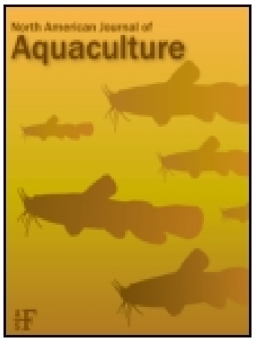

North American Journal of Aquaculture

ISSN: 1522-2055 (Print) 1548-8454 (Online) Journal homepage: http://www.tandfonline.com/loi/unaj20

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To cite this article: John D. Cassinelli, Kevin A. Meyer & Martin K. Koenig (2016) Effects of Rearing Density on Return to Creel of Hatchery Catchable Rainbow Trout Stocked in Idaho Lentic Waters, North American Journal of Aquaculture, 78:3, 208-217, DOI: 10.1080/15222055.2016.1159630

To link to this article: http://dx.doi.org/10.1080/15222055.2016.1159630

Published online: 15 Jun 2016.

North American Journal of Aquaculture 78:208–217, 2016

ISSN: 1522-2055 print / 1548-8454 online
DOI: 10.1080/15222055.2016.1159630

ARTICLE

Effects of Rearing Density on Return to Creel of Hatchery Catchable Rainbow Trout Stocked in Idaho Lentic Waters

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Abstract
Evaluating rearing techniques that maximize angler returns to creel of hatchery trout is an essential tool in shaping hatchery management practices and maximizing the public use of hatchery products. The goal of this study was to determine the effects of raceway rearing density on return to creel of catchable-sized (mean TL ≈ 252 mm) hatchery Rainbow Trout *Oncorhynchus mykiss*. In 2011 and 2012, Idaho Department of Fish and Game reared catchable-sized trout targeting three maximum density indices (0.15, 0.25, and 0.30 lb·ft^{-3}·in^{-1}) at three different state fish hatcheries. Each hatchery stocked fish into the same 11 lakes and reservoirs to evaluate return-to-creel rates by rearing density. Although there was a trend of lower angler catch for fish reared at a higher raceway density, the relationship was not statistically significant. Instead, angler catch was significantly influenced by fish size at stocking and the surface area of the water being stocked, whereby larger fish and smaller waters had higher return-to-creel rates. At the densities tested in this study, we concluded that fish size at stocking is more important than rearing density in determining return-to-creel rates for hatchery catchable Rainbow Trout. Rearing trout at a lower density reduces total hatchery production while not providing a sufficient increase in returns to creel to offset the decreased production.

The stocking of catchable-sized hatchery trout (i.e., about 250 mm TL; hereafter termed catchables) is an important component of coldwater fisheries management programs throughout North America. Catchable trout provide instantaneous fisheries in waters where wild trout are absent or catch rates are low. This is especially important in irrigation reservoirs of western North America, which often fill during springtime snowmelt but may be drawn down so low (or completely drained) by late summer or fall that few fish can overwinter. This precludes the stocking of fry or fingerlings since they require at least one full year to grow to catchable size. Hatchery rearing and transport costs continue to rise sharply (IDFG 2011), while funding of hatchery programs has stagnated or declined (Pergams and Zaradic 2008; USFWS 2011). As a result, since 2008 the Idaho Department of Fish and Game (IDFG) has reduced the number of catchable Rainbow Trout *Oncorhynchus mykiss* stocked in Idaho waters from 2.4 to 1.9 million fish, despite a consistent angler demand for hatchery catchables. Such economizing has underscored the ever-increasing need to maximize return-to-creel rates (i.e., the percentage of stocked fish that are caught by anglers) for resident hatchery fish. One potential avenue to increase return-to-creel rates of catchable trout is to adjust hatchery rearing methods to increase performance after stocking (Elrod et al. 1989).

Examples of hatchery rearing conditions that might be adjusted to increase performance include diet, growth, water quality, flow, size at stocking, and raceway rearing density (e.g., Mullan 1956; Larmoyeux and Piper 1973; Elrod et al. 1989; Banks and LaMotte 2002; Barnes et al. 2009). The effect of rearing density on postrelease survival of hatchery salmonids has been widely studied for anadromous species such as

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Received December 22, 2015; accepted February 22, 2016

Atlantic Salmon *Salmo salar* (Brockmark et al. 2007), Chinook Salmon *O. tshawytscha* (Martin and Wertheimer 1989), Coho Salmon *O. kisutch* (Fagerlund et al. 1981; Schreck et al. 1985; Banks 1992), and steelhead (the anadromous form of Rainbow Trout; Tipping et al. 2004; Kavanagh and Olsen 2014). Unfortunately, results are often inconsistent and have differed between species, brood years, and hatcheries (Ewing and Ewing 1995), making the cumulative results from these studies difficult to interpret. Investigations on resident (i.e., nonanadromous) salmonids have also been conducted for several species, including Cutthroat Trout *O. clarkii* (Kindschi and Koby 1994; Wagner et al. 1997), Lake Trout *Salvelinus namaycush* (Soderberg and Krise 1986), and Rainbow Trout (Papoutsoglou et al. 1987; Kindschi et al. 1991; Wagner et al. 1996; Procarione et al. 1999). These studies on resident salmonids have primarily focused on the effects of rearing density on performance in the hatchery rather than after stocking. A recent exception was a study on juvenile Brown Trout *Salmo trutta*, which found that when stocked in an experimental stream, hatchery fish reared at a high density showed decreased survival relative to fish reared at low or medium densities (Brockmark et al. 2010).

