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ARTICLE

The Effect of Raceway Grading on Return to Creel for Catchable-Sized Hatchery Rainbow Trout

Kevin A. Meyer*
Idaho Department of Fish and Game, 1414 East Locust Lane, Nampa, Idaho 83686-8451, USA

John D. Cassinelli
Idaho Department of Fish and Game, 15950 North Gate Boulevard, Nampa, Idaho 83686, USA

Abstract
Hatchery trout of catchable size (i.e., about 250 mm total length; hereafter termed "catchables"), which are stocked into put-and-take fisheries, are expensive to raise, so fisheries management agencies strive to modify rearing practices to maximize the proportion of stocked catchables that anglers catch. We graded fish in production-level hatchery rearing units at both fingerling and catchable size, dividing the fish into "leaders" (herein, the larger fish in a rearing unit, separated during a grading event) and "laggers" (the smaller fish). We hypothesized that (1) grading and immediate stocking of catchable leaders and short-term retention and continued feeding of catchable laggers might increase lagger growth and result in a larger average size of fish being stocked (relative to fish from ungraded raceways), potentially improving overall return to creel for the graded group and (2) grading and separation of fingerling leaders and laggers early in the rearing process may reduce competition between smaller and larger fish for the remainder of the rearing period, potentially improving overall poststocking return to creel for the entire group without the need for catchable grading at the time of stocking. We found that grading catchables just prior to stocking slightly increased the mean size at stocking (compared with ungraded control fish) for the first stocking period, which resulted in slightly higher return to creel for stocked fish. However, across the entire stocking period and with equal feed between groups, mean size at release was nearly identical between the graded and the control fish, as was return to creel by anglers. Grading fingerlings to separate leaders and laggers for the remainder of the rearing period also had no positive effect on angler catch. Our findings suggest that production-level grading is ineffective at increasing the growth of laggers, so it will not increase overall size at stocking. Consequently, improvements in angler catch are unlikely to materialize from grading hatchery trout prior to stocking them into put-and-take fisheries.

Stocking catchable-sized hatchery trout (i.e., about 250 mm total length [TL]; hereafter termed "catchables") into put-and-take fisheries has long been used to create recreational fisheries in waters that cannot support wild trout or can support so few that no trout fishery would exist without the stocking program (Butler and Borgeson 1965; Johnson et al. 1995). While such fisheries are popular among anglers (Park 2007; Hunt et al. 2017), raising catchables is expensive (Johnson et al. 1995; Hunt et al. 2017; Losee and Phillips 2017). Thus, maximizing the proportion of stocked catchables that anglers catch is a common goal for fisheries management agencies that are engaged in such hatchery programs.

The postrelease performance of catchable trout (in terms of angler catch) can be influenced by the conditions that they face both prior to and after stocking. Numerous studies have reported about the influence of hatchery rearing practices on the postrelease performance of catchables including diet, water quality and chemistry, flow, rearing density, and size at stocking (e.g., Mullan 1956;

*Corresponding author: kevin.meyer@idfg.idaho.gov
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Larmoyeux and Piper 1973; Elrod et al. 1989; Banks and LaMotte 2002; Barnes et al. 2009; Cassinelli et al. 2016; Cassinelli and Meyer 2018). In particular, size at release has recently been the focus of much investigation. The current target length for a catchable trout that is released from an Idaho Department of Fish and Game (IDFG) hatchery is 254 mm TL. Recent studies have shown that even minor increases in size at release can positively increase return to creel for catchable hatchery-reared trout (e.g., Cassinelli et al. 2016; Cassinelli and Meyer 2018). However, while larger trout may return to the creel at a higher rate, there is an incremental added cost and a reduced production capacity of rearing catchables to a larger size, so it is paramount to balance size-at-release, rearing costs, and return to creel.

Size grading is one method that could be used to select for larger fish from a given rearing unit. Literature on fish grading and its effect on hatchery rearing date back to the mid-1900s (e.g., Brown 1946; Mullan 1956; Pyle 1966), and grading practices continue to be used as a tool for rearing hatchery trout by some state agencies (Mark Clifford, State of California Department of Fish and Game, personal communication; Kris Urquhart, Nevada Division of Wildlife, personal communication). Hatcheries grade fish to achieve a uniform size, to reduce cannibalism in certain species, and to increase the accuracy of weight estimates by reducing size variation during sample counts. The practice is also based on some evidence that smaller fish may experience increased growth rates after being separated from larger fish. Indeed, grading effectively decreased the variation in size and increased the mean size of hatchery Yellow Perch *Perca flavescens* (Wallat et al. 2005), and it also increased the growth of hatchery Brown Trout *Salmo trutta* (Brown 1946) and Atlantic Salmon *S. salar* (Gunnes 1976). However, other studies have found grading to have no growth benefit for Arctic Char *Salvelinus alpinus* (Wallace and Kolbeinshavn 1988) or for Brown Trout, Brook Trout *Salvelinus fontinalis*, and Rainbow Trout *Oncorhynchus mykiss* (Pyle 1966).

