Evaluation of Methods to Minimize Weight Change of Potential Record Fish During the Certification Process

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Abstract: Catching a state record fish is a significant accomplishment in the life of any angler. The need to have a state agency biologist present to verify the record fish can delay the certification of the fish, possibly leading to changes in the fish's weight. Few published studies have directly investigated the impact of preservation method on weight change of fish following capture. We examined four fish species: black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), flathead catfish (*Pylodictis olivaris*), and largemouth bass (*Micropterus salmoides*) to identify the best preservation method for minimizing change in weight post-catch. We evaluated four preservation methods including holding fish alive, on ice, in an ice bath, and in a freezer for either 24 or 48 h. Preservation method and time post-catch significantly affected the weight of fish, but effects varied with species. In general, weights of fish preserved in an ice bath increased 5–10% over 48 h, whereas largemouth bass and flathead catfish that were retained alive lost 3–6% of their weight over 48 h. Conversely, fish preserved in ice and in a freezer appeared to experience minimal change in weight. Results of this study represent the first published investigation of the impact of preservation method on the change in weight of fish post-catch. This information will inform choice of recommendations by management agencies regarding preservation methods for fish that might be state records.

Key words: certification, angler, weight change, Florida

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Catching a certified state record fish is a monumental accomplishment in any angler's life. In Florida, certification of a state record fish follows a procedure implemented by the Florida Fish and Wildlife Conservation Commission (FWC). In this process, a biologist must be present to confirm the species and verify the weight of the fish using a certified scale. However, angling effort primarily occurs on weekends, when limited availability of state biologists can delay certification up to 48 h (Chizinski et al. 2014). There are concerns that the method anglers use to preserve a potential record fish could significantly alter its weight during a prolonged delay in certification. As a result, the angler may not receive the credit deserved for the fish or could be credited erroneously with a new state record.

Studies have investigated the length changes associated with preservation in ethanol, in formalin, or in a freezer for research purposes (Engel 1974, Fowler and Smith 1983, Jennings 1991, Smith and Walker 2003, Ajah and Nunoo 2003) and as it relates to enforcement of regulations (Rice et al. 1989, Natsume 1995, Blackwell et al. 2003, Chesnes et al. 2009, Dunn et al. 2021). Change in weight after preservation in formalin has also been evaluated (Parker 1963, Stobo 1972, Yeh and Hodson 1975). Halliday and Roscoe (1969) evaluated the effect of icing and freezing on the change in weight of marine ground fish species and found that all preservation methods altered length and weight, but the magnitude of change differed by method. Treasurer (1990) found that length and weights of European perch (*Perca fluviatilis*) and northern pike (*Esox lucius*) decreased following freezing. Similarly, Crane et al. (2016) noted a loss in weight after freezing for emerald shiner (*Notropis atherinoides*) and rudd (*Scardinius erythrophthalmus*). However, the effects of various preservation methods

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on weight of freshwater fish after catch have not been researched.

The scientific basis for recommendations regarding fish preservation methods is often minimal or non-existent. For instance, FWC advises anglers awaiting weight certification for a potential record to keep the fish alive if possible, otherwise to place it in ice water. Anglers are further instructed to avoid freezing the fish because it may lose weight through dehydration (FWC 2019). However, there was no scientific basis for these recommendations. Conversely, the International Game Fish Association, which maintains world records for all game fish species, provides no recommendations on preservation methods or short-term requirements for weight certification. Thus, our objective was to identify preservation practices that minimize change in post-catch weight for four Florida popular sportfish species. These results will help natural resource professionals provide anglers with scientifically sound recommendations for post-catch fish preservation practices.

Methods

Experimental Design

Four fish species were selected to evaluate the impact of preservation method on weight after capture: black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), flathead catfish (*Pylodictis olivaris*), and largemouth bass (*Micropterus salmoides*). These species are all popular freshwater sportfish in Florida that collectively represent half of the families for which official Florida state records exist (FWC 2022). We evaluated four preservation methods: (1) fish preserved live in a 560-L cattle tank equipped with a 12-V aerator and housed in a temperature controlled portable shed, hereafter called "live" or "alive"; (2) fish preserved on ice in a 380-L cooler allowed to drain excess water ("ice"); (3) fish preserved in a 50/50 ice-and-water slurry in a 380-L cooler ("ice bath"); and (4) fish preserved frozen in a plastic bag at −18 C ("freezer" or "frozen"). Preservation methods were selected and conducted to align with practices typically available to and used by anglers. Cooler and tank space limitations only allowed for four replicates of each treatment concurrently. Three experimental trials were conducted for each species, each consisting of four replicates per treatment yielding a total of $n = 12$ replicates per treatment for each species. One largemouth bass assigned to live preservation died during the experiment and was excluded from analysis.