Taken collectively, the aforementioned studies have generally concluded that rearing fish at lower densities improves feed conversion ratios, fish health, growth, and survival both before and after stocking. However, none of these studies have focused on poststocking performance of catchables relative to return-to-creel rates for anglers. Managing hatchery conditions such as rearing space, water flows, and rearing densities are critical to successful hatchery operations (Banks and LaMotte 2002). In particular, optimizing rearing density may help enhance the performance of hatchery-reared fish in stocked fisheries (Elrod et al. 1989). Indeed, lower rearing densities may increase the return to creel of stocked fish or provide an economic benefit to hatcheries if losses from disease outbreaks are reduced (Ogut et al. 2005). However, because rearing fish at lower densities inherently results in fewer total fish being produced, potential increases in angler catch rates from low-density groups must be high enough to offset the reduced numbers of trout reared and eventually stocked (Martin and Wertheimer 1989).

The goal of this study was to investigate whether reducing rearing densities, in the course of typical hatchery production, would result in increased return-to-creel rates of catchable Rainbow Trout. We stocked tagged catchables, reared at various raceway densities, into a variety of lentic waters, and used angler reports of tagged fish to evaluate return-to-creel rates. In addition, we evaluated whether relationships between rearing density and the return to creel were consistent across multiple hatcheries involved in the study.

METHODS

Catchable Rainbow Trout were raised from eggs purchased from Troutlodge Inc., Twin Falls, Idaho, using an all-female triploid stock commonly purchased for IDFG hatchery facilities. Density trials were conducted in 2011 and 2012 at the three IDFG facilities (Hagerman, Nampa, and American Falls fish hatcheries) that produce the majority of catchable trout stocked in Idaho. At each hatchery, fish were reared under typical rearing conditions for that facility and only raceway densities were manipulated.

At American Falls Fish Hatchery, study fish were reared in 13°C, single-pass, spring water. Fry were started in indoor concrete vats (5.3 × 1.2 × 0.8 m) and were fed using a combination of hand-feeding and belt feeders. After reaching approximately 55 mm, fish were inventoried and moved to outdoor concrete raceways (30 × 2.4 × 0.6-m sections). Fish were reared in these raceways and hand-fed for the remainder of the rearing period.

At Hagerman Fish Hatchery, study fish were reared in 15° C, single-pass, spring water. Fry were started in indoor concrete vats (4.3 × 0.8 × 0.6 m). After reaching approximately 50 mm, fish were inventoried using pound counts (i.e., extrapolated from number per pound) and moved to small outdoor concrete raceways (30 × 1.1 × 0.5 m). After reaching 75 mm, fish were again inventoried and moved to large concrete raceways (30 × 2.4 × 0.6-m sections). Upon reaching 200 mm, fish were inventoried for a final time and moved to larger concrete raceways (30 × 3.7 × 0.6-m sections) where they were raised for the remainder of the rearing period. Fish were fed by hand until reaching 100 mm in the large raceways, at which time they were fed mechanically with a tractor-pulled feed cart.

At Nampa Fish Hatchery, study fish were raised in 15°C, single-pass, spring water. Density treatment groups were hatched into small concrete outdoor raceways (7.6 × 1.5 × 0.6-m sections) and fed using a combination of hand-feeding and belt feeders on a 12-h timer. After reaching approximately 80 mm, fish were inventoried and moved to large outdoor concrete raceways (30 × 3.7 × 0.6-m sections) and hand-fed for the remainder of the rearing period.

At all three hatchery facilities, a single large outdoor raceway was used for each treatment. All fish were fed the same floating commercial trout diet (EXTR 450, Rangen, Buhl, Idaho), based on guidelines provided by the manufacturer and sized for fish length. A subsample of fish was weighed monthly and feed rations were adjusted to target 25 mm of growth per month and a final length of 255 mm at the time of stocking.

Three weeks prior to the first stocking of each release year, all treatment groups at each hatchery were tested for pathogens by IDFG's fish health laboratory using routine diagnostic examinations. Fish health was further evaluated using a modified version of the autopsy-based condition assessment outlined by Goede and Barton (1990). Briefly, 20 fish from each group were randomly sampled. Blood was collected and the following blood constituents were measured: hematocrit, leukocrit, and serum protein levels. Next, fish were qualitatively scored for percent (0–100%) of normal for eyes, gills, pseudobranchs, spleen, kidney, and liver. These percentages were averaged to create a "normality" index (NI) of these specific fish health measures. Finally, fish health scores (ranging from 0 to 2, with lower being better) were also generated for appearance of the thymus (level of petechial hemorrhage), gut (level of hemorrhage), fins (level of erosion), and opercle (level of erosion). These four scores were converted to percentages (scored mean/2 × 100) and averaged to create a "severity" index (SI) of fish health.