While in-hatchery grading results have been equivocal, the effects of grading on postrelease metrics such as return to creel have rarely if ever been evaluated. We hypothesized that production-level grading at facilities that rear catchable hatchery trout, thereby dividing the fish into “leaders” (herein, the larger fish in a rearing unit) and “laggers” (the smaller fish), may have two postrelease benefits. First, grading followed by the immediate stocking of catchable “leaders” and the short-term retention and continued feeding of catchable “laggers” might increase the growth of the laggers and result in fish of a larger average size being stocked (relative to fish from ungraded raceways), potentially improving overall return to creel for the entire rearing unit. Second, grading and separation of fingerling “leaders” and “laggers” early in the rearing process may reduce competition between smaller and larger fish during the remainder of the rearing period, resulting in less size variation at the time of stocking and potentially improving overall poststocking return to creel for the entire group regardless of whether the fish were graded again as catchables prior to stocking.

METHODS

Rearing and grading.— Catchable Rainbow Trout were raised from eggs that were purchased from Troutlodge, Inc. (Twin Falls, Idaho) by using an all-female triploid stock that is commonly purchased for IDFG fish hatchery facilities. The grading experiments were conducted at the three IDFG fish hatcheries (American Falls, Hagerman, and Nampa) that raise the vast majority of catchable Rainbow Trout that are annually stocked in Idaho. At each facility, the grading experiments spanned most of the stocking season (i.e., April–October).

At each hatchery facility, the fish were reared on single-use spring water at 13–15°C. The fry were started in small indoor concrete raceways and fed by using a combination of hand-feeding and belt feeders. After reaching 50–75 mm in length (depending on the facility), the fish were inventoried and moved to outdoor concrete raceways (the rearing sections were usually about 30 × 3 × 1 m) and fed by hand or with tractor-pulled feed carts. The fish were fed commercial floating extruded pellet feed, which consisted of a formula of 55% protein and 17% fat as fry in the indoor raceways and 45% protein and 16% fat after being moved to the outdoor raceways. The feeding rate was approximately 4% body weight/d after moving to the outdoor raceways, and it was gradually decreased to 1.5% body weight/d as the fish approached the targeted size for stocking. Other rearing conditions and practices, such as inventorying, raceway density, and truck loading rates were also similar among hatcheries. There were no differences in the rearing practices that were used for the graded and ungraded fish at any given facility except for the grading events. The fish were reared to catchable size, with a target of 254 mm TL at the time of stocking.

Two grading experiments were conducted: one in 2013 and 2014 that involved grading only catchables just prior to stocking and the other in 2015 and 2016 that involved grading fingerlings early in the rearing phase as well as grading the same fish again as catchables just prior to stocking. At each hatchery, a group of control (i.e., ungraded) fish were maintained to allow paired stocking in each study water.

Graded catchables experiment.— In the first experiment, there were two catchable grading events and three stocking events. Once the catchables reached the ~250 mm target size for stocking in both raceways (about 10–11 months after egg hatch), the treatment fish were passively

graded for the first time by using crowding racks that consisted of 20-mm gaps. The fish were crowded from the upper and lower end of the treatment raceways toward the middle, with smaller fish (i.e., the laggers) being able to swim through the gaps in the crowding racks while larger fish (the leaders) could not. The crowding racks were compressed as needed as the smaller fish left the crowded area. The duration of the grading process was variable depending on the visual observations of the hatchery staff, but it generally lasted 1–3 d. While the exact proportion of fish that were graded into leaders and laggers with this process was unknown, visual inspections of the raceway suggested that the first grading event produced approximately a 50:50 split in most instances.

Once the grading was complete, the leaders were stocked into lakes and reservoirs, rivers, or community ponds as per normal stocking requests by IDFG fisheries managers until all of the leaders were stocked out to fishing waters. An equivalent number of control (ungraded) fish were stocked from adjacent raceways for each stocking event so that the full stocking request for each stocking event was comprised of approximately equal numbers of fish from each group. This was considered the early period of stocking.

The laggers in each graded raceway were reared for another 4–5 weeks at the same growth ration as before; the control fish were fed the same ration to keep feed allocation equivalent between treatments. At the end of this period, the grading process was repeated a second time in the same manner as was described above. Leaders were again stocked into various waters, along with an equivalent number of control fish. This was considered the middle period of stocking.

The remaining laggers and control fish were reared as noted above for another 4–5 weeks, at which point the laggers were stocked without further grading, along with an equivalent number of control fish. This was the late period of stocking.

Graded fingerlings and catchables experiment.— The second experiment was conducted in 2015 and 2016 at the American Falls and Hagerman fish hatcheries only. The treatment groups were first graded as fingerlings (around 50 mm TL and 1–2 months after egg hatch) while they were still in indoor raceways. The fish were netted into floating box graders with 5-mm gaps, which allowed the smaller fish to escape while the larger fish could not. This effectively divided the fish into the smallest 1/3 of the fish (i.e., the laggers that escaped) and the largest 2/3 (i.e., leaders that were too large to escape); the leader group was further split into two equal groups. Soon after grading the fingerlings, all three groups were moved to separate outdoor raceways and reared to catchable size, along with a group of control fish that had not been graded as fingerlings. The feeding rates were controlled so that all four groups reached the target size for stocking at the same time.

Once these fish reached the general target size for stocking in all four raceways, catchable grading was conducted as described above for the fingerling lagger group and one of the fingerling leader groups (which was chosen at random from the two leader groups). The other fingerling leader group was not graded again as catchables; instead, it was treated the same as the control group was prior to release. These methods resulted in four groups of catchables being released at each stocking event from each hatchery for the second experiment: (1) fish that graded out as laggers during fingerling grading that were graded two more times as catchables, (2) fish that graded out as leaders during fingerling grading that were graded two more times as catchables, (3) fish that were graded out as leaders during fingerling grading that *were not* graded again as catchables, and (4) control fish that were not graded as fingerlings or catchables.

