Do Hatchery Trucks Make Happy Anglers? Evaluating Entrenched Assumptions Of Put-And-Take Fisheries.

Thesis submitted in partial fulfillment of requirements for Master of Science Degree in Environment and Management, Royal Roads University, B.C., Canada

Alberta Conservation Association

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DO HATCHERY TRUCKS MAKE HAPPY ANGLERS?

EVALUATING ENTRENCHED ASSUMPTIONS OF PUT-AND-TAKE FISHERIES

By

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A thesis submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE
in
ENVIRONMENT AND MANAGEMENT

We accept this thesis proposal as conforming
to the required standard

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Abstract

Stocking trout to create successful sport fisheries is an irresistible lure to fisheries managers and sport anglers alike, but the implicit assumptions behind this simple process have seldom been questioned or assessed. Using common fisheries monitoring techniques, combined with social surveys, at nine Alberta lakes, I quantified three main assumptions behind put-and-take stocking. Surprisingly, 1) stocking high densities of Rainbow Trout created very low-density populations; 2) these populations supported mediocre fisheries; 3) these mediocre fisheries, if above a threshold catch rate, attracted very large numbers of satisfied anglers. Based on these findings, the stocking density and the direct cost of stocking were reduced by 80% at three experimental lakes. No major decreases in fishing quality, angler participation, or angler satisfaction were observed. I suggest refinements in the stocking process focus on determining how to provide adequate numbers of trout to create a basic level of satisfaction with the fishing experience.

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Introduction

Stocking trout to create put-and-take trout fisheries is a popular tool used by government and not-for-profit organizations to provide recreational opportunities. Since domesticated, hatchery-reared trout generally do not survive long after stocking, the lakes that receive trout have become known as put-and-take fisheries (Johnson, Behnke, Harpman, & Walsh, 1995; Miller, 1954; Miller & Thomas, 1957). Artificial propagation and the stocking of fish has a long and irresistible attraction for fisheries managers and sport fishers, however; stocking programs have themselves produced debate about whether they do more harm than good (Walters & Martell, 2004). In Western Canada, both the Alberta Government (Sustainable Resource Development, ASRD) and the Alberta Conservation Association (ACA) stock harvestable-size Rainbow Trout (*Oncorhynchus mykiss*) into "pothole" lakes (Miller & Thomas, 1957, p. 261). The number of lakes stocked with Rainbow Trout has grown from three to 242 since 1950.

The implicit conceptual model of put-and-take fisheries is deceptively simple and attractive; stocking fish creates fisheries, which will attract and satisfy anglers, and furthermore, more stocking will create better, more satisfactory fisheries, which will attract even more anglers. The assumptions underlying this model, for example, stock trout to make fishing (Butler & Borgeson, 1965), have become entrenched in managers and anglers, yet are seldom explicitly tested or questioned within the context of stocking programs (Hartzler, 1988; Johnson et al., 1995; Mauser, 1994; Powers, Lackey, & Zuboy, 1975).

Fishing quality is typically cited as a weak indicator to levels of satisfaction acquired from fishing (Ross & Loomis, 2001). A common finding of angler surveys is while fishing quality (i.e., the number and size of fish caught) contributes to anglers' fishing satisfaction it is for most anglers a less important determinant than other factors such as the physical setting of the fishing experience and accompanying social factors (Ready, Epp, & Delavan, 2005). Studies conclude that angler satisfaction is related to a variety of non-fishing attributes, for example, a sense of freedom, excitement, angling competency, relaxation, natural setting, or reflection (Holland & Ditton, 1992; Spencer, 1993). Hence, the motivation for recreational anglers to fish is disconnected from recreational angling (Arlinghaus, 2006). In spite of this evidence, a positive and powerful relationship between fishing quality and angler satisfaction seems so intuitive that stocking programs and the conceptual stocking model remains predicated on its existence (Hartzler, 1988; Johnson et al., 1995).

As an example of the powerful belief in these intuitive measures, consider the following quote from a keynote article in the journal Fisheries,

> Although it is difficult to assess suitable changes in fisheries management goals…our results indicate that yield is deeply entrenched as a goal in fisheries management programs. Comparison of the "desires" of the angling public for a multifaceted fishing experience to the managers heavy orientation towards yield suggests a concerning disparity (Bennet, Hampton, & Lackey, 1978, p. 14).

The assumption of stock-trout-to-make fishing or a yield oriented approach to stocking are widespread. Many conservation agencies and organizations expend a large proportion of their fishery management budgets to create and maintain put-and-take fisheries yet this has occurred without studying the success of creating fishable populations or the economic efficiency of stocking catchable trout (Johnson et al., 1995).

These programs are very expensive, but their speculative success is also correspondingly large. In Alberta, the stocking of 3.7 million trout species costs approximately $7.3 million per year (Park, 2007). However, the popularity of these fisheries, estimated at 627,000 angler-days (i.e., 24% of angler-days expended at sport fisheries), economically contributes $31.4 million annually (Park, 2007). The perception of the success of the program is correspondingly strong, with 80% of Alberta anglers describing the trout stocking program as important or very important, even though only 47% actually fished at stocked lakes (Park, 2007).

After 60 years of development, stocking programs in Alberta (i.e., ASRD and ACA) are large and expensive. The programs stock 242 lakes with approximately three million Rainbow Trout annually. Sustainable Resource Development operates several hatcheries that raise, grow and stock trout while Alberta Conservation Association contracts private hatcheries to rear and stock Rainbow Trout. In total, the number of stocked Rainbow Trout varied from 2.2 to 2.9 million from 2008-2010.

With such major expenditures, optimizing the cost-effectiveness of these programs would seem to be a reasonable goal. For example, the cost of angler-recreation ($/angler-hr) derived from the cost to stock a lake with harvestable-size trout (approximately 20 cm) and the angler participation may provide a unit to help investigate and understand how agencies may optimize the cost of put-and-take fisheries. In spite of the simple socio-economic basis for put-and-take trout stocking, and the magnitude of direct and indirect costs involved (e.g., administration, infrastructure, utilities, transportation), very little quantitative assessment of the created fisheries and accompanying recreational angling has been conducted. Rather, agencies simply note that stocking is demanded by the public and consequently they have conducted a successful public service program (Halverson, 2010; Hartzler, 1988). Subsequently, quantification of the stocking trout conceptual model, optimization of program costs or measurements of success receives little to no consideration. As a result, status quo perseveres.

The basic assumptions of the Alberta agencies that stock trout, their program managers, and anglers regarding stocking are described in a simple and attractive conceptual model. The interpretation is stocking more trout or possibly stocking better (e.g., larger fish) may create a higher quality fishery (in terms of catch and size of fish) and results in higher levels of angler satisfaction and participation. This conceptual model of put-and-take trout fisheries provides a ready framework for testing the inherent assumptions.

Alberta's stocking programs have explicitly stated goals: establish populations in suitable lakes, increase angling opportunities, and increase the diversity of fishing experiences (Alberta Sustainable Resource Development Stocking Report, n.d.; Alberta Conservation Association Enhanced Fishing Stocking Project, n.d.). For these goals to be met, however, the implicit assumptions of the stocking model must also be met: stocking creates populations, which create fisheries of a quality high enough to attract anglers, who are satisfied with their fishing experience.

My objectives were to quantify these three implicit goals of stocking Rainbow Trout into small lakes and use the results to design, implement and assess an optimum stocking strategy. Specifically, I designed my study to answer the following questions,

1. How successful is stocking in creating trout populations?
2. How do these populations relate to sport fishery quality?
3. How is the sport fishery quality related to anglers' satisfaction and participation?

Based on the quantified relationships of the three-part model, a fourth aspect of the research used this knowledge to investigate the efficiency of the stocking program, specifically, by asking the question,

4. Can I optimize stocking costs while maintaining or improving angler satisfaction and participation?

To investigate these questions, I conducted a series of studies that quantified the relationships of: stocking to the created trout populations, populations to the quality of the sport fisheries, and the level of satisfaction and participation from anglers to the quality of the sports fisheries. I studied stocked Rainbow Trout fisheries at nine lakes in central and southern Alberta, using creel survey, gillnetting and a social survey, during the summer fishing seasons of 2008, 2009, and 2010.

