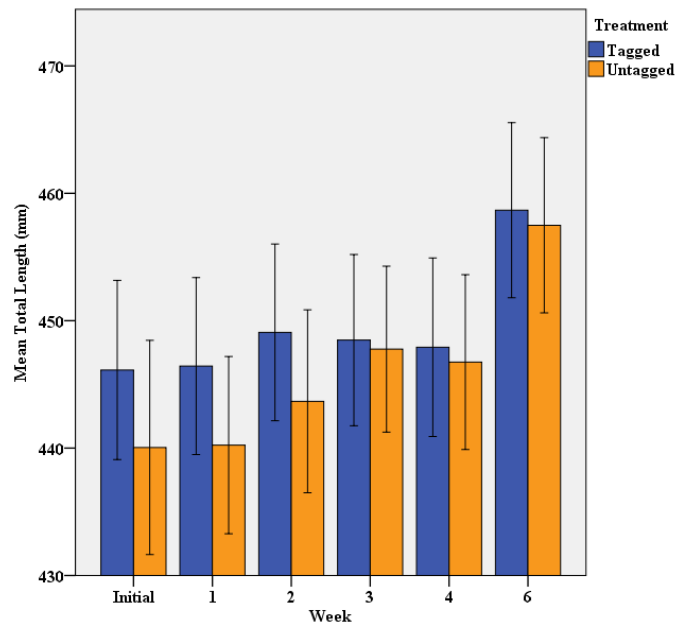


Figure 1. Mean total length (mm) of rainbow trout that were either jaw-tagged or untagged over a six-week experimental trial. There was no significant difference between treatments over the course of the trial ($F_{4.6, 550.2} = 0.301$, $p = 0.900$).

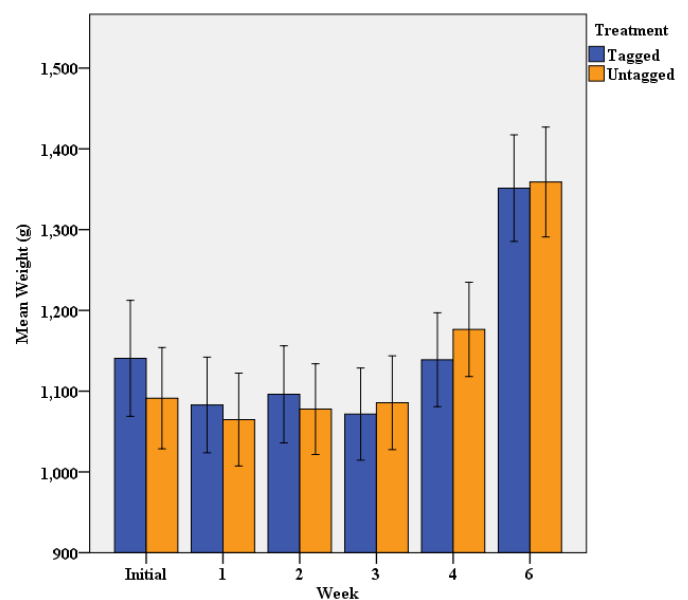


Figure 2. Mean total weight (g) of rainbow trout that were either jaw-tagged or untagged over a six-week experimental trial. There was no significant difference between treatments over the course of the trial ($F_{5, 600} = 0.499$, $p = 0.780$).

observed that jaw-tagged brook trout were smaller than untagged fish after 93 days. In addition, jaw-tagged juvenile rainbow trout have grown more slowly compared to untagged counterparts over 11 months (Shetter, 1967).