Tagging and stocking.— To estimate poststocking angler catch of experimental fish, a portion of all of the catchables that were reared in the treatment (i.e., graded) and control (i.e., nongraded) raceways were tagged with 70-mm fluorescent orange T-bar anchor tags. To facilitate the reporting of tagged fish that were caught by anglers, the anchor tags were labeled with "IDFG" and a tag-reporting phone number on one side, with a unique tag number on the reverse side. The fish were collected for tagging by crowding them within the raceways (to ensure that a representative sample was collected for each tagging event, not as part of the grade crowding) and capturing them with dip nets. The fish were sedated, measured to the nearest mm TL, and tagged just under the dorsal fin following the methods of Guy et al. (1996). There was no reward for tag returns, but a recent summary from this particular tag-reporting program indicated that Idaho anglers report about 45% of the nonreward tags that they encounter on hatchery trout (Cassinelli et al. 2016).

After tagging, the trout were returned to an empty section of the raceway or were held separately in a holding pen (1.5- × 1.5- × 1.5-m wood-framed enclosure) in the raceway for at least 12 h. Within 48 h of tagging, the tagged fish were loaded by dip net into stocking trucks with the normal lot of untagged fish and transported to stocking locations. To avoid potential angler fatigue with encountering tagged fish, which could diminish anglers' willingness to report tags (Henny and Burnham 1976), no more than 10% of the total number of fish that was released into each water received tags. Mortalities and shed tags prior to stocking were rare (<1%), but they were collected and recorded prior to loading the fish for transport. Assuming that anglers report 45% of the nonreward tags that they encounter and a 7% tag-loss rate after the fish were stocked (Cassinelli et al. 2016), the proportion of

tagged fish that is reported herein as captured by anglers can be multiplied by about 2.4 to approximate the proportion of stocked fish that was caught by anglers.

Most of the waters that were stocked were open to angling all year, though angling effort at trout-stocked waters in Idaho is generally highest in the summer months (i.e., Memorial Day to Labor Day). Angling regulations at most waters that were stocked allowed for six trout to be harvested per day. Tags were reported by anglers anywhere from the day of stocking to 1,524 d after stocking, but the number of days at large for the tagged fish that were stocked as part of this study and were eventually reported by anglers averaged 132 d (SE = 2.2 d).

Data analysis.— The effect of grading on angler tag returns was evaluated with the use of generalized linear mixed models by using Proc GLIMMIX in the SAS statistical software package (SAS Institute 2009). Each stocked fish was considered the unit of observation for these analyses, and each experiment (catchable grading only and fingerling and catchable grading) was analyzed separately. The dependent variable in the model was a dummy variable of either 1 or 0, which represented tags that were or were not reported by anglers, respectively.

In addition to the grading aspects of the study, a number of other factors were also included as predictive variables in the models to explain as much of the variation in tag returns as possible. For example, fish length was included to evaluate the effect that the grading process had on size at stocking because larger trout are better able to escape predators, have higher energy reserves, and may be more aggressive in foraging and thus they are more vulnerable to angler catch (Wiley et al. 1993; Yule et al. 2000; Cassinelli et al. 2016). Rearing hatchery was included because fish health (Iwama et al. 1997) and water quality and chemistry (Bosakowski and Wagner 1994; Trushenski et al. 2019) often vary between hatcheries, and these issues can carry over to differences between hatcheries in the poststocking performance of catchables (Cassinelli and Meyer 2018). The water type being stocked (lake/reservoir, river, or community pond) was included as a predictive variable because angler catch of stocked catchables can vary between lentic, lotic, and community pond waters (Wiley et al. 1993; Cassinelli 2015).

For the first experiment, involving catchable grading only, the independent fixed effects included the length of the fish, rearing hatchery, and water type being stocked as well as treatment (graded versus control) and the period of stocking (early, middle, or late). A treatment × period interaction term was included because we speculated that any effect that grading had on postrelease performance might not be constant throughout the rearing period. Individual water bodies were included as a random effect in all of the multiple-factor models.

Candidate models were limited to the full model (including all possible predictive parameters), the top two multiple-factor models (from all possible multiple-factor combinations), and all of the single-factor models. The candidate models were ranked by using Akaike's information criterion corrected for small sample size (AIC_c; Burnham and Anderson 2002), and we considered the most plausible models to be those with AIC_c scores within 2.0 of the best model (Burnham and Anderson 2004). We also used AIC_c weights (w_i) to assess the relative plausibility of each model. For the second experiment, involving fingerling and catchable grading, the analyses were identical except that there were three grading treatment levels (as noted above) instead of only one. Coefficients were estimated and reported only for the most plausible models. Once exponentiated, the coefficients were multiplicative. For instance, if the coefficient for grading was 1.12 in the first experiment, this means that angler catch and reporting of tagged fish was 1.12 times higher for the graded fish than for the control fish.

Including fish length as a covariate in each model accounted for any differences in the sizes of the fish that were stocked between the grading treatments and the control fish. As such, the inclusion of the treatment parameter in any top model indicated that return to creel was influenced by the grading treatment itself, not the effect that grading had on size at release.

RESULTS

Graded Catchables Experiment

For the experiment with catchable grading only, a total of 19,789 graded fish and 19,559 control fish were tagged and stocked into 50 unique water bodies by using 110 unique stocking events across 2 years (2013 and 2014). A total of 3,220 tagged fish (8.2%) were caught and reported by anglers.