Methods

Study Sites

I intensively studied and manipulated Heritage, Salter's and Star lakes during the summer fishing seasons of 2008-2010. These put-and-take fisheries were all within 100 km of the City of Edmonton, Alberta (Figure 1). I also collected comparable stocking and creel data from six additional control put-and-take trout lakes (i.e., Blood Indian, Hansen's, Mirror, Morinville and Outpost). All lakes had easy access, with paved roads and developed areas for fishing, float-tube or boat launching and day-use (e.g., toilets, picnic tables, park areas). These lakes shared the typical characteristics of Alberta put-and-take trout lakes; they were relatively small, subject to periodic winterkills and consequently holding no persistent populations of native sport fish, and having adequate water quality to support Rainbow Trout for at least one angling season. The underlying strategy for Alberta's put-and-take trout fisheries are: larger fish (approximately 20 cm) are stocked because they are immediately available for harvest, the majority of fish are harvested during their first season, few fish are expected to survive their first winter because of inadequate dissolved oxygen, therefore few fish survive into the second summer angling season. Information on the physical characteristics of these lakes, stocking data, and travel distances is presented in Table 1.

Stocking Protocols

Brood stocks of trout are maintained in Alberta's Raven and Allison Creek Fish Hatcheries. The brood trout are artificially stripped of eggs and milt upon maturation. Eyed eggs are distributed to Cold Lake and Sam Livingstone Fish Hatcheries and are incubated to

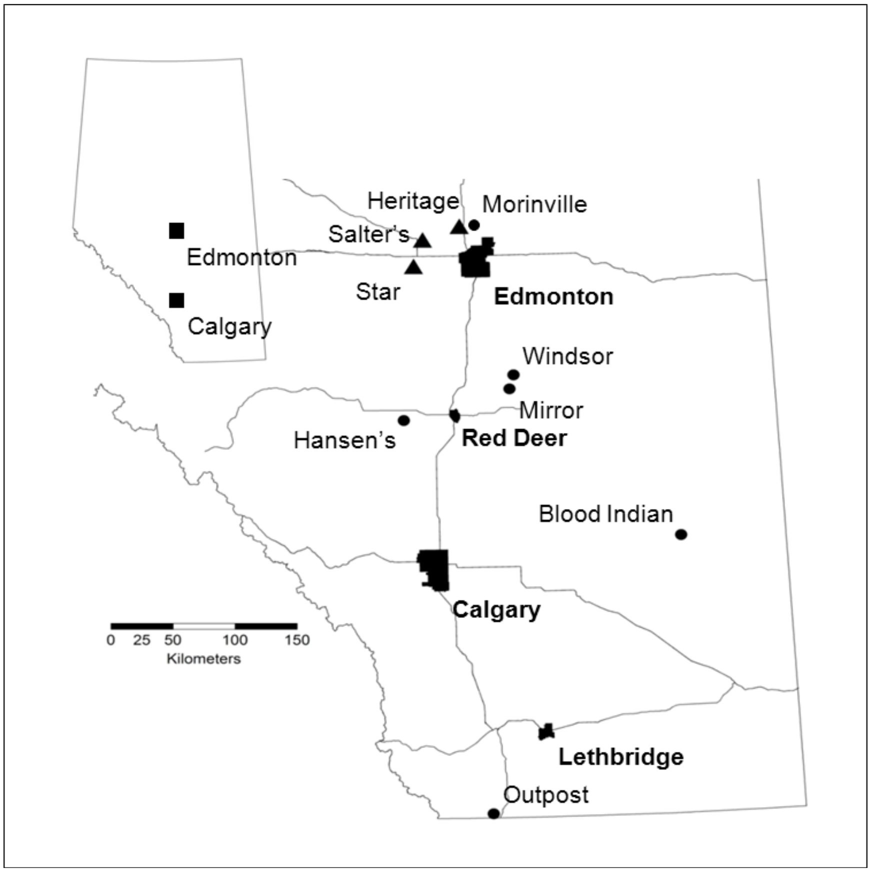

Figure 1. The locations of the experimental and control lakes with respect to the Province of Alberta. The three experimental lakes are symbolized with triangles while the six control lakes are symbolized by circles. Alberta's major cities are indicated and labeled with bold font. Grey lines that connect cities are highways.

hatching. The fingerling trout are raised in high-density raceways (i.e., approximately 10,000 fish in 28,000 litres of water) until they are stocked. Rainbow Trout are reared in hatcheries for 18 months and then stocked at a harvestable sizes (i.e., approximately 20 cm). The Alberta Conservation Association contracts private growers (e.g., Ackenberry Trout Farm) to raise and stock Rainbow Trout. Private growers purchase eyed eggs from producers of eyed salmonid eggs and use comparable procedures to Alberta's hatcheries to rear, transport and stock trout.

Table 1. *Physical characteristics and stocking data for Alberta stocked trout lakes.*

Lake	Lake area (ha)	Trout stocked per year (no.)	Strain of Rainbow Trout	Size stocked (mm)	Stocking hatchery	Nearest major city (km)	Distance to hatchery (km)
Blood Indian	90	150,000	Mt Lassen x Mt Lassen	12	SLFH	261	258
Hansen's	4	3,000	Gerrard x Kamloops	20	ATF	46	190
Heritage	12	6,000	Gerrard x Kamloops	20	ATF	34	86
Mirror	5	4,000	Gerrard x Kamloops	20	ATF	67	76
Morinville	3	1,000	Gerrard x Kamloops	20	ATF	34	86
Outpost	98	43,000	Bietty x Beaver	11	SLFH	120	270
Salter's	14	20,400	Mt Lassen x Mt Lassen	20	CLFH	67	340
Star	27	8,100	Mt Lassen x Mt Lassen	20	CLFH	63	360
Windsor	15	4,000	Gerrard x Kamloops	20	ATF	100	68

Note. SLFH – Sam Livingstone Fish Hatchery, ATF – Ackenberry Trout Farm, CLFH – Cold Lake Fish Hatchery

Trout were stocked in mid-May, prior to the summer angling season of June-August. Immediately prior to stocking, trout are captured from the hatchery raceways and moved to aerated tanks (1.8 m^3) on transport trucks. The density of trout in the transport tanks was approximately 944 fish/m^3. The numbers of trout stocked in a lake are estimated by hatchery staff using the weights of the fish. The transport trucks drove for approximately one to four hours to the receiving trout lakes (Table 1). Prior to stocking, water temperature of the receiving lake and the transport tanks were measured and trout were only stocked if temperatures in the receiving lakes were below 19^0C (C. Copeland, personal communication, October 26, 2010). Trout were stocked by running a large diameter collapsible polyethylene hose from the transport tanks to the receiving lake and draining the trout and transport water directly into the lake. As stocked trout lakes usually have one access point, the truck driver cannot disperse the trout throughout the lake.

All amounts are presented in Canadian dollars. The cost of stocking Rainbow Trout for ASRD and ACA was $1.74 and $1.78 per fish, respectively (Alberta Sustainable Resource Development, 2006; T. Council, personal communication, June 8, 2010). Thus, a value of $1.76 per fish was used to calculate the direct cost of stocking. No administrative costs were included because it was unknown how administrative costs would change in proportion to changes in rearing and stocking costs.

Methods Used for Question 1: How Successful is Alberta's Stocking in Creating Trout Populations?

For the purposes of this study, I defined a trout population as the number of trout available to anglers. This consists of the sum of the number of trout harvested by anglers, and the number of trout surviving to autumn and therefore available for later harvest. To quantify the effectiveness of stocking fish to create a population, I compared the number of trout stocked to the estimated size of the subsequently created population (described below).

