Received: 20 September 2022 | Revised: 30 October 2022 | Accepted: 1 November 2022

DOI: 10.1111/fme.12605

Fisheries Management and Ecology

WILEY

ARTICLE

Effects of elevated water temperature on cutthroat trout angler catch rates and catch-and-release mortality in Idaho streams

Kevin A. Meyer[1] | Joshua L. McCormick[1] | Joseph R. Kozfkay[2] | Jeff C. Dillon[2]

[1]Idaho Department of Fish and Game, Nampa, Idaho, USA

[2]Idaho Department of Fish and Game, Boise, Idaho, USA

Correspondence
Kevin A. Meyer, Idaho Department of Fish and Game, 1414 E. Locust Lane, Nampa, Idaho 83686, USA.
Email: kevin.meyer@idfg.idaho.gov

Abstract

The concern is growing that angling may need to cease at elevated summer water temperatures to protect salmonid populations. Cutthroat Trout *Oncorhynchus clarkii* in streams were caught, marked and released using artificial dry flies at temperatures from 13.5 to 25.7°C to evaluate whether subsequent recapture with backpack electrofishing (an index of relative survival) was reduced when the water temperature was elevated at the time of landing, and to evaluate the effect of water temperature on angler catch rates. The electrofishing recapture rate of marked fish (i.e. relative survival) declined as water temperature increased, from 0.58 for fish landed at <21°C to 0.35 at 21–23°C and 0.17 at >23°C. However, angler catch declined similarly as water temperature increased, from 5.2 fish/h at <21°C to 4.1 fish/h at 21–23°C and 1.2 fish/h at >23°C. After accounting for both declines, fish mortality/angler might be higher at cooler water temperatures than at warmer temperatures. Therefore, inhibiting fishing at elevated water temperatures may not benefit trout populations any more than at cooler temperatures.

KEYWORD
hoot owl regulations

1 | INTRODUCTION

Climate change models predict large reductions in salmonid occupancy of flowing waters during the 21st century as some streams become too warm to support cold-water fish populations (Filipe et al., 2013; Isaak, Muhlfeld, et al., 2012; Isaak, Wollrab, et al., 2012). In addition to restricting the ability of cold-water species, such as salmonids, to occupy warmer sections of streams, elevated stream temperature will also likely impact their ability to tolerate and recover from human-induced stressors (reviewed in McCullough et al., 2009). One stressful event to which salmonids are commonly exposed is human handling when they are caught and released by anglers.

Catch-and-release angling in recent decades has become popular among all types of anglers, especially trout anglers (Policansky, 2002, 2008). While catch-and-release angling, whether voluntary or mandatory, can be effective in limiting fishing-related mortality in recreational fisheries (e.g. Mallet & Thurow, 2022), not all fish released by anglers survive (High & Meyer, 2014; Hunsaker et al., 1970; Schisler & Bergersen, 1996). In general, the level of fishing mortality caused by anglers during catch-and-release is directly related to physical injury and stress level a fish experiences while being hooked, landed and handled prior to release (reviewed by Muoneke & Childress, 1994, and Bartholomew & Bohnsack, 2005). Some stress factors, such as fight and air exposure times during landing and releasing (Lamansky Jr. & Meyer, 2016; Roth et al., 2018), and terminal tackle used (Schisler & Bergersen, 1996; High & Meyer, 2014) are within the control of anglers. Other factors, such as the water temperature that fish experience while being hooked and landed, cannot be controlled by anglers unless they cease fishing when the temperature is elevated.

Temperature-related angling restrictions on trout and salmon in North America (colloquially termed "hoot owl regulations") have been implemented in some Canadian provinces (Dempson et al., 2001) and some U.S. states (Boyd et al., 2010), and have been considered in Europe (Pinder et al., 2019). A study in Montana, USA, found that angling on days in which maximum water temperature was ≥23°C resulted in 13% mortality on rainbow trout (*Oncorhynchus mykiss*) and 3% mortality on brown trout (*Salmo trutta*), which were caught and held in sentinel cages for 3 days, compared to zero mortality on both species caught and held on days in which maximum water temperature never exceeded 20°C (Boyd et al., 2010). However, the differential mortality of free-ranging trout relative to water temperature at the time of capture has not been investigated. Moreover, angler catch rates for stream-dwelling salmonids may decline at higher water temperatures (McMichael & Kaya, 1991; Van Leeuwen et al., 2021), thereby dampening the effect of elevated water temperature on lotic fish populations by reducing the number of fish landed by anglers when temperatures are warmer. Our objective was to determine if elevated water temperature affected angler catch rates and catch-and-release mortality in stream-dwelling trout populations.

2 | METHODS

Our study was in four streams in Eastern Idaho, USA, each with summer water temperatures that were relatively high but that nonetheless maintained relatively abundant populations of stream-resident trout, primarily cutthroat trout (*O. clarkii*). Stream reaches where angling occurred were 1.0–1.5 km in length, 3–11 meters in wetted width, 0.6%–1.9% gradient, and 1780–1900 meters in elevation (Table 1). Angling regulations prohibited the harvest of cutthroat trout in all study streams.