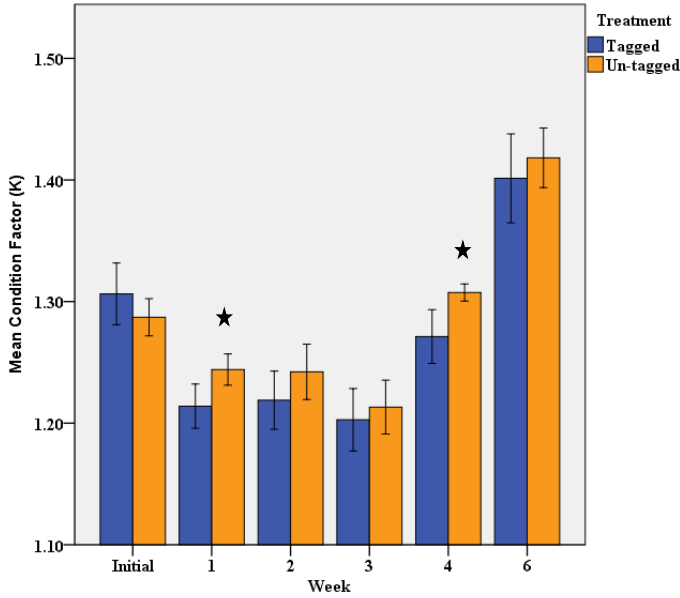


Figure 3. Mean condition factor (K) of rainbow trout that were either jaw-tagged or untagged over a six-week experimental trial. There was a significant difference between the treatments over the six-week period ($F_{5, 30} = 3.30, P = 0.017$), with specific significant differences in week 1 ($p = 0.035$) and week 4 ($p = 0.02$). $K = 10^5 \times [\text{total weight (g)} / \text{total length (mm)}]^3$.

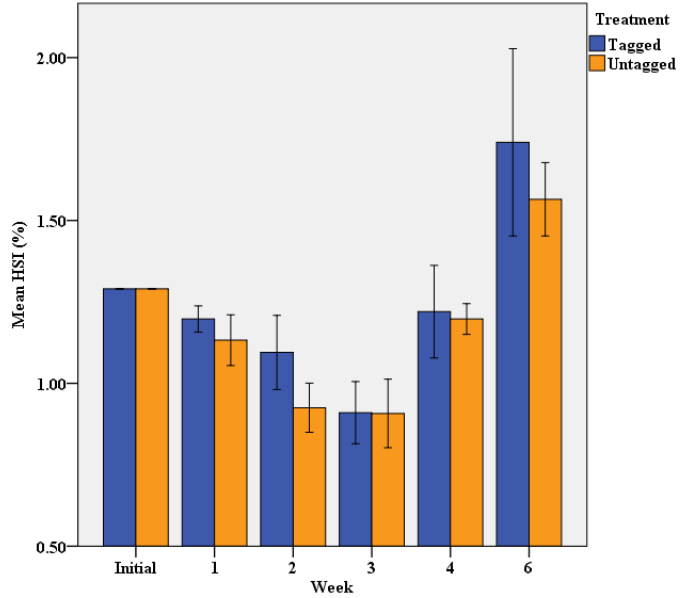


Figure 5. Mean Hepatosomatic Index (HSI) levels of rainbow trout that were either jaw-tagged or untagged over a six-week experimental trial. There was no significant difference between the treatments over the course of the trial ($F_{5, 30} = 0.995, p = 0.44$). $HIS = [\text{liver weight (mg)} / \text{total weight (mg)}] \times 100$.

