Factors influencing return-to-creel of hatchery catchable-sized Rainbow Trout stocked in Idaho lentic waters

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A B S T R A C T
In recent years, increases in hatchery rearing and transport costs coupled with stagnant or declining funding has often resulted in reduced numbers of hatchery fish stocked in public waters. This has intensified the need to better understand how to maximize return-to-creel rates of hatchery trout by identifying factors contributing to better post-stocking performance. From 2011 through 2014, we tagged 50,745 catchable-sized hatchery Rainbow Trout *Oncorhynchus mykiss* and stocked them into 54 different lentic waters in Idaho (mostly impoundments) across 226 individual stocking events. Angler tag returns (*n*= 5092) were used to generate water-specific estimates of angler return rates (i.e., the proportion of stocked fish caught by anglers) and average days-at-large of captured fish. We then modeled water-specific angler return rates and days-at-large against a suite of water- and stocking-specific characteristics to determine what factors most influenced both angler returns and fishery longevity. First-year angler return rates across all four study years averaged 23% and ranged from 0% to 76% for individual stocking events; the variation in angler returns was best explained by mean fish length at stocking, water size, rearing hatchery, and water elevation. Average days-at-large for angled fish in individual waters varied from a low of 10 d to a high of 297 d, and this variation was best explained by water size, stocking season, and the rearing hatchery. We found the highest angler returns for larger trout stocked into smaller waters at lower elevations. However, these smaller waters also had shorter fisheries, requiring more frequent stocking to prolong the fisheries through the entire angling season. When considering these findings, managers must also consider the balance between angler catch, effort, and satisfaction as they work towards maximizing the benefit to anglers from put-and-take fisheries.

1. Introduction

Numerous state and provincial agencies in North America use hatchery trout as a means to create or enhance fisheries, stocking either fingerlings for put-and-grow fisheries or catchable-sized trout for put-and-take fisheries. Over time, many agencies have gradually stocked fewer fingerling trout, switching their production largely to catchable-sized fish (Cresswell, 1981; Halverson, 2008), because larger trout survive better and return to creel at higher rates (Leitritz, 1970; Wiley et al., 1993; Yule et al., 2000) than do smaller trout. Catchable-sized hatchery trout (herein, catchables) have become an important component of many fisheries management programs in coldwater habitats, because they provide instantaneous fisheries once they are stocked. This is especially important in altered habitats such as impounded reservoirs, which typically do not support wild trout populations, and often do not provide adequate conditions to sustain trout over a sufficient time period for put-and-grow fisheries to develop (Trushenski et al., 2010).

While catchable stocking programs continue to be used as a fishery management tool and valued by anglers, hatchery rearing and transport costs continue to rise precipitously (IDFG, 2011), and funding of hatchery programs has remained unchanged 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* annually stocked in Idaho waters from 2.4 to 1.9 million fish. Such economizing has intensified the desire to (1) better understand how to maximize return-to-creel rates of hatchery catchables, and (2) identify what factors contribute to better harvest of hatchery fish. Numerous factors have been shown to influence post-stocking performance of catchables, including (but not limited to) the temperature, size, elevation, water quality, and fish species composition of the water being stocked, hauling distance from the hatchery, fish size-at-stocking, stocking season, hatchery feed used, and stocking density (e.g., Wiley et al., 1993; Yule et al., 2000; Barnes et al., 2009; Koenig and Meyer, 2011; Asbe et al., 2014). While not all of these factors can be controlled by hatchery staff or fisheries managers to
boost angler return-to-creel rates, it is nevertheless valuable to understand the effect such factors have on post-release performance of catchables, regardless of the level of control that can be exerted on them. This is especially true at broad scales and through time, because post-release catchable performance is notoriously inconsistent (e.g., Wiley et al., 1993; Koenig and Meyer, 2011; Patterson and Sullivan, 2013), making it difficult to establish overarching relationships that can be used to guide stocking strategies. The primary objective of our study was to determine what factors most influenced the angler catch rates of catchables stocked into lowland lentic waters throughout the state of Idaho, across multiple stocking events, and over multiple years.