Angling occurred from July 27 to August 12, 2020, during some of the warmest days of the year. The angling method was standardised across all four anglers involved in the study. Anglers generally fished from about 0900 to 1800 h each day as water temperatures increased from an overnight low towards a late-afternoon daily peak (Figure 1). One or two anglers fished each reach over part or all of any given day, and each reach was fished 1–3 times over the course of the study. Anglers recorded their start and end times for each period of angling, and time recording was halted throughout the day for any nontrivial interruptions in angling effort (e.g. lunch break). Anglers used 4- or 5-weight fly rods and size 10–14 artificial dry flies to capture fish, and a landing net was used to minimise handling stress.

For each fish caught, species were recorded and the total length (TL = cm) was measured in the net underwater using a tape measure. Nearly all fish landed were cutthroat trout. Brook trout (*Salvelinus fontinalis*) were not included in the survival analysis because only a few were landed (n = 5), and the survival of caught-and-released salmonids at elevated temperatures differs among species (Boyd et al., 2010). The time of capture was recorded, and water temperature at the time of capture was measured in the thalweg with a digital thermometer. Fight time was minimised to the extent possible but was not recorded explicitly. Landed fish were tagged with an individually numbered anchor tag inserted just below the base of the dorsal fin following standard procedures (Guy et al., 1996). We assumed that tagging mortality was inconsequential (Meyer & Schill, 2014). An adipose fin clip was used to determine if anchor tags were shed prior to recapture. No fish were landed by anglers more than once. Fish were released at the point of capture, with no air exposure during the catch-and-release process.

Post-release survival was evaluated by recapturing tagged fish on August 25–27, 2020, using a single-backpack electrofishing pass through each stream reach where angling occurred. Electrofishers were set at 60 Hz, 25% duty cycle and enough volts to emit about 100 watts of average power output, which is efficient for capturing stream-dwelling salmonids (Meyer et al., 2021). Captured fish were identified to species, examined for anchor tags and adipose fin clips (no recaptured fish lost their tag), measured in total length (TL = cm) and released. The recapture probability of fish landed by anglers was not estimated because only one electrofishing pass was conducted but was clearly not 100% with backpack electrofishing in the study streams (cf. Chiaramonte et al., 2020). Moreover, some landed fish likely emigrated out of study reaches prior to electrofishing. For these reasons, estimates of relative survival (i.e. recapture rate of angled fish) did not represent actual survival and were therefore only meaningful for comparison.

The effect of water temperature on catch-and-release relative survival was modelled using logistic regression. Each landed fish was the experimental unit, with fish landed and tagged by anglers

TABLE 1 Characteristics of streams in Eastern Idaho where cutthroat trout and brook trout were landed in summer 2020 to evaluate the effect of elevated summer water temperatures on relative survival and angler catch rates

Stream	Latitude	Longitude	Reach length (km)	Elevation (m)	Gradient (%)	Mean width (m)	Fish landed	
							n	Mean length (cm)
Willow Creek	43.311°	111.777°	1.2	1800	1.9	10.8	36	24.9
Canyon Creek	43.785°	111.445°	1.4	1787	0.6	3.8	7	27.0
McCoy Creek (lower)	43.159°	111.206°	1.5	1860	1.0	8.7	13	29.5
McCoy Creek (upper)	43.161°	111.275°	1.2	1887	1.0	6.4	29	24.1
Clear Creek	43.162°	111.286°	1.0	1896	0.9	3.2	15	26.2

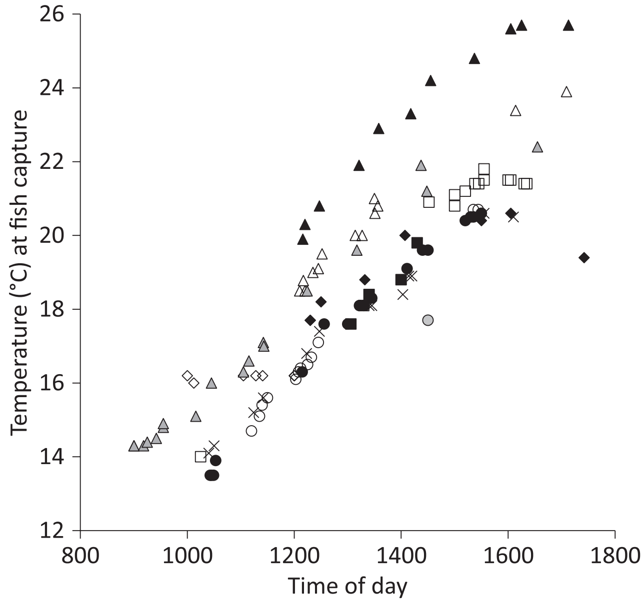

FIGURE 1 Water temperature at the time cutthroat trout were landed and tagged by fly anglers in summer 2020 in Eastern Idaho streams. Each symbol depicts data at one reach (see Table 1), with the symbol colour indicating different days in the same reach

treated as the response variable (0 = not recaptured, 1 = recaptured). To account for differences among streams that may have affected individual recaptures of tagged fish, the stream was included as a random effect. The fish length was included as a fixed effect because relative mortality could depend on fish length. Angler and instantaneous water temperature at the time of landing were included as fixed effects. Angler was included to account for potential differences in handling stress of landed fish among anglers. Finally, fish length × temperature and angler × temperature interaction terms were included to evaluate whether any effect of water temperature on the relative survival of caught-and-released fish was mediated by fish length or angler.