For each raceway, both density index (DI; $\text{lb}\cdot\text{ft}^{-3}\cdot\text{in}^{-1}$) and flow index (FI; $\text{lb}\cdot\text{gal}^{-1}\cdot\text{min}^{-1}\cdot\text{ft}^{-3}$) were measured at a minimum of once a month following the methods of Piper et al. (1982). We report the values of these two metrics in Standard English units for ease of interpretation. In essence, DI is the relationship of fish size (weight and length) to the water volume of a rearing unit (Piper et al. 1982) and is meant to account for the spatial requirements of hatchery fish. In contrast, FI is the water inflow rate in relation to fish weight and length, and is meant to account for the physiological needs of hatchery fish. Target carrying capacity for both metrics at any given hatchery should be adjusted based on factors such as water temperature, elevation above sea level, and dissolved oxygen. Although in our study we manipulated DI only, FI was also monitored because both metrics can affect poststocking performance (Elrod et al. 1989), and adjustments in DI inherently alter FI as well, although not in a directly proportional manner.

The facilities included in our study typically target a maximum DI of 0.30 $\text{lb}\cdot\text{ft}^{-3}\cdot\text{in}^{-1}$ for catchable trout, based on both the recommendations in Piper et al. (1982) and past fish culture experience. We targeted three maximum rearing density treatment levels of 0.15 (50% of the typical target), 0.23 (75% of the typical target), and 0.30 (typical target) $\text{lb}\cdot\text{ft}^{-3}\cdot\text{in}^{-1}$, which we categorized as low, medium, and high density, respectively. All three treatment groups were administered at all three facilities in both years of the study, except that only two treatment levels (low and high density) were raised at Hagerman Fish Hatchery in 2011 due to space limitations relative to other IDFG hatchery production commitments.

We purposefully implemented our study design within the constraints of normal IDFG hatchery operations. As such, we could not maintain a constant raceway density at the specified density treatment level throughout the entire study, because that would have required almost constant evaluation of fish size and associated adjustments to density in the raceways. Instead, our goal was to periodically approach but not exceed the specified maximum DI for each treatment level during the study. As fish grew and densities increased, rearing space was expanded into lower raceway sections to avoid exceeding the specified maximum DI values. Additionally, fish sizes were monitored closely to minimize size differences between treatment groups and hatcheries.

Catchables were crowded within raceways and collected with dip nets for fish tagging. Crowding the fish ensured a more representative sample from the entire raceway and reduced size-selective bias when netting fish for tagging. Fish were sedated, measured for TL (nearest mm), and tagged dorsally using 70-mm, fluorescent orange, T-bar anchor tags (with 51 mm of tubing). After tagging, the trout were returned to submerged enclosures or empty raceway sections and allowed to recover overnight. Tagged trout were loaded by dip net onto stocking trucks and transported to stocking locations within 48 h of tagging. Mortalities and shed tags were collected and recorded before loading fish for transport, and truck tanks were checked for shed tags after stocking. Trout were tagged from their respective experimental raceways and then combined and loaded with the normal lot of untagged fish scheduled for that stocking event. For each water body, we tagged 200 fish from each treatment group at each hatchery. In cases where tagged fish were the only fish being stocked into a particular water by a particular hatchery, tagged fish were transported alone without additional production fish. There were 13 unique stocking events (seven in 2011 and six in 2012) that occurred in 11 unique water bodies across the state. All three hatcheries stocked fish from each treatment, at each stocking event, on the same day. Stockings occurred in the spring and early summer, which corresponds to the time of year when IDFG annually stocks the majority of hatchery catchable trout. We calculated the surface area (km^2) of all stocked waters using ArcGIS software; surface area ranged from 0.11 to 30.47 km^2.

To facilitate angler reporting of tagged fish they caught, anchor tags were labeled with "IDFG" and a tag-reporting phone number (IDFG 1-866-258-0338) on one side, and a unique tag number on the reverse side. Anglers could report tags using the IDFG "Tag-You're-It" phone system or website, as well as at regional IDFG offices or by mail.

Tag reporting rates were estimated using the high-reward method (Pollock et al. 2001). For a detailed explanation of this method see Meyer et al. (2012) and Meyer and Schill (2014). Angler nonreward tag-reporting rate (λ) was estimated using the equation

$$\lambda = \frac{Rr/Rt}{Nr/Nt},$$

where R_t and R_r are the number of nonreward tags stocked and reported, and N_t and N_r are the number of high-reward tags (US$50 in our study) stocked and reported. This equation was calibrated to account for the estimated 88% of $50 tags that are encountered by anglers are actually reported (Meyer et al. 2012). A portion of the trout were double-tagged to calculate tag loss rates following the methods of Meyer and Schill (2014).

We calculated unadjusted total catch (u) as the number of nonreward tagged fish reported as caught within 1 year of stocking divided by the number of nonreward tags stocked. Total catch was adjusted (u') by incorporating the average angler tag reporting rate (λ), tag loss (Tag_l), and tagging mortality (Tag_m; which was taken from Meyer and Schill 2014). Adjusted total catch was estimated for each individual stocking event using the formula