In addition to understanding the factors that influence the angler returns of catchables, it is also important for managers to better understand what factors might influence the duration of catchable fisheries post-stocking. If a desirable percentage of the stocked trout are caught by anglers, but all of the catch occurs in a short period of time post-stocking, receiving waters might need to be stocked more than once during the angling season to maintain return rates acceptable to anglers. Besides the speed at which angler harvest occurs in the fishery, the biggest factor influencing the longevity of a catchable fishery is fish survival after stocking. While numerous studies have shown poor survival of hatchery catchables stocked into streams (Miller, 1952; Reimers, 1963; Erskbak and Haase, 1983; High and Meyer, 2009), hatchery trout survival in lentic waters is generally higher, and more variable (Wiley et al., 1993). Waters with low to moderate angler exploitation and high catchable survival should produce a prolonged fishery, whereas waters having high angler exploitation, low survival, or a combination of both, should produce a much shorter fishery. A secondary objective of our study was to determine what factors influenced the longevity of the fishery subsequent to each stocking.

2. Methods

From 2011 to 2014, catchable Rainbow Trout were raised from eggs either purchased from TroutLodge, Inc. (all-female triploids) or fertilized internally from IDFG’s Hayspur strain (mixed-sex triploids). These two sources annually provide nearly all of the eggs used in the IDFG hatchery trout program. Fish were reared at eight different hatcheries for this study, but the vast majority of fish (roughly 90%) were reared at the three largest IDFG hatchery trout facilities (i.e., Hagerman, Nampa, and American Falls fish hatcheries). At all facilities, fish were reared on single-use spring water at 13–15 °C. Fry were started in small concrete vats and were fed using a combination of either hand-feeding and belt feeders. After reaching 60–80 mm in length (depending on the facility), fish was inventoried and moved to outdoor concrete raceways (usually in 30 m × 3 m × 1 m sections) and fed by hand-feeding, belt feeders, or tractor-pulled feed carts. Other rearing conditions and practices, such as inventorying, raceway density, and truck loading differed little among hatcheries. Fish was reared to catchable size, with a target of 255 mm (total length) at time of stocking.

To evaluate post-stocking performance of catchables from each stocking event, a subsample of catchables was tagged prior to stocking with 70-mm fluorescent orange T-bar anchor tags (Dell, 1968). Fish were collected for tagging by crowding them within raceways and capturing them with dip nets. This ensured a representative sample was collected from the entire raceway. Fish were sedated, measured to the nearest mm, and tagged just under the dorsal fin following the methods of Guy et al. (1996). After tagging, trout were returned to an empty section of raceway or to a holding pen in the raceway for at least 12 h. Within 48 h of tagging, tagged fish were loaded by dip net onto stocking trucks with the normal lot of untagged fish and transported to stocking locations. Mortalities and shed tags were rare (< 1%), but they were collected and recorded before loading fish for transport.

Stocking locations to receive tagged fish were scattered across the state of Idaho (Fig. 1). Stocking locations were selected from waters on IDFG’s annual catchable stocking program, and we targeted lentic waters that received the bulk of all catchables stocked each year so that we were annually evaluating the performance of a majority of the catchables that IDFG stocks. Stocking events occurred from March through November annually. All stocked waters included in this study were managed under general trout rules with a daily trout limit of 6 fish with no size limit.

We generally tagged 100–400 fish for each stocking event, depending on how many untagged fish were also being stocked, but we never tagged more than 10% of the fish being stocked. Overall stocking numbers for each water were determined by regional fishery managers based on local knowledge of the receiving water – including water quality, food availability, presence of other species, expected harvest, and fishing pressure – as well as factors such as statewide stocking budget and fish availability, but there were no strict guidelines on choosing stocking density. Most waters were stocked only one time in a calendar year but multiple times across the duration of the study, and usually during multiple seasons (except winter).