The effect of water temperature on catch rate was examined using general linear models. Each landed fish (including brook trout) was the experimental unit. The catch rate (fish landed/h) of each landed fish (i.e. the response variable) was calculated by dividing 60 by the number of minutes since the last fish was landed. For example, for a fish that was landed 25 min after the previous fish, the catch rate for that fish was calculated as 60/25 = 2.4 fish/h. For each angler's last fish caught on each day, if the fishing effort did not end at the time a fish was landed, then any extra fishing time that resulted in no fish landed was added to the time recorded for the last fish (average = 18 min). Predictor variables included a random effect for stream and fixed effects for angler and water temperature at the time of landing. The angler × temperature interaction term was included to evaluate whether the effect of water temperature on catch rate was mediated by the angler.

For both analyses, candidate models included all combinations of predictive factors, but the random effect of the stream was included in all candidate models. Models were ranked using Akaike's information criterion corrected for small sample size (AIC_c; Burnham & Anderson, 2002), the most plausible models were those with AIC_c scores within 2.0 of the best model and AIC_c weights (w_i) were used to assess the relative plausibility of each model (Burnham & Anderson, 2004). Coefficients were estimated for all plausible models, but coefficients were only considered influential if their 90% confidence intervals (CIs) did not include zero. This more lenient interpretation of CIs was used to balance type I and type II errors in light of the relatively small sample size. All statistical analyses used SAS (SAS Institute Inc, 2009).

3 | RESULTS

Of 100 cutthroat trout and 5 brook trout landed, cutthroat trout ranged from 17 to 37 cm TL and brook trout ranged from 20 to 26 cm TL. The length of landed fish was similar in all streams (Table 1). Water temperature at the time fish were landed ranged from 13.5 to 25.7°C (Figure 1). During electrofishing, 50 tagged cutthroat trout were recaptured (brook trout were not tagged, so no tagged brook trout were recaptured).

Relative survival of angled and tagged cutthroat trout (across all streams combined) generally declined as water temperature increased, from 0.58 (SE = 0.06) for fish landed at <21°C to 0.35 (SE = 0.10) at 21–23°C and 0.17 (SE = 0.12) at >23°C (Figure 2). The most parsimonious model explained variation in cutthroat trout catch-and-release relative survival as a function of fish length, the water temperature at the time of fish landing and angler (Table 2). Three additional models were also supported, with various combinations of these parameters and the interaction term, fish length × temperature. In the most parsimonious model, relative survival was reduced at higher water temperatures for smaller fish and fish caught and released by angler 3 compared to angler 1 (Table 3). Effects of fish length and angler were also influential in the next best model.

Angler catch rate also generally declined as water temperature increased, with a rate of 5.2 fish/h (SE = 0.6 fish/h) at <21°C, 4.1 fish/h (SE = 0.9 fish/h) at 21–23°C and 1.2 fish/h (SE = 0.4 fish/h) at >23°C (Figure 2). The most parsimonious model explained variation in angler catch rate as a function of water temperature at the time of fish landing (Table 4). The null (stream only) model, a model with water temperature and angler and a model with only angler were also supported. Water temperature was not influential in the most parsimonious model but was influential in the third best model (Table 5), which indicated that catch rates declined at higher water temperatures. Catch rates also varied among anglers (Table 5).

4 | DISCUSSION

We found that both relative survival and catch rate of stream-dwelling trout declined as water temperature increased. This concurs with prior studies demonstrating that catch-and-release survival was negatively related to elevated water temperature for stream-dwelling rainbow trout, brown trout, mountain whitefish (*Prosopium williamsoni*; Boyd et al., 2010) and Atlantic salmon (*S. salar*; Van Leeuwen et al., 2021), but was also negatively related to angler catch rates for stream-dwelling rainbow trout (McMichael & Kaya, 1991), brown trout (Taylor, 1978) and Atlantic salmon (Dempson et al., 2002; L'Abée-Lund & Aspås, 1999; Van Leeuwen et al., 2021). The decline in angler catch rate at higher water temperatures is important because anglers presumably will either curtail their fishing effort due to lack of success (Askey & Johnston, 2013; Chizinski et al., 2014), or they will handle fewer fish per hour spent angling at warmer water temperatures than at cooler temperatures. Consequently, inhibiting fishing at elevated water temperatures may be no more beneficial to trout populations than at lower water temperatures. Moreover, fish populations can offset the loss of individuals to angling-related mortality via compensatory density-dependent processes such as increased rates of growth and recruitment and decreased rates of natural mortality (McFadden, 1977; Rose et al., 2001), so it is difficult to ascertain what population-level differences (if any) would materialise between trout streams with and without angling closures triggered by elevated water temperatures.

