North American Journal of Fisheries Management 15:26–32, 1995
American Fisheries Society

Economic Benefits and Costs of Stocking Catchable Rainbow Trout: A Synthesis of Economic Analysis in Colorado

DONN M. JOHNSON

Department of Economics, University of Northern Iowa, Cedar Falls, Iowa 50614, USA

ROBERT J. BEHNKE

Department of Fishery and Wildlife Biology, Colorado State University
Fort Collins, Colorado 80523, USA

DAVID A. HARPMAN

U.S. Bureau of Reclamation
Post Office Box 25007 (D-5810), Denver, Colorado 80225-9772, USA

RICHARD G. WALSH

Department of Agricultural and Resource Economics, Colorado State University

Abstract.—Many fish and wildlife management agencies expend a large proportion of their fishery management budgets to provide catchable-size trout for the creation and maintenance of put-and-take fisheries. Increasingly, this practice has been called into question. This study examines the economic issues involved and compares the economic costs of providing catchable rainbow trout *Oncorhynchus mykiss* in two Colorado streams with anglers' willingness to pay for them. The apparent discrepancy between the economic costs of providing catchable trout and their economic benefits suggests that the Colorado catchable trout program and those in other states should be reviewed on efficiency grounds.

Since the 1940s, the number of coldwater fishing days in the United States has grown more than fourfold (Walsh et al. 1988a), greatly increasing the fishing pressure on available waters. As a consequence, there has been a decline in the quality of wild trout fisheries, especially in streams. State fish and game agencies have responded in part by investing public funds in hatcheries to produce and stock catchable-size trout (mainly domesticated rainbow trout *Oncorhynchus mykiss*) in an attempt to maintain fishing quality. Because domesticated, hatchery-reared trout generally do not survive long after stocking, these programs have become known as put-and-take fisheries. Over time, managers have increased production of catchable trout to sustain put-and-take fisheries, and the operation and management of production facilities has become the largest single component of many state agencies' fisheries budgets. This emphasis on catchable trout production has occurred without study of the biological ramifications (until the last decade: Vincent 1987; Goodman 1990) or of the economic efficiency of stocking catchable trout.

The objective of this paper is to present the economic and biological issues pertinent to put-and-take fisheries, to present recent empirical estimates of the costs and benefits of catchable trout stocking in Colorado, and to recommend a future course of action. The results from three studies are integrated.

The first section of this paper discusses put-and-take fisheries and their management implications. The second section presents the results of an exhaustive effort to estimate the economic costs of providing catchable rainbow trout in Colorado. The third section reviews two recent studies of the economic benefits of trout caught by recreational anglers in Colorado. The fourth section compares the economic benefits of recreational fish catch at two sites in Colorado with the economic costs of stocking catchable rainbow trout.

Put-and-Take Fisheries

In states with both warmwater and coldwater fisheries, a variety of species are hatched and reared in hatcheries for stocking in public waters. Because this paper concerns catchable trout programs, we should clarify the difference between hatchery and catchable fish. All of the noncatchable-size fish are stocked as fry, fingerlings, or advanced juveniles (often grouped as subcatchable fish in relation to size stocked). The principles on which the stockings of subcatchable fish are based involve taking advantage of the natural capacity

ciety

of waters to grow fish,
reproduction is unsuc
stocked under the assu
vive and grow so that
stocked fish will contri
terms of the weight of f
than was originally stoc
program results in wha
put-and-grow fisheries.
In contrast, in put-a
trout are typically stoc
create instantaneous fis
of catchable trout mai
been selectively bred
modification of behavi
ilation of artificial die
These modifications re
result in genetic chang
cestors. These genetic
trout poorly adapted
conditions. Thus, in hi
h/acre per year or more
(50% or more) of the
within the first 7–10 d
Borgeson 1965). Less
trout survive 1 year, pa
1952; Vincent 1975, 1
A brief review of his
basic pros and cons of
helpful to better unde
What is frequently ref
hatchery bureaucracy"
trout has historical a
well over 100 years. T
eries Society began in
of the American Fish
The first serious org
able trout stocking cam
of Trout Unlimited in
(TU) was founded wit
changing the emphasi
agement program fro
trout. Although TU h
on wild trout managem
duction of catchable t
hatcheries increased b
TU was founded (Beh
stocking is still a maj
in the total fisheries bu
and Johnson 1989).
It has been a gener
agement tenet that s
fishing pressure (500–
annually) require stoc

North American Journal of Fisheries Management 18:168–174, 1998

An Economic Analysis of the Cost-Effectiveness of Privatizing Additional Production of Catchable Rainbow Trout: A Case Study in Colorado

DONN M. JOHNSON[1]

Department of Economics, Quinnipiac College
Hamden, Connecticut 06518, USA

RICHARD G. WALSH

Department of Agricultural and Resource Economics
Colorado State University, Fort Collins, Colorado 80523, USA

Abstract.—This study examines the cost of increasing state production of catchable rainbow trout *Oncorhynchus mykiss* and compares this cost with the cost of purchasing fish from private producers in Colorado. The results suggest that the scope of the analysis and the manner in which costs are identified will determine whether purchasing fish can result in cost savings. When the scope of the study is the state and reported state costs are used, purchasing fish could result in a loss of US$0.53/lb. When the scope of the study is the state and opportunity costs are estimated, purchasing could result in a loss of as much as $0.02/lb or a savings of as much as $0.51/lb. When the scope of the study is the nation, and opportunity costs are estimated, purchasing could result in cost savings of $1.71–2.24/lb. Further research is needed to determine whether private producers are a reliable source of supply and to assess the quality of the rainbow trout purchased from private producers.

This paper explores the issue of privatizing the production of catchable rainbow trout *Oncorhynchus mykiss*. Because there has been little previous research, there is little basis for knowing whether it costs less to produce catchable rainbow trout in state hatcheries or to buy them from private producers.

The importance of this study stems from the fact that commercial fish farming has been one of the most rapidly growing sectors of the agricultural economy (Meade 1989; Weld et al. 1990). Private sector production of catchable rainbow trout, typically 8–12 in, is more than three times larger than state production (USDA 1990).

Because it is possible to contract for the size and number of rainbow trout desired, the benefits to anglers of catching state-produced and privately produced catchable rainbow trout are assumed to be the same. The economic issue is a determination of which of the two parties produces catchable rainbow trout in the most cost-effective manner. This issue is addressed by comparing the opportunity cost (the value of resources used to produce catchable rainbow trout) of stocking public waters with catchable rainbow trout produced in Colorado state hatcheries with the cost of purchasing fish from private producers in Colorado. It can then be determined whether purchasing fish from private producers can result in cost savings.

The primary data were obtained from Colorado Division of Wildlife (CDOW) accounting reports, estimates by state fish managers, and a survey of private producers in Colorado. The intent was to conduct an economic evaluation based on the best available information in Colorado.

Case Study of Colorado

The initial impetus for this study was a 1988 CDOW proposal to increase coldwater fish production and stocking by as much as 400,000 lb by 1995 because of a projected increase in fishing days. Catchable rainbow trout were to account for approximately 94% of the projected increase. The state of Colorado reported that because state hatcheries were already producing at maximum capacity, an increase in catchable rainbow trout production would require expansion of state hatchery capacity. The specific question addressed here is whether it would have cost less to expand current state production capacity or to contract with private producers for some portion of the increased production.

A Colorado Department of Agriculture survey, conducted in 1986, showed that 9 of 11 producers responding reported interest in bidding on the sale

[1] Corresponding author: johnsond@quinnipiac.edu

November 13, 1998

TO: Bob Behnke

FROM: Mike Stone

SUBJECT: Wyoming Hatchery Information

Bob Wiley and I visited about your note on Wyoming hatchery production. This discussion stimulated the following additions to his last note. The point of these additions is not to quibble about the costs or your calculations. As Bob Wiley mentioned, these are in the ball park with calculations we have made. Instead, the following is meant to fill you in on some of the information which is not apparent from just looking at costs and numbers or sizes of fish produced. As state wildlife management agencies, we cannot always manage for lowest unit cost alone or we would be negligent in other areas.

1. Native trout restoration programs are costly. For example, Colorado River and Bonneville cutthroat stocks for restoration purposes are much more expensive to maintain and culture than our domesticated fall rainbow or Auburn Snake River cutthroat. Even the Bar BC Snake River cutthroat and new source of Yellowstone cutthroat which requires capture of stock from Yellowstone National Park for use in establishing a brood stock are much more expensive. Separating costs for native trout culture would be time consuming and I am sure the costs, especially brood stock start up and scheduled infusion of wild fish into the stocks would be several times the costs of domestic trout production. Native trout culture inflates our overall hatchery costs somewhat, but it is the cost of this kind of management which I fully support.

2. WGFD maintains brood stocks for more species and strains (approx. 12) than other states with the goal of providing flexibility to meet specific management needs. We could reduce costs by maintaining fewer, easier to rear brood stocks. However, that would fail to meet fisheries management objectives.