Angler catch data was based on the anchor tags that were reported by anglers. For a detailed description of the angler tag reporting system we used, see Meyer et al. (2012) and Meyer and Schill (2014). In short, anglers could report tags using the IDFG “Tag-You’re-It” phone system or website (set up specifically for this program), as well as at regional IDFG offices or by mail. To facilitate angler reporting of tagged fish, anchor tags were labeled with “IDFG” and a tag reporting phone number on one side, with a unique tag number on the reverse side. Each year, a subset of study waters received $50 reward tags in addition to standard non-reward tags. In locations that received reward tags, rewards were distributed at a constant rate of 10% of the total tags stocked. Reward tags were identical to non-reward tags in size, shape, and color, but contained additional text (“Reward”) and the reward amount (“$50”).

To estimate the reporting rate ($\lambda$) of non-reward tags, we used the high-reward method (Pollock et al., 2001) and equation:

$$\lambda = \frac{R_s / R_t}{N_t / N_s}$$

Fig. 1. Lentic waters stocked from 2011 to 2014 as part of an Idaho-wide evaluation of factors influencing the return-to-creel of catchable-sized hatchery Rainbow Trout.
where \( R_c \) and \( R_r \) are the number of non-reward tags stocked and reported, respectively, and \( N_c \) and \( N_r \) are the number of reward tags stocked and reported, respectively. This equation was calibrated to account for the fact that an estimated 88% of 50 tags are actually reported (Meyer et al., 2012). We estimated the mean tag reporting rate for each stocking year from waters that received reward tags to correct angler return rates at all waters for that year.

In each study year, a portion of the trout was double tagged to calculate year-specific tag loss. Double-tagged fish received two tags implanted next to each other on the same side of the fish. All anglers returning tags were asked if the fish they caught was tagged with one or two tags. Any double-tagged fish that had lost a tag were used to calculate tag loss rates (Tagl) following the formula:

\[
\text{Tagl}_t = \left( \frac{n_{DT1}}{2 \times n_{DT2}} \right) + \left( \frac{n_{DT1}}{2 \times n_{DT2}} \right)^2
\]

where \( n_{DT1} \) is the number of double-tagged fish for which anglers reported that only a single tag was present, and \( n_{DT2} \) is the total number of double-tagged fish reported, whether one tag or both tags were present. The second part of the equation accounts for fish that lost both tags and therefore had no chance of being reported (Miranda et al., 2002).

We calculated total angler returns (c) as the number of non-reward tagged fish reported as caught within one year of stocking divided by the number of non-reward tagged fish stocked. This included all fish caught, including those released back into the fishery. While some catch and release occurred, it was not very common for hatchery catchables in put-and-take fisheries in Idaho (J. Cassinelli, unpublished data). We only evaluated angler returns within the first year post-stocking, because returns beyond one year at large were inconsequential. Total angler returns were adjusted (c), to estimate the total proportion of stocked catchables caught by anglers for each stocking event, by incorporating the angler tag reporting rate (λ), tag loss (Tagl), and tagging mortality (Tagm, which was taken from Meyer and Schill (2014) to be 0.8%). Estimates were calculated for each individual stocking event using the formula:

\[
c' = \frac{c}{\lambda(1 - \text{Tagl})(1 - \text{Tagm})}
\]

We measured a number of water-specific and stocking-specific characteristics we felt might influence angler return rates or days-at-large for the catchables our agency stocks (Table 1). Continuous independent variables included the elevation (m) and surface area (km²) of the water being stocked; mean total length (mm) of fish for each stocking event; landing distance (km) from hatchery to stocking location; cumulative precipitation (cm) three months pre- and post-stocking; average three-month air temperature (°C) pre- and post-stocking; the human population size within 50 km of the stocked water; and the stocking density (fish/km²). Categorical independent variables included the rearing hatchery and season of stocking. Hatcheries other than American Falls, Hagerman, and Nampa fish hatcheries were lumped together into a group called “other” since remaining hatcheries had too few releases to be analyzed independently. Seasons were classified as spring (March–May), summer (June–August), and fall (September–November). We did not stock any tagged fish in the winter months.