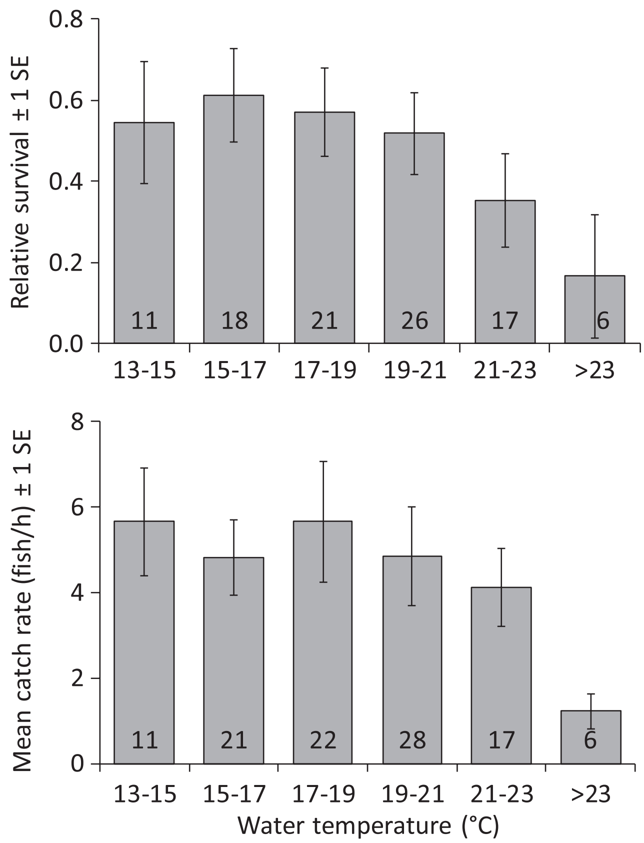

FIGURE 2 Relative survival of cutthroat trout landed and marked by anglers (i.e., recapture rate of landed and tagged fish), and mean angler catch rate of all trout (including brook trout), in relation to summer instantaneous water temperature at the time that fish were landed by fly anglers in summer 2020 in Eastern Idaho streams. The sample size for each temperature bin is provided inside the bars.

We observed catch inequality among anglers, which has been widely reported in freshwater recreational fisheries (e.g. Baccante, 1995; Bloom, 2013; Ward et al., 2013). Differences in the survival of released fish among anglers were surprising because all aspects of our angling practices (i.e. fishing gear, landing nets, air exposure and fight time) were standardised, and our fish handling experience was extensive and equivalent. This finding suggests that even subtle differences in angling and handling practices can result in measurable differences in angler-induced mortality, and supports the assertion that educating anglers on best-handling practices for caught-and-released fish can be beneficial (reviewed in Brownscombe et al., 2017), especially for anglers that catch and release the most fish. Most agencies and provinces provide guidance on best handling and release practices for anglers (Pelletier et al., 2007).

The most important limitation of our study that could have affected our conclusions was that our pilot study had a relatively small sample size, so our findings were limited by a lack of statistical power

TABLE 2 Comparison of logistic regression models constructed to evaluate the relative survival of cutthroat trout in relation to elevated summer water temperatures in summer 2020 in Eastern Idaho streams.

Model	Log likelihood	AIC_c	ΔAIC_c	w_i	AUC
Length + temperature + angler + stream	121.70	136.94	0.00	0.28	0.77
Length + angler + stream	125.06	137.98	1.04	0.17	0.75
Length + temperature + length*temperature + angler + stream	121.22	138.82	1.88	0.11	0.78
Temperature + stream	132.60	138.85	1.91	0.11	0.70
Temperature + angler + stream	126.22	139.13	2.19	0.10	0.75
Temperature + length + stream	131.16	139.58	2.64	0.08	0.69
Null (stream only)	136.15	140.28	3.34	0.05	0.67
Angler + stream	129.91	140.55	3.61	0.05	0.74
Length + stream	134.53	140.79	3.85	0.04	0.67
Length + temperature + angler + temperature*angler + stream	120.45	142.95	6.01	0.01	0.77

Note: Estimates of log-likelihood, Akaike's information criteria (AIC_c), change in AIC_c (ΔAIC_c), AIC_c weights (w_i), and area under the curve (AUC) were all used to assess plausible models. All parameters were fixed effects except stream, which was a random effect included in all models.

that caused imprecise parameter estimates. Our findings agree with prior research (Boyd et al., 2010; Dempson et al., 2002; L'Abée-Lund & Aspås, 1999; McMichael & Kaya, 1991; Taylor, 1978; Van Leeuwen et al., 2021), but we nevertheless encourage additional research on effects of elevated stream temperature on angler catch rates and catch-and-release survival to more fully elucidate these relationships. Our study was also limited to one summer, only a few streams, involved only one trout species and used one type of terminal tackle, so our results relating water temperature to angler catch rates and post-release relative survival may differ in other seasons, streams, species and settings. While some movement of tagged fish likely occurred prior to recapture sampling, our results would be biased if the level of movement was a function of water temperature at the time the fish landed. Post-release movement of stream-dwelling salmonids in relation to water temperature has not been investigated to our knowledge, but studies of anadromous salmonids have shown