The mean length of the fish that were stocked was 254.2 mm TL (SD = 27.2; range, 100–443 mm) across the entire experiment. At all three hatcheries, grading increased fish size at stocking and decreased size variation for the stocked fish (mean = 255.5 mm; SD = 21.6) compared with the control fish (mean = 238.6 mm; SD = 26.2) for the first stocking period (Figure 1; Table 1). However, by the final stocking period the control fish (mean = 266.4 mm) were larger than the remaining graded fish (254.5 mm). Thus, across the entire experiment, the mean size at release was very similar for the graded fish (mean = 255.3 mm) and the control fish (253.0), though the graded fish were less variable in size at stocking (SD = 24.1) than the control fish were (SD = 30.0).

Across the entire experiment, the proportion of tags that was returned for the graded fish (8.4%) was slightly

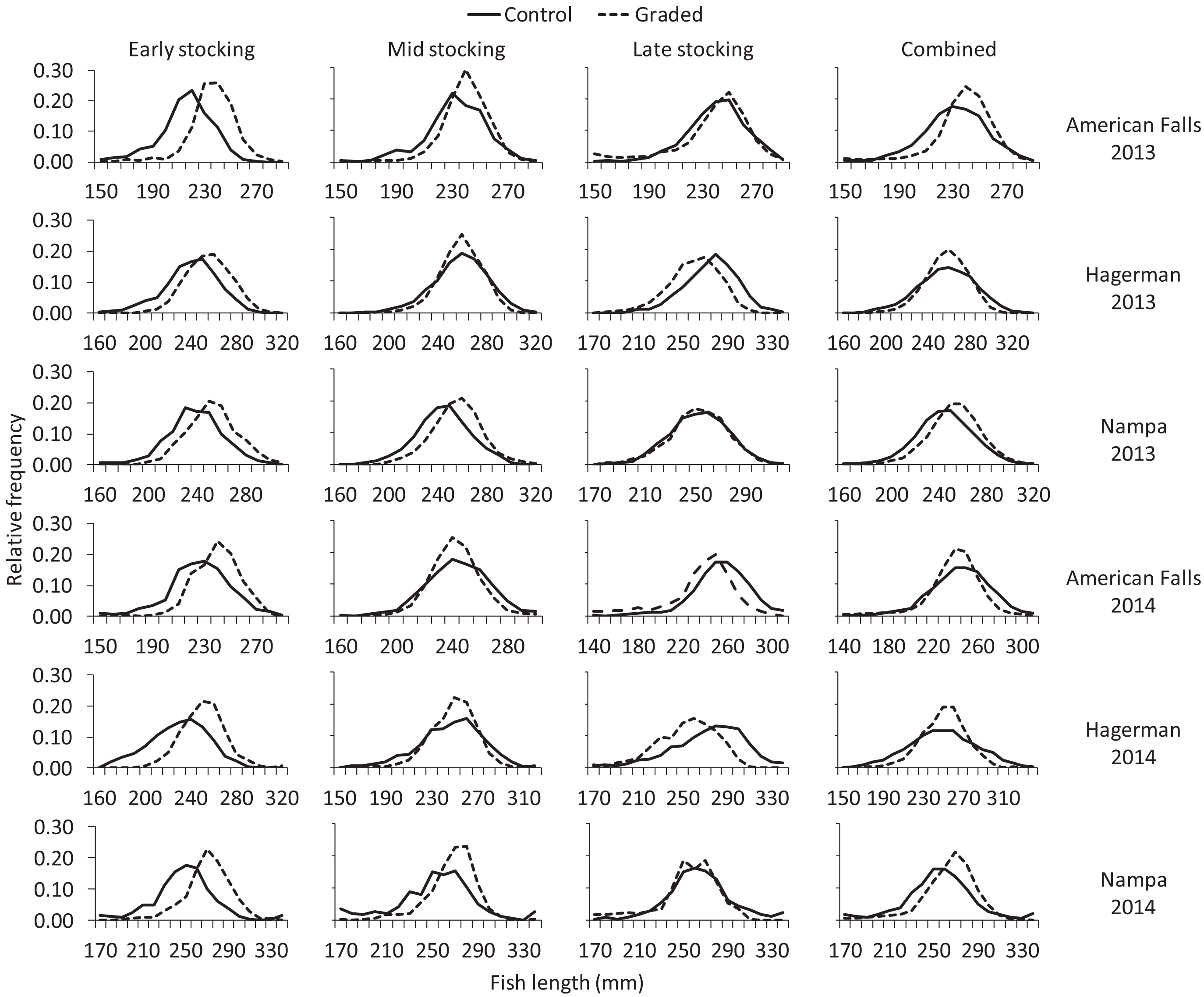

FIGURE 1. Relative frequency of the size of fish that were stocked in 2013 and 2014 into various Idaho waters from three fish hatcheries (American Falls, Hagerman, and Nampa) that graded catchable Rainbow Trout prior to stocking them. The graded fish were stocked after one grading event (early stocking), after an additional 4–5 weeks of rearing and an additional grading event (mid stocking), and after 4 to 5 more weeks of rearing but no additional grading (late stocking). Control fish were stocked at the same intervals, but they were not graded at any time during the experiment.

higher than that for the control fish (7.9%; Figure 2). Tag returns were highest for the middle stocking event (9.4%) and lowest for the early stocking event (6.2%). The largest difference in return to creel between the graded and control fish was for the early stocking period, when the relative proportion of tag returns for the graded fish (7.2%) was 28% higher than that for the control fish (5.7%), but by the late stocking period tag returns were higher for the control fish (8.8%) than for the graded fish (8.2%).