$$u' = \frac{u}{\lambda(1 - Tag_l)(1 - Tag_m)}.$$

We compared angler catch across rearing densities and hatcheries using a general linear model. Each unique hatchery × density treatment combination was considered the experimental unit for our analyses. Replicate sampling of the experimental unit was the multiple waters that were stocked with each hatchery × density combination, giving us a total of 110 unique observations. The dependent variable in the model was the adjusted total angler catch for each particular stocking. Independent variables included the average DI experienced by catchables during rearing, average FI, the rearing hatchery, mean length of fish for the stocking event, fish health normality index, fish health severity index, and the surface area of the water being stocked. The size of the water was included because we expected different angler catches across waters (Koenig and Meyer 2011; Meyer and Schill 2014), and we hypothesized that at least some of this variation might be explained by the size of the water receiving stocked fish (Ashe et al. 2014), since per capita fishing effort is often a function of water size and angler catch is often related to fishing effort (Kuparinen et al. 2010). Plausible first-order interaction terms were also included as potential independent variables. All possible subset models were evaluated, and Akaike's information criterion (AIC) corrected for sample size (AIC_c) was used to judge the best model (Akaike 1973). We determined the most plausible models as those with AIC_c scores within 2.0 of the best model (Burnham and Anderson 2004). We used AIC_c weights (w_i) to assess the relative plausibility of each model and adjusted r^2 to show the amount of variation explained by each model. Residuals were evaluated for normality and heteroscedasticity. Analyses were conducted using the SAS statistical software package (SAS Institute 2010) with an α value of 0.05.

RESULTS

In both 2011 and 2012, raceway DI values fluctuated widely over time at all hatcheries as fish grew and as rearing space was adjusted. Though there were many fluctuations, the treatments typically fluctuated in unison and there was only a small amount of overlap in DI values between treatments throughout the rearing period (Figure 1). Periodic measurements of DI values met or came close to meeting target DI values for all treatment groups at various points during rearing (Figure 1; Table 1).

Catchable Rainbow Trout averaged 252 mm TL at the time of stocking. Mean length of hatchery- and treatment-specific study groups ranged from 235 to 270 mm and differed slightly between hatcheries and density treatments in both years (Table 1). For the 2011 stockings from all three hatcheries, low-density-reared fish were slightly larger than both medium- and high-density-reared fish, but this difference was most pronounced at Nampa Fish Hatchery. For the 2012 stockings from Hagerman and American Falls fish hatcheries, low-density-reared fish were slightly larger than both medium- and high-density-reared fish, while at Nampa Fish Hatchery fish reared at medium density were the largest (Table 1).

There were no pathogens detected in any of our fish groups in either year of our study. Blood hematocrit, leukocrit, and serum protein levels were all considered within the normal range for hatchery Rainbow Trout (Miller et al. 1983, Goede and Barton 1990, Řehulka et al. 2004) for all groups (Table 2), as were the qualitative indices of fish health (i.e., NI and SI; Table 2).

Across both years of the study, we tagged a total of 22,000 catchable Rainbow Trout, of which 2,755 were returned by anglers. Angler tag-reporting rate for nonreward tags was 45% across the 2 years of the study, while the tag loss rate was 7% for the first 365 d poststocking. Adjusted total angler catch across all stockings averaged 29% and ranged from 0 to 80%.

The best general linear model for explaining the variation in angler catch (based on AIC_c scores) included water surface area and average fish length at stocking (Table 3). These two variables alone explained 28% of the variation in angler catch. In addition to the fish size and water-body size variables, other plausible models also included either the fish health severity or normality index, rearing hatchery, or FI (Table 3), but the addition of a third term to the best model introduced no additional explanatory power compared with the best model. While the DI did not play a meaningful role in any of our top models, we did observe a nonsignificant trend towards increasing angler catch with decreasing DI, whereas FI showed no relation to angler catch (Figure 2). The percentage of fish that were caught by anglers increased as mean fish length at stocking increased (Figure 3) and as the size of water decreased (Figure 4).

DISCUSSION

The effects of raceway rearing density on prestocking performance of hatchery trout are well documented in the literature. Prestocking benefits of reduced rearing density