TABLE 3 Coefficient estimates and 95% confidence intervals (CIs) for the most plausible models constructed to evaluate the relative survival of cutthroat trout in relation to elevated summer water temperatures in summer 2020 in eastern Idaho streams

Coefficient	Estimate	90% CI
Model: length + temperature + angler + stream		
Intercept	1.23	−2.38 to 4.84
Fish length	0.08	0.00 to 0.16
Water temperature	−0.16	−0.31 to −0.01
Angler 2	−1.14	−2.85 to 0.57
Angler 3	−1.33	−2.47 to −0.19
Angler 4	0.49	−0.56 to 1.53
Stream	0.32	−0.53 to 1.16
Model: length + angler + stream		
Intercept	−1.99	−4.12 to 0.13
Fish length	0.08	0.01 to 0.16
Angler 2	−1.13	−2.77 to 0.51
Angler 3	−1.17	−2.25 to −0.09
Angler 4	0.64	−0.35 to 1.63
Stream	0.32	−0.41 to 1.05
Model: length + temperature + length × temperature + angler + stream		
Intercept	6.78	−7.19 to 20.74
Fish length	−0.14	−0.67 to 0.40
Water temperature	−0.46	−1.20 to 0.28
Fish length * water temperature	0.01	−0.02 to 0.04
Angler 2	−1.02	−2.73 to 0.70
Angler 3	−1.30	−2.43 to −0.17
Angler 4	0.43	−0.62 to 1.49
Stream	0.32	−0.51 to 1.15
Model: temperature + stream		
Intercept	3.00	0.19 to 5.82
Water temperature	−0.16	−0.30 to −0.01
Stream	0.34	−0.43 to 1.11

Note: All parameters were fixed effects except stream, which was a random effect included in all models.

TABLE 5 Coefficient estimates and 95% confidence intervals (CIs) for the most plausible models constructed to evaluate catch rates of trout in relation to elevated summer water temperatures in summer 2020 in eastern Idaho streams

Coefficient	Estimate	90% CI
Model: temperature + stream		
Intercept	10.88	4.49 to 17.27
Water temperature	−0.32	−0.64 to 0.01
Stream	4.12	−2.58 to 10.81
Model: null (stream only)		
Intercept	4.92	3.19 to 6.65
Stream	3.19	−2.21 to 8.58
Model: temperature + angler + stream		
Intercept	12.07	5.72 to 18.41
Water temperature	−0.32	−0.64 to −0.01
Angler 2	−3.30	−6.52 to −0.08
Angler 3	−2.57	−4.81 to −0.34
Angler 4	−1.05	−3.20 to 1.09
Stream	3.61	−2.60 to 9.81
Model: angler + stream		
Intercept	5.90	4.00–7.79
Angler 2	−3.45	−6.73 to −0.18
Angler 3	−2.41	−4.66 to −0.15
Angler 4	−0.88	−3.03 to 1.28
Stream	2.85	−2.25 to 7.96

Note: All parameters were fixed effects except stream, which was a random effect included in all models.

TABLE 4 Comparison of linear regression models constructed to evaluate catch rates of trout in relation to elevated summer water temperatures in summer 2020 in eastern Idaho streams

Model	Log-likelihood	AIC_c	ΔAIC_c	w_i
Temperature + stream	640.10	648.49	0.00	0.34
Null (stream only)	642.73	648.97	0.48	0.27
Temperature + angler + stream	634.29	649.43	0.94	0.22
Angler + stream	637.18	650.03	1.54	0.16
Temperature + angler + temperature*angler + stream	633.53	655.84	7.35	0.01

no negative temperature effect on upstream arrival at spawning locations of fish landed by anglers (Jensen et al., 2010; Lennox et al., 2015; Twardek et al., 2018), even at elevated water temperatures (Richard et al., 2014). To minimise the distance of electrofishing recapture effort, we kept each angling reach short (≤1.5 km), so we cannot be certain that angling the same reach over multiple days (sometimes 2 consecutive days) did not affect angler catch rates. However, we saw no evidence of reduced catch rates at later dates, and we never landed the same fish twice, which suggests that our angling effort was relatively light in each segment we fished. Finally, smaller fish may have experienced lower relative survival than larger fish, as our findings suggest, but this relationship may have simply been the result of higher backpack electrofishing capture efficiency for larger trout (Chiaramonte et al., 2020; Meyer & High, 2011).