The most plausible generalized linear mixed model fit to these data indicated that angler catch and reporting of tagged fish was 1.001 times higher for every 1-mm increase in the length of fish at the time of stocking (Tables 2 and 3). Additionally, the most plausible model indicated that fish that were stocked at the midpoint of the experiment and that were reared at Nampa Hatchery were slightly more likely to be caught and reported by an angler than were fish that were reared at Hagerman Hatchery and that were stocked at the start of the experiment. There was essentially no support for any of the other competing models, so there was no evidence that return to creel was influenced by grading, except for the influence that grading had on size at release for the three stocking periods.

TABLE 1. Means and standard deviations (SD) for the total length of the fish that were stocked by each fish hatchery in the two grading experiments for evaluating return to creel of fish that were stocked in various Idaho waters. The first experiment included grading only as catchables, whereas the second experiment included both fingerling and catchable grading (see text for details). In both experiments, the catchables were stocked after one grading event (early), after an additional 4–5 weeks of rearing and an additional grading event (mid), and after 4 to 5 more weeks of rearing but no additional grading (late). The control fish were not graded at any time during the experiment.

		Early		Middle		Late		Combined	
Hatchery	Treatment	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Graded catchables experiment									
American Falls	Control	225.6	23.0	243.6	23.8	252.3	26.7	243.1	27.1
	Graded	242.3	17.9	245.5	17.2	240.6	31.0	242.5	24.5
Hagerman	Control	239.8	25.4	257.0	27.1	277.9	29.3	258.1	31.4
	Graded	257.0	20.4	257.6	20.3	261.2	25.6	258.6	22.3
Nampa	Control	244.4	26.8	249.7	26.3	259.8	26.6	251.3	27.3
	Graded	260.9	22.7	261.7	21.7	256.8	25.1	259.8	23.3
Graded fingerlings and catchables experiment									
American Falls	Control	225.3	28.1	246.6	25.9	257.1	23.4	246.4	28.2
	Fingerling laggers graded again as catchables	241.7	28.1	254.0	22.3	256.9	26.6	252.5	26.3
	Fingerling leaders graded again as catchables	246.9	22.5	256.3	19.6	259.4	20.7	255.5	21.4
	Fingerling leaders not graded again as catchables	226.3	26.5	247.0	22.4	252.4	19.5	244.7	24.5
Hagerman	Control	270.6	25.0	282.1	30.0	295.2	27.7	285.9	29.5
	Fingerling laggers graded again as catchables	276.4	21.5	273.9	19.1	272.1	26.7	273.6	23.6
	Fingerling leaders graded again as catchables	275.9	21.5	279.8	19.1	276.8	30.8	277.5	25.9
	Fingerling leaders not graded again as catchables	265.4	25.0	279.8	28.5	300.0	32.0	286.3	32.8

Graded Fingerlings and Catchables Experiment

For the experiment with both fingerling and catchable grading, roughly 4,500 fish from each treatment condition, including control fish (total = 18,160 fish), were tagged and stocked into 32 unique water bodies (53 unique stocking events) across 2 years (2015 and 2016). A total of 1,877 tagged fish (10.3%) were caught and reported by anglers.

The mean length of the stocked fish was 268.0 mm TL (SD = 31.3; range, 119–390 mm) across the entire experiment. As with the catchable-grading-only experiment, grading just prior to the first stocking period helped to slightly increase size at release and decrease size variation (Figure 3; Table 1) for the fingerling leaders (mean = 263.8 mm; SD = 26.2) and the fingerling laggers (mean = 261.9 mm; SD = 29.8) compared with the fingerling leaders that were not graded as catchables prior to stocking (mean = 249.0 mm; SD = 32.1) and the control fish (mean = 251.6 mm; SD = 34.5). However, as in the first experiment, by the late stocking period the control fish were slightly larger at the time of stocking than the fish in the graded groups were. Consequently, across the entire experiment, mean size at release was very similar between (1) the fingerling leaders that were also graded as catchables (mean = 268.5), (2) the fingerling leaders that were *not* graded as catchables (268.9), (3) the fingerling laggers that were also graded as catchables (264.9), and (4) the control fish (269.7). As in the first experiment, size variation across the entire second experiment was lower for the fish that were graded as catchables (combined SD = 26.7) than for the fish that were not graded as catchables (combined SD = 35.4).

The proportion of tags that was returned by anglers was slightly higher overall in the fingerling and catchable grading experiment than in the first experiment (Figure 2). Tag returns were highest for the control fish (11.8%), lowest for the fingerling laggers that were graded again as catchables (9.9%), and intermediate for the fingerling leaders that were either graded again as catchables or not graded as catchables (10.2% for both groups). Unlike in the first experiment with graded catchables only, there was no consistent pattern of higher or lower returns between stocking periods.