3. WGFD emphasizes genetics in brood stock management. This increases dollar costs, but again we believe the payoff in the product produced is worthwhile. This results in higher costs to maintain larger brood stock populations than egg requests alone would demand for strains with small egg requests.

4. WGFD emphasizes quality vs. quantity in fish production. The notion of reducing production when necessary to maintain or increase quality is fairly well accepted within our agency culture. Of course, this increases the cost per pound. The real key, of course, is survival, not purely cost per pound. Increased costs are easily off set if chances of survival are markedly increased. For example, producing 100,000 fish at a low cost per pound with only 10% survival is a poorer choice than producing 80,000 fish with 30+% survival.

5. Stocking strategies for several of the major reservoirs employ large, catchable size trout for basic yield management to avoid large predators. While these are catchable size trout, which show in the total catchable trout figures you reference, they are not part of a traditional put-and-take catchable program. Most notable are the reservoirs in the North Platte system. A recent evaluation proved this management strategy sound, at least for the time being. To my surprise, the growth and catch rates were high enough to meet standards set for basic yield fisheries.

6. I am enclosing a chart for 1996 and 1997 which you may find interesting if you don't have it already.

1996 and 1997 Salmonid (Trout, Salmon & Grayling) Stocking in Wyoming

1996 Stocking

Size	Number Stocked	Pounds Stocked	Average NO/LB
Size 1 (Fry 0-1.0")	1,874,641	428.9	4,371
Size 2 (Fingerling 1.1-3.0")	1,011,246	6,238.9	162
Size 3 (Adv. Fingerling. 3.1-5.0")	2,338,078	47,270.9	49.5
Size 4 (Sub-Catchable 5.1-8.0")	1,108,778	107,079.2	10.4
Size 5 (Catchable 8.1 to +")	681,373	182,896.6	3.7
Size 6 (Brood Culls)	9,464	19,859.0	.48
1996 Totals Stocked =	7,023,580	363,773.5	19.3
1996 Sub-Catchables (Sizes 1-4) = (Percentage of Stocking)	6,332,743 (90.16%)	166,017.4 (45.64%)	38.15
1996 Catchables (Sizes 5-6) = (Percentage of Stocking)	690,837 (9.84%)	197,755.6 (54.36%)	3.49

1997 Stocking

Size	Number Stocked	Pounds Stocked	Average NO/LB
Size 1 (Fry 0-1.0")	0	0	0
Size 2 (Fingerling 1.1-3.0")	1,608,151	9,392.8	171
Size 3 (Adv. Fingerling. 3.1-5.0")	2,571,302	67,574.0	38
Size 4 (Sub-Catchable 5.1-8.0")	1,123,495	122,186.7	9.2
Size 5 (Catchable 8.1 to +")	744,246	203,356.0	3.7
Size 6 (Brood Culls)	13,894	43,063	.32
1997 Totals Stocked =	6,061,088	445,572.5	13.6
1997 Sub-Catchables (Sizes 1-4) = (Percentage of Stocking)	5,032,948 (87.50%)	199,153.5 (44.70%)	26.63
1997 Catchables (Sizes 5-6) = (Percentage of Stocking)	758,140 (12.50%)	246,419.0 (55.30%)	3.10

Stocking numbers are for trout, salmon and grayling stocked in the state of Wyoming by state and federal facilities combined. This does not include coolwater and warmwater species that are stocked in the state through trades.

WYOMING
GAME AND FISH DEPARTMENT

5400 Bishop Boulevard
WYOMING GAME & FISH DEPARTMENT
Cheyenne, WY 82006

CHEYENNE
NOV 13'98
WY

U.S. POSTAGE
00,32
H METER 406298

Dr. Robert Behnke
Dept. of Fish. & Wild. Biology
Colorado State University
Ft. Collins, Co. 80523

North American Journal of Fisheries Management 19:110–119, 1999

A Statistical Approach to Estimating Costs of Propagating Hatchery Rainbow Trout

JOHN LOOMIS* AND PETER FIX

Department of Agricultural and Resource Economics,
Colorado State University, Fort Collins, Colorado 80523, USA

Abstract.—A statistical cost function is estimated and used to calculate the marginal cost and average total cost of production of rainbow trout *Oncorhynchus mykiss* in Colorado. The marginal cash costs in the short run to produce another rainbow trout caught by anglers from the existing hatchery system is US$0.61, which is less than three different estimates of the marginal recreational benefit of harvesting another rainbow trout. However, the average total cash costs and long-run economic cost per catchable-size rainbow trout harvested by a recreational angler are estimated as $1.85 and $2.69, respectively. These costs are considerably higher than the $1.10 average benefit of a rainbow trout caught.

Natural resource management programs often have many goals, and fisheries management is no exception. Conserving the resource and insuring its sustainable use are frequent objectives in fisheries management. Over the last several decades, a great deal of emphasis has been placed on the use of hatcheries to increase salmonid populations. Often hatcheries have been seen by state and federal agencies as "quick fixes" to mitigate for loss of habitat from dams or for habitat degradation caused by logging, mining, or livestock grazing. For recreationally fished species, an important issue is whether the benefits of hatchery production exceed the costs. In addition, the millions of dollars annually spent on hatcheries could, in many cases, be spent on habitat restoration. In this paper, we demonstrate a technique for estimating the marginal and long-run average cost of producing rainbow trout *Oncorhynchus mykiss* and compare these with the fishing benefits. Our analysis identifies and, where possible, quantifies several of the nonfinancial costs of hatcheries that must be accounted for in a more complete benefit-cost analysis of decisions to rely on hatcheries instead of habitat improvements. Such costs include opportunity costs of land and water used by hatcheries. We end with some observations on opportunities to change the emphasis in fisheries management.

Differences in Economic Benefits, Impacts, and Financial Analyses

Some past evaluations of the efficiency of hatchery and habitat management have blurred important distinctions between financial profitability, economic benefits, and local impacts (FishPro 1994). For example, financial analyses that compare the cash costs to an agency to raise catchable fish with license revenues misses much of the economic benefits of fishing realized by anglers. An agency may lose money, but provide a sizeable economic benefit to its constituents. Public, as opposed to private, ownership of natural resources is, in part, justified because the public economic benefits often exceed what could be collected as revenue (Loomis 1993).

Just as economic benefits may exceed revenues, economic costs may exceed financial costs or expenditures. There are additional costs that must be considered in public decisions, such as the costs of capital improvements and opportunity cost of natural resources, such as land and water (Reiling et al. 1983). Opportunity costs represent foregone benefits of using the resources in their next best use. For example, river-front property occupied by a hatchery could be used as a state park. These economic costs are usually larger than direct financial costs, but are more difficult to delineate. Nonetheless, the opportunity costs can be estimated by determining the payments necessary for similar resources elsewhere.

Some past evaluations of hatchery production have confused the distinction between economic benefits and economic impacts. Economic benefits of any good or service, including recreational fishing, is measured by the consumer's additional willingness to pay in excess of current costs. This net willingness to pay of the consumer is sometimes referred to as "consumer surplus" (Sassone and Schaffer 1978; Loomis 1993). Economic impacts are measured as the local jobs and wage income–

* Corresponding author:
jloomis@ceres.agsci.colostate.edu

Received February 5, 1998 Accepted July 17, 1998

Forthcoming in No. Am. J of Fish Mgmt

Bob- Here is the paper + our attempt to statistically sort out costs. Came reasonably close to what Don Johnson, et al got with simpler methods
John L.

A Statistical Approach to Estimating Costs of Propagating Hatchery Trout

John Loomis and Peter Fix,
Department of Agricultural and Resource Economics,
Colorado State University, Fort Collins, Colorado, 80523, USA.

Forthcoming in No. Am. J of Fish Mgmt

A Statistical Approach to Estimating Costs of Propagating Hatchery Trout

John Loomis and Peter Fix,
Department of Agricultural and Resource Economics,
Colorado State University, Fort Collins, Colorado, 80523, USA.

ABSTRACT

A statistical cost function is estimated and used to calculate the marginal cost and average total cost of rainbow trout Oncorhynchus mykiss production in Colorado. Key findings include the marginal cash costs in the short-run to produce another trout caught by anglers from the existing hatchery system is US$.61, which is less than three different estimates of the marginal recreational benefit of harvesting another trout. However, the average total cash costs and long-run economic cost per catchable size trout harvested by a recreational angler are estimated as $1.85 and $2.69, respectively. These costs are considerably higher than the average benefit of a trout caught of $1.10.