The number of trout caught by anglers was estimated using standard creel survey techniques (described below). The number of trout surviving to autumn was estimated using gillnets and the relationship between gillnet catch and fish density, $C / f = q (N / A)$, where C =

catch, f = netting effort, q = efficiency of the gear, N = number of fish in sample, and A = area in hectares occupied by the fish stock (Hansen, Newman, & Edwards, 2004; Pierce & Tomcko, 2010). The catch equation assumes that catch per effort (C / f) is linearly related to density (N / A) with a slope equal to q. The catchability coefficient (q) of 1.15 was derived from a population density estimate in an Alberta stocked lake (George Sterling, ASRD, Fisheries Management Branch, Foothills Area, unpublished data) for Cutthroat Trout (*Oncorhynchus clarkii*), a very similar species to Rainbow Trout (Behnke, 1992; Behnke & Zarn, 1976).

Because of the small size of these stocked lakes, I used three multi-mesh gillnets (Fipec Industry, model FEX-03) to estimate the abundance of each population. The gill nets are 61 m long and comprised of eight 3.8 m long and 1.8 m deep panels with the mesh sizes: 25, 38, 51, 64, 76, 102, 127, and 152 mm (stretched measurements). Depth and dissolved oxygen profiles were collected to determine whether gill net locations were anoxic. The gill nets were set at randomly selected sites and soaked for 24 hr to ensure fish were caught through a full circadian cycle. The nets were fished during the autumn when water temperature at time of netting was between 10 ^{o}C and 15 ^{o}C. To reduce possible bias due to variations in habitats, areas along steep gradients or heavy vegetation were avoided. To reduce effects of local fish depletion, nets were set >500 m apart. All fish captured were sampled for total length (mm), weight (g), gender and stage of maturity, and otoliths were collected (Mackay, Ash, & Norris, 1990). Before being sampled, moribund trout were euthanized with a cranial concussion and cervical dislocation.

Methods used for Question 2: How do These Populations Relate to Sport Fishery Quality?

Since catching fish is likely the motivation for angling and useful in determining angler's level of enjoyment (Hicks, Belusz, Witter, & Haverland, 1983; Miko, Schramm, Arey, Dennis,

& Mathews, 1995), the class of the sport fishery was quantified using angler catch rate and size of harvested fish. Since Rainbow Trout are a recreationally important species, length categories can be used to evaluate length frequencies of fish samples in terms of management objectives (Anderson and Neumann, 1996, p. 447), therefore, length categories are important to monitor over time in response to management strategies. The size categories (size, cm) listed in Anderson and Neumann (1996, p. 464) for Rainbow Trout are Stock (<25), Quality (25-40), Preferred (40-50), Memorable (50-65), Trophy (65-80). Therefore, I assumed a catch rate >1 fish/angler-hr and fish >25 cm in size represented a quality stocked Rainbow Trout sport fishery.

Roving creel surveys following the procedures in Pollock, Jones, & Brown (1994) and Rasmussen, Staggs, Beard, & Newman (1998) were conducted from June-August, 2008-2010 (Appendix Table A1). Creel surveys were scheduled following a stratified design with lake and time of day stratum (i.e., 8:00 to 12:00 a.m., 1:00 to 5:00 p.m., and 6:00 to 9:00 p.m.). I assumed angler catch and trip length were the same on weekdays as on weekends and holidays. Creel surveys provided estimates of catch, effort (described below), and harvest. Anglers were interviewed at the completion of their angling trip. Catch rate (fish caught per unit effort) was calculated as a total ratio estimator following Malvestuto (1983). Effort was estimated from instantaneous counts of anglers (described below), and harvest was estimated as the product of effort (i.e., angler-hr) and harvest rate (fish caught/angler-hr). By-catch mortality was calculated as 10% of released fish (Jenkins, 2003; Schill, 1996; Schisler & Bergersen, 1996).

Methods Used for Question 3: How is the Sport Fishery Quality Related to Anglers' Satisfaction and Participation?

Angler satisfaction

During the creel survey interviews, anglers were asked if they would participate in a voluntary face-to-face survey regarding their experience with the stocked sport fishery. The survey preamble included a brief description of the project, indicated that participant answers would be anonymous, and the participant could withdraw from the survey at any time. I used a five point Likert-scale (i.e., very satisfied, satisfied, neutral, unsatisfied, very unsatisfied) to rate anglers' levels of satisfaction with the sport fishery (Dawes, 2008; Mogey, 1999). Data on anglers' motivations for sport fishing were collected using a consistent response format (Fedler & Ditton, 1994). The questions used are listed below with the possible responses in brackets,

"Are you satisfied with fishing at this lake?" (Yes or No)

"How do you feel about the number of fish you are catching?" (Likert-scale)

"How do you feel about the sizes of fish you are catching?" (Likert-scale)

"Why did you decide to fish this lake?" (Number of trout stocked, Species of fish stocked, Good fishing, Close to home, Scenery, and Other)

Angler participation

To quantify angler participation, I developed a cost-effective method that used digital wildlife reconnaissance cameras (i.e., trail cameras) following van Poorten, Parkinson, & Walters (2008). A trail camera was located at each lake and programmed to capture images at hourly intervals (i.e., 8:00 a.m. to 9:00 p.m.) every day (13 hr/day x 91 survey days). Trail cameras were attached to trees or posts at 2 – 3 m in height. Camera locations provided good vantage points and were accessible for downloading pictures and changing batteries. Image analysis was conducted by projecting the images onto a large screen and tallying anglers visible in the images. Each angler visible in an image was assumed to represent one hour of angler participation (i.e., angler-hr). Because of low camera resolution (3.0 megapixels), anglers could not be personally identified. Because the camera photographed a portion of each lake, field verification was conducted. The area photographed by each camera was demarcated using either white signs or landscape features and the number of anglers inside and outside each demarcated area was recorded. In combination with the creel survey schedule, instantaneous counts of anglers were also conducted. These instantaneous or census counts were compared to the sample counts obtained using the trail camera. I simulated the likelihood profile of sample counts/census counts to derive a spatial correction that was used to calculate the trail camera-derived estimate of angler participation including the confidence interval (95% CI).

Methods Used for Question 4: Can I Optimize Stocking Costs While Maintaining or Improving Angler Satisfaction and Participation?

The initial estimates of trout population, angler catch and size of fish (i.e., sport fishery quality), angler satisfaction and participation from 2008 and 2009 provided a baseline of comparison after an experimental manipulation of stocking rates. In 2010, I reduced stocking densities by 80% at Heritage, Salter's and Star lakes and then reassessed the trout population, sport fishery quality, and angler satisfaction and participation following the above methods. The costs and savings were also calculated in terms of angler participation as $/angler-hr.

Data Management and Analysis

Data were recorded on field survey forms and were transcribed into Microsoft Excel workbooks (Microsoft Corporation 2010). SigmaPlot v.11.0 (Systat Software, Inc. 2008) was used for regression analysis and normality tests. Linear regression analysis was used to investigate the relationships of; the number of trout stocked to the estimated size of the trout population, the estimated size of the trout population to the angler catch rate, angler catch rate to the size of trout caught, and angler catch rate to angler participation. To investigate the curvilinear relationship of angler catch rate to angler satisfaction, non-linear regression analysis was used. The catch rate data was not normally distributed and therefore log-transformed. After transformation, the Shapiro-Wilk normality test indicated normality (*W-Statistic* = 0.991). Angler satisfaction data was normally distributed therefore no transformation was required.

I used a bootstrap technique to calculate estimates and 95% confidence intervals (95% CI) for angler participation (i.e., angler-hr), harvest, and fall populations. The bootstrap technique approximates the distribution of values that would have arisen from repeatedly sampling the original population (Haddon 2001). The simulated group of means has the same scale of variation as observed in the original data set. I extrapolated each survey parameter to include strata that were not surveyed. With the simulation procedure described above, I calculated estimates as likelihood profiles using either multiplication or addition.

After reducing the stocking density by 80% at the experimental lakes, t-Test ($\alpha = 0.05$) was used to test the assumption of no difference in angler catch rate, satisfaction and participation. This comparison assumes that each fishing season at each lake is an independent sample, and accepts that these sample sizes are small.

Using histograms, I compared catch rate and angler participation data using histograms from lakes used in this study to other Alberta and British Columbia sport fisheries that are available to Alberta sport anglers.