The elevation and surface area of each water, along with hauling distance from release hatchery, were measured using ArcGIS software. Human population within 50 km of stocking locations was also generated using ArcGIS, by creating 50 km buffers around each water body and then using data from the most recent (i.e., 2010) U.S. Census to determine the population within the buffer. Pre- and post-stocking cumulative precipitation and pre- and post-stocking average air temperature estimates were generated using data from the National Weather Service Cooperative Observer Stations downloaded from the Western Regional Climate Center website (wrcc.dri.edu). Data were pulled from a single observation site nearest to the stocking location.

We first produced scatterplots relating independent variables to dependent variables to evaluate data skewness and linearity (Figs. 2 and 3). Water surface area, human population size, and stocking density were all highly skewed variables that required natural-log transformation prior to any statistical analyses.

Next, we checked for multicollinearity among independent variables and found that stocking density and surface area were highly correlated (Pearson’s r = −0.86). Surface area and stocking density are not inherently related, but owing to budget limitations, larger waters in Idaho and elsewhere are typically stocked at lower densities. We chose to exclude stocking density from our analyses, because we felt it would have less of an influence on the percentage of hatchery catchables caught than water surface area (cf. Ashe et al., 2014). Collinearity was not an issue with any other variables.

We compared tag returns across waters using general linear models. Each stocking event was considered the unit of observation for our analyses. Two separate models were developed. The dependent variable in the first model was the adjusted total angler return rates for each particular stocking event, while the dependent variable in the second model was average days-at-large (post-stocking) of all fish caught for each stocking event. Selection of variables to include in the general linear models followed the methods outlined in detail by Hosmer et al. (2013); these authors termed their method purposeful selection of variables. In short, we included all plausible variables in the full models, and assessed the importance of each variable using the P-value of its F-statistic. Variables were continually removed (in order of least significant P-values) until all remaining variables in the reduced models were statistically significant. Then, plausible first-order interactions between the remaining variables were tested and included if statistically significant. Finally, each previously removed variable was added back into the reduced models singularly to verify insignificance, resulting in the final models. For categorical variables that were statistically significant, Duncan’s Multiple Range Test was used to determine which levels differed. Normal probability plots and histograms of the residuals, and plots of residuals vs. fitted values, were produced to assess model normality and heteroscedasticity of the residuals. Analyses were conducted using the SAS statistical software package (SAS, 2010) with an α value of 0.05.

### 3. Results

During the four years of our study, we tagged 50,745 catchables and stocked them into 54 different waters (Fig. 1) across 226 individual stocking events. Anglers reported a total of 5110 tags. First-year angler return rates (c') across all four study years averaged 23.8% and ranged from 0.0% to 76.4% for individual stocking events. The number of days-at-large prior to harvest were similar across all four years of the study. Of the fish that were eventually caught and reported, on average it took anglers 22 d to catch 25% of the fish, 51 d to catch 50%, and 122 d to catch 75%. Average days-at-large for caught fish for individual stocking events varied from 10 to 297 d.

The best general linear model for explaining the variation in angler return rates included fish length (\( F = 17.73, P = 0.001 \)), the size of the water stocked (\( F = 29.51, P < 0.001 \)), the elevation of the water stocked (\( F = 6.85, P = 0.010 \)), and the rearing hatchery (\( F = 3.65, P = 0.014 \)). This model explained 23% of the variation in angler returns, which were highest in smaller waters at lower elevations stocked with larger fish (Fig. 2). Angler return rates were highest for fish stocked from those hatcheries classified as “other” (30.6%), followed by returns from Nampa Fish Hatchery (24.6%), American Falls Fish Hatchery (21.6%), and Hagerman Fish Hatchery (20.8%). Duncan’s Multiple Range Test showed that angler return rates from “other” hatcheries differed from Hagerman and American Falls fish hatcheries; no other differences were significant.