Natural resource management programs often have many goals and fisheries management is no exception. Conserving the resource and insuring its sustainable use are frequent objectives in fisheries management. Over the last several decades, a great deal of emphasis has been placed on hatcheries to increase salmonid populations. Often hatcheries have been seen by state and federal agencies as "quick fixes" to mitigate for loss of habitat from dams or for allowing habitat degradation from logging, mining or livestock grazing. For recreationally-fished species, an important issue is whether the benefits of hatchery production exceed the costs. In addition, the millions of dollars annually spent on hatcheries could, in many cases, be spent on habitat restoration. In this paper we demonstrate a technique for estimating the marginal and long run average cost of producing primarily rainbow trout Oncorhynchus mykiss and compare these to the fishing benefits. Our analysis identifies and, where possible, quantifies several of the non-financial costs of hatcheries that must be accounted for in a more complete benefit-cost analysis of decisions to rely on hatcheries instead of habitat improvements. Such costs include opportunity costs of land and water used by hatcheries. We end with some observations on opportunities to change the emphasis in fish management.

Differences in Economic Benefits, Impacts and Financial Analyses

Some past evaluations of the efficiency of hatchery and habitat management have blurred important distinctions between financial profitability, economic benefits and local impacts (FishPro 1994). For example, financial analyses which compare the cash costs to an agency to raise catchable fish with license revenues misses much of the economic benefits of fishing realized by the anglers. An agency may lose money, but provide a sizeable economic benefit to its constituents. Public, as opposed to private, ownership of natural resources is, in part, justified because the public economic benefits often exceed what could be collected as revenue (Loomis 1993).

Just as economic benefits may exceed revenues, so do economic costs exceed financial costs or expenditures. There are additional costs that must be considered in public decisions such as the costs of capital improvements and opportunity cost of natural resources such as land and water (Reiling et al. 1983). Opportunity costs represent foregone benefits of using the resources in their next best use. For example, river front property occupied by a hatchery could be used as a state park. These economic costs are usually larger than direct financial costs, but are more difficult to observe. Nonetheless, the opportunity costs can be estimated by determining the payments necessary for similar resources elsewhere.

Some past evaluations of hatchery production have confused the distinction between economic benefits and economic impacts. Economic benefits of any good or service, including recreational fishing, is measured by the consumer's additional willingness to pay in excess of current costs. This net willingness to pay (WTP) of the consumer is sometimes referred to as "consumer surplus" (Sassone and Shaffer 1978; Loomis 1993). Economic impacts are measured as the local jobs and wage income/profits generated by angler and agency spending. While there are jobs supported by agency management and visitor expenditures, this does not change the fact that such expenditures are costs rather than benefits. Increases in agency expenditures, unless matched by increased angler satisfaction (measured by the additional amount they would pay) is a real cost to anglers and the state as a whole. Further, shifting agency funds from hatcheries to habitat restoration would likely generate an equivalent number of jobs.

This distinction between economic benefits and economic impacts is well established in the benefit-cost analysis literature (Sassone and Shaffer 1978; Loomis 1993). The Federal guidelines for agencies performing benefit-cost analyses require that local job gains/losses be ignored as they are simply transfers of economic activity from one geographic area to another or one commercial sector to another (U.S. Water Resources Council 1979, 1983).

For the purpose of this article, we will focus on estimating the marginal and average cost of fish production from hatcheries operated by the Colorado Division of Wildlife (CDOW). The purpose of this paper is to not to perform a complete benefit-cost analysis. However, we will compare the marginal cost estimates from our analysis to the marginal benefits per fish caught estimated by Johnson et al. (1995) in two Colorado studies and the Colorado state average estimate from the 1991 National Survey of Fishing, Hunting and Wildlife Associated Recreation (Waddington et al. 1994). It should be recognized that catching wild, self-reproducing rainbow trout often has an economic premium as compared to fishing for hatchery trout. For example, in Idaho the "wild" trout streams had economic values in 1982 dollars of US$56-66 per trip, while the statewide average for all coldwater fishing sites in Idaho was $34 (Loomis et al. 1986). Therefore, anglers would pay an additional $22-32 per trip for the extra satisfaction of fishing for wild trout.

Distinguishing between Short Run and Long Run Costs: When to Use Each

For economically efficient decisions about the size or scale of a fisheries management program, the relevant comparison is between the incremental (marginal) benefit and incremental (marginal) cost. For short run decisions involving operation of existing hatcheries, previous investments in capital goods such as raceways can be viewed as fixed or sunk costs. Thus, the marginal costs reflect only the variable costs. For long run decisions regarding replacement of hatcheries, all costs (including capital) are variable and must be considered. In the long run the budget could be used for habitat protection or water rights acquisition. In this study we compute the short run marginal costs and two long run costs: (a) average total cash costs which include the direct costs the agency incurs in operating the hatchery system including administrative overhead, vehicles, etc.; and (b) total long run average costs includes the average total cash costs as well as replacement costs of facilities and opportunity costs of the land used by the facilities. In principle the land used by the hatcheries could be put to some other use by the state government or even sold. The research of Johnson et al. (1995) illustrates several of these distinctions between short run (their average variable cost) and long run (their average total cost). However, their cost analysis only evaluates the average cost rather than the marginal cost.

The purpose of this article is to answer the following questions:

■ Do the recreational fishing benefits of propagation under current conditions outweigh the short run marginal costs of operating existing trout hatcheries in Colorado?

■ Would the recreational fishing benefits of replacing old facilities outweigh the long run average costs?

■ Would the recreational fishing benefits of expanding the hatchery system or capacity outweigh the long run average costs?

Methods to Estimate Costs of Hatchery Production

Budgeting Method

The most common method of estimating the cost per trout or per pound of rainbow trout produced has involved construction of a hatchery budget. The total or variable cost of the hatchery is divided by output in terms of number of fish or pounds produced to yield an average cost per trout or pound. This approach is relatively straightforward, especially when the output is pounds of fish. In this case it does not matter whether the fish are catchables ($\geq$8 in) or subcatchables (<8 in) as pounds are pounds. Unfortunately, what recreational anglers usually value is number of fish caught, not pounds per se. Thus, use of cost per pound makes comparison to the benefits of hatcheries difficult. Recent examples of the budget approach include Behnke (1989) who calculated the cost to produce a catchable trout was $.56 per fish in 1986 dollars. While this is a systematic effort across multiple states, the primary difficulty with this approach is that many hatcheries produce multiple fish including subcatchable trout, subcatchable kokanee *Oncorhynchus nerka* and catchable trout. To correctly estimate the cost of producing catchable trout requires allocating much of the common or joint cost of operating the hatchery to one specific output. In economics this is known as the joint cost allocation problem and it is difficult to calculate separable costs in an objective fashion without a statistical model such as we propose in the next section.

Johnson et al. (1995) relied upon CDOW's own estimates of cost allocation to estimate the costs of catchable trout production. Using the CDOW's cost allocation, Johnson et al.'s (1995) estimate of the average variable cost were $.57 per 8 oz (10 in) catchable trout (1988 dollars). This is the average cost for all 11 CDOW coldwater hatcheries. Johnson et al. (1995) then included $.90 of fixed, overhead and capital costs to arrive at an average total cost of $1.47 per catchable trout, in 1988 dollars. Deloitte Touche LLP (1995) report the U.S. Department of Agriculture Trout Production Report average variable cost for the western states of $.88 per catchable trout and the average total cost per catchable trout of $1.13. Hinshaw et al. (1990) as well as several books on trout farms (Sedgwick 1990) and aquaculture (Stickney 1994) also use the budgeting approach for estimating the cost of trout production.

Cost Function Method

Estimating a total cost function provides several advantages over the budgeting approach. First, the estimated total cost function can be differentiated and, more appropriate for decision making, marginal cost can be calculated for a range of different output levels. In addition, average variable and average total costs can also be calculated for a range of output levels. Second, use of the estimated coefficients solve the joint allocation of cost for multiple output hatcheries. That is, analysis of production and cost data observed at different hatcheries over a long period of time reveal the incremental costs of producing each type of output as well as the determinants of the total costs of production. Third, one can identify whether the cost of production exhibits economies of scale and where in that range the hatchery is currently operating can be identified.

The attractiveness of the cost function method must be balanced with the suitability of the available data. State agencies generally maintain data on costs and expenditures to satisfy state accounting requirements, not to allow estimation of cost functions. Thus the ideal measure of some variables are unavailable and approximations must be used in the model. The general form of a cost function is:

(1) TC= f(Q, Pinput, Capacity)

where TC is total cost; Q is quantity of output such as subcatchable or catchable trout; Pinput is the price of inputs such as labor, feed, and electricity; Capacity is a measure of the size of physical structures or size of capital facility used to raise trout.

To estimate equation (1) a functional form must be specified and the analyst needs to observe how TC varies with output. In our model we collected data on a number of hatcheries over time (1987 to 1995). Given the time series nature of the data, we tested for autocorrelation and then corrected for it using an auto-regressive procedure (Greene 1990). To further observe variation in TC with changes in output, we pooled data across similar types of hatchery or rearing units. We did this by separating the hatchery units into two relatively homogenous groups: (a) self sufficient hatcheries that produced fingerlings and catchable trout from eggs; and (b) rearing units that received fingerlings and grew them to catchable trout.

