Sampling and analysis techniques and their application for estimating recruitment of juvenile rainbow trout in the Henrys Fork of the Snake River, Idaho

by Matthew George Mitro

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Fish and Wildlife Biology

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Abstract:

Juvenile rainbow trout were sampled to quantify production and recruitment processes in the Henrys Fork, to identify factors limiting the trout population, and to propose management actions to improve natural recruitment. The study area was a 25-km river reach that varied in width from 50 to 150 m. I used distance sampling to identify spawning areas in the Henrys Fork and to quantify spawning activity therein. I developed and evaluated mark-recapture and removal techniques to address the inherent difficulties in the sampling and analysis of large abundances of age-0 salmonids over a large spatial scale. Mark-recapture data were collected from 100-m long sample areas. I found the Chao Mt estimator for mark-recapture data to have minimal bias and interval coverage close to the nominal level in simulations with mean capture probabilities (0.02-0.106) and rates of emigration (0-10%) based on actual Henrys Fork data sets. Three-pass removal data were collected along the banks in 15-m units. I developed and rigorously evaluated simple linear regression and mean capture probability models to predict abundance from the first-pass catch. These models worked particularly well for estimating abundance over a large spatial scale, allowing effort to be reallocated from intensively sampling few areas to sampling many areas with reduced effort, resulting in gains in estimate precision. These techniques were used to provide a comprehensive analysis of age-0 rainbow trout recruitment in the Henrys Fork. There was suitable habitat throughout the study area to support the yearly production of 150,000 to 250,000 age-0 trout through summer and autumn. Recruitment to the fishery was limited by poor survival during their first winter. I identified a flow-survival relation for age-0 trout in a river section with complex bank habitat. The number of age-0 trout that survived their first winter was related to higher discharge during the latter half of winter. The higher discharge during the latter half of winter created more available habitat in the section with complex bank habitat and coincided with the loss of age-0 trout from non-bank areas. Movement of age-0 trout was detected from river sections with simple bank habitat to sections with complex bank habitat. I recommended that winter discharge be managed to increase the availability of complex bank habitat, thereby improving recruitment of age-0 rainbow trout.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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TABLE OF CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

Figure | Page

Figure Page

Figure | Page

ABSTRACT

Juvenile rainbow trout were sampled to quantify production and recruitment processes in the Henrys Fork, to identify factors limiting the trout population, and to propose management actions to improve natural recruitment. The study area was a 25-km river reach that varied in width from 50 to 150 m. I used distance sampling to identify spawning areas in the Henrys Fork and to quantify spawning activity therein. I developed and evaluated mark-recapture and removal techniques to address the inherent difficulties in the sampling and analysis of large abundances of age-0 salmonids over a large spatial scale. Mark-recapture data were collected from 100-m long sample areas. I found the Chao Mt estimator for mark-recapture data to have minimal bias and interval coverage close to the nominal level in simulations with mean capture probabilities (0.02-0.106) and rates of emigration (0-10%) based on actual Henrys Fork data sets. Three-pass removal data were collected along the banks in 15-m units. I developed and rigorously evaluated simple linear regression and mean capture probability models to predict abundance from the first-pass catch. These models worked particularly well for estimating abundance over a large spatial scale, allowing effort to be reallocated from intensively sampling few areas to sampling many areas with reduced effort, resulting in gains in estimate precision. These techniques were used to provide a comprehensive analysis of age-0 rainbow trout recruitment in the Henrys Fork. There was suitable habitat throughout the study area to support the yearly production of 150,000 to 250,000 age-0 trout through summer and autumn. Recruitment to the fishery was limited by poor survival during their first winter. I identified a flow-survival relation for age-0 trout in a river section with complex bank habitat. The number of age-0 trout that survived their first winter was related to higher discharge during the latter half of winter. The higher discharge during the latter half of winter created more available habitat in the section with complex bank habitat and coincided with the loss of age-0 trout from non-bank areas. Movement of age-0 trout was detected from river sections with simple bank habitat to sections with complex bank habitat. I recommended that winter discharge be managed to increase the availability of complex bank habitat, thereby improving recruitment of age-0 rainbow trout.