Results

Question 1: How Successful is Alberta's Stocking in Creating Trout Populations?

During the course of this study (2008 to 2010), 274,800 Rainbow Trout were stocked at nine study lakes (Table 1), with an average stocking rate of 623 trout/ha (*SE* ± 143, *n* = 14). Anglers harvested 9,829 trout (*95% CI* = 7,726 – 12,060, n = 14) or 3.6% of stocked fish and killed an additional 1,218 trout (*95% CI* = 773 – 1,206, n = 14) or 0.4% of stocked fish as by-catch (i.e., trout caught and released but then died of hooking mortality). An additional 11,219 (*95% CI* = 7,570 – 14,420, n = 14) or 4.1% of stocked trout survived through the first summer of fishing and were then available for harvest during the autumn and, possibly, subsequent seasons (Table 2).

Stocking created populations at all study lakes. However, at Mirror (2010) and Salter's (2008) no fish were reported harvested by anglers even though autumn gillnetting provided a population estimate at these lakes. On average, at each lake, only 10.9% of the stocked trout were accounted for by angler harvest, the estimated by-catch, or the estimate of the numbers of trout surviving their first fishing season to autumn. The remaining 89.1% of trout were assumed to have died of natural causes. In part, because of this assumed high mortality rate, there was not a significant relationship (R^2 = 0.16, p = 0.157, df = 13) between the number of trout stocked and the size of the subsequently created trout population (Figure 2).

Table 2 . *Characteristics of the sport fisheries at the stocked trout ponds in Alberta.*

Lake	Year of study	Trout harvest (No.)	95% CI	Fall pop'n (No.)	95% CI	Angling effort (hr/ha)	95% CI	HPUE	CPUE
Blood Indian	2009	6,873	5,567-8,179	4,860	3,305-5,978	979	793-1,165	0.078	0.513
Hansen's	2010	433	307-567	348	237-418	382	271-501	0.286	0.508
Heritage	2009	315	265-372	324	268-390	487	409-575	0.054	0.175
Heritage	2010	145	104-190	48	0-73	255	184-334	0.047	0.120
Mirror	2010	0		5	0-15	35	9-74	0.000	0.000
Morinville	2008	55	29-95	3	0-9	590	307-1,021	0.031	0.094
Outpost	2009	38	17-59	2,548	2,087-3,391	96	44-148	0.004	0.740
Salter's	2008	0		14	8 19	202	115-327	0.000	0.171
Salter's	2009	270	197-348	1,050	315–1,428	126	92-163	0.153	1.315
Salter's	2010	517	357-703	84	50-140	205	141-279	0.180	0.673
Star	2008	246	84-460	918	573-1,311	246	189-312	0.038	0.282
Star	2009	832	724-949	864	658-996	392	341-447	0.079	0.314
Star	2010	99	72-130	108	70-139	198	145-259	0.019	0.052
Windsor	2010	5	2-8	45	0-112	41	20-67	0.008	0.021

Note. hr/ha – angler-hr/hectare, pop'n – population, HPUE – fish harvest per unit effort, CPUE – fish caught per unit effort

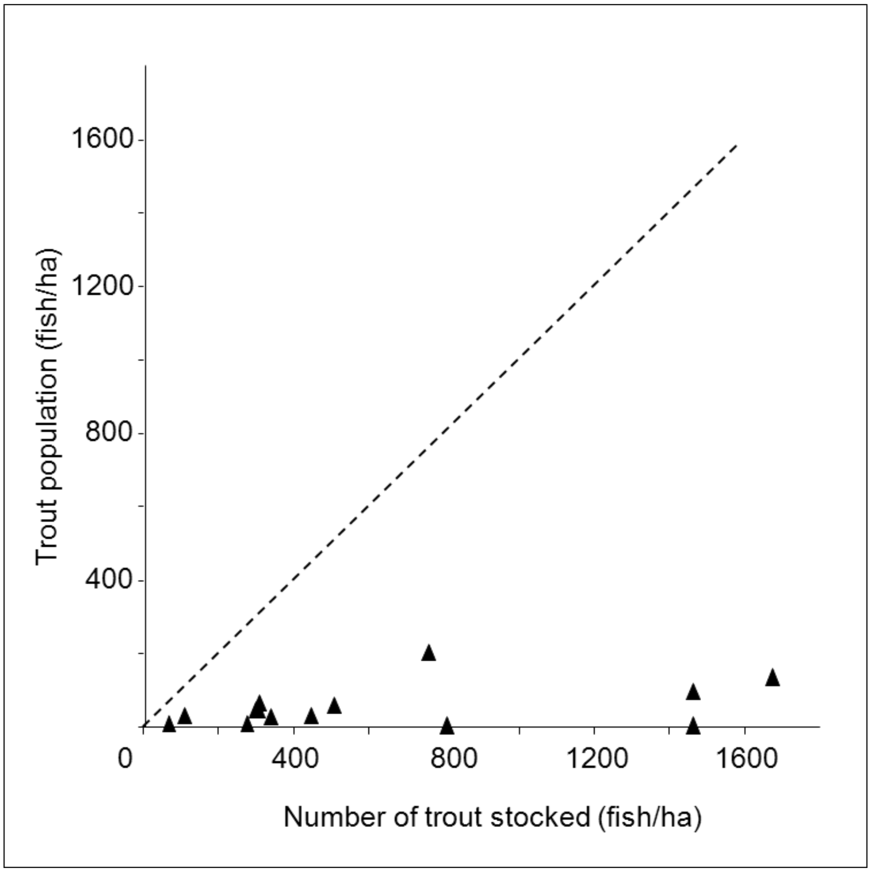

Figure 2. Relationship between numbers of trout stocked and the subsequently created trout population. The regression of trout stocked versus trout population was not significant (R^2 = 0.16, p = 0.157, df = 13). The dashed line represents the theoretical relationship if all stocked trout survived to become part of the population and available for harvest by anglers.

Question 2: How do These Populations Relate to Sport Fishery Quality?

At all but one of the stocked lakes, angling catch rates were < 1.0 fish/angler-hr, with an average total catch rate of 0.36 fish/angler-hr (Table 2). In comparison to other sport fisheries available to Alberta anglers, such as Alberta's Walleye sport fisheries and stocked trout sport fisheries in British Columbia, the angler catch rates from stocked trout lakes are poor quality (Figure 3).

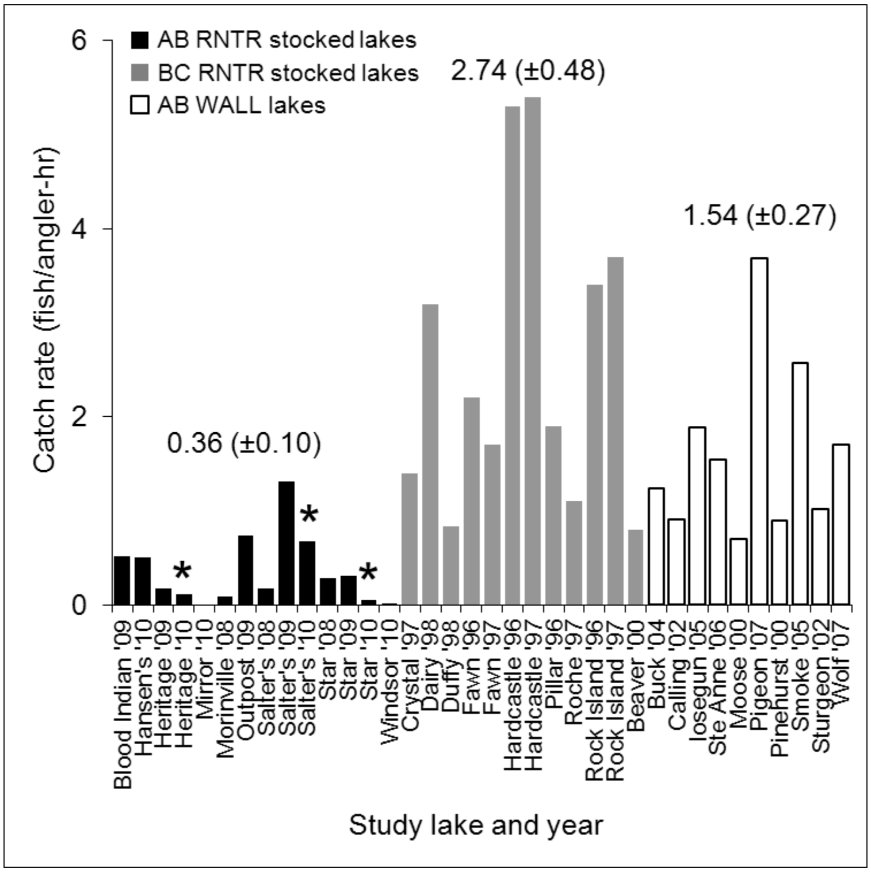

Figure 3. Total catch rates from Alberta (AB) and British Columbia (BC) sport fisheries. The catch rate data for the British Columbia Rainbow Trout (RNTR) and the Alberta Walleye (WALL) sport fisheries came from Cox (2000) and the ASRD (Unpublished data). Mean catch rate (±*SE*) is indicated above each sport fishery. Lakes with an experimental 80% reduction in stocking rate are indicated by an asterix.