To guide the data collection, our initial model specification was a quadratic in output model to allow for non-linearity in costs:

(2) $TCA = B0+B1(SUBCTRT)+B2(SUBCTRT^2)+B3(CATRT)+B4(CATRT^2)$

$+B5(PFDA)+B6(PERSA)+B7(TEMSA)+B8(TOTCAP)+B9(TGHCAP)$

$+B10(NRSEPDS)+B11(ELEA)+B12(YEAR)+(\rho\epsilon_{it-1} + \eta_{it})$

where: TCA= TOTAL COST (hatchery budget + feed cost) adjusted for inflation- ($1992)

SUBCTRT: number of sub-catchable (<8 in) trout planted or transferred that year.

CATRT: number of catchable (>8 in) trout planted in that year.

PFDA: price of feed in 1992 $'s.

PERSA: permanent employee salary cost per person in 1992 $'s.

TEMSA: temporary employee salary cost per person in 1992 $'s.

TOTCAP: the total capacity, measured in cubic feet, of the raceways.

TGHCAP: the total capacity, measured in cubic feet, of the hatchery troughs.

NRSEPDS: the number of nurse ponds the unit has.

ELEA: average price of electricity in constant 1992 $'s (per 500 kwh).

YEAR: a trend variable to test whether cost function is shifting over time.

ρ is the first-order serial correlation coefficient

ϵ_{it-1} is the previous periods error term

η_{it} is the unconditional error

There are some overall agency costs such as administration, support staff such as procurement, etc., that are necessarily "joint" costs that are difficult to assign to a particular hatchery or output. Underestimation of these costs will not bias the estimates of marginal and average variable costs, since these overhead and administration costs do not vary significantly with the exact number of fish produced. However, if these costs are underestimated it will result in a downward bias in the average total cash costs. We discuss below how these overhead and administrative costs were included in the analysis.

Other commonly estimated cost function specifications include the translog cost function, and its simpler, special case the Cobb-Douglas (or double log) cost function (Binswanger 1974). As explained below, the Cobb-Douglas model performed poorly for rearing units and was therefore not used in this study.

Data

The first step in gathering data was to contact the CDOW headquarters in Denver, Colorado. The Assistant to the Chief of Hatcheries provided a list of all of the hatcheries along with information on physical characteristics of the hatcheries such as acres of the unit, number of raceways, raceway capacity; full time and part time employees and salaries; number of subcatchable and catchable trout produced from each unit; the yearly actual dollar budget appropriations to each hatchery (our measure of total cost) and the feed cost. Consistent data were available for years 1987 to 1995.

The CDOW fish hatchery system is made up of 18 units which play varying roles within the system. For example, some specialize in egg production, while others are rearing units specializing in the rearing of subcatchables to catchable sizes. Of these 18 units, Las Animas and Wray are dedicated to the production of warm-water fish and will not be considered as this study is concerned with trout. The Chatfield Planting Base distributes trout raised elsewhere. Since no production takes place there it also will be excluded from the statistical analysis of the hatchery and rearing units, but its costs are part of the overall propagation system costs. Therefore, like administrative overhead, costs of the planting base will be added back in to calculate average total cash costs of production.

According to the Assistant to the Chief of Hatcheries, there are large shipments of subcatchable fish among hatcheries. To account for production which took place at a unit which was not accounted for in their stocking numbers, we contacted each unit and asked about fish which they produced that were transferred elsewhere for stocking. The trout reported transferred to other units were added to the shipping unit's production.

In total, there was complete data on ten trout hatchery units over nine years. Of these ten, seven were considered self-sufficient as they conducted every stage of production from eggs to catchable trout. The seven units which are self sufficient are: Bellvue-Watson, Durango, Glenwood Springs, Mt. Shavano/Mt. Ouray, Pitkin, Rifle, and Roaring Judy. Rearing units only raise fingerlings into catchable trout. The three rearing units are: Chalk Cliffs/Buena Vista, Finger Rock, and Poudre River.

The other main cost consideration is overhead/administrative costs for the hatchery system as a whole. Running the hatchery system requires administrative coordination and support. There are often large scale purchases and contracts, for example, negotiating and monitoring the CDOW hatchery wide feed contract. We obtained information on these costs from the assistant to the chief of fisheries, CDOW. He indicated these administrative costs were $579,000 in 1996, with about 70% being attributable to coldwater hatchery units. We split this out between the self-sufficient hatchery units (7 CDOW analysis units, reflecting 8 individual self-sufficient hatchery units) and the rearing units (3 CDOW analysis units reflecting four individual hatchery units). We then adjusted this to 1992 dollars which is the base year, inflation adjusted dollars for our study[1].

Statistical Results

The autocorrelation-corrected model for the seven CDOW units that are producing significant quantities of both subcatchables and catchables is reported in Table 1. The explanatory power of this model is quite good ($R^2 = 0.76$). Several of the candidate independent variables such as price of electricity and various capacity measures were statistically insignificant and were therefore dropped from the final model to avoid a loss of statistical efficiency from retaining insignificant variables (Kmenta 1971) and to conserve degrees of freedom in the three rearing unit regression where the available $n = 27$. The primary interest in this model is estimation of the marginal cost of subcatchables, and those variables are significant at the .01 and .09 levels. The performance of the double-log or Cobb-Douglas cost function was decidedly poorer, with an $R^2 = 0.22$, and the subcatchable variable had a t-statistic less than one. In the quadratic model, Rho is the autocorrelation correction term and, as can be seen by the Durbin-Watson being very close to two, autocorrelation is absent in the adjusted quadratic model. (DW between 1.77 and 2.28 indicates no autocorrelation, Kmenta 1971). The negative sign on the quadratic terms on subcatchable and catchable trout indicate that marginal costs of producing additional numbers of fish decreases throughout the range in our data.

The regression model for the three rearing units is presented in Table 2. This model also performed very well, explaining 90% of the variation in total costs. All of the variables were statistically significant at the .01 level or better except for catchable trout squared which is significant at the .065 level. There does appear to be a slight upward trend in real costs over time. In addition, the Durbin-Watson statistic suggests we are in the inconclusive region regarding the presence of autocorrelation despite using a first order autoregressive correction.

Economic Cost Estimates

Short Run Cash Costs of Producing Subcatchable Trout

Using the regression coefficients from Table 1, we calculate marginal costs (MC) of producing additional subcatchables as the first derivative of the total cost regression:

(3) $MC_{st} = 0.13963 + (2*(-0.000000027552*SUBCTRT))$

To this we added the cost of $.00608 or .608 cents for the cost of eggs provided from the Crystal River Hatchery (self-produced eggs are already included in the regression).

To calculate average total cash costs (ATCC) two steps are needed: (a) allocating the fixed cost from the regression, the constant term ($90,781), the permanent employee salary plus the self-sufficient hatcheries share of overhead--$37,700 by the proportion of costs related to subcatchables. This was done using the ratio of the contribution to total cost of the self-sufficient hatchery units from subcatchables (42%) and catchables (58%); (b) dividing these prorated estimates of fixed costs by each output level:

(4) $ATCC_{st}$ =

[($37,700+(90781+ (4.044(36530))*.42)+ (0.13963 * SUBCTRT)+

(-0.000000027552*(SUBCTRT^2))]/SUBCTRT

Short Run Cash Costs of Producing Catchable Trout

Using the regression coefficients from Table 2, we calculate marginal costs (MC) of producing additional catchables as the first derivative of the total cost regression plus the marginal cost of the subcatchable received by the rearing units. The cost of subcatchables was compounded by the year carry over period at 10% interest and multiplied by 1.176 to account for the 85% survival of subcatchables to catchables (A. Ganek, Bellvue, CDOW, letter; T. Robinson, Gunnison, CDOW, letter). The marginal costs of the subcatchables was shown above in equation 3:

(5) MC_{ct}= [0.393+(2*(-.00000018129*CATRT))]+(MC_{st}*1.10)*1.176

Using equation (5) we calculated the MC_{ct} for a typical rearing unit at the average production over the last decade (500,000 catchable trout) to be $0.37 per trout stocked.

To calculate average total cash costs (ATCC) we divide total costs (which include the regression equation estimate of fixed cost plus the rearing unit's share of the hatchery systems administrative overhead, $37,696 plus the costs of the Chatfield Planting Base--$40,454) by output plus the ATCC of producing the subcatchables received from the hatcheries, compounded at the 10% interest (but not subcatchables that were directly planted):

(6) $ATCC_{ct}$ =

$$[37696+40454+(-12843000+(6.2825(37000)+(1.0307*93960)+(6337*1991)+ (0.393 * CATRT)+(-.00000018129*(CATRT^2))/CATRT)]+(ATCC_{st}*1.10)*1.176$$

Using equation (6) we calculated the $ATCC_{ct}$ for a typical rearing unit at the average production over the last decade (500,000 catchable trout) to be $1.11 per trout stocked.