Length (TL, mm) and weight (g) values were recorded for live, ice, and ice-bath treatments at time intervals of 0, 6, 12, 24, and 48 h. Freezer fish had lengths and weights recorded at the start of the experiment and were placed in the freezer for either 24 or 48 h. Freezer fish were thawed in water for 4–6 h in the same plastic bag in which they were frozen, then lengths and weights were recorded again. This was done in accordance with state record certification requirements which necessitate accurate length and weight measurements that cannot be recorded from frozen fish. For live fish, water temperature and dissolved oxygen values were recorded for each tank at the time of measurement. Temperatures for live fish varied as result of seasonal and daily temperature variation, despite being housed in an enclosed shed equipped with air conditioning. Black crappie experienced the lowest mean temperature (16.51 C) and the greatest mean range in temperature (4.86 C) across replicates. Largemouth bass (mean = 17.97 C, range = 1.66 C) and bluegill (mean = 20.34 C, range = 2.53 C) experienced similar temperature ranges, and flathead catfish (mean = 24.02 C, range = 2.03 C) experienced the highest temperatures.

Sampling Design

We intended to use only fish of at least the preferred TL (Gabelhouse 1984, Quinn 1989) for each species: flathead catfish, 710 mm; black crappie, 250 mm; largemouth bass, 380 mm; and bluegill, 200 mm. Because it was difficult to capture enough flathead catfish ≥710 mm TL, we reduced the minimum to quality size for this species (i.e., 610 mm). All fish were collected by boat electrofishing (7.5 GPP, Smith-Root Inc., Vancouver, Washington) from local rivers or reservoirs in March and April of 2018 and 2019 except for flathead catfish, which were collected from two rivers in July and August 2018. Following capture, fish were transported in a 1500-L aerated hauling tank to the FWC's Joe Budd Field Office in Gadsden County, Florida. Treatments were randomly assigned to fish, with trials commencing after initial length and weight values were recorded.

Data Analysis

We used measured weights of fish at given intervals to calculate the proportional change in weight after capture. To normalize change-in-weight data, which could include positive, zero, and negative values, we first applied the range method of the normalize function from the "BBmisc" package in program R to rescale changes in weight from 0.01 to 0.99 (R Core Team 2020, Bischl et al. 2017). We then applied an arcsine transformation to the rescaled values to normalize the data. We used ANOVA to compare normalized change in weight among preservation methods at both 24-h and 48-h intervals. When significant variations were detected, Tukey's honest significant difference (HSD) test was used to identify differences among preservation methods. Additionally, repeated measures ANOVA was conducted for live, ice, and ice bath treatments across all time intervals to examine effects of preservation method, time, and method × time on change in weight. The repeated measures design was used to account for remeasuring the same individual at various intervals (Maceina et al. 1994).

Frozen fish were not evaluated in this analysis as they did not include measurements at each time interval. When significant variations were detected, we used contrast analysis to identify differences between preservation methods. All tests were considered significant at $P \leq 0.05$.

Results

Changes After 24 h

Percentage change in weight of black crappie at 24 h was low and similar among frozen, ice, and live preservation methods, whereas black crappie in ice baths gained 6.2% body weight on average (ANOVA; $F_{3,44} = 59.98$, $P < 0.01$; Table 1). Similarly, bluegill change in weight at 24 h was minimal for fish preserved in ice and live. However, bluegill that were preserved frozen lost 2.5% body weight on average, while bluegill preserved in ice baths gained 10.0% body weight on average ($F_{3,44} = 35.20$, $P < 0.01$; Table 1). Correspondingly, flathead catfish change in weight at 24 h was low for ice and frozen preservation methods but this species decreased by 4.8% body weight on average alive and increased by 4.0% body weight on average in ice baths ($F_{3,44} = 137.69$, $P < 0.01$; Table 1). Mirroring results from bluegill and flathead catfish, largemouth bass change in weight at 24 h was minimal for ice and frozen preservation methods but largemouth bass decreased by 3.1% body weight on average alive and increased by 3.2% body weight on average in ice baths ($F_{3,43} = 24.43$, $P < 0.01$; Table 1).

