FACTORS LIMITING THE ABUNDANCE OF NORTHERN SQUAWFISH IN LOWER GRANITE RESERVOIR

A Thesis

Presented in Partial Fulfillment of the Requirements for the

Degree of Master of Science

with a

Major in Fisheries Resources

in the

College of Graduate Studies

University of Idaho

by

Thomas A. Cichosz

August 1996

Major Professor: David H. Bennett, Ph.D.

FACTORS LIMITING THE ABUNDANCE OF NORTHERN SQUAWFISH IN LOWER GRANITE RESERVOIR

A Thesis

Presented in Partial Fulfillment of the Requirements for the

Degree of Master of Science

with a

Major in Fisheries Resources

in the

College of Graduate Studies

University of Idaho

by

Thomas A. Cichosz

August 1996

Major Professor: David H. Bennett, Ph.D.

AUTHORIZATION TO SUBMIT

THESIS

This thesis of Thomas A. Cichosz, submitted for the degree of Master of Science with a major in Fisheries Resources and titled "Factors Limiting the Abundance of Northern Squawfish in Lower Granite Reservoir", has been reviewed in final form, as indicated by the signatures and dates given below. Permission is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor ______________________ Date 9 Oct '96
Dr. David H. Bennett

Committee Members ______________________ Date 10 Oct '96
Dr. Kirk Steinhorst

______________________ Date 10/21/96
Dr. C. Michael Falter

Department Administrator ______________________ Date 10/21/96
Dr. George W. Labar

College Dean ______________________ Date 10/21/96
Dr. Charles R. Hatch

Final Approval and Acceptance by the College of Graduate Studies

______________________ Date ______________
Jean'ne M. Shreeve

ABSTRACT

Concern over declining salmonid populations in the Snake and Columbia rivers have underscored the importance of understanding population dynamics of salmonid predators including northern squawfish *Ptychocheilus oregonensis*. I modeled the relationship of egg through larval, juvenile, and adult mortality with abundance of northern squawfish in Lower Granite Reservoir, and examined the relative importance of density dependent and density independent mortality.

My data indicate that northern squawfish abundance in Lower Granite Reservoir is probably limited in the egg through larval stage, although variable mortality estimates suggest that juvenile mortality is also important. Modeling suggested that density independent factors are most important in controlling egg through juvenile survival of northern squawfish. Stable water levels during June and July lead to increased larval survival, although limited availability of preferred rearing habitats in the reservoir may also limit larval survival (S ranged from 2.1×10^{-7} to 0.25). Timing of temperature conditions was most important in predicting survival of juvenile northern squawfish, with earlier reservoir warming resulting in higher survival (S ranged from 0.11 to 0.28). Survival of juvenile northern squawfish increases with increased growth (G ranged from 0.22 to 0.61). Juvenile growth is determined primarily by timing of temperature conditions that dictate the length of growing season. Turbidity conditions affect juvenile growth rates,

probably through their influence on feeding success. My data suggest that high temperatures (> 20^0C) may adversely affect larval development and juvenile growth of northern squawfish. Reservoir management practices aimed at facilitating outmigrating salmonid smolts also impact survival of northern squawfish. Both cool water flow augmentation and the maintenance of minimum operating pool conditions during spring and summer may enhance survival of larval northern squawfish and reduce survival of juvenile northern squawfish in Lower Granite Reservoir.

ACKNOWLEDGMENTS

I would like to thank my major professor, Dr. David Bennett, for providing me with the opportunity to complete this project, for his guidance and, in particular, his patience. I also thank Dr. Kirk Steinhorst and Dr. C. Michael Falter for their assistance and review of this manuscript. Tom Dresser, Steve Chipps, and Steve Anglea each gave freely of invaluable assistance and advice. Too numerous to mention but no less deserving of thanks are the field and lab crews who assisted in my work, and my family and friends who supported me throughout the completion of this work. The U.S. Army Corps of Engineers, Walla Walla, Washington, funded this project.

DEDICATION

All efforts and achievements included herein are dedicated to the memory of my grandmother, Isabelle Ihlenfeld, with my deepest love.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

INTRODUCTION

Declining salmonid populations in the Snake and Columbia river basins, and subsequent listing of stocks under the Endangered Species Act are a major concern of fisheries managers. One aspect of recovery strategies for depleted salmonid stocks has been an attempt to define and control significant predator populations within the Columbia River system. Predation on juvenile salmonids by northern squawfish *Ptychocheilus oregonensis* has been well documented within the Columbia River system (Tabor et al. 1993; Vigg et al. 1991), and northern squawfish account for up to 78% of the predation on juvenile salmonids (Rieman et al. 1991). Annual loss of juvenile salmonids to northern squawfish predation has been estimated at about 2.1 million in John Day Reservoir (Rieman et al. 1991), and 128,000 in Lower Granite Reservoir (Chandler 1993).