Long Run Cost Estimates that Include Replacement Costs and Opportunity Costs

While the estimates of short run costs are appropriate for near term decisions regarding the level to operate existing hatcheries, several additional costs become relevant for long run decisions about replacing or expanding hatchery capacity. In addition, some of these long run costs are directly relevant to CDOW decisions regarding new investments in hatchery facilities to make existing units whirling disease free.

These long run costs include the replacement costs of nursery units, ponds and raceways. We estimate these costs using budgets from Hinshaw et al. (1990) for establishment costs of a large trout farm. They estimated a cost for construction of a pair of raceways which have a total capacity of 2,520 cubic feet, comparable to the average sizes of the CDOW hatcheries raceways. The estimate for concrete, labor, and various supplies necessary to construct such a raceway is $16,592. We provide estimates of the replacement cost of facilities in Table 4.

The public land the facilities occupy has a social opportunity cost as well. This land could be sold and the funds invested in other agency programs to aid fishing or aquatic resources (e.g., purchase of access, habitat improvements, etc.). In addition, even if the land is retained in public ownership, alternative uses such as campgrounds, picnic areas or to house other state agencies remain an option. As a result, a land cost, based on the current listings of suitable river properties is added in. The land cost also includes a cost for buildings, which are needed for offices, equipment storage, and hatchery troughs. Based upon comparable real estate property listings available at the time of the study in the geographic areas where the CDOW facilities are located, two costs for land were used: $27,000 per acre for hatcheries less than 75 acres, $6,000 per acre for hatcheries over 75 acres. Smaller parcels had higher costs per acre than larger parcels. These land costs provide only rough approximations of the opportunity costs of land. Precise estimates require a formal real estate appraisal of each parcel, which is beyond the scope of this study. The land replacement cost estimates are summarized in Table 4.

The average replacement capital and land costs calculated from Table 4 for a typical CDOW hatchery is $1,940,250. This is comparable to the estimates of purchasing a hatchery estimated by Deloitte & Touche LLP (1995). To calculate an annualized long-run average capital cost for the construction of facilities called LRACAP Cost in Table 3, three conditions were specified: 1) average annual production of 500,000 catchable trout and 1,000,000 subcatchable trout; 2) a 15-year amortization schedule and 3) a 10% interest rate. The long run average total cost per fish is the sum of the average total cash costs (ATCC) from the regression presented and the long run average capital costs.

These costs do not include the external costs that hatcheries have on wild fish. Often hatchery fish out-compete native fish for available food or habitat. In other cases, hatchery fish have introduced diseases into waters (e.g., whirling disease in the Western U.S., Satterfield 1995). These costs also do not include any water rights that may be needed by hatcheries. Thus our estimates of long run cost are conservative.

The marginal cost of providing another catchable fish to anglers requires an adjustment of our marginal cost per stocked catchable fish to account for fish survival. That is, not all stocked trout survive to be caught by anglers. Data on the relationship between planted trout and trout caught appears scarce. Johnson et al. (1995) draw upon a CDOW study to suggest that it takes 1.67 stocked trout to produce one trout actually caught by anglers. Given this ratio, our short run marginal cost per caught fish is about $.61, about half the inflation adjusted estimate of Johnson et al (1995). Our estimate of Average Total Cash Costs (ATCC) per fish caught is $1.85 at the average production levels of the past decade. Our estimate of the Total Long Run Average Cost is $2.68 per fish caught at these same production levels. This is slightly lower than Johnson et al.'s (1995) inflation adjusted estimate of $2.84 per fish caught. If only half the trout planted are caught, then the marginal cost per fish caught is double the planted cost or $.73 and the ATCC are $2.22. Nonetheless, our conclusions are invariant to reasonable ranges of the percent of stocked trout that are caught, as the average total cash costs and total long run average costs are substantially above the average benefit for a wide range of reasonable ratios of planted trout to caught trout.

The range of short run costs of catchable production is shown in Figure 1. The range includes the mean of catchable trout production (about 500,000), the high end (about 900,000) and a low end (around 200,000 catchables). This represents most of the year to year variation in our data for the three rearing units. As can be seen from Figure 1 the marginal cost of rearing catchable trout also exhibits economies of scale in production. If one were to use a budgeting approach as compared to the cost function, one would end up with an underestimate of the average total cash costs. The extent of underestimate depends on how one allocated the joint costs associated with the self sufficient hatchery units between subcatchables (the main output) and catchables (a smaller, secondary output). The budget procedure estimate of the catchable units equals its regression estimate, because there is essentially a single output (e.g., catchable size trout) from these units. Another source of underestimate with the budget approach arises because the analyst only gets a point estimate of cost, at the current production level and not a cost function. Because of the non-linearity of the cost function (e.g., economies of scale), one cannot accurately apply the average cost from the currently very large subcatchable production level to the subcatchable output levels used as an input to the catchable program. Doing so underestimates the costs of providing subcatchables to the rearing units, if one wishes to focus the analysis primarily on the costs of producing catchable trout. Applying the budgeting approach to our data would result in ATCC of $1.67 compared with $1.85 using our regression approach.

Benefit-Cost Comparison of Catchable Trout

To estimate the marginal benefits to recreational anglers increasing their harvest of catchable trout we use the two empirical studies of fishing in Colorado cited in Johnson et al. (1995). Both of these studies are carefully performed, high quality studies that provide a reasonably good estimate of the value of catching an additional trout. Their estimates of the marginal benefits from catching an additional trout range from about $.70 to $1. This compares favorably with an independently estimated statewide marginal value of $.71 from the U.S. Fish and Wildlife Service's 1991 National Survey of Hunting, Fishing and Wildlife Associated Recreation (Waddington et al. 1994). The average benefit per trout caught for the current average catch rate in Colorado is $1.10 (Johnson et al. 1995).

What does a comparison of benefits and costs tell us? For near term decisions regarding operating the existing propagation system, the marginal benefits of producing catchable trout for anglers are greater than the short run marginal or incremental costs to CDOW. However, the average total cash cost (including overhead and administration) to CDOW of $1.85 to produce a trout caught by anglers is 1.7 times the average benefit to anglers from harvesting an additional trout ($1.10). Long run facility replacement or expansion is also not economically efficient in terms of angler benefits relative to these replacement costs. The estimated social long run cost when we account for replacement of facilities and the opportunity cost of the land (but not water costs nor replacement of the Chatfield Planting Base) results in a cost of $2.69 per trout caught. This cost is about 2.4 times the average benefit to anglers of catching trout at current harvest rates. Even replacing hatcheries to maintain current catch rates is likely to be uneconomic, as Johnson et al. (1995) found that at half the current catch rates the marginal benefit of catching a trout was $1 to $1.40, is still substantially less than the long run costs of replacing the hatchery.

Conclusions and Recommendations for Management

Using statistical estimation of the cost function, we find the marginal or incremental benefit to anglers is greater than the short run marginal costs of producing trout from the existing CDOW hatcheries during the last ten years. However, the average cash costs including administration and overhead results in a cost per trout 1.7 times the average benefit to anglers from catching trout. Further, the long run decision on whether to expand the hatchery system or build replacement hatcheries to maintain the current capacity does not pass a benefit-cost test: the estimated total social cost including replacement cost of facilities and opportunity costs of land result in the costs substantially outweighing the benefits for the range of trout production observed in the data.

Additional opportunity costs that are not quantified include water costs and the occasional adverse effect of stocking game fish on other fish, especially native game, non-game and threatened and endangered fish. This latter opportunity cost may manifest itself as reduced native fish populations and increased costs of endangered fish recovery efforts now and in the future. Thus, to determine whether hatcheries are the most economically efficient use of agency funds, it is not enough to show that benefits of hatcheries outweigh their cost, the net benefits of the hatchery operation must exceed the net benefits of the next best alternative use of those funds and other adverse effects that may be induced by hatcheries.

Acknowledgements

This research would not have been possible without the support and assistance of numerous individuals. Without implicating, we thank John Epifanio and David Nickum of Trout Unlimited for their financial support and insightful comments. William Weiler, Colorado Division of Wildlife (CDOW) was most generous in providing the raw data and fact sheets used in the statistical analysis. Without his cooperation this study could not have been completed. We also thank the CDOW hatchery managers who took the time to respond to our letters on fish production and shipments between hatcheries. Without this important data, accuracy of our results would have been in doubt. David Smeltzer of the Belluve Watson Fish Hatchery was especially helpful in educating us in the basic relationships involved in the CDOW hatchery production system. Robert Behnke of Colorado State University also helped to motivate this study. Dana Hoag of Colorado State University graciously provided us with much technical guidance and references for specifying the statistical cost function. David Harpman and Andrew Seidl provided important suggestions for improving this report. Tom Powell, CDOW, was most helpful in providing detailed comments as well as the relative importance of reservoir versus stream fishing in Colorado. We also thank two anonymous reviewers for improving the completeness of the paper as well as suggesting refinements in the analysis. The opinions expressed are those of the authors and do not represent those of Colorado State University.