Changes After 48 h

Percentage change in weight of black crappie at 48 h was nearly identical to results 24 h post catch. Change in weight was low for frozen, ice, and live preservation methods but ice baths produced an increase of 6.0% body weight on average ($F_{3,44} = 59.98$, $P < 0.01$; Table 1). Similarly, bluegill change in weight at 48 h was minimal for frozen, ice, and live preservation methods but body weight increased 10.3% on average in ice baths ($F_{3,44} = 47.32$, $P < 0.01$; Table 1). Flathead catfish change in weight at 48 h was also minimal for frozen and ice preservation methods. However, flathead catfish preserved alive lost 5.6% body weight on average while those preserved in ice baths gained 5.2% body weight on average ($F_{3,44} = 83.89$, $P < 0.01$; Table 1). Largemouth bass change in weight at 48 h mirrored results for flathead catfish with minimal change for frozen and ice preservation methods, but largemouth bass lost 3.1% body weight on average preserved alive and gained 4.9% body weight on average in ice baths ($F_{3,43} = 30.107$, $P < 0.01$; Table 1).

Table 1. Mean, standard error (SE), minimum observed (min), and maximum observed (max) values for black crappie (BLCR), bluegill (BLUE), flathead catfish (FHCA), and largemouth bass (LMB) proportional change in weight 24- and 48-h post catch. Superscript letters represent significant variation between preservation methods (Tukey HSD, $P \leq 0.05$).

		24 h				48 h			
Species	Treatment	Mean	SE	Min	Max	Mean	SE	Min	Max
BLCR	Freezer	0.00^a	0.002	–0.01	0.01	0.00^a	0.005	–0.04	0.03
	Ice	0.00^a	0.003	–0.01	0.02	0.00^a	0.002	–0.01	0.01
	Ice bath	0.06^b	0.005	0.03	0.09	0.06^b	0.006	0.02	0.09
	Live	0.00^a	0.322	–0.02	0.02	0.00^a	0.004	–0.02	0.03
BLUE	Freezer	-0.03^a	0.006	–0.07	0.02	-0.01^a	0.006	–0.06	0.02
	Ice	0.01^b	0.005	–0.02	0.04	0.01^a	0.007	–0.02	0.05
	Ice bath	0.10^c	0.007	0.07	0.13	0.10^b	0.008	0.06	0.15
	Live	0.01^b	0.006	–0.02	0.04	0.00^a	0.005	–0.03	0.02
FHCA	Freezer	0.01^b	0.002	0.00	0.02	0.00^b	0.004	–0.02	0.02
	Ice	0.00^b	0.002	–0.01	0.01	0.00^b	0.003	–0.01	0.02
	Ice bath	0.04^c	0.002	0.03	0.05	0.05^c	0.004	0.03	0.07
	Live	-0.05^a	0.003	–0.07	–0.03	-0.06^a	0.005	–0.08	–0.03
LMB	Freezer	-0.01^b	0.002	–0.01	0.01	-0.01^b	0.003	–0.02	0.01
	Ice	0.00^b	0.001	0.00	0.01	0.01^b	0.002	0.00	0.02
	Ice bath	0.03^c	0.003	0.02	0.05	0.05^c	0.005	0.03	0.08
	Live	-0.03^a	0.008	–0.10	0.00	-0.03^a	0.008	–0.10	0.00

Changes Across Time Intervals

Repeated measures ANOVA revealed significant change in weight of black crappie across preservation methods ($F_{2,33} = 92.76$, $P < 0.01$) and time intervals ($F_{4,128} = 21.94$, $P < 0.01$) and identified a significant interaction between preservation method and time interval ($F_{8,128} = 25.63$, $P < 0.01$). Contrast analysis revealed significant variation at 6, 12, 24, and 48 h, with ice-bath fish gaining significantly more weight than ice and live fish (Figure 1). Similarly, bluegill exhibited significant change in weight across preservation methods ($F_{2,33} = 61.93$, $P < 0.01$) and time intervals ($F_{4,128} = 26.58$, $P < 0.01$), and significant interaction between preservation method and time interval ($F_{8,128} = 16.64$, $P < 0.01$). Contrast analysis revealed significant variation at 6-, 12-, 24-, and 48-h intervals, with ice bath fish gaining significantly more weight than ice and live fish (Figure 1). Change in weight of flathead catfish also was affected by preservation method ($F_{2,33} = 185.97$, $P < 0.01$) with significant interaction between preservation method and time interval ($F_{8,128} = 85.33$, $P < 0.01$). However, change in weight was similar across time intervals ($F_{4,128} = 0.46$, $P = 0.76$). Contrast analysis revealed significant variation at 12-, 24-, and 48-h intervals, with ice bath fish gaining significant weight, live fish losing significant weight, and ice fish remaining unchanged (Figure 1). Largemouth bass exhibited significant change in weight across preservation methods ($F_{2,32} = 38.08$, $P < 0.01$) and time intervals ($F_{4,128} = 4.18$,