The most plausible generalized linear mixed model for the second experiment, involving both fingerling and catchable grading, indicated that the influence of fish

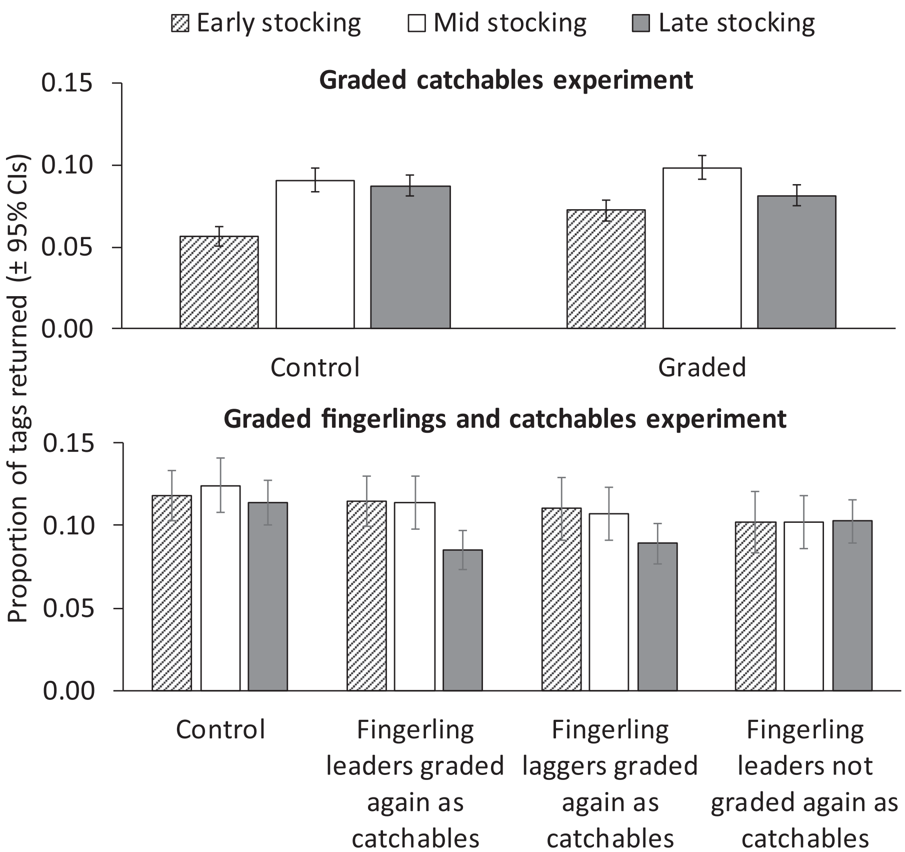

FIGURE 2. Proportion of tags implanted in catchable-sized hatchery Rainbow Trout that were caught and reported by anglers (with ±95% confidence intervals [CIs]) in two experiments for evaluating return to creel of fish that were stocked into various Idaho waters that were graded prior to stocking. The first experiment (top panel) included grading only as catchables, whereas the second experiment (bottom panel) included both fingerling and catchable grading (see text for details).

length on the likelihood of anglers catching and reporting tagged fish was identical to that in the first experiment with graded catchables only (Tables 2 and 3). In addition, angler catch and reporting of tagged fish was 1.016 times higher for control fish than for fingerling laggers (Tables 2 and 3). There was very little support for any of the other competing models.

DISCUSSION

We speculated that production-level grading of hatchery trout could have two primary benefits that improve return to creel of catchable-sized fish that are stocked into put-and-take fisheries. In the first experiment, we hypothesized that by grading and immediately stocking catchable-sized leaders, the remaining laggers (which were held up to 10 weeks longer) might experience improved growth given the absence of larger competitors in the raceway (Gunnes 1976; Wallat et al. 2005), potentially increasing their overall size at release compared with fish from ungraded raceways and thereby improving angler return to creel (Cassinelli et al. 2016; Cassinelli and Meyer 2018). In reality, size at release for graded fish was only larger for the early stocking period, which coincided with the largest difference in return to creel between the graded and ungraded fish. By the late grading period, the ungraded fish were larger and had higher return to creel rates than the graded fish did. Thus, the benefit of grading fish to stock them at a larger overall size was not achieved by only grading catchables prior to release.

In the second experiment, we hypothesized that by separating leaders and laggers early in the rearing process, laggers could avoid the negative consequences of competition with larger fish in their cohort throughout the remainder of their rearing period, which might improve their overall return to creel regardless of any potential increase in stocking size or other benefit of grading just prior to stocking. However, the only grading effect that we observed was that fingerling laggers that were separated from fingerling leaders early in the rearing process and graded again as catchables were less likely to be caught by anglers than were control fish. This was not a size-at-

TABLE 2. Comparison of logistic regression models that were used to estimate the probability of hatchery Rainbow Trout being caught and reported by anglers in select Idaho waters. Akaike's information criteria (AIC_c), change in the AIC_c value (ΔAIC_c), and AIC_c weights (w_i) were used to select the top models from a set of candidate models that included a full model, all single-factor models, and the top two models that could be generated.

Model	AIC_c	ΔAIC_c	w_i
Graded catchables experiment			
Best model: Water body + Fish length + Hatchery + Grade time	6,777.19	0.00	0.99
Next best model: Water body + Fish length + Hatchery + Grade time + Treatment	6,785.93	8.74	0.01
Full model (with Treatment × Grade time interaction term)	6,808.39	31.20	<0.01
Water body	7,190.11	412.92	<0.01
Fish length	8,858.78	2,081.59	<0.01
Hatchery	8,937.84	2,160.65	<0.01
Grade time	9,230.96	2,453.77	<0.01
Treatment × Grade time	9,250.96	2,473.77	<0.01
Intercept	9,280.12	2,502.93	<0.01
Treatment	9,289.02	2,511.83	<0.01
Water type	9,299.76	2,522.57	<0.01
Graded fingerlings and catchables experiment			
Best model: Water body + Fish length + Treatment	7,044.87	0.00	0.95
Next best model: Water body + Fish length + Treatment + Hatchery	7,050.62	5.75	0.05
Full model (with Treatment × Grade time interaction term)	7,107.86	62.99	<0.01
Water body	7,211.54	166.67	<0.01
Fish length	8,213.85	1,168.98	<0.01
Hatchery	8,340.20	1,295.33	<0.01
Water type	8,341.98	1,297.11	<0.01
Intercept	8,353.98	1,309.11	<0.01
Grade time	8,361.02	1,316.15	<0.01
Treatment	8,373.00	1,328.13	<0.01
Treatment × Grade time	8,423.70	1,378.83	<0.01