The size of the harvested trout was small (mean length of 31.8 cm, *SE* ± 1.9) compared to the size range listed in Anderson and Neumann (1996, p. 464). In comparison to standard size indices used to assess management strategies for quality of fisheries, all but one of the study lakes had less than quality sizes (i.e., <25 cm) of fish (Figure 4).

There was a positive trend, but highly variable relationship between the size of the trout population and the angling catch rate ($R^2 = 0.57$, $p = 0.001$, $df = 13$, Appendix Figure A1).

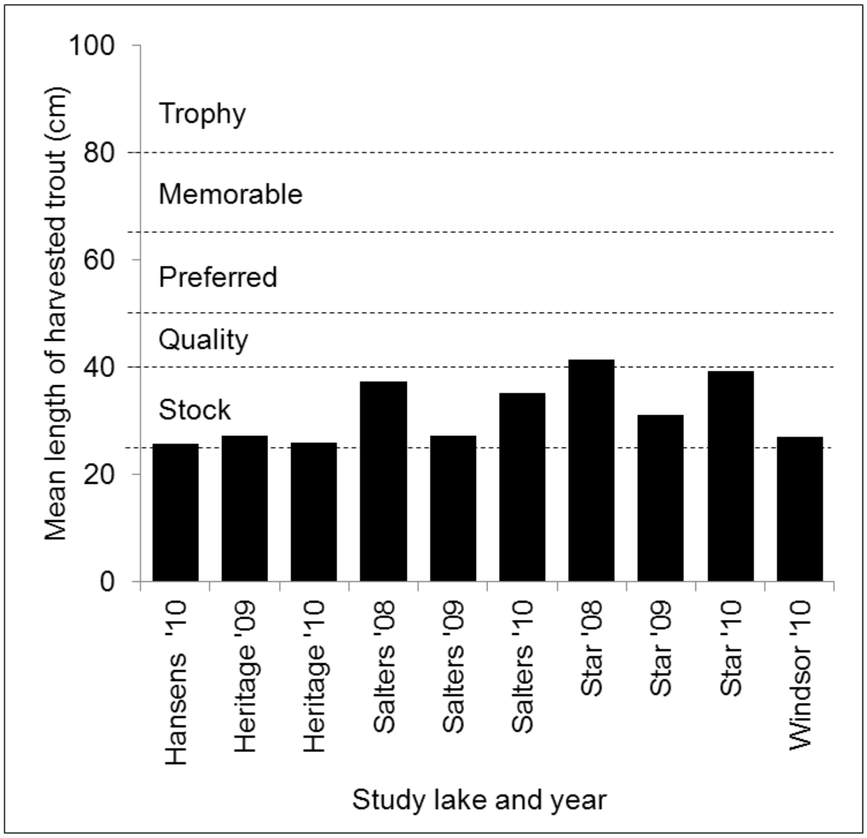

Figure 4. The mean length of trout harvested by anglers at stocked Rainbow Trout lakes in Alberta (2008-2010). Length categories have been proposed to monitor and assess the quality of fish populations in response to management strategies (Anderson and Neuman, 1996, p. 464).

Assuming that a catch rate of >1 fish/angler-hr represents a threshold for good quality fishing, this regression suggests that a trout population at these lakes must be greater than approximately 200 trout/ha to produce a good quality catch rate.

Question 3: How is the Sport Fishery Quality Related to Anglers' Satisfaction and Participation?

Anglers' satisfaction

The majority of anglers (69%, n =572) reported that they were satisfied with their overall angling experience at the stocked trout lakes. When asked to rate their level of satisfaction with the numbers of trout caught, 41% of anglers rated this as “satisfactory” or “very satisfactory”. Relating this response (i.e., the percentage of anglers stating either satisfactory rating) to the measured catch rate at each lake suggested a uniform and high level of satisfaction when catch rates rose above 0.2 fish/angler-hr. The equation for the logarithmic regression of catch rate versus anglers’ satisfaction was $Y = 11.541 \ln(X) + 62.652$ ($R^2 = 0.53$, $p = 0.01$, $df = 11$, Figure 5a). When asked to rate their satisfaction specifically with the size of the trout caught, 49% rated this as “satisfactory” or “very satisfactory”. Relating this response to the harvested size of fish at each lake, however, showed a weak positive response of an increase in satisfaction with increasing size of fish ($R^2 = 0.21$, $p = 0.18$, $df = 8$, Figure 5b).

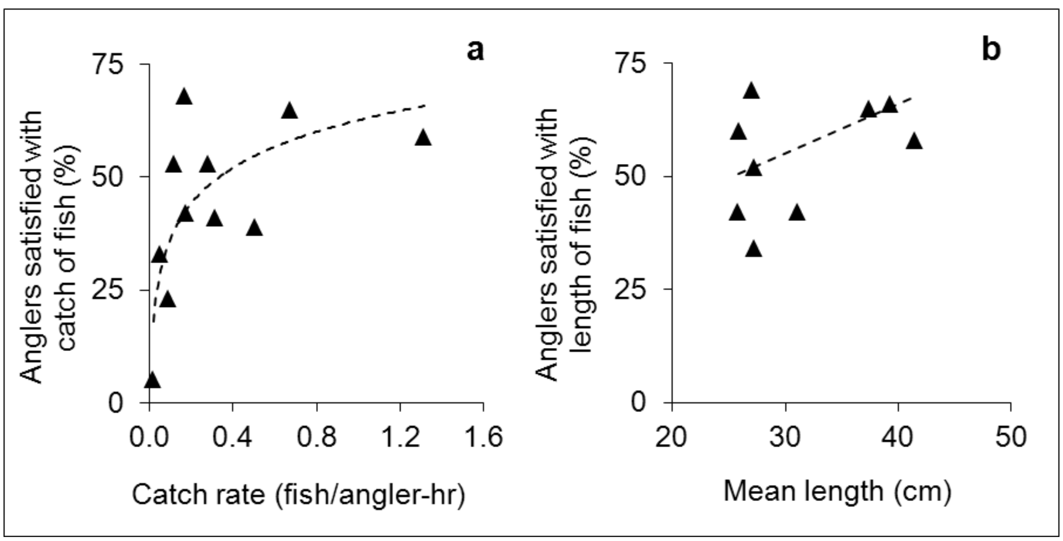

Figure 5. Relationships between total catch rate of Rainbow Trout at stocked lakes in Alberta (2008-2010) and the percent of anglers that were satisfied with their catch (panel a), and the percent of anglers that were satisfied with the length of trout caught (panel b). The regression of catch rate versus anglers satisfaction with catch of fish was significant ($R^2 = 0.53$, $p = 0.01$, $df = 11$) while the regression of the length of trout caught versus anglers satisfaction with the length of trout caught was not significant ($R^2 = 0.21$, $p = 0.18$, $df = 8$).