CHAPTER 1

INTRODUCTION

The Henrys Fork of the Snake River has long been renowned as one of the world's best rainbow trout *Oncorhynchus mykiss* fly fishing rivers. Since 1978, the river section from Island Park Dam to Riverside Campground has been managed under special regulations to protect the fishery, including catch-and-release since 1988. However, rainbow trout abundances there have generally declined since 1988, but with large, unexplained annual fluctuations according to Idaho Department of Fish and Game population estimates and angler surveys. An increase in numbers of rainbow trout occurred in 1993 following the 1992 drawdown of Island Park Reservoir, but the fishery began to decline again thereafter. The causes of these fluctuations in the rainbow trout fishery are not well understood. Recruitment may have been limited by the loss of concealment cover resulting from overgrazing of aquatic macrophytes by trumpeter swans *Cygnus buccinator* and siltation and dewatering of interstitial spaces from drawdowns of Island Park Reservoir. Prior to the screening of most of the discharge from the dam beginning in 1993 to prevent fish migration downstream to the river, recruitment may have been augmented by rainbow trout escaping from Island Park Reservoir.

Adult abundance estimates, such as those obtained for the Henrys Fork, tell us how many fish were recruited to the adult life stage, and a time series of such data may identify whether or not a recruitment problem exists. However, adult abundance estimates cannot tell us why a particular recruitment pattern exists or at what life stage recruitment is limited. Recruitment is defined as the cumulative outcome or survival through a series of life stages (Trippel and Chambers 1997). The abundance of adult rainbow trout will necessarily depend on the survival of rainbow trout through early life stages beginning with spawning and fertilization and extending through the juvenile life stage. The study of these early life history stages is critical to the understanding of year-class formation and changes in fish populations (Elliott 1994; Trippel and Chambers 1997).

Sampling methods used by the Idaho Department of Fish and Game and by Angradi and Contor (1988) to obtain data for abundance estimation have precluded making inferences on abundances of juvenile rainbow trout in the Henrys Fork. Rainbow trout less than 150 mm were consistently underrepresented in samples collected in successive years by Angradi and Contor (1988). The failure to capture small trout is often a result of the sampling method; electrofishing is widely recognized as a size-selective sampling technique that favors capture of larger individuals (e.g., White et al. 1982; Bohlin et al. 1989; Jones and Stockwell 1995). Juvenile rainbow trout are also ecologically distinct from adults in their habitat requirements. Juvenile salmonids tend to occupy shallow, low velocity stream areas and may move to deeper habitat as they grow (Bohlin 1977; Gatz et al. 1987; Maki-Petays et al. 1997). Therefore, sampling must be directed specifically at juvenile rainbow trout if inferences concerning juvenile abundances are to be made.

Studies that have been directed at juvenile rainbow trout in the Henrys Fork have been limited in scope such that inferences on river-wide recruitment could not be made. We know that cobble-boulder concealment cover along banks is used by juvenile rainbow trout during winter (Contor 1989; Griffith and Smith 1995). Movement of juvenile rainbow trout from macrophyte cover to cobble-boulder cover along banks has been observed (Griffith and Smith 1995). Experimental studies indicated that winter survival of age-0 rainbow trout was higher in cages with cobble-boulder substrate than in cages without cover (Smith and Griffith 1994) and survival was higher with warmer water temperatures (3.1-4.3 °C versus 1.5-4.3 °C; Meyer and Griffith 1997). Most mortality in cages has been observed in early winter (95%; Smith and Griffith 1994). Size-dependent mortality (age-0 rainbow trout < 90-100 mm total length) occurred in cages with no cover or with colder water temperatures (Smith and Griffith 1994; Meyer and Griffith 1997). Angradi and Contor (1988) estimated age-0 rainbow trout density by sampling along one bank in each of four river sections in summer. However, these estimates could not be extrapolated to both banks of the river because sampling was not representative of both banks. Studies of juvenile rainbow trout in the Henrys Fork must include multiple time periods and sampling areas representative of a large river reach such that recruitment can be quantified.

Estimates of temporal and spatial abundances of juvenile rainbow trout are essential to the evaluation of recruitment in the Henrys Fork. The estimation of survival and movement rates complements abundance estimation by aiding in the interpretation of temporal and spatial differences in abundances. Seasonal survival rates may be related to environmental changes in temperature and discharge, and spatial changes may be related to the movement of juvenile rainbow trout as habitat availability and habitat requirements change. The quantification of movement may also delineate the upper bound on the portion of a loss rate attributable to actual mortality. Therefore, a comprehensive study of juvenile rainbow trout to evaluate recruitment limitations should include the estimation of abundance, survival, movement, and habitat use across time and space.