Climate change will clearly be one of the most influential factors in the sustainability of recreational fisheries in the 21st century (Jeanson et al., 2021), especially for cold-water species such as salmonids (Wenger et al., 2011). As climate change increasingly causes warmer stream water temperatures, concern regarding the stress imposed by catch-and-release angling on stream-dwelling salmonid populations is growing in both the scientific literature (e.g. Isaak, Muhlfeld, et al., 2012; Isaak, Wollrab, et al., 2012; Hague & Patterson, 2014; Cahill et al., 2018) and popular articles and social media (Painter, 2021; Peterson, 2021). Recent debate has largely focused on the potential impact of elevated water temperatures on the growth and survival of released fish, but the effect of increased temperature on angler catch rates should be given equal attention because if anglers' ability to land fish is diminished at elevated temperatures, so is their likelihood of inadvertently causing catch-and-release mortality. Consequently, until evidence shows that trout populations are being negatively impacted in areas where angling is permitted at elevated water temperatures, we urge caution before implementing what has been termed "hoot owl regulations."

ACKNOWLEDGEMENTS

Funding for this project was provided by anglers and boaters through their purchase of Idaho fishing licenses, tags and permits from federal excise taxes on fishing equipment and boat fuel through the Federal Aid in Sport Fish Restoration Program.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Kevin A. Meyer https://orcid.org/0000-0002-1192-3906

REFERENCES

Askey, P.J. & Johnston, N.T. (2013) Self-regulation of the Okanagan Lake kokanee recreational fishery: dynamic angler effort response to varying fish abundance and productivity. *North American Journal of Fisheries Management*, *33*, 926–939. Available from: https://doi.org/10.1080/02755947.2013.818082

Baccante, D. (1995) Assessing catch inequality in walleye angling fisheries. *North American Journal of Fisheries Management*, *15*, 661–665. Available from: https://doi.org/10.1577/1548-8675(1995)015<0661:aciiwa>2.3.co;2

Bartholomew, A. & Bohnsack, J.A. (2005) A review of catch-and-release angling mortality with implications for no-take reserves. *Reviews in Fish Biology and Fisheries*, *15*, 129–154. Available from: https://doi.org/10.1007/s11160-005-2175-1

Bloom, R.K. (2013) Capture efficiency of barbed versus barbless artificial flies for trout. *North American Journal of Fisheries Management*, *33*, 493–498. Available from: https://doi.org/10.1080/02755947.2013.769920

Boyd, J.W., Guy, C.S., Horton, T.B. & Leathe, S.A. (2010) Effects of catch-and-release angling on salmonids at elevated water temperatures. *North American Journal of Fisheries Management*, *30*, 898–907. Available from: https://doi.org/10.1577/M09-107.1

Brownscombe, J.W., Danylchuk, A.J., Chapman, J.M., Gutowsky, L.F. & Cooke, S.J. (2017) Best practices for catch-and-release recreational fisheries–angling tools and tactics. *Fisheries Research*, *186*, 693–705. Available from: https://doi.org/10.1016/j.fishres.2016.04.018

Burnham, K.P. & Anderson, D.R. (2002) *Model selection and multimodel inference: a practical information-theoretic approach*. New York: Springer Verlag.

Burnham, K.P. & Anderson, D.R. (2004) Multimodel inference: understanding AIC and BIC in model selection. *Sociological Methods & Research*, *33*, 261–304. Available from: https://doi.org/10.1177/0049124104268644

Cahill, C.L., Mogensen, S., Wilson, K.L., Cantin, A., Sinnatamby, R.N., Paul, A.J. et al. (2018) Multiple challenges confront a high-effort inland recreational fishery in decline. *Canadian Journal of Fisheries and Aquatic Sciences*, *75*, 1357–1368. Available from: https://doi.org/10.1139/cjfas-2018-0086

Chiaramonte, L.V., Meyer, K.A., Branigan, P.B. & Reynolds, J.B. (2020) Effect of pulsed DC frequency on capture efficiency and spinal injury of trout in small streams. *North American Journal of Fisheries Management*, *40*, 691–699. Available from: https://doi.org/10.1002/nafm.10440

Chizinski, C.J., Martin, D.R., Pope, K.L., Barada, T.J. & Schuckman, J.J. (2014) Angler effort and catch within a spatially complex system of small lakes. *Fisheries Research*, *154*, 172–178. Available from: https://doi.org/10.1016/j.fishres.2014.02.013

Dempson, J.B., Furey, G. & Bloom, M. (2002) Effects of catch and release angling on Atlantic Salmon, *Salmo salar* L., of the Conne River, Newfoundland. *Fisheries Management and Ecology*, *9*, 139–147. Available from: https://doi.org/10.1046/j.1365-2400.2002.00288.x

Dempson, J.B., O'connell, M.F. & Cochrane, N.M. (2001) Potential impact of climate warming on recreational fishing opportunities for Atlantic Salmon, *Salmo salar* L., in Newfoundland, Canada. *Fisheries Management and Ecology*, *8*, 69–82. Available from: https://doi.org/10.1046/j.1365-2400.2001.00225.x

Filipe, A.F., Markovic, D., Pletterbauer, F., Tisseuil, C., De Wever, A., Schmutz, S. et al. (2013) Forecasting fish distribution along stream networks: brown trout (*Salmo trutta*) in Europe. *Diversity and Distributions*, *19*, 1059–1071. Available from: https://doi.org/10.1111/ddi.12086

Guy, C.S., Blankenship, H.L. & Nielsen, L.A. (1996) Tagging and marking. In: Murphy, B.R. & Willis, D.W. (Eds.) *Fisheries Techniques*, 3rd edition. Bethesda, Maryland: American Fisheries Society, pp. 353–383.