release effect because size was accounted for by including fish length as a covariate in the models. Rather, this suggests that smaller hatchery fish are inherently inferior (i.e., less fit) than are their larger conspecifics, as has been observed in other hatchery settings (Lindroth 1965) and separating them from larger fish does not alleviate their inferiority. Such a conclusion suggests that eliminating the laggers or stocking them as fingerlings could save feeding costs on fish that have a lower likelihood of being caught at catchable size by anglers, improving hatchery efficiency. However, across the entire second experiment, control fish had at least a 15% higher relative tag return rate by anglers than did fish from any of the grading treatments, suggesting that the best option for maximizing return to creel of stocked catchables was to avoid grading fish altogether. Such a conclusion is supported by previous studies that have demonstrated how stressful grading can be on hatchery fish (Iwama et al. 1995; Dunlop et al. 2004; but see Flos et al. 1988), especially if the process is prolonged as in our study.

TABLE 3. Exponentiated coefficient estimates and 95% confidence intervals (CIs) for the most highly supported logistic regression models that were used to estimate the probability of hatchery Rainbow Trout being caught and reported by anglers in select Idaho waters. In the graded catchables experiment, the middle grading period and Nampa Hatchery were the reference levels for the two discrete fixed-effects parameters, whereas in the graded fingerlings and catchables experiment, "fingerling laggers that were graded again as catchables" was the reference level.

Coefficient	Estimate	95% CIs
Graded catchables experiment		
Intercept	0.8864	0.8374–0.9354
Fish length	1.0010	1.0008–1.0012
Water body	1.0068	1.0039–1.0098
Grade time (early)	0.9830	0.9748–0.9913
Grade time (late)	0.9918	0.9832–1.0005
Hatchery (American Falls)	0.9634	0.9095–1.0172
Hatchery (Hagerman)	0.9442	0.8918–0.9966
Graded fingerlings and catchables experiment		
Intercept	0.8308	0.7747–0.8868
Fish length	1.0011	1.0010–1.0013
Water body	1.0087	1.0042–1.0133
Treatment (fingerling leaders graded again as catchables)	1.0004	0.9883–1.0124
Treatment (fingerling leaders not graded again as catchables)	1.0016	0.9895–1.0137
Treatment (control)	1.0155	1.0035–1.0276

The largest and most consistent effect on return to creel was fish length, with angler tag returns improving by about 1% (which translates to an approximate 2.4% increase in angler catch) for every 10-mm increase in the