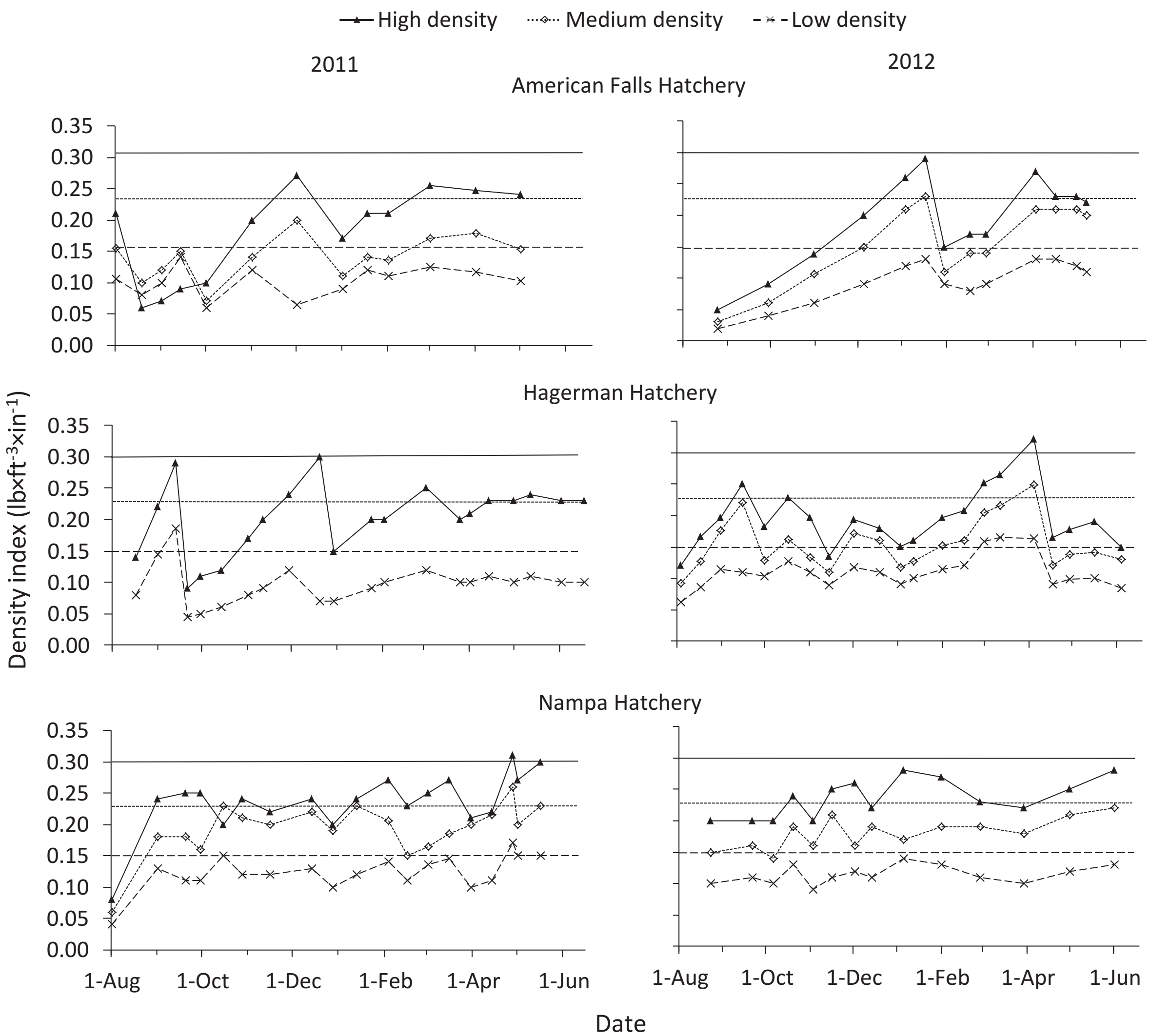

FIGURE 1. Density indices during hatchery rearing for low (0.15 lb·ft^{-3}·in^{-1}), medium (0.23 lb·ft^{-3}·in^{-1}), and high (0.3 lb·ft^{-3}·in^{-1}) treatment groups at American Falls, Hagerman, and Nampa fish hatcheries. Horizontal lines depict the low (dashed line), medium (dotted line), and high (solid line) targets for raceway density treatments.

typically include improved survival, growth, condition factor, and food conversion efficiency (Soderberg and Krise 1986; Kindschi et al. 1991; Kindschi and Koby 1994; Wagner et al. 1997; Procarione et al. 1999). With so many studies showing positive effects of reduced densities on fish performance in the hatchery, it seems reasonable to expect these positive effects to carry over to performance after stocking. Unfortunately, the influence of rearing density on poststocking performance for resident hatchery trout has rarely been investigated, although numerous studies have been conducted on anadromous salmon. Generally speaking, rearing density is almost always negatively related to survival of salmon smolts and subsequent adult returns. However, in nearly all studies, the higher number of smolts produced in high-density raceways has offset the negative effects of higher rearing density, ultimately returning more adults (e.g., Martin and Wertheimer 1989; Banks 1992; Banks and LaMotte 2002; Tipping et al. 2004). Our results concur with these findings insofar as reduced rearing density did not result in a significant increase in returns to creel of catchable Rainbow Trout stocked into Idaho lakes and reservoirs.

Angler catch was strongly influenced by the length of fish at stocking, and larger fish generated higher return to creel. Previous studies have shown strong positive correlations between size at stocking and return to creel for hatchery trout. For example, Mullan (1956) found increased angler returns with increased size at stocking of Rainbow Trout, Brown Trout, and Brook Trout *Salvelinus fontinalis*. Larger Rainbow Trout and Cutthroat Trout in Wyoming

TABLE 1. Mean density index (DI; lb·ft^{-3}·in^{-1}) and flow index (FI; lb·gal^{-1}·min^{-1}·ft^{-3}) during the entire rearing period by hatchery and by raceway density treatment for catchable Rainbow Trout stocked in Idaho lentic waters. Length is the mean TL (mm) at the time of stocking (with the 95% CIs in parentheses). Each treatment consisted of 200 tagged fish groups released into seven waters in 2011 and six waters in 2012.