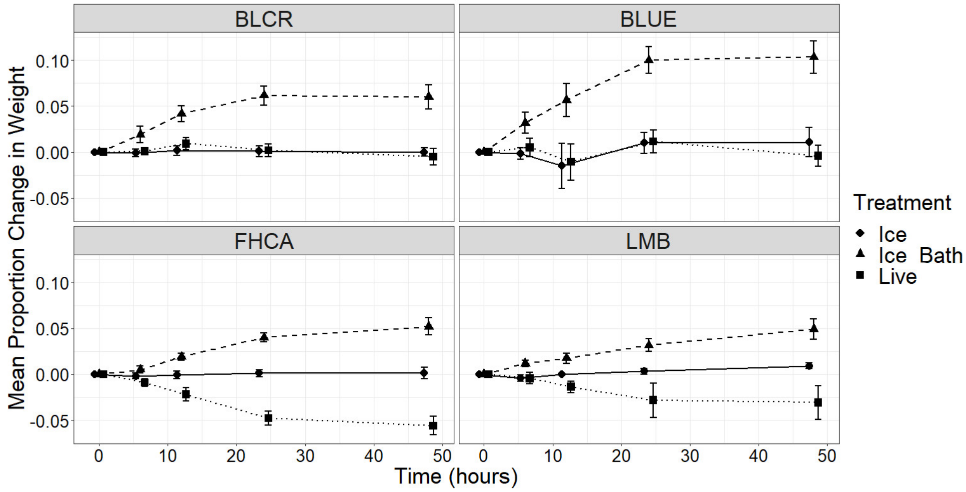

Figure 1. Mean proportional change in weight by preservation method at 6-, 12-, 24-, and 48-h post-catch for black crappie (BLCR), bluegill (BLUE), flathead catfish (FHCA), and largemouth bass (LMB). Error bars denote 95% confidence intervals.

$P<0.01$), as well as significant interaction between preservation method and time interval ($F_{8,128}=23.57$, $P<0.01$). Contrast analysis revealed significant variation at 12-, 24-, and 48-h intervals, with ice-bath fish gaining significant weight, live fish losing significant weight, and ice fish remaining unchanged. (Figure 1).

Discussion

Our results indicate that preservation method can significantly affect the change in weight of fish 6–48 h post-catch. Additionally, the impact of these preservation methods can vary depending on species and length of time a fish is held. For all species, holding fish in an ice bath increased the weight of a fish, but the amount of increase varied among species. When held alive, flathead catfish and largemouth bass lost a significant amount of weight, but weights of black crappie and bluegill changed only slightly.

The main purpose of this study was to evaluate methods for minimizing weight loss post-catch and to provide recommendations regarding those methods. However, our results show that weight gain, not loss, is a greater concern. Weight gains in fish preserved in an ice bath were not predicted but could have been expected, as a dead freshwater fish, immersed in water and unable to osmoregulate, absorbs water and thus gains weight (Evans and Claiborne 2009). Not surprisingly, the weight of the larger predatory species that were held alive decreased, likely a result of several factors including stress, metabolism, and regurgitation. Vignon and Dierking (2011) observed frequencies of regurgitation in grouper (*Epinephelinae*) ranging from 8.2% to 22.9%. During this study, 1 of 12 (8.33%) largemouth bass held alive and 4 of 12 (33.33%) flathead catfish regurgitated food items, contributing to the greater mean decline in weight within both species.