The best general linear model for explaining the variation in days-
at-large for catchables caught by anglers included the size of the water stocked \((F = 30.59, P < 0.001)\), the season of stocking \((F = 20.79, P < 0.001)\), and the rearing hatchery \((F = 4.45, P = 0.005)\). This model explained 39% of the variation in days-at-large. Fish stocked in larger waters took longer to catch (Fig. 3), as did fish stocked in the fall \((146\) d) compared to those stocked in the spring and summer \((82\) and \(77\) d, respectively). Fish reared at Nampa Fish Hatchery were at-large \((146\) d) compared to those stocked in the summer and spring \((82\) and \(77\) d, respectively). Fish reared at Nampa Fish Hatchery were at-large \((146\) d) compared to those stocked in the summer and spring \((82\) and \(77\) d, respectively). Fish reared at Nampa Fish Hatchery were at-large \((146\) d) compared to those stocked in the summer and spring \((82\) and \(77\) d, respectively). Fish reared at Nampa Fish Hatchery were at-large \((146\) d) compared to those stocked in the summer and spring \((82\) and \(77\) d, respectively). Fish reared at Nampa Fish Hatchery were at-large \((146\) d) compared to those stocked in the summer and spring \((82\) and \(77\) d, respectively). Fish reared at Nampa Fish Hatchery were at-large \((146\) d) compared to those stocked in the summer and spring \((82\) and \(77\) d, respectively). Fish reared at Nampa Fish Hatchery were at-large \((146\) d) compared to those stocked in the summer and spring \((82\) and \(77\) d, respectively).

4. Discussion

The results of our study suggest that several water- and stocking-specific conditions affect angler return rates and fishery longevity for catchables stocked in lentic waters, some of which are under the direct purview of fisheries managers. For example, stocking larger catchables had the predictable effect of generating higher return rates, as has been previously observed in both flowing waters (Cresswell, 1981; Wiley et al., 1993) and lentic settings (Butler and Borgeson, 1965; Wiley et al., 1993; Yule et al., 2000; Cassinelli et al., 2016). Wiley et al. (1993) speculated that larger hatchery trout was better able to deal with environmental changes such as reservoir drawdown and might not be as affected by limited food or the presence of predators. While previous studies have shown larger hatchery catchables generate greater angler catch, our study is unique in emphasizing the effect of catchable size across a wide range of environmental conditions. Given that increased fish size results in increased angler returns, simply increasing the size-at-stocking should result in increased statewide return-to-creeel rates. However, the cost of growing hatchery trout to a larger size increases exponentially, especially at catchable size (Southwick and Loftus, 2003). Given a fixed budget and a limited amount of rearing space, rearing larger fish would require decreasing the total number of catchables produced, and may result in fewer total fish caught by anglers unless the reduced production was offset by increased catchability of the larger fish. A better understanding of how to maximize the tradeoff between size-at-stocking, numbers of fish produced (and subsequently stocked), and angler return-to-creeel is necessary before any specific management recommendations can be made with regard to size-at-release of hatchery catchables.

Fisheries managers also have direct control over when to stock catchables. Our results showing no significant differences in angler return rates across stocking seasons were surprising considering that numerous studies have found that hatchery trout stocked in the summer and especially in the fall return to anglers at lower rates than fish stocked in the spring (Shetter, 1962; Cresswell, 1981; Wiley et al., 1993), although this has been demonstrated more so for lotic than lentic waters. However, Yule et al. (2000) found that fall stocking of hatchery Rainbow Trout resulted in higher survival and angler catch in waters with piscivores, suggesting that perhaps the lack of seasonal difference we observed in angler catch was an artifact of some of our waters having piscivores, which may have obscured such a relationship.