References

Behnke, R. 1989. Summary of progress in wild trout management: 1974-1989. Pages 12-17. in F. Richardson and R. H. Hamre, editors. Proceedings of Wild Trout IV Symposium. Yellowstone National Park, Wyoming.

Binswanger, H. 1974. A cost function approach to the measurement of elasticities of factor demand and elasticities of substitution. American Journal of Agricultural Economics 56:377-386.

Deloitte and Touche LLP. 1995. Hatchery system analysis: final report, July 1995. Report for Colorado Division of Wildlife, Denver.

FishPro, Inc. 1994. California statewide trout needs assessment and facility evaluation. Portland, Oregon.

Greene, W. 1990. Econometrics. Macmillian Publishing Co. New York.

Harpman, D., E. Sparling and T. Waddle. 1993. A methodology for quantifying and valuing the effects of flow changes on a fishery. Water Resources Research 29:575-582.

Hinshaw, J., L. Rogers and J. Easley. 1990. Budgets for trout production. Southern Regional Aquaculture Center Publication Number 221. Southern Regional Aquaculture Center. North Carolina State University, Raleigh.

Johnson, D., R. Behnke, D. Harpman and R. Walsh. 1995. Economic benefits and costs of stocking catchable rainbow trout: a synthesis of economic analysis in Colorado. North American Journal of Fisheries Management 15:26-32.

Kmenta, J. 1971. Elements of econometrics. MacMillian Publishing Co. New York.

Loomis, J., C. Sorg and D. Donnelly. 1986. Evaluating regional demand models for estimating recreation use and economic benefits. Water Resources Research 22:431-38.

Loomis, J. 1993. Integrated public lands management: principles and applications to national forests, parks and wildlife refuges, and BLM lands. Columbia University Press, New York.

Reiling, S., M. Anderson, and K. Gibbs. 1983 Measuring the costs of publicly supplied outdoor recreation facilities: a methodological note. Journal of Leisure Research 15:203-218.

Sassone, P., and W. Schaffer. 1978. Cost-benefit analysis: A handbook. Academic Press, New York.

Satterfiled, J. 1995. Whirling disease facts. Colorado Dvision of Wildlife. Denver.

Segwick, S. 1990. Trout farming handbook. 5th edition. Alden Press, Oxford.

Stevenson, J. 1987. Trout farming manual. Page Brothers, Great Britain.

Stickney, R. 1994. Principles of aquaculture. John Wiley and Sons, New York.

U.S. Water Resources Council. 1979. Procedures for evaluation of national economic development (NED) benefits and costs in water resources planning (Level C). Federal Register, 44(243): 72892-72976.

U.S. Water Resources Council. 1983. Economic and environmental principles and guidelines for water and related land resources implementation studies. U.S. Government Printing Office, Washington, DC.

Waddington, D., K. Boyle and J. Cooper. 1994. 1991 Net economic values for bass and trout fishing, deer hunting and wildlife watching. Report 91-1, Division of Federal Aid, U.S. Fish and Wildlife Service, Washington, DC.

FOOTNOTES

1. It is difficult to calculate all of the costs, as some of the costs are common to administration of several of CDOW's functions (e.g., Directorate or fish research facilities) and some costs, such as fish health programs, were omitted. Thus, we believe our estimated costs may be slightly conservative.

Table 1.

Quadratic regression for cost of producing rainbow trout from self-sufficient hatchery units

Variable	Coefficient	T statistic.	P-value	Mean of X
Constant	90781.0	0.676	0.49876	
CATRT	0.46610	3.391	0.00070	0.4074E+06
$CATRT^2$	-0.20782E-06	-1.592	0.11139	0.2312E+12
SUBCTRT	0.13963	3.041	0.00236	0.9715E+06
$SUBCTRT^2$	-0.27552E-07	-1.666	0.09570	0.1429E+13
PERSA	4.0444	1.196	0.23171	0.3653E+05
Rho	0.80257	10.593	0.00000	

R^2 = .76 N = 63 Durbin-Watson: 2.06

Table 2. Quadratic regression for cost of producing rainbow trout from three rearing units

Variable	Coefficient	T statistic	P value	Mean of X
Constant	-0.12843E+08	-6.330	0.00000	
CATRT	0.39300	3.360	0.00078	0.4822E+06
$CATRT^2$	-0.18129E-06	-1.842	0.06541	0.2785E+12
PERSA	6.2825	6.308	0.00000	0.3700E+05
YEAR	6337.3	6.293	0.00000	1991.
TOTCAP	1.0307	13.388	0.00000	0.9396E+05
Rho	-0.39242	-2.175	0.02960	

$R^2 = .90$ N = 27 Durbin-Watson: 2.34

Table 3. Average total cash cost (ATCC), long run average capital cost (LRACAP) and total long run average cost per trout produced and delivered to fishing waters, 1987 to 1995 (in 1992 dollars).

	ATCC	LRACAP cost	Total long run average cost
Catchable	$1.11	$.50	$1.61
Subcatchable	$ .24	$.25	$ .49

Table 4. Replacement land and capital costs for each unit.

Unit	Acres	Cost per acre	Land cost (millions)	Pair of raceways	Cost (millions)	Total cost (millions)
Hatcheries						
BWT	58	$27,000	$1.566	36.4	$.604	$2.170
MSO/MOH	185	$ 6,000	$1.110	15.6	$.260	$1.370
PKN	76	$ 6,000	$.456	14.0	$.231	$ .687
RIF	597	$ 6,000	$3.582	22.7	$.376	$3.958
ROJ	781	$ 6,000	$4.686	49.6	$.822	$5.508
DUR	29	$27,000	$.783	17.7	$.293	$1.076
GSU	1.75	$27,000	$.047	.8	$.013	$ .060
Rearing Units						
CCL/BVU	62	$27,000	$1.674	37.9	$.629	$2.303
PRU	50	$27,000	$1.350	7.9	$.131	$1.481
FRO	23	$27,000	$.621	10.2	$.169	$ .790

Where: BWT is Bellvue-Watson; MSO/MOH is Mt. Shavano/Mt. Ouray, PKN is Pitkin, RIF is Rifle, ROJ is Roaring Judy, DUR is Durango, GSU is Glenwood Springs, CCL/BVU Chalk Cliffs/Buena Vista, PRU is Poudre River and FRO is Finger Rock.

FIGURE 1 CAPTION

The average total cash costs (ATCC) and marginal cost (MC) per trout caught

NEVADA

FISHING SEASONS & REGULATIONS
Effective March 1,1999 through February 29, 2000

REDBAND TROUT
Jani Kreutzjans
(Carson City, Nevada)

NEVADA DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

NEVADA DIVISION OF WILDLIFE

DIVISION OF WILDLIFE
CR 98-9

Check our fishing clinics and fishing forecast on the web at www.state.nv.us/cnr/nvwildlife/

CONTENTS

ON THE COVER

Nevada artist Jani Kreutzjans, of Carson City, is the first to win both the Nevada duck stamp and trout stamp contests. Here is her winning painting of the Redband Trout, which is found in northeastern Nevada streams and is established in the Jarbidge, Owyhee, and Bruneau river systems. The Redband Trout is nearly indistinguishable from the more common rainbow trout.

This publication receives partial funding through the Federal Aid in Sport Fish Restoration program as educational material.

Federal and state law require that there shall be no difference in the treatment of individuals because of race, color, creed, religion, national origin, sex or disability.

Anyone receiving alleged discriminatory treatment in any Division of Wildlife program, activity or facility should report it to either of the following: Administrator

Division of Wildlife
P.O. Box 10678
Reno, Nevada 89520-0022 or
The Office for Equal Opportunity
U.S. Department of the Interior
Office of the Secretary
Washington D.C. 20240