These findings represent the first published evaluation of the impacts of multiple preservation methods on change in weight of freshwater fish post-catch. However, each species evaluation was conducted within 3–4 wk intervals that represented narrow seasonal and water-temperature variations. Results may have been different if the study was conducted at different times of the year or under different ambient and water temperatures, particularly for live-held fish. For example, during the spawning season, the weight of eggs can account for as much as 10% of the body weight of a gravid female largemouth bass (Davis and Lock 1997). Larger fish, like largemouth bass and flathead catfish, preserved alive, might also have experienced more stress than smaller fish because of their larger size relative to the holding tank. The stress of confinement in a livewell has been documented to elicit negative physiological responses in black bass, in some cases leading to mortality (Gustaveson et al. 1991, Cooke et al. 2002, Suski et al. 2003, Dinken et al. 2022). It is unlikely that most anglers would have a tank larger than the one used in these experiments, thus our study likely represented minimum containment stress situations for angler-caught fish. Future research of impacts of preservation method on weight change of fish post-catch should focus on broader time windows, a wider range of ambient temperatures, and evaluation of additional popular sportfish species.

The Florida state record flathead catfish was caught from the Yellow River on Sunday, 30 June 2019. The fish was held in an ice bath until it was certified the next day at a weight of 69 lbs. 5 oz, which broke the prior record of 63 lbs. 13 oz. Our findings suggest that a flathead catfish held in an ice bath over a 24-h period gains approximately 4% of its body weight; thus, this fish may have weighed around 66 lbs. 8 oz at capture. Although that weight still would have broken the record, the margin would have been cut in half. However, if the fish had been captured at the certified weight of 66 lbs. 8 oz and then held alive for 24 h, our results suggest that it may have weighed around 63 lbs. 5 oz at certification (–4.8% weight change). Under that scenario, the fish would have fallen 7 oz short of the state record simply because of the preservation method used.

Natural resource management agencies should revisit management recommendations when the scientific basis of those recommendations is questioned. Our findings indicate that for some species, preserving fish in an ice bath or alive as recommended by FWC can result in the greatest change in weight among four preservation techniques. Thus, FWC should revise its recommendations to ensure that certified weights of possible state-record fish more accurately reflect weight at capture. Agencies may also consider increasing the margin required to replace the current state record or disallowing record size fish which may have experienced a significant alteration in weight as a result of preservation method. Natural resource professionals depend on the trust of the public based on credibility as experts in their area of study. As such, it is important that they identify and investigate areas in which knowledge gaps exist. Any management recommendations should be based on the best available science, and it is our duty to build upon and continue to improve available information.

Based on our findings, to minimize change in weight we suggest that anglers either hold a fish in a cooler with ice and the drain plug pulled, or freeze it in a plastic bag and thaw it in the same bag in water before certification. Thawing fish outside of a plastic bag is not reflective of methods evaluated in this study and likely would yield similar results as our ice bath treatment. Smaller fish such as bluegill and black crappie could be preserved alive with lower risk of change in weight. Conversely, preserving larger fish such as flathead catfish and largemouth bass alive may risk significant weight loss due to regurgitation or metabolic processes.

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Literature Cited

Ajah, P. O. and F. K. E. Nunoo. 2003. The effects of four preservation methods on length, weight, and condition factor of the clupeid *Sardinella aurita* Val. 1847. Journal of Applied Ichthyology 19:391–393.

Bischl, B., M. Lang, J. Bossek, D. Horn, J. Richter, and D. Surmann. 2017. BBmisc: miscellaneous helper functions for B. Bischl. R package version 1.11.

Blackwell, B. G., M. J. Hubers, and R. G. Losco. 2003. Postharvest length changes of angler-caught walleyes. North American Journal of Fisheries Management 23:770–778.

Chesnes, T. C., R. E. Waldner, and C. S. Krahforst. 2009. Postmortem length changes in six Florida fish species stored on ice. North American Journal of Fisheries Management 29:1242–1252.

Chizinski, C. J., D. R. Martin, K. L. Pope, T. J. Barada, and J. J. Shuckman. 2014. Angler effort and catch within a spatially complex system of small lakes. Fisheries Research 154:172–178.

Cooke, S. J., J. F. Schreer, D. H. Wahl, and D. P. Philipp. 2002. Physiological impacts of catch-and-release angling practices on largemouth bass and smallmouth bass. Pages 489–512 *in* D. P. and M. S. Ridgway, editors. Black bass: ecology, conservation, and management. American Fisheries Society, Symposium 31, Bethesda, Maryland.

Crane, D. P., C. C. Killourhy, and M. D. Clapsadl. 2016. Effects of three frozen storage methods on wet weight of fish. Fisheries Research 175:142–147.