In contrast to no seasonal effect on angler return rates, catchables stocked in the fall were at-large significantly longer (by about 50%) than those stocked in the spring and summer. Fish stocked in the spring and early summer are likely caught more quickly since they are stocked when angling pressure increases the following spring. While overall angler return rates were not different for fish stocked in the fall, prolonged catch of these fish in winter fisheries and into the following spring makes fall stocking a valuable management tool in some instances.

Rearing hatchery influenced both angler return rates and the days-at-large until capture. However, trout from the three largest hatcheries (Nampa, Hagerman, and American Falls) had similar angler return rates. The hatcheries grouped into the “other” category had the highest return rates but consisted of only a small number of stockings from

### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
<th>Connection to catchable post-release performance</th>
<th>Citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation of water (m)</td>
<td>447–2143</td>
<td>Elevation of impounded reservoirs may influence water quality (temperature, pH, etc.), which can affect post-release catchable performance.</td>
<td>Bryan (1982)</td>
</tr>
<tr>
<td>Surface area of water (km²)</td>
<td>0.07–223.7</td>
<td>Smaller, shallower lentic waters are often more productive, and often contain fewer species, which can reduce competition and predation.</td>
<td>Ashe et al. (2014)</td>
</tr>
<tr>
<td>Stocking density (fish stocked/km²)</td>
<td>12–50,000</td>
<td>Should be a direct relationship between the number of fish stocked and encounter rates by anglers, though this is not always supported by empirical study.</td>
<td>Mikó et al. (1995); but see Patterson and Sullivan (2013)</td>
</tr>
<tr>
<td>Mean length (mm) of stocked fish</td>
<td>220–298</td>
<td>Larger trout are better able to escape predators, have higher energy reserves, and may be more aggressive in foraging, and thus more vulnerable to angling.</td>
<td>Wiley et al. (1993), Yule et al. (2000), and Cassinelli et al. (2016)</td>
</tr>
<tr>
<td>Hauling distance from hatchery to water (km)</td>
<td>2.4–840.1</td>
<td>Lengthy hauling distances can impart physiological stress on hatchery fish prior to release, diminishing their post-release condition and subsequent performance.</td>
<td>McDonald et al. (1993) and Barton (2000)</td>
</tr>
<tr>
<td>Nearby cumulative three month pre- and post- stocking precipitation (cm)</td>
<td>pre (0.6–22.2) post (0.4–18.0)</td>
<td>Nearby precipitation strongly influences drawdown, which can influence water quality and food availability in impounded reservoirs, which in turn can influence trout survival.</td>
<td>Bryan (1982)</td>
</tr>
<tr>
<td>Nearby average three month pre- and post- stocking air temperature (°C)</td>
<td>pre (7.4–21.9) post (6.7–22.7)</td>
<td>Air temperature can be a surrogate for water temperature, which in turn can influence water quality and trout survival.</td>
<td>Barwick et al. (2004)</td>
</tr>
<tr>
<td>Human population size within 50 km of water</td>
<td>105–428,042</td>
<td>Affects amount of angler effort on waters, which is inherently related to overall catch and longevity.</td>
<td>Post et al. (2008) and Post and Parkinson (2012)</td>
</tr>
<tr>
<td>Rearing hatchery</td>
<td>–</td>
<td>Fish health often varies between hatcheries, which in turn can affect growth and production. These issues can carry over to post-stocking performance.</td>
<td>Iwama et al. (1997)</td>
</tr>
<tr>
<td>Season of stocking (spring, summer, or fall)</td>
<td>–</td>
<td>Stocking often coincides with peak angling effort, which is typically spring and summer and not fall. But poor summer water quality may hinder survival of stocked fish at that time.</td>
<td>Wiley et al. (1993) and Yule et al. (2000)</td>
</tr>
</tbody>
</table>
several hatcheries scattered across the state. These facilities were a mix of small rearing hatcheries and redistribution hatcheries. As mentioned earlier, controllable rearing conditions and practices (feeding rates and methods, inventoring, rearing density, truck loading) differed little among hatcheries, but there are other factors such as water quality, water temperature, and disease transmission that are less controllable and clearly vary among facilities. The only published study we are aware of comparing the post-release performance among several hatcheries showed no difference between facilities (Cassinelli et al., 2016). In our study, controlling for a hatchery effect on angler return rates and days-at-large improved our ability to detect other meaningful relationships.