Angler Participation

Angler participation was very high at the stocked trout lakes, in comparison to Alberta Walleye sport fisheries and British Columbia stocked trout sport fisheries (Figure 6). On average, each Alberta stocked lake received 3,056 angler visits (*SE* ± 1,233), representing an average effort of 308 angler-hr/ha (*SE* ± 70). This angler participation, however, was unrelated to either the catch rate of trout ($R^2 < 0.05$, $p = 0.62$, $df = 13$, Figure 7a), or to the sizes of trout caught ($R^2 = 0.03$, $p = 0.62$, $df = 9$, Figure 7b).

Anglers were asked to select the primary reason for visiting the stocked lakes. Consistent with these findings was that the fishing quality (i.e., low catch rate and small size of trout) of these sport fisheries was not the primary motivation for visiting the stocked trout lakes. The majority (57%, $n = 572$) of anglers stated that being "Close to home" was the main reason for visiting the stocked lakes (Figure 8).

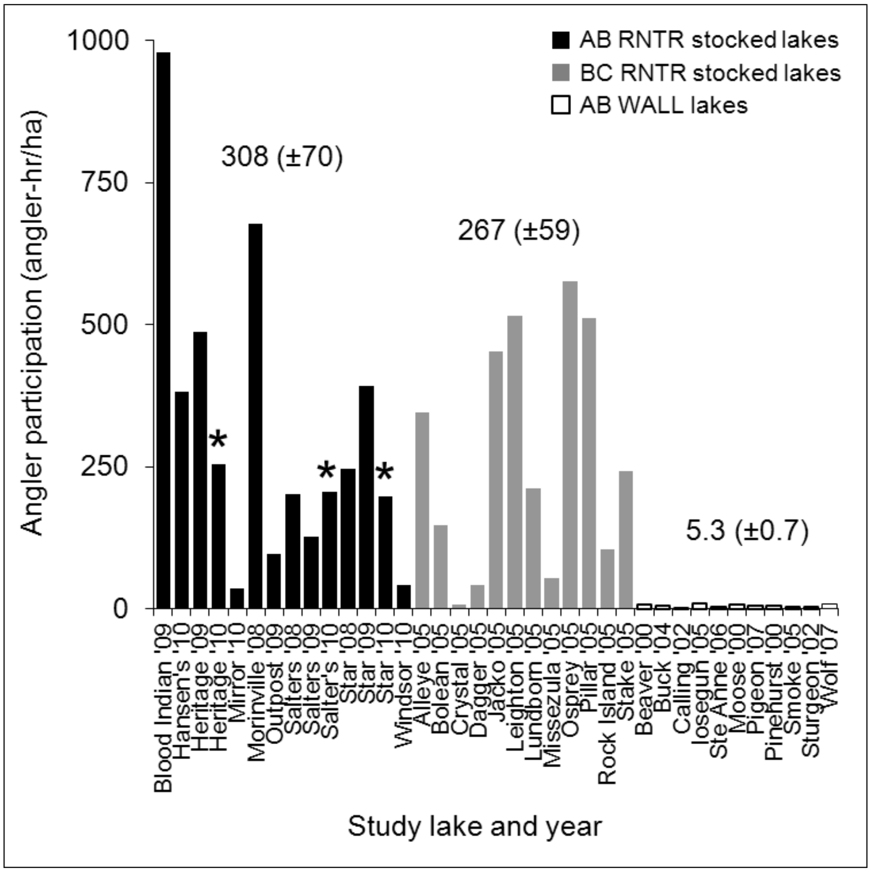

Figure 6. Angler participation at Alberta (AB) and British Columbia (BC) sport fisheries. The participation data for the British Columbia Rainbow Trout (RNTR) and the Alberta Walleye (WALL) sport fisheries came from van Poorten (Unpublished data) and ASRD (Unpublished data). Mean catch rate (±*SE*) is indicated above each sport fishery. Lakes with an experimental 80% reduction in stocking rate are indicated by an asterix.

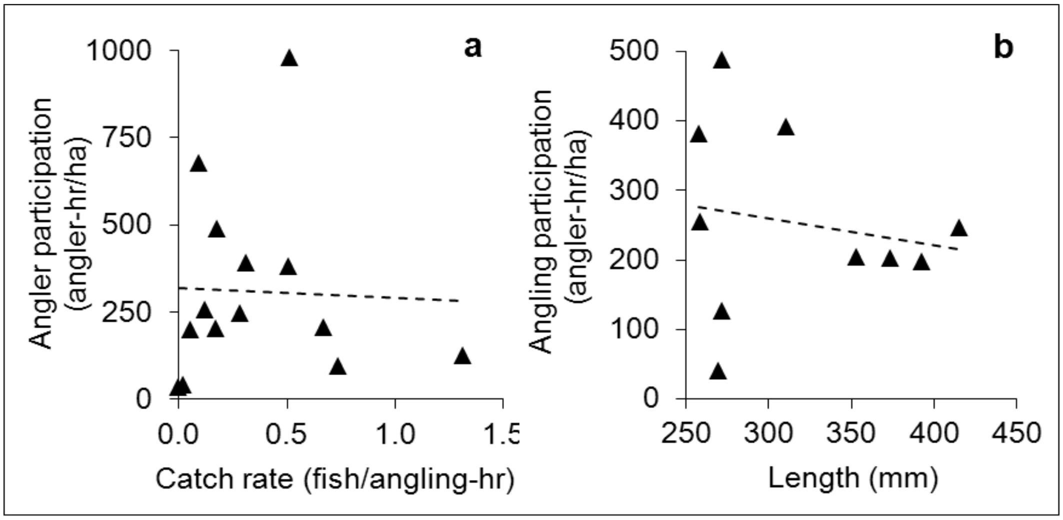

Figure 7. Relationships between the total catch rate from anglers' reports of catches of Rainbow Trout and angler participation (panel a), and the harvested length of trout and angling participation (panel b) at stocked lakes in Alberta (2008-2010). The regressions of catch rate versus angler participation, and length of trout caught versus angler participation were not significant (panel a, $R^2 = 0.001$, $p = 0.62$, $df = 13$; panel b, $R^2 = 0.032$, $p = 0.62$, $df = 9$.

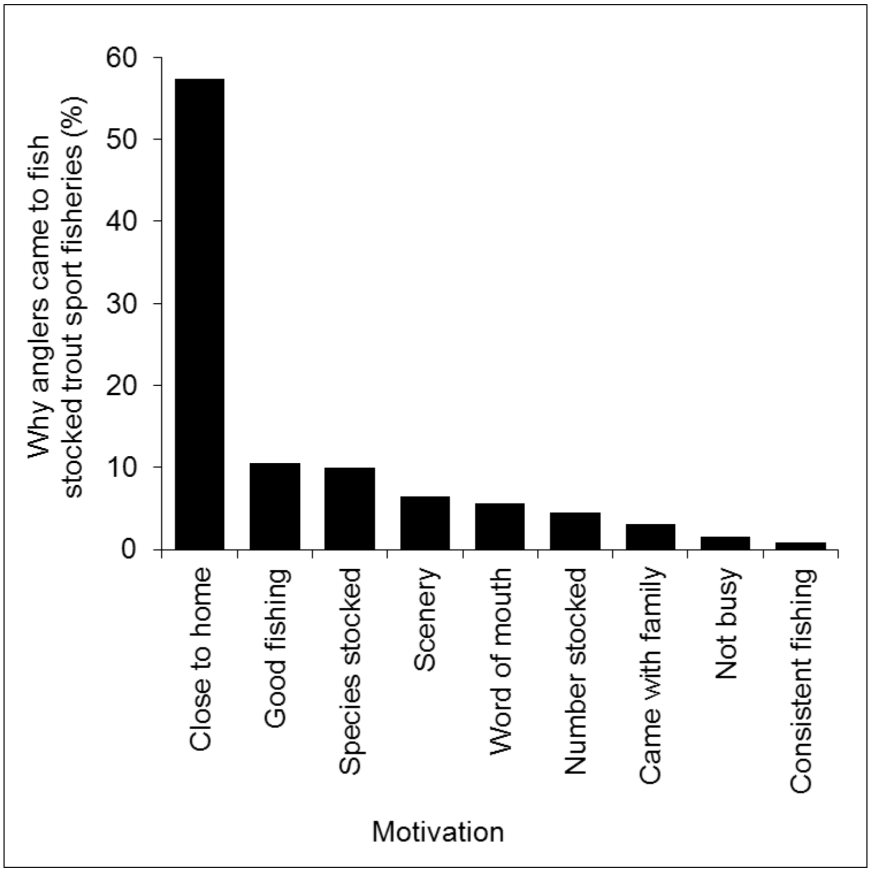

Figure 8. Stated reasons why anglers came to stocked Rainbow Trout sport fisheries (2008-2010). 572 questionnaires were completed.