Inferences concerning fish abundance, survival, movement, and habitat use are inherently difficult to make because individuals are not readily observable and information is only available on fish that are captured (Otis et al. 1978; Burnham et al. 1987; Gowan et al. 1994; Hilborn and Mangel 1997). Additional difficulties with juvenile fish are the typically large abundances and low capture probabilities that result in large variances and wide interval estimates (Cormack 1992). The yearly production of age-0 trout in the Henrys Fork may exceed 100,000. The size of the management area of interest, which is 25 km long with an average width of 90 m, poses additional sampling problems concerning sampling efficiency (Kennedy and Strange 1981; Bohlin et al. 1989). Obviously, only a small percentage of such a population could ever be sampled given typical personnel and equipment constraints. However, sampling strategies and methods of analysis can be tailored and improved to meet the demands of a recruitment study in a river such as the Henrys Fork.

I developed and evaluated sampling methodologies to obtain data to quantify spawning activity and seasonal abundance, survival, movement, and habitat use of age-0 rainbow trout in the Henrys Fork. Existing methods of analysis for collected data were evaluated and adapted, and new methods of analysis were developed, to improve inference on salmonid recruitment at the juvenile life stage. The methods of analysis were applied to the collected data to produce a comprehensive analysis of age-0 rainbow trout recruitment in the Henrys Fork.

The results of my study are organized into five chapters. Each chapter is written in a format suitable for journal publication and is self-contained. Chapters two to four describe the development and evaluation of sampling methodologies and their application to the Henrys Fork study. In Chapter two I describe the evaluation and adaptation of distance sampling techniques to identify spawning areas in river sections of the Henrys Fork and to quantify spawning activity therein. In Chapter three I describe a sampling methodology I developed to obtain mark-recapture data to estimate abundances of age-0 rainbow trout in the Henrys Fork. I evaluated the utility of closed and open population models for such data and recommended an appropriate estimator. In Chapter four I describe the development and evaluation of competing predictive models for obtaining abundance estimates from single-pass removal data along bank areas in the Henrys Fork. The models were developed for use in the Henrys Fork, but can be calibrated for use in other streams or rivers or anywhere removal sampling is appropriate.

Chapters five and six describe the application of the sampling methodologies developed and evaluated in Chapters two to four. Chapter five constitutes a comprehensive analysis of the production and recruitment of age-0 rainbow trout in the Henrys Fork. I identified spawning areas and quantified spawning activity therein and I quantified seasonal abundance, survival, movement, and habitat use of age-0 rainbow trout. In Chapter six I describe a flow-survival relation identified for age-0 rainbow trout in the Box Canyon section of the Henrys Fork and a winter discharge experiment, based on this relation, to improve natural recruitment of age-0 rainbow trout in the Henrys Fork.

The results of this study improved our understanding of the processes affecting rainbow trout recruitment rates in the Henrys Fork downstream of Island Park Reservoir.

Whereas past studies in the Henrys Fork have been limited in scope such that inferences on river-wide recruitment could not be made, this study provided detailed information on river-wide production, survival, movement, and habitat use of rainbow trout at the age-0 life stage. These results were used to assist management policy for maintaining and improving the Henrys Fork wild rainbow trout fishery. Sampling and analysis techniques developed and evaluated in this study provided the tools necessary to study the recruitment process for age-0 trout and can be used to efficiently monitor age-0 trout recruitment and evaluate the effects of management actions in the future.

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CHAPTER 2

USE OF DISTANCE SAMPLING TO ESTIMATE RAINBOW TROUT REDD ABUNDANCES IN THE HENRYS FORK OF THE SNAKE RIVER, IDAHO

Introduction

Redds are spawning nests of salmonids constructed by digging a depression in gravel substrate, depositing eggs, and covering the eggs with loose gravel. Redd counts are typically conducted to identify spawning areas, to confirm that spawning has occurred, and to obtain a total number of redds present in an area. Redd counts are obtained by censusing an area or stream and it is generally assumed that all redds are detected. Redd censusing may be conducted on foot or by canoe in small streams (e.g., Beland 1996) or by aerial observation in larger streams (e.g., Heggberget et al. 1986). However, it may be unreasonable to assume that all redds can be detected, especially when searching large areas. Censusing may yield biased results if some redds remain undetected.