The wide range of lake and reservoir habitats across Idaho allowed us to evaluate angler returns of catchables across a wide range of elevations (477–2143 m above sea level). Our finding of lower return rates at higher elevations is somewhat counter intuitive, as higher elevation waters are generally thought to have better water quality and cooler temperatures (Miranda and Bettoli, 2010), both important characteristics for Rainbow Trout (Swales, 2006). However, Hubert and Chamberlain (1996) found that the size and abundance of Rainbow Trout (mostly of hatchery origin) were negatively correlated with increased elevation for lakes and reservoirs ranging from 1113 to 3338 m above sea level in Wyoming. Higher elevation waters are typically less productive (Donald et al., 1980; Hubert and Chamberlain, 1996) and are usually more remote, resulting in less angler effort. Conversely, lower elevation waters typically are more productive and therefore support higher Rainbow Trout survival and growth (Hubert and Chamberlain, 1996; Swales, 2006), and such waters are generally more heavily fished. While managers could likely boost returns by simply shifting stocking towards lower elevation, more productive waters, this could negatively impact anglers who enjoy fishing more scenic, remote, higher elevation waters (Harris and Bergersen, 1985; Beardmore et al., 2015).

We found that in larger waters, a smaller percentage of the stocked fish were caught by anglers, and days-at-large increased with water size. Similarly, in Maine lakes, water size was the most influential factor affecting (negatively) angler catch of hatchery Brook Trout Salvelinus fontinalis (Ashe et al., 2014). However, as mentioned earlier, water size and stocking density were highly negatively correlated in our study (Pearson’s $r = -0.86$), thus we cannot be certain which factor most

![Fig. 2. Scatterplots of water- and stocking-specific characteristics against angler return rates for Idaho lentic waters stocked with tagged hatchery catchable trout from 2011 to 2014. Stocking density, water surface area, and human population are plotted on logarithmic scales. Lines depict linear regressions fitted to the data; $r$ is Pearson’s correlation coefficient.](image)
influenced angler return rates. In small Alberta put-and-take fisheries, stocking either low or high densities of trout produced low angler return rates (Patterson and Sullivan, 2013), indicating that stocking density was not a good predictor of angler returns in their waters. In Idaho, as in most western states and provinces, angler return rates of stocked trout are highest in smaller waters, and we believe this has little to do with stocking density but rather, is related to the size of the water. Smaller lakes usually contain proportionally more littoral habitat, which is particularly well suited for catchable trout (Vehanen, 1997; Swales, 2006), and anglers are more efficient at targeting these areas. However, regardless of whether water size causatively influences return-to-creel of stocked catchables, managers must be cautious about adjusting stocking rates based on water size alone. Increasing stocking numbers in larger waters as a means to boost returns would likely be cost prohibitive and ineffective (Miko et al., 1995), while reducing or eliminating stockings in these waters could inadvertently reduce angler satisfaction at these waters, which could lead to reduced effort and a decline in economic expenditures in communities where larger waters reside. As long as enough fish are stocked into put-and-take fisheries to achieve a threshold level of return rates, angler satisfaction may be sufficient to generate ample angling effort (Loomis and Fix, 1998; Patterson and Sullivan, 2013).