Hague, M.J. & Patterson, D.A. (2014) Evaluation of statistical river temperature forecast models for fisheries management. *North*

American Journal of Fisheries Management, *34*, 132–146. Available from: https://doi.org/10.1080/02755947.2013.847879

High, B. & Meyer, K.A. (2014) Hooking mortality and landing success using baited circle hooks compared to conventional hook types for stream-dwelling trout. *Northwest Science*, *88*, 11–22. Available from: https://doi.org/10.3955/046.088.0104

Hunsaker, D., Marnell, L.F. & Sharpe, F.P. (1970) Hooking mortality of Yellowstone cutthroat trout. *The Progressive Fish-Culturist*, *32*, 231–235. Available from: https://doi.org/10.1577/1548-8640(1970)32[231:hmoyct]2.0.co;2

Isaak, D.J., Muhlfeld, C.C., Todd, A.S., Al-Chokhachy, R., Roberts, J., Kershner, J.L. et al. (2012) The past as prelude to the future for understanding 21st-century climate effects on Rocky Mountain trout. *Fisheries*, *37*, 542–556. Available from: https://doi.org/10.1080/03632415.2012.742808

Isaak, D.J., Wollrab, S., Horan, D. & Chandler, G. (2012) Climate change effects on stream and river temperatures across the northwest U.S. from 1980–2009 and implications for salmonid fishes. *Climatic Change*, *113*, 499–524. Available from: https://doi.org/10.1007/s10584-011-0326-z

Jeanson, A.L., Lynch, A.J., Thiem, J.D., Potts, W.M., Haapasalo, T., Danylchuk, A.J. et al. (2021) A bright spot analysis of inland recreational fisheries in the face of climate change: learning about adaptation from small successes. *Reviews in Fish Biology and Fisheries*, *31*, 181–200. Available from: https://doi.org/10.1007/s11160-021-09638-y

Jensen, J.L.A., Halttunen, E., Thorstad, E.B., Naesje, T.F. & Rikardsen, A.H. (2010) Does catch-and-release angling alter the migratory behaviour of Atlantic salmon? *Fisheries Research*, *106*, 550–554. Available from: https://doi.org/10.1016/j.fishres.2010.08.013

L'Abée-Lund, J.H. & Aspås, H. (1999) Threshold values of river discharge and temperature for anglers' catch of Atlantic salmon, *Salmo salar* L. *Fisheries Management and Ecology*, *6*, 323–333. Available from: https://doi.org/10.1111/j.1365-2400.1999.tb00083.x

Lamansky, J.A., Jr. & Meyer, K.A. (2016) Air exposure time of trout released by anglers during catch-and-release. *North American Journal of Fisheries Management*, *36*, 1018–1023. Available from: https://doi.org/10.1080/02755947.2016.1184200

Lennox, R.J., Uglem, I., Cooke, S.J., Næsje, T.F., Whoriskey, F.G., Havn, T.B. et al. (2015) Does catch-and-release angling alter the behavior and fate of adult Atlantic salmon during upriver migration? *Transactions of the American Fisheries Society*, *144*, 400–409. Available from: https://doi.org/10.1080/00028487.2014.1001041

Mallet, J. & Thurow, R.F. (2022) Resurrecting an Idaho icon: How research and management reversed declines of native Westslope cutthroat trout. *Fisheries*, *47*, 104–117. Available from: https://doi.org/10.1002/fsh.10697

McCullough, D.A., Bartholow, J.M., Jager, H.I., Beschta, R.L., Cheslak, E.F., Deas, M.L. et al. (2009) Research in thermal biology: Burning questions for Coldwater stream fishes. *Reviews in Fisheries Science*, *17*, 90–115. Available from: https://doi.org/10.1080/10641260802590152

McFadden, J.T. (1977) An argument supporting the reality of compensation in fish populations and a plea to let them exercise it. In: Van Winkle, W. (Ed.) *Proceedings of the conference on assessing the effects of power-plant-induced mortality on fish populations*. Tarrytown, New York: Pergamon, pp. 153–183.

McMichael, G.A. & Kaya, C.M. (1991) Relations among stream temperature, angling success for rainbow trout and brown trout, and fisherman satisfaction. *North American Journal of Fisheries Management*, *11*, 190–199. Available from: https://doi.org/10.1577/1548-8675(1991)011<0190:RASTAS>2.3.CO;2

Meyer, K.A., Chiaramonte, L.V. & Reynolds, J.B. (2021) The 100-watt method: a protocol for backpack electrofishing in small streams. *Fisheries*, *46*, 125–130. Available from: https://doi.org/10.1002/fsh.10535

Meyer, K.A. & High, B. (2011) Accuracy of removal electrofishing estimates of trout abundance in Rocky Mountain streams. *North American Journal of Fisheries Management*, *31*, 923–933. Available from: https://doi.org/10.1080/02755947.2011.633684

Meyer, K.A. & Schill, D.J. (2014) Use of a statewide angler tag reporting system to estimate rates of exploitation and total mortality for Idaho sport fisheries. *North American Journal of Fisheries Management*, *34*, 1145–1158. Available from: https://doi.org/10.1080/02755947.2014.951803

Muoneke, M.I. & Childress, W.M. (1994) Hooking mortality: a review for recreational fisheries. *Reviews in Fisheries Science*, *2*, 123–156. Available from: https://doi.org/10.1080/10641269409388555

Painter, J. (2021) Two states, two approaches: Idaho and Montana experts react differently to drought effects on fish. Post Register, July 2022.