Davis, J. T. and J. T. Lock. 1997. Largemouth bass: biology and life history. Southern Regional Aquaculture Center, Publication No. 200, Stoneville, Mississippi.

Dinken, C. P., K. R. Keretz, H. L. Schramm Jr., L. Petrie-Hanson, M. W. Schilling, and P. J. Allen. 2022. The effects of water temperature and simulated angling on the physiological stress response of largemouth bass. Transactions of the American Fisheries Society 151:487–506.

Dunn, K., J. Moran, J. Sexton, T. Lange, and K. Bonvechio. 2021. Quantifying and identifying factors influencing length changes in popular freshwater fishes preserved in ice. Journal of the Southeastern Association of Fish and Wildlife Agencies 9:54–60.

Engel, S. 1974. Effects of formalin and freezing on length, weight and condition factor of cisco and yellow perch. Transactions of the American Fisheries Society 103:136–138.

Evans, D. H. and J. B. Claiborne. 2009. Osmotic and ionic regulation in fishes. Pages 295–366 *in* D. H. Evans, editor. Osmotic and ionic regulation: cells and animals. CRC Press, Boca Raton, Florida.

Fowler, G. M. and S. J. Smith. 1983. Length change in silver hake (*Merluccius bilinearis*) larvae: effects of formalin, ethanol, and freezing. Canadian Journal of Fisheries and Aquatic Sciences 40:866–870.

Florida Fish and Wildlife Conservation Commission [FWC]. 2019. How to certify a state record freshwater fish. Florida Fish and Wildlife Conservation Commission, Tallahassee. <https://myfwc.com/media/15724/fwrecord application.pdf>. Accessed 15 June 2022.

_____. 2022. Record fish. Florida Fish and Wildlife Conservation Commission, Tallahassee. <https://www.bigcatchflorida.com/state-record.aspx>. Accessed 15 June 2022.

Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273–285.

Gustaveson, A. W., R. S. Wydoski, and G. A. Wedemeyer. 1991. Physiological response of largemouth bass to angling stress. Transaction of the American Fisheries Society 120:629–636.

Halliday, R. G. and B. Roscoe. 1969. The effects of icing and freezing on the length and weight of groundfish species. International Commission for the Northwest Atlantic Fisheries Research Document 69(2):79–93.

Jennings, S. 1991. The effects of capture, net retention, and preservation upon lengths of larval and juvenile bass, *Dicentrarchus labrax* (L.). Journal of Fish Biology 38:349–357.

Maceina, M. J., P. W. Bettoli, and D. R. DeVries. 1994. Use of a split-plot analysis of variance design for repeated-measures fishery data. Fisheries 19(3): 14–20.

Natsume, M. 1995. Shrinkage of fish body length by rigor mortis. Scientific Reports of Hokkaido Fisheries Experimental Station 47:1–6.

Parker, R. R. 1963. Effects of formalin on length and weight of fishes. Journal of the Fisheries Research Board of Canada 20:1441–1455.

Quinn, S. P. 1989. Evaluation of a length-categorization system for flathead catfish. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:146–152.

Rice, K. W., R. K. Riechers, G. W. Standard, and J. E. Clark. 1989. Shrinkage of spotted seatrout held in ice. Texas Parks and Wildlife Department, Fisheries Division, Management Data Series 15:1–15.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Smith, B. B. and K. F. Walker. 2003. Shrinkage of 0+ carp (*Cyprinus carpio* L.) after preservation in ethanol. Marine and Freshwater Research 54:113–116.

Stobo, W. T. 1972. Effects of formalin on the length and weight of yellow perch. Transactions of the American Fisheries Society 101:362–364.

Suski, C. D., S. S. Killen, M. B. Morrissey, S. G. Lund, and B. L. Tufts. 2003. Physiological changes in largemouth bass caused by live-release angling tournaments in southeastern Ontario. North American Journal of Fisheries Management 23:760–769.

Treasurer, J. W. 1990. Length and weight changes in perch (*Perca fluviatilis*) and pike (*Esox lucius*) following freezing. Journal of Fish Biology 37:499–500.

Vignon, M. and J. Dierking. 2011. Prey regurgitation and stomach vacuity among groups and snappers. Environmental Biology of Fishes 90:361–366.

Yeh, C. F. and R. G. Hodson. 1975. Effects of formalin on length and weight of bluegill and white crappie from Lake Nasworthy, Texas. Southwestern Naturalist 20:315–322.