— CR 98-9, CR 98-9 #2, #3 —

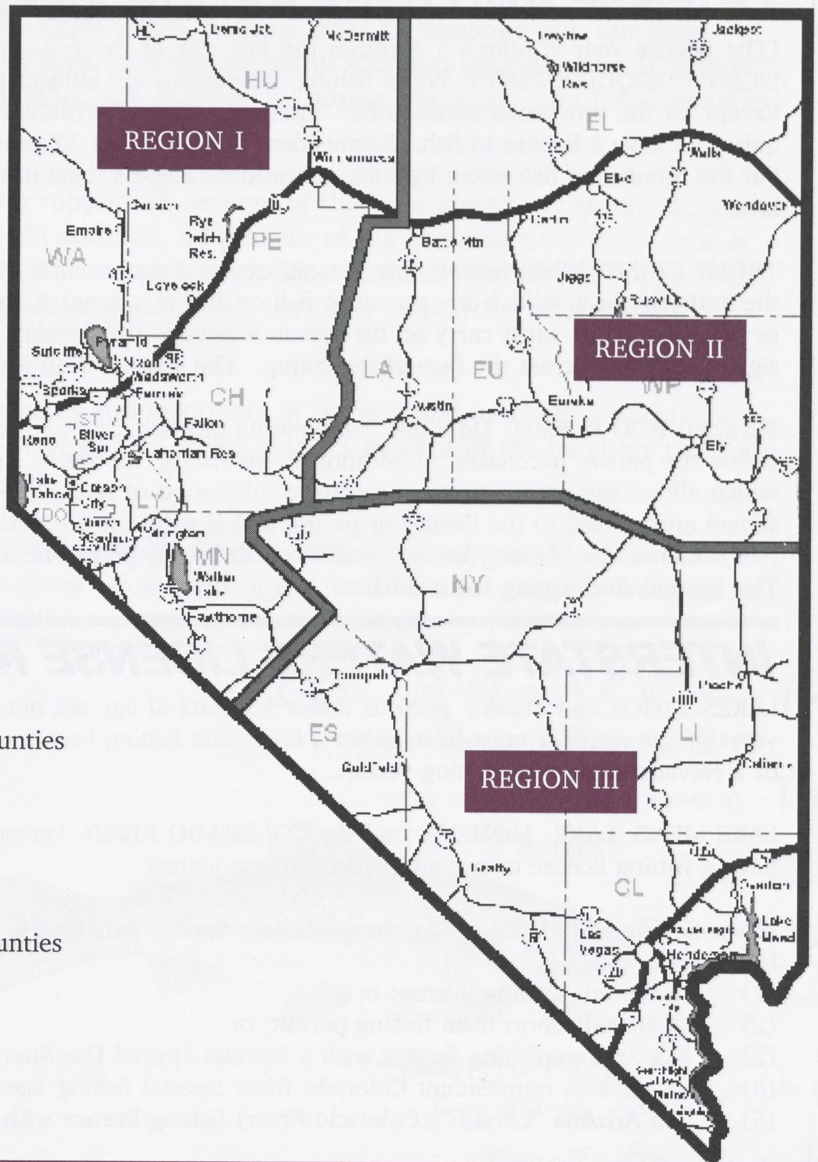
The Nevada State Board of Wildlife Comissioners adopts fishing regulations under the authority of Nevada Revised Statutes 501.105, 501.181, 503.290 and 503.300. The regulations are adopted for the management and protection of Nevada's fishery resources.

This booklet contains only a synopsis of the fishing and boating laws for the State of Nevada. Complete text of the laws and regulations may be obtained by contacting the Division of Wildlife or by checking our internet site at

www.state.nv/cnr/nvwildlife/

NEVADA REGIONAL REFERENCE MAP

For further information contact one of the following Division of Wildlife Offices:



STATE HEADQUARTERS

1100 Valley Road
Reno, NV 89512
(775) 688-1500

REGION I

380 West B Street
Fallon, NV 89406
(775) 423-3171
Serving Carson City, Churchill, Douglas Humboldt, Lyon, Mineral, Pershing, Storey, and Washoe counties

REGION II

1375 Mountain City Hwy.
Elko, NV 89801
(775) 738-5332
Serving Elko, Eureka, Lander and White Pine counties

REGION III

4747 W. Vegas Dr.
Las Vegas, NV 89108
(702) 486-5127
Serving Clark, Esmeralda, Lincoln, and Nye counties

HOW TO USE THESE REGULATIONS

1. Review the General Statewide Regulations including seasons, hours, limits, etc. on pages 4 - 8.
2. Consult the reference map above to find the area in which you are interested in fishing and determine the Region (I, II, or III) in which the area is located.
3. Turn to the appropriate Region and review both General Regulations and the Special Regulations for that Region.
4. If fishing in a Wildlife Management Area, review pages 24-25.
5. Most text from the Nevada Revised Statutes and the Nevada Administrative Code is printed in *italics,* changes and new regulations are printed in *color italics*.

GENERAL STATEWIDE REGULATIONS

LICENSE AND FEES REQUIREMENTS

(The license year is March 1 through the last day of the following February)
LICENSE REQUIREMENTS: While fishing, all persons are subject to the license requirements as listed below. Except for the provisions noted under "interstate waters," resident anglers under 12 years of age are not required to have a license to fish. Nonresident anglers under 12 years of age are not required to have a license, but the number of fish taken by such nonresident anglers must not exceed 50 percent of the limit as provided by law.

TROUT STAMP: While fishing, any person, except a person under the age of 12 or a person who is fishing under the authority of a valid 1-day permit to fish or during a consecutive day validly added to that permit, who takes or possesses trout, must carry on his person a Nevada trout stamp affixed to his license which is validated by his signature in ink across the face of the stamp. The Trout Stamp fee is $5.

SECOND ROD PERMIT: Only one combination of hook, line and rod may be used by a person at any one time unless the person purchases, in addition to his fishing license or short term fishing permit, a "Second Rod Stamp" which allows the person to use a second combination of hook, line and rod. The Second Rod Stamp must be signed and affixed to the license or permit and is valid for the period specified. A person, regardless of age, must first obtain a valid fishing license or short term fishing permit before he can use a Second Rod Stamp.
The Second Rod Stamp fee is $10.

INTERSTATE WATERS LICENSE REQUIREMENTS

LAKES TAHOE and TOPAZ- persons under 16 years of age are not required to have a fishing license. Persons 16 years of age or older must have either a California fishing license; or a Nevada fishing license and a trout stamp; or a Nevada short term fishing permit.

LAKE MEAD, LAKE MOHAVE, and the COLORADO RIVER- Persons under the age of 14 are not required to have a fishing license or permit to fish in these waters.

When fishing from the Nevada shore of these waters persons 14 years of age or older must possess one of the following:

(1) A Nevada fishing license; or
(2) A Nevada short term fishing permit; or
(3) An Arizona fishing license with a Nevada Special Use Stamp; or
(4) A Nevada, nonresident Colorado River Special fishing license; or
(5) An Arizona "Class E" (Colorado River) fishing license with a Nevada Special Use Stamp.

When fishing these waters from a boat or other floating device persons 14 years of age or older must possess one of the following:

(1) A Nevada fishing license with an Arizona Special Use Stamp; or
(2) A Nevada short term fishing permit with an Arizona Special Use Stamp; or
(3) An Arizona fishing license with a Nevada Special Use Stamp; or
(4) A Nevada, nonresident Colorado River Special fishing license with an Arizona Special Use Stamp; or
(5) An Arizona "Class E" (Colorado River) fishing license with a Nevada Special Use Stamp.

The fee for the Arizona Special Use Stamp is $3 and it is valid from March 1 through the last day of the following February.

The fee for the Nevada nonresident Colorado River Special fishing license is $21 and it is valid from March 1 through the last day of the following February.

To possess trout while fishing these waters from the Nevada shore or from a boat or other floating device, a person with an annual Nevada fishing license or a Nevada nonresident Colorado River Special fishing license must also have a current Nevada Trout Stamp.

[1999]

NEVADA'S HATCHERY SYSTEM

The State of Nevada has four fish cultural facilities which produce trout for stocking into our state waters. The combined production from these stations averages about 430,000 pounds of trout annually. And, although rainbow trout make up the bulk of this production, brown, cutthroat, and brook trout as well as certain hybrids are also produced.

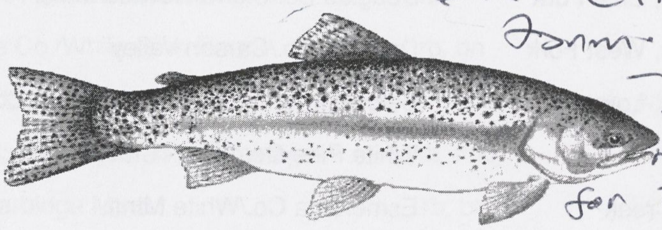
The 20 most heavily fished waters in Nevada support 86 percent of the total angler-use statewide, and 15 of these are stocked with hatchery trout. In addition, 80 percent of the fisherman use in Nevada is on lakes and reservoirs and 20 percent is on streams and rivers. Most streams provide self-supporting trout populations capable of maintaining the fisheries and only the most heavily fished streams in Nevada are stocked with hatchery trout.

By contrast, trout do not reproduce in most lakes and reservoirs in Nevada and hatchery stocking is needed to maintain quality trout fishing in these waters. More than 75 percent of the hatchery trout are stocked in lakes and reservoirs.

While the trout stocking program is popular and provides quality fishing in many waters of the state, it is also very expensive and utilizes currently about 50 percent of the total fisheries program budget. Current trout production costs are about $2.85 per pound of trout produced.

ID AQUACULT. NEW
spring/summer 99
+ re. Cline's Trout Farm
– In Colo.
The range in prices for trout for fee fishing is $2.00 to 2.70/lb.
trout fm. 10" to 23 lbs

SPRING CREEK REARING STATION
Scott Adams, Supervisor
Baker, Nevada 89311
(775) 234-7319



LAKE MEAD HATCHERY
245 Lake Shore Road
Boulder City, Nevada 89005
(702) 486-6889
(702) 486-6738 - Fish Stocking

GALLAGHER HATCHERY
Larry Burton, Supervisor
Ruby Valley, Nevada 89833
(775) 779-2231

MASON VALLEY HATCHERY
Dan Fulton, Supervisor
50 Hatchery Way
Yerington,Nevada 89447
(775) 463-4488

Visitors are welcome at all Nevada State Fish Hatcheries between the hours of 8:00 a.m. and 4:00 p.m.. Group tours can be arranged by contacting the hatchery supervisor prior to a planned visit. Station staff will gladly answer questions about the facility and its operation.