Pelletier, C., Hanson, K.C. & Cooke, S.J. (2007) Do catch-and-release guidelines from state and provincial fisheries agencies in North America conform to scientifically based best practices? *Environmental Management*, *39*, 760–773. Available from: https://doi.org/10.1007/s00267-006-0173-2

Peterson, C. (2021) The future of trout fishing in the west could be in hot water. *Outdoor Life* September 2021. Available from: https://www.outdoorlife.com/conservation/future-trout-fishing-and-drought/

Pinder, A.C., Harrison, A.J. & Britton, J.R. (2019) Temperature effects on the physiological status and reflex impairment in European grayling *Thymallus thymallus* from catch-and release angling. *Fisheries Research*, *211*, 169–175. Available from: https://doi.org/10.1016/j.fishres.2018.11.014

Policansky, D. (2002) Catch-and-release recreational fishing: a historical perspective. In: Pitcher, T. & Hollingworth, C. (Eds.) *Recreational fisheries: Ecological, economic, and social evaluation*. Oxford, UK: Blackwell Science, pp. 74–94.

Policansky, D. (2008) Trends and developments in catch and release. In: Aas, O. (Ed.) *Global challenges in recreational fisheries*. Hoboken, NJ: Wiley-Blackwell, pp. 202–236.

Richard, A., Bernatchez, L., Valiquette, E. & Dionne, M. (2014) Telemetry reveals how catch and release affects prespawning migration in Atlantic salmon (*Salmo salar*). *Canadian Journal of Fisheries and Aquatic Sciences*, *71*, 1730–1739. Available from: /10.1139/cjfas-2014-0072

Rose, K.A., Cowan, J.H., Jr., Winemiller, K.O., Myers, R.A. & Hilborn, R. (2001) Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. *Fish and Fisheries*, *2*, 293–327.

Roth, C.J., Schill, D.J. & Quist, M.C. (2018) Fight and air exposure times of caught and released salmonids from the south fork Snake River. *Fisheries Research*, *201*, 38–43.

SAS Institute Inc. (2009) *SAS/STAT® 9.2 User's guide*, 2nd edition. Cary, NC: SAS Institute Inc.

Schisler, G.J. & Bergersen, E.P. (1996) Postrelease hooking mortality of rainbow trout caught on scented artificial baits. *North American Journal of Fisheries Management*, *16*, 570–578. Available from: https://doi.org/10.1577/1548-8675(1996)016<0570:phmort>2.3.co;2

Taylor, A.H. (1978) An analysis of the trout fishing at eye brook-a eutrophic reservoir. *The Journal of Animal Ecology*, *47*, 407–423. Available from: https://doi.org/10.2307/3791

Twardek, W.M., Gagne, T.O., Elmer, L.K., Cooke, S.J., Beere, M.C. & Danylchuk, A.J. (2018) Consequences of catch-and-release angling on the physiology, behaviour and survival of wild steelhead *Oncorhynchus mykiss* in the Bulkley River, British Columbia. *Fisheries Research*, *206*, 235–246. Available from: https://doi.org/10.1016/j.fishres.2018.05.019

Van Leeuwen, T.E., Dempson, J.B., Cote, D., Kelly, N.I. & Bates, A.E. (2021) Catchability of Atlantic salmon at high water temperatures: implications for river closure temperature thresholds to catch and release angling. *Fisheries Management and Ecology*, *28*, 147–157. Available from: https://doi.org/10.1111/fme.12464

Ward, H.G.M., Quinn, M.S. & Post, J.R. (2013) Angler characteristics and management implications in a large, multistock, spatially structured recreational fishery. *North American Journal of Fisheries Management*, *33*, 576–584. Available from: https://doi.org/10.1080/02755947.2013.785991

Wenger, S.J., Isaak, D.J., Luce, C.H., Neville, H.M., Fausch, K.D., Dunham, J.B. et al. (2011) Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. *Proceedings of the National Academy of Sciences*, *108*, 14175–14180. Available from: https://doi.org/10.1073/pnas.1103097108

How to cite this article: Meyer, K. A., McCormick, J. L., Kozfkay, J. R. & Dillon, J. C. (2023). Effects of elevated water temperature on cutthroat trout angler catch rates and catch-and-release mortality in Idaho streams. *Fisheries Management and Ecology*, *30*, 134–141. https://doi.org/10.1111/fme.12605