Question 4: Can I Optimize Stocking Costs While Maintaining or Improving Angler Satisfaction and Participation?

At three experimental lakes (Heritage, Salter's and Star), where the number of trout stocked was reduced by 80%, the angling catch rate decreased by 31%, 83% and 9% at each lake, respectively, compared to the previous angling season. Compared to the catch rates at the six control lakes, however, the manipulated lakes' catch rates were not significantly different (t = 0.381, p = 0.70, df = 12, Figure 3).

The percentage of anglers satisfied with their angling experience was not different at control and manipulated lakes (mean satisfaction at normal-stocking-rate lakes = 69%, $n = 9$ lakes, mean satisfaction at reduced-stocking-rate lakes = 69%, $n = 3$ lakes; $t = 0.009$, $p = 0.50$, $df = 10$).

The mean participation at the study lakes after the reduction in stocking was not significantly lower than at the lakes with normal rates of stocking (mean angler participation at normal stocking lakes = 325 angler-h/ha, n = 11 lakes, mean angler participation at reduced stocking lakes = 219 angler-h/ha, $n = 3$ lakes; $t = 0.624$, $p = 0.27$, $df = 12$, Figure 6).

The cost to ASRD and ACA to stock these fish at the three experimental lakes was reduced by a considerable amount, after manipulation. The cost of stocking (i.e., direct costs only) under the normal stocking strategy averaged $22,141 (range = 10,560 - 35,904, SE ± 5,657). Under the reduced (80%) stocking strategy, the costs averaged $4,048 (SE ± 1,581) or a cost saving of $18,093 per lake. At the experimental lakes with the normal stocking rate, the average cost was $7.66/angler-hr. Under the reduced stocking strategy, the average cost at the three lakes was $1.24/angler-hr.

Discussion

The assumptions of the conceptual model of put-and-take trout stocking at Alberta lakes were quantified, although the findings did not fully support the expected assumptions. Specifically, stocking high densities of trout unexpectedly and consistently created very low density populations. The low density populations (expectedly) created low quality fisheries. These low quality fisheries (unexpectedly) attracted very large numbers of anglers who (unexpectedly) were satisfied with their experience. Although it appeared that the usual policy of “stock trout to make fishing” (Butler & Borgeson, 1965) was successful, this study suggested that the actual success in the program had relatively little to do with stocking more trout. Rather, angler satisfaction at Alberta lakes was more associated with simply being able to fish at a lake “close to home” than with measures of fishing quality or rates of stocking.

Angler satisfaction has widely been linked to non-fishing attributes, such as physical setting, outdoor experience and social factors (Arlinghaus, 2006; Driver & Knopf, 1976; Fedler & Ditton, 1994; Harris & Bergersen, 1985; Ready, Epp, & Delavan, 2005; Spencer, 1993). Fisheries managers, however, largely focus on yield-based stocking management (Bennet, Hampton, & Lackey, 1978; Ross & Loomis, 2001) in spite of the discrepancy between what fisheries can provide and what anglers might want (Miko et al., 1995). Although anglers as a larger social grouping may be satisfied with non-catch attributes, program managers, in my experience, typically do not exclusively cater to large social groupings, but tend to react to complaints from individual anglers or special-interest groups who demand more stocking.

This “grease the squeaky wheel” principle appears to have been inherent in stocking programs since their inception. In his history of Rainbow Trout stocking in North America, Halverson (2010, p. 38) cites a letter written in the 1870s from Spencer Baird (the first Head of the United States Fish Commission) to a staff member concerned with survival of stocked fish eggs,

> It does not make much difference what Rockwood does with the salmon eggs. The object is to introduce them into as many States as possible and to have credit with Congress accordingly. If they are there, they are there, so we can swear, and that is the end of it.

The pervasiveness of "stock trout to make fishing" is also illustrated by the reaction of hatchery managers to the current study's information that stocking large numbers of fish had little effect on catch rate or fishing success. Although they believed the information was interesting, hatchery managers stated it was at least equally important to "stock more" when faced with angry anglers and uncomfortable phone calls; no manager wants to defend stocking less. The "stock more" response supports the stocking treadmill dilemma described by Loomis and Fix (1999), where stocking more trout in itself creates expectations and demands for stocking even more trout, regardless of the quality of the fishery. This study may assist managers in finding a rational balance between the current economic costs, the potential optimization through reducing stocking densities, and the social benefits of stocked trout lakes.

My most important finding was that Alberta anglers appear to have a threshold of satisfaction at a catch rate of approximately 0.2 trout caught/angler-hr. This is important because it provides stocking program managers a measurable objective. Above this catch rate, satisfaction was relatively constant and high. This provides managers with a target catch rate, similar to the findings of Miko et al. (1995), as one determinant of successful program management. The importance of this catch rate (0.2 fish caught/angler-hr) may have a functional explanation. At Alberta stocked lakes, two anglers generally fish together, with a trip length of approximately 2.5 hours. With these parameters, a catch rate of 0.2 fish/angler-hr therefore corresponds to an overall catch of one fish per angling trip. Perhaps simply catching a single fish per angling trip is the threshold for satisfaction and therefore could be a rational objective for stocking management.

The most controversial finding was the very low survival of stocked fish. This finding was controversial because managers were particularly surprised, and somewhat dismissive and defensive about this finding. On average, only 11% of the stocked fish survived long enough to be available to anglers, with no lake having higher than 27% survival. Other researchers, however, found that these high rates of mortality are not unusual (Johnson, et al., 1995; Reimers, 1963; Vincent, 1987; Wiley, Whaley, Satake, & Fowden, 1993), although low mortality has also been observed (Miko et al., 1995; Pawson 1982). Certainly, this study sampled a small proportion of Alberta stocked lakes (i.e., 9 lakes studied out of 242 lakes stocked). The physical characteristics of the study lakes (e.g., size, depth, limnology), however, were typical of Alberta's stocked "pothole" lakes (Miller & Thomas, 1957, p. 261). Comparative studies of lakes believed to have high rates of trout survival would be very useful in furthering the understanding of stocking success.

At the study lakes, low angler catch rates were observed immediately after stocking, suggesting that few stocked trout entered the fishery and may have died within days of stocking. However, other than a single report of dead fish at Salter's Lake after being stocked in 2008, no large die-offs of trout were observed by fisheries staff or reported by anglers at any of the lakes. Live trout captured by gill netting or angling were not visibly starved or emaciated. Predation (by birds such as pelicans, loons, or cormorants or by mammals such as otters and mink) was not observed in any degree that could explain the loss of thousands of trout at each lake. Further, mortality from stress, predation, and injuries does not seem to entirely account for poor survival of stocked trout in other studies (Barr, 1996; Barton & Peters 1982; Barwick, 1985; Smith & Hubert, 2003). I attempted to determine when and how these fish were lost by using short duration gillnet sets and underwater videography. The catches in the gill nets were very low and highly variable, however, and the results were inconclusive. The murky conditions (typical of Alberta trout lakes) made videography impractical. The unexplained cause of the apparent low survival is clearly one of the most important questions raised by this study.