	Release year 2011					Release year 2012				
	DI		FI			DI		FI		
Density treatment	Mean	Range	Mean	Range	Length (mm)	Mean	Range	Mean	Range	Length (mm)
American Falls Fish Hatchery										
Low	0.11	0.05–0.14	0.32	0.08–0.67	257 (±6)	0.09	0.01–0.13	0.36	0.28–0.42	251 (±4)
Medium	0.15	0.07–0.20	0.49	0.18–1.31	255 (±11)	0.15	0.03–0.23	0.56	0.47–0.70	249 (±7)
High	0.13	0.06–0.28	0.67	0.23–1.44	252 (±6)	0.19	0.05–0.29	0.59	0.31–0.85	241 (±5)
Hatchery mean					255 (±4)					251 (±3)
Hagerman Fish Hatchery										
Low	0.10	0.05–0.19	0.50	0.20–1.25	267 (±13)	0.11	0.06–0.17	0.54	0.19–1.10	271 (±5)
Medium						0.15	0.09–0.25	0.66	0.37–0.99	261 (±6)
High	0.21	0.09–0.30	0.79	0.37–1.39	253 (±10)	0.19	0.12–0.32	0.84	0.38–1.95	251 (±5)
Hatchery mean					260 (±8)					251 (±3)
Nampa Fish Hatchery										
Low	0.13	0.04–0.22	0.29	0.09–0.56	257 (±3)	0.11	0.09–0.14	0.26	0.12–0.41	242 (±3)
Medium	0.20	0.06–0.35	0.50	0.15–0.99	251 (±4)	0.18	0.14–0.22	0.48	0.14–1.19	247 (±4)
High	0.25	0.08–0.50	0.59	0.20–1.29	242 (±3)	0.24	0.20–0.28	0.49	0.20–0.84	238 (±4)
Hatchery mean					251 (±3)					242 (±2)

returned to the creel at a higher rate and at a reduced mean cost per fish than did smaller-sized trout (Wiley et al. 1993) and resulted in increased returns to creel in the presence of a predator species (Yule et al. 2000). There are likely numerous reasons that larger trout return to creel at a higher rate. Wiley et al. (1993) noted that larger trout are better able to avoid predators, may not be as seriously affected by a limited food supply, and might be better equipped to handle environmental changes, such as rapid drawdown in reservoirs. The relationship we observed suggests that the larger the mean size of fish at stocking, the better the angler catch will be. However, the costs of raising fish to a larger size increase exponentially, especially as fish size approaches catchable size. At the current level of production, this would make it cost prohibitive to rear fish much larger than the size we stocked.

The size of the water body stocked also influenced angler catch, whereby catch was inversely related to water size. In Maine lentic waters, water size was the most influential factor affecting angler catch of hatchery Brook Trout, whereby smaller waters similarly provided higher return rates of stocked catchables (Ashe et al. 2014). If physiological or habitat requirements for catchable trout are not adequately met in larger waters, survival of stocked fish may be reduced, and anglers would subsequently catch fewer of the stocked fish. Environmental factors that we did not measure, but may be influenced by water size and have been shown to affect catchable fish survival, include water quality (Koenig and Meyer 2011), food availability (Wiley et al. 1993), and predator abundance and diversity (Baldwin et al. 2003). Additionally, stocking density might explain much of the reduced catch of stocked fish in larger water bodies (Miko et al. 1995), as fewer stocked fish per acre of water inherently reduces angler encounters of these fish unless angling pressure increases proportionally to increased water size. Because a lower percentage of fish are returned in larger waters and stocking these waters at a high enough stocking density to increase catch is cost prohibitive and usually unsuccessful (Miko et al. 1995; Patterson and Sullivan 2013), fisheries managers may be inclined to reduce stocking in larger waters and focus stocking on smaller waters with higher returns. However, fisheries managers should use caution when considering stocking reductions in larger waters simply to maximize total angler use of stocked catchables. Reducing stocking in larger waters based solely on angler catch could inadvertently reduce angler satisfaction at larger waters, leading to reduced angler effort and ultimately a decline in economic expenditures in communities where larger waters reside. Fisheries managers must keep in mind that the goal of rearing and stocking catchable trout is to maximize angler satisfaction, not angler catch rates. As long as enough fish are stocked into put-and-take fisheries to achieve threshold catch rates, angler satisfaction may be sufficient to generate ample angling effort (Patterson and Sullivan 2013).

TABLE 2. Fish health results from an autopsy-based condition assessment of each treatment group at each hatchery. Normality scores are based on a percentage of normal values, while severity scores are a percentage of severity values. Scores were administered by IDFG's resident fish pathologist. Indices, written in italics, are averages of the individual scores.

					Normality (% of normal)							Severity (% of severity)				
Rearing hatchery	Density treatment	% Hematocrit	Leukocrit	Serum protein	Eyes	Gills	Pseudobranchs	Spleen	Kidney	Liver	Index	Thymus	Hind gut	Fin	Opercle	Index
2011 Stocking year																
American Falls	Low	38.4	0.95	3.54	100	100	100	100	100	100	*100.0*	40.0	0.0	55.0	0.0	*15.6*
	Medium	42.0	0.58	3.22	100	100	100	100	100	100	*100.0*	45.0	0.0	55.0	5.0	*26.3*
	High	41.8	0.80	3.58	100	100	100	100	100	100	*100.0*	25.0	0.0	37.5	0.0	*23.8*
Hagerman	Low	37.0	0.98	3.34	95	90	100	100	100	100	*97.5*	32.5	0.0	22.5	0.0	*13.8*
	High	39.4	0.93	3.27	100	85	100	95	95	100	*95.8*	28.0	0.0	25.0	5.0	*14.4*
Nampa	Low	37.5	0.99	3.35	100	95	100	100	100	100	*99.2*	40.0	0.0	2.5	7.5	*12.5*
	Medium	40.2	0.99	3.19	100	90	100	95	100	100	*97.5*	7.5	0.0	42.5	7.5	*14.4*
	High	39.3	0.99	2.74	100	70	100	95	100	100	*94.2*	40.0	0.0	17.5	10.0	*18.1*
2012 Stocking year																
American Falls	Low	39.9	1.05	3.67	100	100	100	100	100	100	*100.0*	27.5	0.0	32.5	0.0	*15.0*
	Medium	42.1	0.89	3.49	95	100	100	100	100	100	*99.2*	40.0	0.0	35.0	2.5	*19.4*
	High	39.6	0.95	3.10	100	100	100	100	100	100	*100.0*	32.5	0.0	47.5	2.5	*20.6*
Hagerman	Low	43.6	0.45	3.89	100	100	100	100	100	100	*100.0*	35.0	0.0	7.5	2.5	*11.3*
	Medium	36.7	1.00	3.94	100	95	100	100	100	100	*99.2*	47.5	0.0	30.0	7.5	*21.3*
	High	42.6	1.15	3.92	95	100	100	100	100	100	*99.2*	55.0	0.0	45.0	5.0	*26.3*
Nampa	Low	39.1	1.10	3.72	100	100	100	100	100	100	*100.0*	37.5	0.0	10.0	5.0	*13.1*
	Medium	45.4	0.80	3.77	100	100	100	100	100	100	*100.0*	55.0	0.0	17.5	5.0	*19.4*
	High	40.9	1.35	3.58	100	90	100	100	100	100	*100.0*	35.0	0.0	17.5	7.5	*15.0*