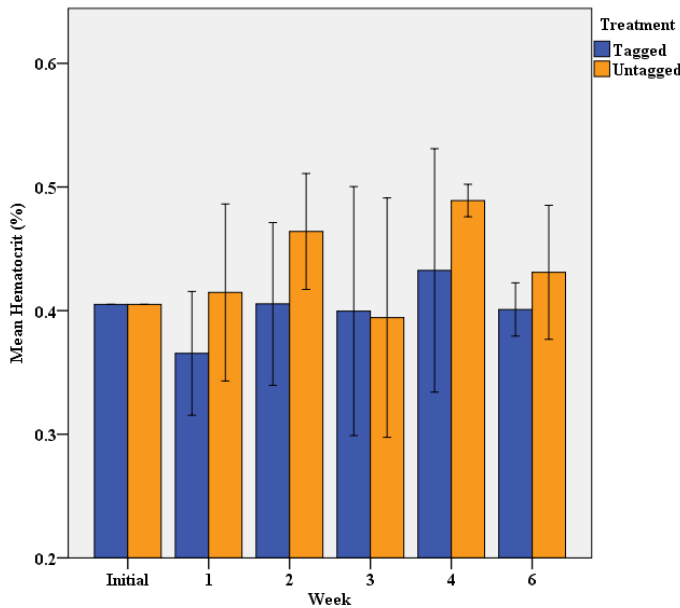


Figure 4. Mean hematocrit levels of rainbow trout that were either jaw-tagged or untagged over a six-week experimental trial. There was no significant difference between the treatments over the course of the trial ($F_{5, 30} = 0.394, p = 0.85$). $\text{Hematocrit (\%)} = [\text{red} / \text{whole blood}] \times 100$.

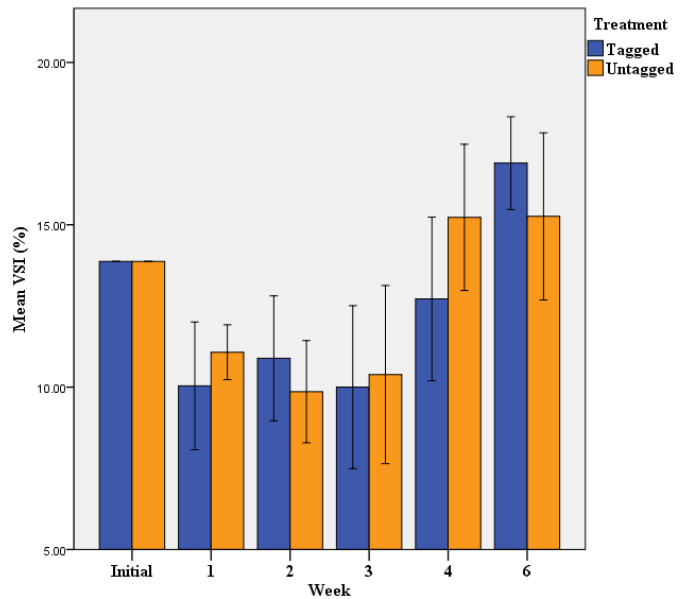


Figure 6. Mean Viscerosomatic Index (VSI) levels of rainbow trout that were either jaw-tagged or untagged over a six-week experimental trial. There was no significant difference between the treatments over the course of the trial ($F_{5, 30} = 1.151, p = 0.356$). $VSI = [\text{viscera weight (mg)} / \text{total weight (mg)}] \times 100$.

Adult lake trout also showed long-term reduced growth after jaw tagging (Deroche, 1963). The increase in growth in this study may have been influenced by the larger size

of the tags used. The No. 16 tag was large enough to accommodate future growth and was also not crimped so tightly to the fish as to restrict mouth movement. Alternatively,

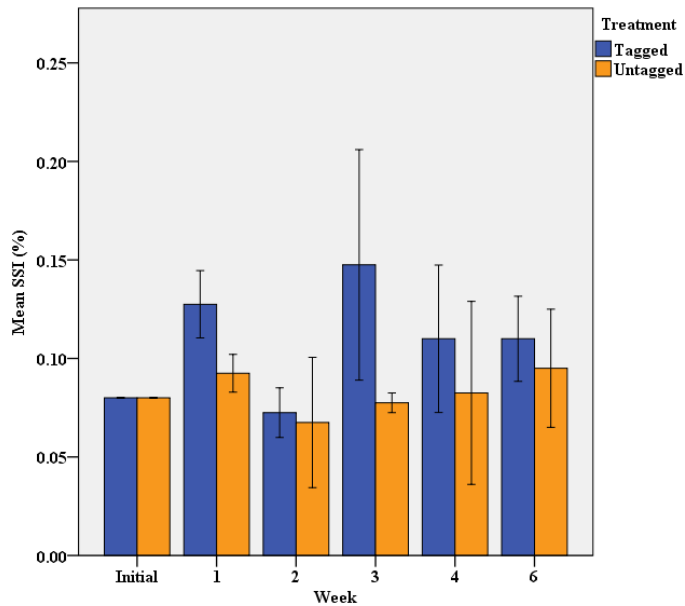


Figure 7. Mean Splenosomatic Index (SSI) levels of rainbow trout that were either jaw-tagged or untagged over a six-week experimental trial. There was no significant difference between the treatments over the course of the trial ($F_{5, 30} = 1.385$, $p = 0.258$). $SSI = [\text{spleen weight (mg)} / \text{total weight (mg)}] \times 100$.

the growth results observed in this study may be attributed to the controlled environment in a hatchery. Rainbow trout were fed pellets ad libitum and did not forage for live food. These conditions allowed the tagged fish to feed without substantial energy expenditure during the tag-healing process.