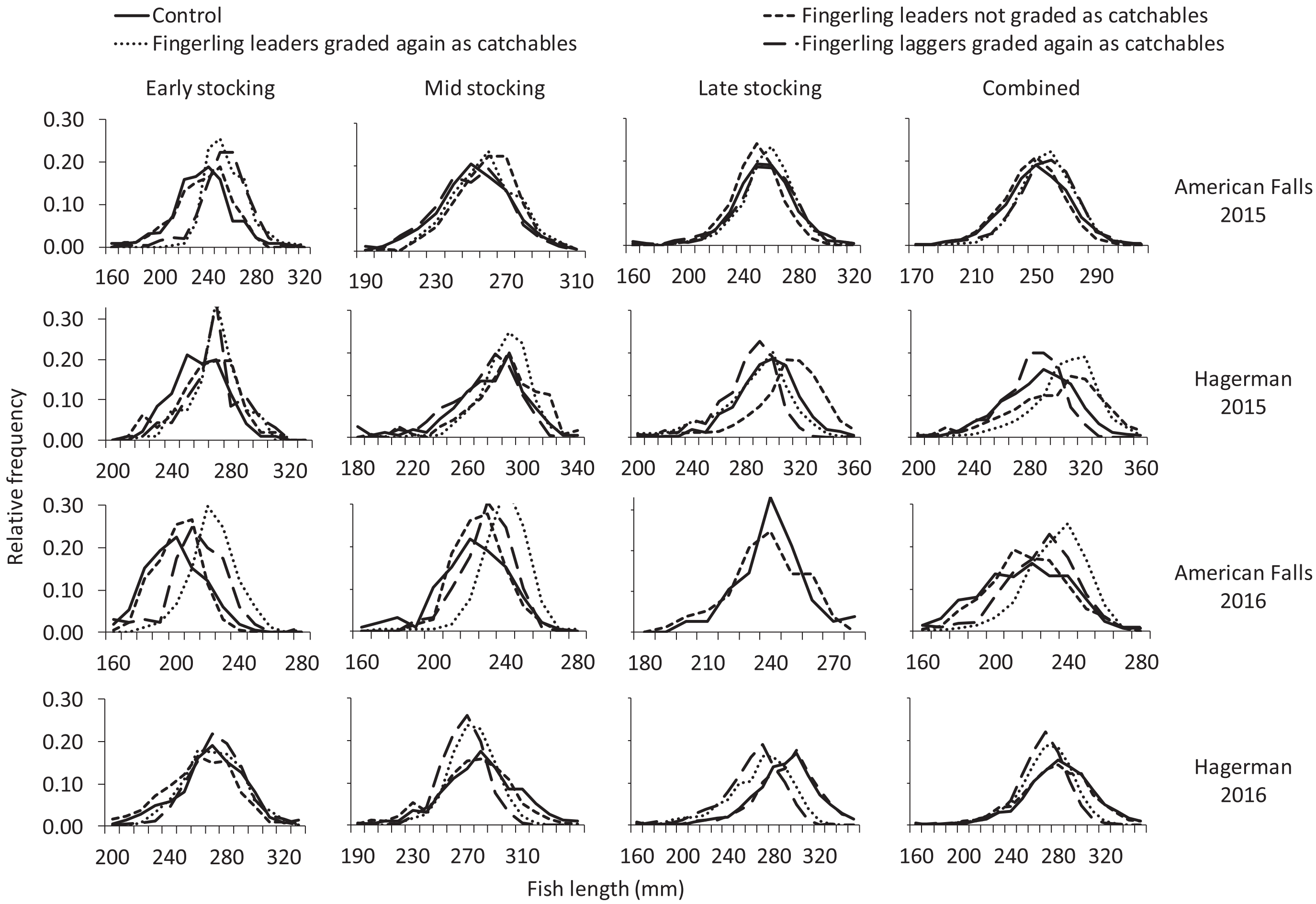

FIGURE 3. Relative frequency of the size of fish that were stocked in 2015 and 2016 into various Idaho waters from two fish hatcheries (American Falls and Hagerman) that graded Rainbow Trout prior to stocking. The grading treatments included (1) fingerlings that graded out as laggers and that were graded again as catchables, (2) fingerlings that graded out as leaders and that were graded again as catchables, (3) fingerlings that graded out as leaders and that were *not* graded again as catchables, and (4) control fish that were not graded at any time during the experiment. See text for details.

size of stocked fish. Such an effect has been observed in several previous studies of return to creel of hatchery catchable trout (e.g., Wiley et al. 1993; Yule et al. 2000; Cassinelli et al. 2016; Cassinelli and Meyer 2018). Wiley et al. (1993) speculated that stocking hatchery trout at a larger size better equips them to handle environmental variability, provides them with more energy reserves, and makes them less vulnerable to predators. However, the cost of growing hatchery trout to a larger size increases exponentially, especially at catchable size (Southwick and Loftus 2003). We speculated that grading fish as fingerlings early in the rearing process or as catchables just prior to stocking might increase overall size at release with no need to extend the rearing period or increase feed costs, but at the hatchery production scale that we investigated no size increase was achieved.

Grading did reduce size variation at stocking, which is one of the primary benefits of grading in commercial aquaculture (Hinshaw 2000), though reduced size variation may also have benefits for hatcheries that are rearing trout for put-and-take fisheries. For example, in the present study 3% of the stocked fish were ≥ 50 mm smaller than the target size for stocking (i.e., 254 mm TL), with some fish as small as 100 mm TL. Angler satisfaction with catching such small fish is substantially lower than it is for fish that measure at or above the target size (K.A.M., unpublished data). While such a small proportion may be considered trivial, grading fish prior to stocking would allow managers to redirect the stocking of undersized fish to less prominent stocking locations. Second, grading prior to stocking may be useful when firm stocking size cutoffs have been established. For example, Yule et al. (2000) concluded that predation of stocked Rainbow Trout by Walleyes *Stizostedion vitreum* in Wyoming reservoirs could be minimized if grading were used to eliminate the stocking of catchables that are smaller than 229 mm.

The rearing hatchery influenced angler tag return rates, despite the fact that controllable rearing conditions and practices (e.g., feeding rates and methods, inventorying methods, rearing density, truck loading) differed little among the hatcheries. Nevertheless, many other factors that cannot be controlled, such as water quality and chemistry, disease transmission, and fish health, are known to vary among hatchery facilities (Bosakowski and Wagner 1994; Iwama et al. 1997; Trushenski et al. 2019). We are aware of very few studies that have compared the postrelease performance of catchables among several hatcheries, and the results have been equivocal (see Cassinelli et al. 2016 and Cassinelli and Meyer 2018). In our study, controlling for a hatchery effect on angler return rates improved our ability to detect other meaningful relationships, most notably a grading effect.

Based on long-term angler tag reporting and tag loss rates for this fish-tagging program (see Meyer et al. 2012 and Meyer and Schill 2014 for details), we estimate that only about 21% of all of the fish that were stocked in this experiment were landed by anglers. Such low return rates for stocked catchable trout is not uncommon (e.g., Cresswell 1981; Bettinger and Bettoli 2002; Cassinelli and Meyer 2018). Nevertheless, the fact that most stocked fish go uncaught by anglers, coupled with the high cost of raising catchable-sized fish (Hunt et al. 2017; Losee and Phillips 2017), highlights the need to continue to manipulate rearing conditions and postrelease strategies (i.e., stocking locations, seasons, and frequency) to maximize angler catch of hatchery trout that are stocked into put-and-take fisheries. While production-level grading was not effective at boosting overall size at stocking or providing a competitive advantage for graded fish, other factors that may influence return to creel of stocked catchables will continue to be explored.

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