Distance sampling (Buckland et al. 1993) can be used to systematically search a large area of interest and to obtain an abundance estimate of objects within that area. Distance sampling theory allows for the detectability of objects to decrease as the distance of the object from a line transect increases (Buckland et al. 1993). Therefore, objects can remain undetected without undermining the validity of the estimate. Perpendicular distances from a transect to a detected object are "sampled" and the distances are modeled so that detectability and density can be estimated. As distance from the transect increases, detectability decreases, allowing estimation of the effective area sampled. The use of distance sampling has received little attention in the study of fish populations (for exceptions see Bergstedt and Anderson 1990; Ensign et al. 1995). Distance sampling has not been used in the estimation of redd abundance although it appears to be well suited to this problem. Three assumptions necessary for reliable estimation from line transect sampling are: 1. Objects on a transect are detected with certainty; 2. Objects are detected at their initial location before any movement in response to the observer; and 3. Distances between objects and the transect are measured accurately (Buckland et al. 1993). It is reasonable to assume that redds on a transect will be detected with certainty. Redds are immobile objects; therefore, redds detected off a transect will be detected in their initial location and the distance from a transect to a redd can be measured accurately.

I used distance sampling to identify spawning areas in study sections of the Henrys Fork of the Snake River, Idaho, and to quantify spawning activity therein.

Study Area

The Henrys Fork is a medium-sized river that had a mean annual discharge of 24.3 m^3/s in 1995-1997 at Island Park Dam (range, 6.9 to 78.4 m^3/s). The Henrys Fork at Island Park Dam is at 1,897 m in elevation and drains a 1,246-km^2 area. I divided the Henrys Fork from Island Park Dam to Osborne Bridge into the following five sections for sampling rainbow trout redds: 1. Island Park Dam to the United States Geological Survey (USGS) gauging station (length (L) = 250 m; mean width $\overline{w}$ = 56 m); 2. USGS gauging station to the Buffalo River (L = 350 m; $\overline{w}$ = 42 m); 3. Box Canyon (L = 4 km; $\overline{w}$ = 70 m); 4. Last Chance (L = 4 km; $\overline{w}$ = 95 m); and 5. Harriman State Park (L = 8 km; $\overline{w}$ = 125 m) (Figure 2.1).

The Buffalo River joins the Henrys Fork about 0.6 km downstream of Island Park Dam (Figure 2.1). The Buffalo River is spring-fed and has a relatively constant discharge of 6 m^3/s. A dam at the mouth of the Buffalo River prevented upstream migration of rainbow trout, except during spring runoff, prior to the installation of a fish ladder in October 1996.

The river section from Island Park Dam to the Buffalo River has an intermediate gradient (0.3%) with boulder substrate in the thalweg and gravel substrate in the adjacent shallow areas; there is a larger-gravel substrate area upstream of the USGS gauging station. Box Canyon has a high gradient (0.45%) with cobble-boulder substrate and Last Chance has an intermediate gradient (0.3%) with cobble substrate. Harriman State Park has a low gradient (0.1%) with a highly embedded sand-gravel substrate.

Methods

Replicate transects perpendicular to flow were systematically traversed by a combination of wading and snorkeling, with a random first start within each river section. Locations of redds on either side of a transect of known length were recorded to estimate the effective area sampled and the density of redds. Locations were identified by perpendicular distance (m) from the transect to the redd center. Redd densities were estimated using the computer program DISTANCE (Laake et al. 1994). An estimate of the total number of redds in a section was obtained by extrapolating the estimate of density across the total area within the section. I also searched for redds along alternating sides of the river between transects in Box Canyon, Last Chance, and Harriman State Park to verify that transects were representative of sections (i.e., that there were not many more or less redds between transects versus on or near transects).

Distance sampling was conducted once in 1995 from Island Park Dam to the Buffalo River, in Box Canyon, and in Last Chance. The section between Island Park Dam and the USGS gauging station was sampled on four dates in 1996 and on six dates in 1997. Last Chance and Harriman State Park were each sampled once in 1997. I sampled 10-15 transects on each date in sections between the dam and the Buffalo River and 20 transects on each date in the remaining sections.

The first spawning activity of each season in each river section was verified by digging into suspected redds until eggs were found. Thereafter, depressions in the substrate were identified as redds based on characteristics including a decreasing gravel size-gradient from the redd pit through the redd tail, gravel in a redd that were cleaned of periphyton compared to surrounding gravel, and gravel in a redd pit-area that were loose to the touch.

Results

Rainbow trout spawning activity was concentrated in the section between Island Park Dam and the USGS gauging station on sampling dates in 1995 and 1996 and was limited in other sections. Spawning was limited in all sections of the Henrys Fork on sampling dates in 1997.