The inconsistency and high variability of the length, weight, and condition factor data in this study show that both treatments displayed stress from either the jaw tagging or handling events. The jaw tagged rainbow trout in this study did not increase in length, weight, or condition factor until the fourth week, but then quickly rebounded and drastically increased in all three measurements by the sixth week. Similarly, while the untagged group did display a very modest increase in length the first 2 weeks, their weight and condition factor measurements were negatively impacted. This suggests that the weekly handling events may have caused enough stress to impact growth for the first 4 weeks in both treatments. Furthermore, the high degree of variability in condition factor measurements suggests that while both treatments consumed food, neither returned to basal levels until week 4, with the untagged group having a significantly higher condition factor at that point. Both treatments' condition factor then increased drastically by week 6, indicating a possible acclimation to the handling stress. Salmonids in general are highly sensitive to handling, showing increased signs of stress for multiple days post-handling (Laitinen and Valtonen, 1994; Brydges *et al.*, 2009). A 2-

week recovery period has been proposed to allow brown trout to fully recover from a handling event (Pickering *et al.*, 1982). Because both treatments were impacted until week 4 of this study, it is likely that the weekly handling and anesthetizing caused enough stress to impact growth.

Hematocrit is the ratio of red blood cells to whole blood volume. A reduction in hematocrit indicates anemia, resulting in negative effects on energy utilization due to impaired capacity to transport oxygen. If hematocrit levels in rainbow trout are reduced by 22% or more from basal levels, swimming efficiency and oxygen uptake are greatly reduced (Gallaughier *et al.* 1995). Although hematocrit was highly variable for both treatments over the course of the trial, levels remained either within or slightly above the normal range of 30-40% for both treatments (Wells and Weber, 1991). These levels contrast with results from the use of internal tags, which can cause an extended reduction in hematocrit (Millsap *et al.*, 2023; Wagner *et al.*, 2024). Because neither treatment did not fall below typical hematocrit levels for rainbow trout throughout the course of the experiment, it may be concluded that neither jaw tagging nor weekly handling caused an anemic response.

The lack of differences in HSI and VSI between the two treatments indicates that energy partitioning was the same for tagged and untagged fish. The drop in HSI and VSI levels for the first three weeks of the study may indicate a stress event, with energy and lipids used for recovery instead of being stored (Daniels and Robinson, 1986; Kim and Kaushik, 1992; Barton *et al.*, 2002; Dambo *et al.*, 2021). It is possible that both the initial tagging and handling event, in addition to the weekly handling, imparted some level of stress that persisted until stabilizing by the fourth week.

SSI is an index used to indicate immune response in fish (Abbaci *et al.*, 2023). Because the spleen is directly related to immune function and the production of antibodies, an enlarged spleen can signal physiological stress (Shibasaki *et al.*, 2023). The similar SSI levels between the two groups throughout the experiment suggest that the immune responses for jaw-tagged fish were similar to the responses of untagged fish.

Conclusion

This study documented the relatively benign effects of jaw-tagging relatively large adult rainbow trout. The jaw-tagged fish in this study experienced high tag retention rates and minimal mortality. In addition, jaw-tagged fish physiology and growth was similar to untagged control fish. These factors make appropriately sized jaw tags, like those used in this study, a less invasive alternative to internal tags.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ACKNOWLEDGEMENTS

Thanks to Devon Couillard for conducting the initial literature search for this study. Kali Roduner, Lexi Gerber, Tucker Pickett, and Hunter Robinson assisted with data collection. Thanks also to Alison Coulter for her review of this manuscript.