NEVADA FISH BY WATERS

Species Abbreviations: rainbow trout=rb; brook trout=bk;brown trout=bn;cutthroat trout=ct; rainbow-cutthroat hybrid=rbXct; bull trout=bt; mackinaw trout=mt; kokanee salmon=ks;tiger trout=tt; channel catfish=cc; bullhead catfish=bh; green sunfish=gs; bluegill sunfish=bg; yellow perch=yp; redear sunfish=rs; Sacramento perch=sp; largemouth bass=lmb; northern pike=np; striped bass=stb; small-mouth bass=smb; spotted bass=sb; white catfish=wc; white bass=wb; walleye=wp; crappie=cr; whitefish=wi

BODY OF WATER	LOCATION / COUNTY	SPECIES
Adams McGill Reservoir	Kirch WMA, Nye Co.	rb, lmb,bh
Angel Lake	Elko Co.	rb, bk
Barley Creek	Nye Co.	rb, bk, bn
Beaver Dam Wash	Lincoln Co.	rb
Big Creek	Lander Co./Toiyabe Range	Rb, bk, bn
Big Springs Reservoir	Humboldt Co.	rb, rbXct
Bilk Creek Reservoir	Humboldt Co./Bilk Creek Mtns.	rb, rbXct
Blue Lakes	Humboldt Co./Pine Forest Range	rb, bk, ct, rbXct
Bruneau River	Elko Co.	rb, wi
Cabin Creek	Humboldt Co./Santa Rosa Mtns.	rb, bk, bn
Carson River	Carson, Lyon, Douglas, Churchill Co.	bn, rb, bh, cc, wc, gs, wb, yp
Carson River, East Fork	Douglas Co./Sierra Nevada Mtns.	rb, bn
Carson River, West Fork	Douglas Co./Carson Valley	rb, bn, lmb, bh
Carson River, Lower	Below Lahontan Res. in Churchill Co.	rb, bn, cc, bh
Cave Lake	White Pine Co./Schell Cr. Range	rb, bn
Chiatovitch Creek	Esmeralda Co./White Mtns.	rb, bk
Chimney Dam Reservoir	Humboldt Co./Little Humboldt River	rb, wp, cc, cr
Cleve Creek	White Pine Co./Schell Cr. Range	rb, bn
Cold Creek Reservoir	White Pine Co./Newark Valley	rb
Colorado River	Clark Co./Colorado River Drainage	rb, cc, lmb, stb
Comins Lake	White Pine Co./Steptoe Valley	rb
Cottonwood Creek	Humboldt Co./Santa Rosa Range	rb, bk
Crittenden Reservoir	Elko Co./Thousand Springs	rb, lmb
Dacy Reservoir	Nye Co./Kirch WMA	lmb, (no trout)
Davis Ck. Park Pond	Washoe Co./Carson Range	rb
Desert Creek	Lyon Co./Sweetwater Mtns.	rb, bn
Dorsey Reservoir	Elko Co./N.F. Humboldt River	rb
Dry Creek Reservoir	Elko Co./Bull Run Creek	rb, smb
Dufurena Ponds	Humboldt Co./Sheldon NW	lmb, cr, yp, gs, rs
Eagle Valley Reservoir	Lincoln Co./Spring Valley	rb, bn

BODY OF WATER	LOCATION / COUNTY	SPECIES
East Walker River	Lyon Co/Walker River Valley	rb, bn, bk, wi
Echo Canyon Creek	Elko Co./Ruby Mtns.	rb, bk, ct
Fort Churchill Pond	Lyon Co./Mason Valley	lmb, cc, bg
Galena Creek	Washoe Co.	rb,bk
Gold Creek	Elko Co./Sunflower Flat	rb, bk
Groves Lake	Lander Co./Toiyabe Range	rb, bn
Harmon Reservoir	Churchill Co./Lahontan Valley	cc, lmb
Hinkson Slough	Lyon Co./Mason Valley WMA	rb, rbXct, ct, lmb
Hobart Reservoir	Washoe Co./Carson Range	rb, bk, rbXct
Humboldt River	Elko Co./(Elko Co. Portion)	cc, lmb, smb, bn, cr, gs
Humboldt River, North Fork	Elko Co./Independence Mtns.	rb, bk, ct
Humboldt River	Eureka Co./Humboldt River Drainage	rb lmb, smb, cc, bh
Humboldt River	Humboldt Co./Humboldt River Valley	lmb, smb, cc, bh, cr, wp, bg
Humboldt River	Lander Co./Humboldt River Drainage	lmb, cc
Humboldt River	Pershing County/Humboldt River Valley	lmb, cc, wp, bh, smb, sb,wiper
Hunewill Pond	Lyon Co./Smith Valley	lmb, bg
Idlewild Pond	Washoe Co./Truckee Meadows	rb
Illipah Reservoir	White Pine Co./White Pine Range	rb, bn
Indian Lakes	Churchill Co./Lahontan Valley	bh, cc, wc, lmb, rb, wb, cr
Jakes Creek Reservoir	Elko Co./Salmon Falls River Drainage	rb, lmb
Jarbidge River, West Fork	Elko Co./Jarbidge Mtns.	rb, bt
Jiggs Reservoir	Elko Co./Jiggs	rb, lmb, bg
Kalamazoo Creek	White Pine Co./Schell Creek Range	rb, bk, bn
Kingston Creek	Lander Co./Toiyabe Range	rb, bk, bn
Knott Creek Reservoir	Humboldt Co./Pine Forest Range	rb, bk
Lahontan Reservoir	Churchill, Lyon Co./Lahontan Valley	rb, cc, bh, lmb, wb,sb, yp, wp, wc, cr, wipers
Lake Tahoe	Carson, Douglas, Washoe Co.&Calif.	rb, bn, mt, ks
Lake Mead	Clark Co. and Arizona	rb, lmb, cc, stb, bh, cr, gs
Lake Mohave	Clark Co. and Arizona	rb, lmb, cc, stb, bh, gs
Lamoille Creek	Elko Co./Ruby Mtns.	rb, bk
Little Humboldt River, North Fork	Humboldt Co./Santa Rosa Mtns.	rb, bk, bn, ct
Lorenzi Park Pond	Clark Co./Las Vegas	rb, cc
Martin Creek	Humboldt Co./Santa Rosa Mtns.	rb, bn
Mountain View Park Pond	Lyon Co./Yerington	rb

Fishing Clinics a Hit with Nevada Anglers

The Nevada Division of Wildlife is getting lots of "hits" from its angler education program.

Last year, thousands of Nevadans participated in fishing clinics and Free Fishing Day activities that helped them learn more about fishing.

"We have all kinds of classes-everything from basic bait and spin fishing to beginning fly casting through advanced fly casting," says Angler Education Coordinator Chris Vasey. "In our 3-day fly fishing course we cover basic casting, moving water and still water fishing methods. This course teaches everything from limnology to insect identification."

Classes usually focus on a species or type of fishing. For instance, in Las Vegas, an Introduction to Fly Fishing Class is a regular winter program. The walleye clinic in July at Lahontan Reservoir, held in conjunction with Division of State Parks, is an annual event, as is the summer fishing derby at Angel Lake in northeastern Nevada. Those events are scheduled regionally as the weather warms up. Times and locations are announced via radio and newspapers.

Photo by Debe Rougeau

Chris Vasey, right, Angler Education Coordinator, assists a student from Marvin Picollo School in Reno during an outdoor fishing seminar.

On Free Fishing Day, which will be June 12, 1999, a variety of seminars and activities will be offered statewide. Ongoing fishing seminars for organized groups are also available to a limited extent and are offered primarily in the Reno and Las Vegas metropolitan areas.

Below is a list of winter scheduled classes for 1999. Additional classes will be offered as the fishing season progresses. Call the Reno Office at (775) 688-1500 for more information on classes in Northern Nevada.

February 27, 1999- FREE Colorado River fishing clinic at Big Bend at the Colorado State Park, Laughlin, Nevada. Clinic will be held from 10 a.m. to 2 p.m. near the boat launch area. Registration not required. For more information call Ivy Baker at (702) 486-5127, Ext. 3863.

March 1, 8, 15, & 22, 1999-Free Introduction to Fly Fishing classes at Johnson Community School, 340 Villa Monterey, Las Vegas, Nevada. Introductory class from 7-8:30 p.m. will cover reading the water, choosing equipment, fly tying, and casting techniques.

--Kelly Clark

NEVADA DIVISION OF WILDLIFE
1100 VALLEY ROAD
RENO, NEVADA 89512

FIRST CLASS