The most unexpected finding was the high level of angler use. Angler participation at these stocked lakes was nearly two orders of magnitude higher than at Alberta natural-lake Walleye fisheries (i.e., 302 angler-hr/ha at trout lakes versus 5 angler-hr/ha at Walleye lakes). This is partly a function of the much larger surface area at the natural Walleye lakes (26 ha at trout lakes versus 4,860 ha at Walleye lakes) allowing angler dispersal, but also is an indication of the popularity of these stocked fisheries. It also highlights the dilemma of managing popular fisheries in a cold, unproductive climate. Short summers, cool waters, and low biodiversity combine to limit annual fisheries production from Alberta waters to very low levels. For example, Alberta Walleye fisheries have an annual production (i.e., sustainable harvest of Walleye) of under 1 kg/ha, but angler participation at Alberta Walleye lakes is comparatively much higher (i.e., 5 angler-hr/ha) that catch-and-release mortality alone can lead to overexploitation (Sullivan, 2003). Naturally reproducing Walleye production must be much lower than stocked put-and-take trout production, but trends in similar climate and landscape limitations to food and growth should apply. At Alberta's stocked trout lakes, the observed level of angler participation (302 angler-hr/ha) and the catch rate required to achieve satisfaction (0.2 fish/angler-hr) means that a satisfactory level of catch is 60 trout/ha. Even with relatively small trout (e.g., 30 cm, 250 g), the required production from these lakes would need to exceed 15 kg/ha. The extremely high angler participation observed at the trout lakes (even assuming a high level of trout production) suggests it may be very difficult to satisfy these anglers within the natural limitations of Alberta's fisheries production capabilities.

The technique of using trail cameras to collect the angler-effort data was very successful. By using cameras, the costs of the creel surveys were greatly reduced, to approximately 10% the cost of a typical Alberta creel surveys (i.e., two staff survey two lakes per summer). Simply, the cameras replaced the need for labour- and vehicle-intensive angler counts. The creel survey attendants were needed only to interview comparatively few anglers to collect catch rate and trip length data and maintain the trail cameras. The lower cost allowed by this method makes a large-scale monitoring program of Alberta's trout lake fisheries logistically feasible.

Conclusions

The assumptions of the implicit conceptual stocking model of; stocking trout creates fisheries, which will attract and satisfy anglers, and furthermore, more stocking will create better, more satisfactory fisheries, which will attract even more anglers, were assessed and largely rejected. Rather, most of the stocked trout died, but anglers remained satisfied with the opportunity to catch low numbers of fish at lakes close to home. Interpretations of quantitative data suggested that stocked trout lakes could be more effectively managed with target-based goals. Specifically, these goals are: 1) stock to achieve catch rates high enough to satisfy anglers (approximately 0.2 fish/angler-hr), and 2) attract angler participation at levels to match sustainable trout production. These goals can be achieved not by simply stocking more but by an iterative program measuring the results of stocking (in terms of fish survival, angler satisfaction and participation), and modifying techniques until goals are met. Specifically, we should determine how to avoid the observed high rates of stocking mortality and use this knowledge to stock a density of fish that produces the target catch rate. The considerable economic efficiencies gained in this process could be used, for example, to conduct comparative studies to further our understanding in ways to; reduce stocking mortality, increase stocking success, or increase the number of lakes stocked near concentrations of anglers, rather than improving the already adequate quality of stocked fisheries.

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Appendixes

Table A1 *Observed creel survey parameters from surveys conducted at Alberta stocked trout sport fisheries, 2008-2010.*

Lake	Year of study	Creel survey effort (% of days May-August)	Census counts (No.)	Spatial correction (sample counts / census counts, No. of anglers)	Anglers interviewed (No.)	Angler-hrs	Trout harvested (No.)	Trout released (No.)
Hansen's	2010	7	87	154 / 181	101	209	60	46
Heritage	2009	16	185	292 / 468	179	303	16	37
Heritage	2010	11	130	124 / 336	159	325	15	24
Mirror	2010	9	107	11 / 18	14	10	0	0
Morinville	2008	6	75	39 / 67	159	95	3	6
Salter's	2008	9	105	55 / 100	51	94	0	16
Salter's	2009	18	216	115 / 251	81	195	30	227
Salter's	2010	13	149	98 / 225	84	184	33	91
Star	2008	6	68	116 / 251	93	238	23	44
Star	2009	13	149	908 / 1204	331	1,091	86	256
Star	2010	11	135	425 / 547	190	575	11	19
Windsor	2010	10	123	71 / 99	31	48	0	0

Note. No observed data were provided by Alberta Sustainable Resource Development for the creel surveys at Blood Indian and Outpost lakes.

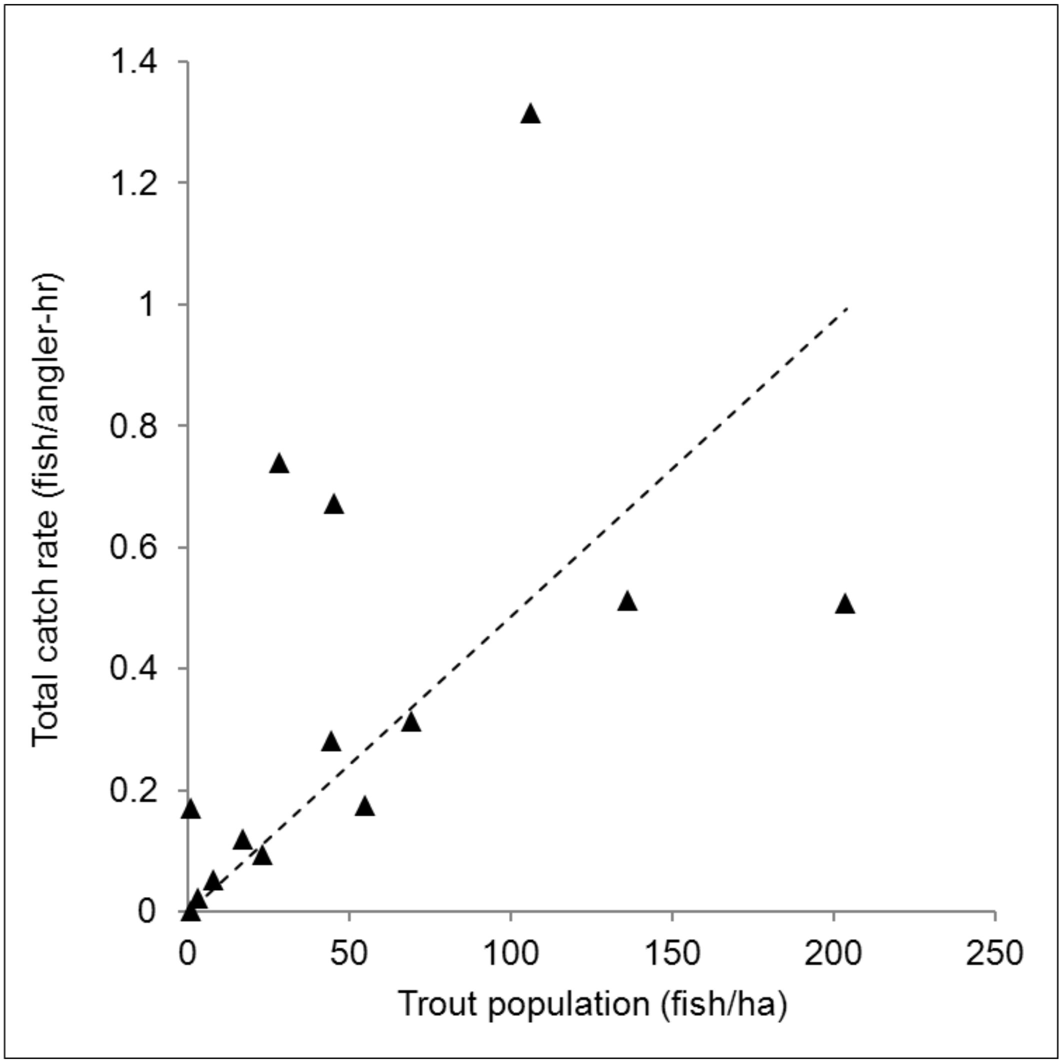

Figure A1. Relationship between trout population and total catch rate. The regression of Trout population versus catch rate was significant (R^2 = 0.57, p < 0.05, df = 13).

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Government of Alberta
Sustainable Resource Development

Alberta Conservation Association