The mean angler return rates that we observed (24%) across the waters we stocked were generally lower than preferred for lentic put-and-take catchable trout fisheries. In fact, 14 individual stocking events across 10 waters produced zero returns of hatchery catchables, of which three waters had zero returns for more than one stocking event. These tended to be larger waters further from populated areas. Identifying and modifying releases that appear to have little to no benefit to anglers is an important component of our multi-year study. However, it should be noted that about 20% of IDFG’s statewide catchable trout stocking program in stocked in community fishing ponds. While these waters are not included in this analysis, previous work has shown these waters have much higher angler return rates. For example, in 2014 the overall average angler return rate from 13 Idaho community ponds was 54% (Cassinelli, 2015). Higher angler return rates from community ponds can help offset lower return rates from larger waters and allow fisheries managers to stock a diversity of waters. This gives anglers more opportunities across a wider variety of fisheries.

While mean angler returns were lower than desired in larger waters, days-at-large of catchables were prolonged in lakes and reservoirs when compared to the community ponds and small impoundments that IDFG

Fig. 3. Scatterplots of water- and stocking-specific characteristics against mean days-at-large for Idaho lentic waters stocked with tagged hatchery catchable trout from 2011 to 2014. Stocking density, water surface area, and human population are plotted on logarithmic scales. Lines depict linear regressions fitted to the data; $r$ is Pearson’s correlation coefficient.
stocks. The average days-at-large for catchables in the lentic waters in our study were much longer than those previously found for catchable stocked in lotic waters (Dillon et al., 2000). However, there is little literature discussing days-at-large of catchable trout stocked in lakes and reservoirs. Wiley et al. (1993) reported that the majority of catchable-sized hatchery trout stocked in Wyoming lakes was caught within the first two months post stocking and nearly 90% were caught in the first year, similar to our results. The trade-off between angler returns and an extended fishery might be reasonable for the management of larger waters in many scenarios.

Our best models only explained 23% of the variation in angler catch rates and 39% of the variation in days-at-large after stocking. Thus, there are clearly other water- and stocking-specific conditions that influence angler return rates and fishery longevity that we did not include in our analyses. One of the more obvious variables is angler effort, which is positively correlated to angler returns (Butler and Borgeson, 1965; Loomis and Fix, 1998; Askey et al., 2013; Patterson and Sullivan, 2013). While we included human population size in our analysis as a potential surrogate for angler effort, the direct correlation between human population size and angling effort remains unclear. Another likely important factor that we could not account for was reservoir drawdown, which varies tremendously from year to year depending on irrigation demands and hydropower operations, and has been implicated in the poor survival and low return rates of stocked trout (Wiley et al., 1993; McLellan et al., 2008; Koenig and Meyer, 2011). In southern Idaho, the abundance of avian predators – especially American white pelicans Pelecanus erythrorhynchos and double-crested cormorants Phalacrocorax auritus – has greatly increased in recent years, and has been shown to negatively impact angler return rates of catchables (Meyer et al., 2016). Unfortunately, at the scale of our study, monitoring these (and other) important factors was not feasible, and this obviously contributed to less explanatory models.

Our results, and those from previous studies relating post-stocking hatchery trout performance to water- and stocking-specific conditions, emphasize some of the complexities that fisheries managers face in allocating catchables in put-and-take fisheries. If the sole focus was to maximize angler returns, managers could simply stock larger catchables, more often, into smaller, low elevation waters. However, the ultimate priority for fisheries managers should not be to maximize yield of catchable angler returns, but rather to maximize angler satisfaction, and these are not necessarily interrelated (Arlinghaus, 2006; Patterson and Sullivan, 2013). Askey et al. (2013) suggest that an optimal stocking strategy at a regional scale is to maximize total angler effort, because anglers will adjust their effort to target waters with higher catch rates, thus balancing catch and effort across numerous waters over each fishing season. In addition to the quantity of fish returned, the quality of the fishing experience is a valuable piece of the management puzzle. By better understanding how certain factors and conditions impact fishery performance following the stocking of catchable trout, fisheries managers can work to improve the efficiency of stocking programs and better explain the variation in stocking performance to anglers and policymakers alike. Finding the balance between angler effort, catch, and satisfaction will ultimately maximize the value of put-and-take trout fisheries.

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