REFERENCES

- Abbaci, S., Mezni, A., Brahmia, S., Hamouda, B., Bensouilah, M., AL-mekhlaf, F. A., Al-Khalifa, M. S., Wadaan, M. A., & Boulkenafet, F. (2023). Assessment of the physiological markers, oxidative stress and neurotoxic effects of nematode *Anisakis* sp. on the *Luciobarbus callensis* (teleosts, cyprinids) in northeast of Algeria. *Journal of King Saud University-Science*, 35(1), 102386.
- Ashton, N. K., Liss, S. A., Walker, R. W., Brown, R. S., Klassen, C. N., Backhouse, S., Bates, P., & Townsend, R. L. (2017). How low can you go? Determining a size threshold for implantation of a new acoustic transmitter in age-0 white sturgeon. *Northwest Science*, 91(1), 69-80.
- Barton, B. A., Morgan, J. D., & Vijayan, M. M. (2002). Physiological and condition-related indicators of environmental stress in fish. In: *Biological Indicators of Aquatic Ecosystem Stress* (111-148), American Fisheries Society.
- Brydges, N. M., Boulcott, P., Ellis, T., & Braithwaite, V. A. (2009). Quantifying stress responses induced by different handling methods in three species of fish. *Applied Animal Behaviour Science*, 116(2), 295-301.
- Coulter, A. A., Coulter, D. P., Lark, E., Fritts, M. W., Davis, C., Glover, D., & Goforth, R. (2022). Sublethal effects of acoustic dummy tag implantation and external tags in silver carp. *North American Journal of Fisheries Management*, 42(6), 1502-1512.
- Dambo, A., Solomon, S. G., Ayuba, V. O., & Okayi, R. G. (2021). Study on condition factor and hepatosomatic index of *Bagrus bayad* (Forsskal, 1775) and *Synodontis nigrita* (Valenciennes, 1840) from Kangimi Reservoir, Kaduna State, Nigeria. *Bayero Journal of Pure and Applied Sciences*, 14(2), 192-197.
- Daniels, W. H., & Robinson, E. H. (1986). Protein and energy requirements of juvenile red drum (*Sciaenops ocellatus*). *Aquaculture*, 53(3-4), 243-252.
- Deroche, S. E. (1963). Slowed growth of lake trout following tagging. *Transactions of the American Fisheries Society*, 92(2), 185-186.
- Felts, E. A., Fincel, M. J., & Graeb, B. D. S. (2021). Angler reporting and tag retention estimates for walleye in Lake Oahe. *Fisheries Research*, 243, 106096.
- Gallaugh, P., Thorarensen, H., & Farrell, A. P. (1995). Hematocrit in oxygen transport and swimming in rainbow trout (*Oncorhynchus mykiss*). *Respiration Physiology*, 102(2-3), 279-292.
- Isermann, D. A., & Knight, C. T. (2005). Potential effects of jaw tag loss on exploitation estimates for Lake Erie walleyes. *North American Journal of Fisheries Management*, 25(2), 557-562.
- Kim, J. D., & Kaushik, S. J. (1992). Contribution of digestible energy from carbohydrates and estimation of protein/energy requirements for growth of rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 106(2), 161-169.
- Laitinen, M., & Valtonen, T. (1994). Cardiovascular, ventilatory and total activity responses of brown trout to handling stress. *Journal of Fish Biology*, 45(6), 933-942.
- Maccrimmon, H. R., & Robbins, W. H. (1979). Suitability of jaw and Atkins streamer tags for marking smallmouth bass, *Micropterus dolomieu*. *Transactions of the American Fisheries Society*, 108(5), 499-501.
- Millsap, E. K., Huysman, N., Gravenhof, D. A., Fincel, M. J., & Barnes, M. E. (2023). Effects of predation tags on growth and stress response in juvenile rainbow trout *Oncorhynchus mykiss*. *Hydrobiology*, 2(3), 467-474.
- Nelson, W. C. (1961). Comparison of jaw, cheek, dart, and spaghetti tags. *The Progressive Fish-Culturist*, 23(3), 137.