TABLE 3. General linear model results relating independent variables to the total catch of hatchery catchable Rainbow Trout reared at different densities and stocked in various lentic waters in Idaho. Only the most plausible models (those with AIC_c scores within 2.0 of the best model) are shown.

Variables	r^2	AIC_c	ΔAIC_c	w_i
Water surface area, average fish length	0.28	−287.46	0.00	0.23
Water surface area, average fish length, severity index	0.28	−286.90	0.56	0.18
Water surface area, average fish length, normality index	0.27	−286.04	1.42	0.11
Water surface area, average fish length, hatchery	0.27	−285.58	1.88	0.09
Water surface area, average fish length, flow index	0.27	−285.47	1.99	0.09

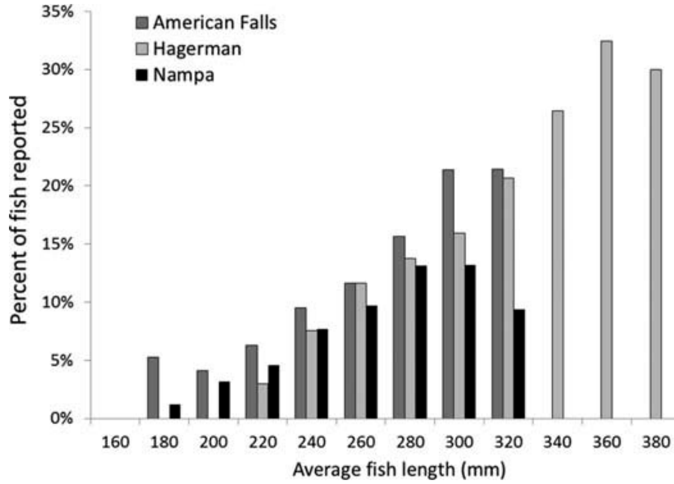

FIGURE 3. Percent of Rainbow Trout reported by anglers (uncorrected for angler reporting rate) binned into 20-mm length groups for each hatchery. Data are for both stocking years combined and represent averages of individual fish lengths at stocking.

As expected, rearing densities for our treatment groups fluctuated greatly during the rearing period, as well as between hatcheries. All three hatcheries achieved the specified separation goal of the density treatments (50, 75, and 100% of the maximum treatment value), but overall, average density treatments were lower than targeted. In general, fish were reared at lower densities at American Falls and Hagerman fish hatcheries than at Nampa Fish Hatchery, and the latter achieved average DI values closest to the specified treatment levels. Because densities only periodically reached the specified maximum treatment levels the effect of rearing density on returns to creel may have been diminished. Had we held raceway densities constant at our three target levels, we may have seen a clearer effect on postrelease return to creel. However, such constant raceway densities would not be practical under typical hatchery production. We intentionally designed our study to evaluate whether different rearing densities, applied under a normal production scale, could improve the return to creel of hatchery Rainbow Trout. The