Twenty-two redds were observed on 27 April 1995 between the dam and the USGS gauging station, yielding an estimate of 28 redds (95% confidence interval (CI), 12-67; Table 2.1). (See Appendix Table A.1 for detection function model specification, encounter rate, and effective strip width.) The discharge was 17.0 m^3/s. Redds were scattered throughout the shallow areas adjacent to the thalweg. There was an insufficient number of redd observations in the other sampled sections to estimate redd density using program DISTANCE (Table 2.2). One redd was observed near the west bank between the USGS gauging station and the Buffalo River on 27 April and one redd was observed near the east bank in Last Chance on 18 April. No redds were observed in Box Canyon on 17 April and no redds were observed along alternating sides of the river between transects in Box Canyon and Last Chance.

There was an increasing trend in the total number of redds between Island Park Dam and the USGS gauging station between 30 March and 21 April 1996 (Table 2.1). An estimate could not be obtained for 30 March because only two redds were observed. The maximum number of redds observed was 11 on 14 April, yielding an estimate of 11 redds (95% CI, 4-30). Visibility was reduced by 21 April because of an increase in discharge to 19.7 m^3/s from 16.0 m^3/s on 14 April; 9 redds were observed, yielding an estimate of 16 redds (95% CI, 6-42) (Appendix Table A.1). Thereafter, it was not feasible to wade or snorkel to sample redds because of an additional increase in discharge.

An increasing trend in the total number of redds between Island Park Dam and the USGS gauging station was not observed between 11 March and 19 April 1997 (Table 2.1). Discharge was 26.2 m^3/s on 11 March and about 21.3 m^3/s from 31 March to 19 April. One redd was first observed on 31 March and no additional redds were identified thereafter. No redds were observed in Last Chance on 20-21 April or in Harriman State

Park on 21 April (Table 2.2); no redds were observed along alternating sides of the river between transects. Visibility was reduced because of an increase in discharge by the last week of April 1997 and it was not feasible to wade or snorkel to sample redds thereafter.

Discussion

A ground-based method of searching for redds in the Henrys Fork was necessary because trumpeter swans *Cygnus buccinator* left depressions in the substrate after feeding on macrophytes and the depressions could be mistaken for redds when viewed from far away (e.g., from an airplane). Distance sampling provided an unbiased approach to identifying spawning areas and to quantifying spawning activity therein. Traditional redd counts are not robust to changes in detectability and therein lies the advantage of distance sampling—detectability can change without affecting the validity of the estimates.

The robustness of distance sampling to changes in detectability was demonstrated when sampling the river section between Island Park Dam and the USGS gauging station on multiple dates in 1996. As discharge increased between sampling dates, the distance at which redds could be detected from a transect decreased. Consequently, fewer redds were detected for a given number of transects. However, the shorter distances of detected redds from transects indicated an increase in redd density and hence an increase in spawning activity. A traditional redd count would have required more effort to detect an increase in spawning activity given the decrease in detectability, and the increase in spawning activity may not have been observed if redds remained undetected.

There was an increasing trend in spawning activity in the river section between Island Park Dam and the USGS gauging station from 30 March to 21 April 1996. This trend was not observed in 1997. The installation of the Buffalo River fish ladder in October 1996 provided access to spawning areas in the Buffalo River in spring 1997 that were previously inaccessible to rainbow trout in the Henrys Fork prior to spring runoff. Spawning rainbow trout that may have formerly used the area near Island Park Dam could have spawned in the Buffalo River instead. The Henrys Fork Foundation reported that 224 rainbow trout greater than 400 mm total length (TL) migrated upstream through the fish ladder during spring 1997 prior to runoff (R. Van Kirk, Henrys Fork Foundation, personal communication). This may explain the estimated differences in redds between 1996 and 1997.

The detectability of redds may depend on stream discharge and light conditions. Increased discharge may decrease the distance at which redds can be detected from a transect. Distance sampling is robust to this situation provided that redds on a transect are still detected with certainty (Buckland et al. 1993). Light may affect visibility by creating a glare on the water surface. If a glare occurs on one side of the transects, observations will be asymmetric about the transects, but estimation will not be adversely affected (Buckland et al. 1993). If a glare occurs in the direction a transect is being traversed, the observer can turn around and look back to make observations (Buckland et al. 1993).