- Newman, S. P., & Hoff, M. H. (1998). Estimates of loss rates of jaw tags on walleyes. *North American Journal of Fisheries Management*, 18(1), 202-205.
- Pickering, A. D., Pottinger, T. G., & Christie, P. (1982). Recovery of the brown trout, *Salmo trutta* L., from acute handling stress: a time-course study. *Journal of Fish Biology*, 20(2), 229-244.
- Ricker, W. E. (1942). Creel census, population estimates, and rate of exploitation of game fish in Shoe Lake, Indiana. *Investigations of Indiana Lakes and Streams*, 2, 215-253.
- Rounsefell, G. A., & Kask, J. L. (1945). How to mark fish. *Transactions of the American Fisheries Society*, 73(1), 320-363.
- Schill, D. J., LaBar, G. W., Elle, F. S., & Mamer, E. R. J. M. (2007). Angler exploitation of redband trout in eight Idaho desert streams. *North American Journal of Fisheries Management*, 27(2), 665-669.
- Schuck, H. A. (1942). The effect of jaw-tagging upon the condition of trout. *Copeia*, 1942(1), 33-39.
- Shetter, D. S. (1967). Effects of jaw tags and fin excision upon the growth, survival, and exploitation of hatchery rainbow trout fingerlings in Michigan. *Transactions of the American Fisheries Society*, 96(4), 394-399.
- Shibasaki, Y., Afanasyev, S., Fernández-Montero, A., Ding, Y., Watanabe, S., Takizawa, F., Lamas, J., Fontenla-Iglesias, F., Leiro, J. M., Krasnov, A., Boudinot, P., & Sunyer, J. O. (2023). Cold-blooded vertebrates evolved organized germinal center-like structures. *Science Immunology*, 8, eadf1627.
- Slatick, E. (1976). Comparative retention of dart and jaw tags on chinook salmon and steelhead trout during their spawning migration. *Marine Fisheries Review*, 38, 24-26.
- Smith, L. L., Butler, R. L., & Krefting, L. W. (1952). Movements of marked walleyes, *Stizostedion vitreum vitreum* (Mitchill), in the fishery of the Red Lakes, Minnesota. *Transactions of the American Fisheries Society*, 81(1), 179-196.
- Stauffer, T. M., & Hansen, M. J. (1969). Mark retention, survival, and growth of jaw-tagged and fin-clipped rainbow trout. *Transactions of the American Fisheries Society*, 98(2), 225-229.
- Thorsteinsson, V. (2002). Tagging methods for stock assessment and research in fisheries. *Report of concerted action FAIR CT*, 96, 179.
- Vandergoot, C. S., Brenden, T. O., Thomas, M. V., Einhouse, D. W., Cook, H. A., & Turner, M. W. (2012). Estimation of tag shedding and reporting rates for Lake Erie jaw-tagged walleyes. *North American Journal of Fisheries Management*, 32(2), 211-223.
- Wagner, A., Huysman, N., Kientz, J., Voorhees, J. M., & Barnes, M. E. (2024). Micro-acoustic transmitter implantation impacts juvenile rainbow trout *Oncorhynchus mykiss* growth, hematocrit and splenosomatic index. *Journal of Fisheries Sciences*, 18(6).
- Welch, D. W., Batten, S. D., & Ward, B. R. (2007). Growth, survival, and tag retention of steelhead trout (*O. mykiss*)

- surgically implanted with dummy acoustic tags. *Hydrobiologia*, 582, 289-299.
- Wells, R. M. G., & Weber, R. E. (1991). Is there an optimal haematocrit for rainbow trout, *Oncorhynchus mykiss* (Walbaum)? An interpretation of recent data based on blood viscosity measurements. *Journal of Fish Biology*, 38(1), 53-65.
- Zerrenner, A., Josephson, D. C., & Krueger, C. C. (1997). Growth, mortality, and mark retention of hatchery brook trout marked with visible implant tags, jaw tags, and adipose fin clips. *The Progressive Fish-Culturist*, 59(3), 241-245.