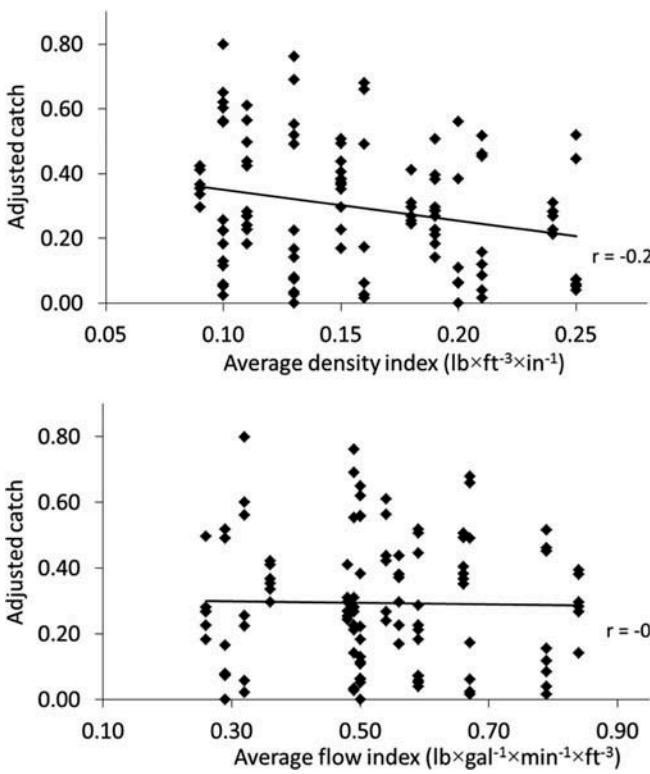

FIGURE 2. Angler catch (percentage of released fish caught) of hatchery Rainbow Trout (adjusted for angler reporting rate, tag loss, and tagging mortality) reared at various raceway densities (top panel) and raceway flows (bottom panel) for all study groups stocked across all waters.

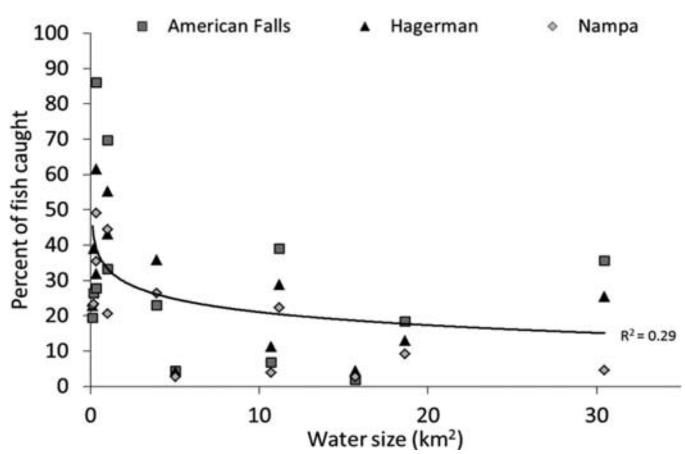

FIGURE 4. Scatter plot of total catch of hatchery catchable Rainbow Trout released from American Falls, Hagerman, and Nampa fish hatcheries in relation to water surface area for each water stocked. A logarithmic relationship was fitted to the data.

variations we saw in DI across time are inherent in typical production-level rearing and are the product of fish growth, changes in rearing containers, and inventory fluctuations as fish are stocked.

Both DI and rearing hatchery appeared to have had little influence on angler catch. However, it is interesting to note that the hatchery with the highest DI values (Nampa) had the lowest average return-to-creel rate and the smallest fish. While it would seem intuitive that fish reared at higher densities might have lower growth rates, for our study we attempted to mitigate that effect by controlling feed rates in order to standardize fish length at the time of stocking across density treatments. Kavanagh and Olson (2014) found that steelhead reared at lower densities had increased growth and were larger both at the time of release and as returning adults. Had we not controlled feeding rates to minimize differences in size at stocking, we would likely have found a more direct effect of density on growth and size at stocking, which in turn would have likely affected angler catch between treatments. However, our hatcheries target a 254-mm release size for catchables, and our goal was to stock fish close to that target, regardless of density treatment. Moreover, because fish length was accounted for in our models, slight differences in fish length between hatchery or raceway densities did not diminish our ability to detect raceway density effects on poststocking catch of stocked Rainbow Trout in our study.

CONCLUSION

Results from our study suggest that lowering hatchery rearing density to levels below normal production capacities will not improve the return to creel of catchable Rainbow Trout stocked in lentic environments. Instead, we found that return to creel was improved by releasing larger fish and releasing fish in smaller water bodies. Rearing density may only limit catchable postrelease performance if it impacts prerelease fish health, disease, or size at stocking through factors such as space limitation and competition in raceways. Based on our results, hatchery managers who rear healthy catchable fish near the maximum recommendations in Piper et al. (1982) will not hinder angler catch of those fish after stocking. However, we are aware of no previous studies that have evaluated, at a hatchery production level, the effects of rearing density on the postrelease performance of catchable trout stocked in lentic settings. Therefore, there is a need for additional studies to further understand the relationships between these in-hatchery conditions and poststocking performance. More information is also needed to assess how fine-scale adjustments to size at stocking may alter angler returns to creel; gaining such knowledge would help maximize rearing cost and angler catch for hatchery catchable trout.

ACKNOWLEDGMENTS

We acknowledge E. Herrera, C. Sullivan, and S. Elle for assisting with tagging fish. We also thank the regional fish managers and staff for recommendations and help in designing and implementing the study. T. Klucken (American Falls Fish Hatchery), J. Chapman (Hagerman State Fish Hatchery), R. Alsager (Nampa Fish Hatchery), and their staffs provided invaluable assistance in tagging, rearing, and releasing fish. T. Lamansky, L. Mamer, K. Stevenson, and D. Jensen were instrumental in managing fish and tag return data. R. Raymondi provided GIS size estimates of waters stocked. D. Burton conducted all fish health evaluations. Finally, we thank D. Schill, J. Trushenski, M. Kavanagh, and several anonymous reviewers for providing valuable comments on earlier versions of this paper. Funding for this work was provided by anglers and boaters through their purchase of Idaho fishing licenses, tags, and permits, and from federal excise taxes on fishing equipment and boat fuel through the Sport Fish Restoration Program.

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