A random and independent distribution of redds is not required for distance sampling if the transects are randomly located in a river section or if a systematic grid of transects in a river section begins with a random first start (Buckland et al. 1993). Therefore, it is important that transects extend from bank to bank perpendicular to the current such that transects are representative of river habitat across a channel. If redds are clustered along a bank, transects that follow the bank will overestimate redd abundance when used to make inference on the river as a whole. However, I do think it is useful to search for redds while moving along the bank from one transect to the next. This additional information cannot be used to calculate redd density, but it can be used to judge the effectiveness of a systematic sampling grid at representing a river section. For example, no redds were observed between transects in Box Canyon, thereby supporting the assumption that the transects were representative of Box Canyon (where no redds were observed on or near the transects).

An estimation problem encountered in this study was small sample size, which led to large confidence intervals on abundance estimates. Buckland et al. (1993) suggest a minimum sample size of 60 to 80 detected objects; my largest sample was 22 redds. Confidence intervals for abundance estimates also had lower bounds less than the actual number of distinct redds observed. Program DISTANCE computes confidence intervals based on the $\log_e$ approach of Burnham et al. (1987), but unlike the $\log_e$ approach used to construct intervals for mark-recapture and removal estimates of abundance, intervals constructed in DISTANCE do not guarantee lower bounds equal to or greater than the number of objects observed.

Distance sampling was particularly useful for sampling large-scale areas such as Box Canyon, Last Chance, and Harriman State Park, where a traditional census was not feasible. This method provided an objective approach to searching large-scale areas for spawning activity and quantifying spawning activity therein. Distance sampling is not useful for sampling redds in small tributaries and streams because of their narrow width. For example, a stream 5 m wide can usually be adequately searched from the bank and a census taken while walking along the stream length would be more efficient and likely more accurate compared to a distance sampling approach. However, distance sampling may be useful for quantifying spawning activity in ponds and lakes, such as for centrarchid nests.

Summary

Distance sampling was used, as an alternative to a census, to sample large-scale areas of the Henrys Fork of the Snake River, Idaho, for rainbow trout spawning redds. Replicate transects perpendicular to flow were traversed by a combination of wading and snorkeling. Perpendicular distances from transects to detected redds were "sampled" and these data were analyzed using the computer program DISTANCE to estimate redd detectability and density. As discharge increased between sampling dates, detectability of redds decreased and most observations were closer to the transects. The effective area sampled was smaller, but an increase in redd density was observed, indicating increased spawning activity and demonstrating the robustness of distance sampling to changes in detectability. Distance sampling provided an unbiased approach to sampling large-scale areas in a river for redds, and may be useful for quantifying nesting spawning activity in similarly large-scale areas in lakes or ponds.

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Table 2.1.—Estimates of redd abundance ($\hat{N}$) and 95% confidence intervals (CI) in the Henrys Fork from Island Park Dam to the United States Geological Survey gauging station (13,750 m^2) in 1995, 1996, and 1997. Estimates were obtained using the computer program DISTANCE; effort equaled the sum of transect lengths; ne = no estimate.

Date	Transects	Effort (m)	Observed redds	$\hat{N}$	95% CI
			1995		
27 Apr	13	716.7	22	28	[12, 67]
			1996		
30 Mar	10	537.5	2	ne	ne
9 Apr	10	520.6	6	12	[3, 44]
14 Apr	10	551.0	11	11	[4, 30]
21 Apr	10	575.0	9	16	[6, 42]

Table 2.1.—Continued.

Date	Transects	Effort (m)	Observed redds	$\hat{N}$	95% CI
		1997			
11 Mar	10	565.0	0	ne	ne
31 Mar	10	579.0	1	ne	ne
6 Apr	10	608.5	1	ne	ne
13 Apr	15	839.0	0	ne	ne
18 Apr	11	660.5	1	ne	ne
19 Apr	11	606.0	1	ne	ne

Table 2.2.—Summary statistics for sampling of redds in the Henrys Fork from the United States Geological Survey (USGS) gauging station to Harriman State Park. Effort equaled the sum of transect lengths; additional effort included the section length for observations made along banks between transects.

Section	Date	Area (m^2)	Transects	Effort (m) (additional)	Observed redds
USGS gauging station to Buffalo River	27 Apr 1995	14,700	10	421.5 (350)	1 (0)
Box Canyon	17 Apr 1995	270,000	20	1,394 (4,000)	0 (0)
Last Chance	18 Apr 1995	336,800	20	1,946 (4,000)	1 (0)
	20-21 Apr 1997		20	1,820 (4,000)	0 (0)
Harriman State Park	21 Apr 1997	1,013,000	20	2,532 (8,000)	0 (0)