Rieman and Beamesderfer (1990) suggested that sustained exploitation of northern squawfish over 275 mm could substantially reduce predation on juvenile salmonids. In 1991 the Sport Reward Program was initiated to pay anglers for the capture and removal of northern squawfish from the Snake and Columbia rivers. Uncertainty about the potential response of the northern squawfish population to exploitation suggested that the role of density independent and density dependent factors in limiting abundance of northern squawfish should be examined (Rieman and Beamesderfer 1990).

As efforts to recover salmonid populations continue, the effect of reservoir management practices on northern squawfish abundance should be considered. Reservoir water level fluctuations may affect the abundance of northern squawfish (Bennett et al. 1994a; Rieman and Beamesderfer 1990) and may provide a means of population regulation. Lower Granite Reservoir has been maintained at minimum operating pool (MOP) during late spring and summer since 1991 to facilitate smolt outmigration. A coincidental increase in abundance of larval and juvenile northern squawfish in 1991 and 1992 (Bennett et al. 1994a) suggested the potential for inadvertent population enhancement through reservoir management. Decreased survival of the 1991 and 1992 year classes in subsequent years (Bennett et al. 1994a) suggested the importance of studying the role of environmental factors in limiting northern squawfish abundance in Lower Granite and other mainstem reservoirs.

Factors which limit the abundance of northern squawfish in mainstem reservoirs, and the mechanisms by which these factors act on the population are poorly understood. This study was initiated to define factors that limit the abundance of northern squawfish in Lower Granite Reservoir.

Specific objectives of my research were:

1. Examine the relative importance of egg-larval, juvenile, and adult mortality in limiting northern squawfish abundance in Lower Granite Reservoir;

2. Determine if abundance of northern squawfish in Lower Granite Reservoir was regulated by density dependent or density independent factors; and

3. Evaluate the role of specific environmental factors in limiting the abundance of northern squawfish in Lower Granite Reservoir.

LIFE HISTORY

Northern squawfish are broadcast spawners and normally spawn from late May through early July (Simpson and Wallace 1982) at water temperatures between 10 and 20^{0}C (Reid 1971). Spawning normally occurs over gravel or cobble substrate (Simpson and Wallace 1982; Patten and Rodman 1969) and stream spawning is preferred (Simpson and Wallace 1982). Adhesive eggs attach to the substrate and hatch within 1 week of fertilization (Casey 1962). Young northern squawfish school in shallow (≤ 1 m deep) low velocity (< 0.06 m/second) areas until the fall of their first year when they move offshore to overwinter (Beamesderfer 1983; Simpson and Wallace 1982). Northern squawfish larvae are collected in highest abundance from the upper reaches (above Rkm 201) of Lower Granite Reservoir (Bennett et al 1994a) and no in-reservoir spawning has been observed. Northern squawfish from Lower Granite Reservoir are believed to spawn in the Snake or Clearwater rivers based on tag returns and seasonal changes in catch rates.

Juvenile northern squawfish feed primarily on zooplankton (Beamesderfer 1983), insects (Falter 1969), and crayfish (Casey 1962). The adult diet consists mainly of fish (Simpson and Wallace 1982) and crayfish (Chandler 1993; Casey 1962). Northern squawfish often reach 400-500 mm in length (1,000-1,300 g) and can reach 700 mm (3,630 g; Carlander 1969). Northern squawfish mature between the ages of 4 and 7, and longevity to 21 years has been reported (Beamesderfer 1983).

Female northern squawfish obtain larger size and survive to older ages than males (Casey 1962). In Lower Granite Reservoir, northern squawfish have been collected at 16 years of age and 526 mm total length (Oregon Department of Fish and Wildlife, Clackamas, Oregon, unpublished data).

STUDY AREA

Lower Granite Reservoir is a run-of-the-river reservoir on the lower Snake River (Rkm 173.0) with arms extending upstream into the Snake and Clearwater rivers near Clarkston, Washington and Lewiston, Idaho (Rkm 223.7; Figure 1). Construction and impoundment of the Lower Granite Lock and Dam Project was completed in 1975 and created a reservoir 3,602 ha in surface area with a mean depth of 16.6 m (Bennett et al. 1983). The project provides recreation, electrical power generation, and navigation.

During March, flows in the lower Snake River are typically low (20-30 Kcfs) and generally increase through May to 60-120 Kcfs (US Army Corp of Engineers (USACE), Walla Walla, Washington, unpublished data). Water temperatures are typically < 7^0 C during March, gradually warm to 10^0 C in April (USACE, Walla Walla, Washington, unpublished data) and peak near 25^0 C in late summer (Funk et al. 1985). Dissolved oxygen is near saturation (> 8 mg/l) throughout the water column during spring (Bennett et al. 1994b) and vertical temperature and oxygen gradients are limited to periods of low flow (< 12,200 cfs; Funk et al. 1985).

The fish community in Lower Granite Reservoir was surveyed in 1985 (Bennett and Shrier 1986) and extensively since 1986 (Bennett et al. 1988, 1989, 1990, 1991, 1993a, 1993b, 1994a, 1994b, 1995). Representatives of nine fish families have been identified from Lower Granite Reservoir, including 14 native and 13 introduced species.

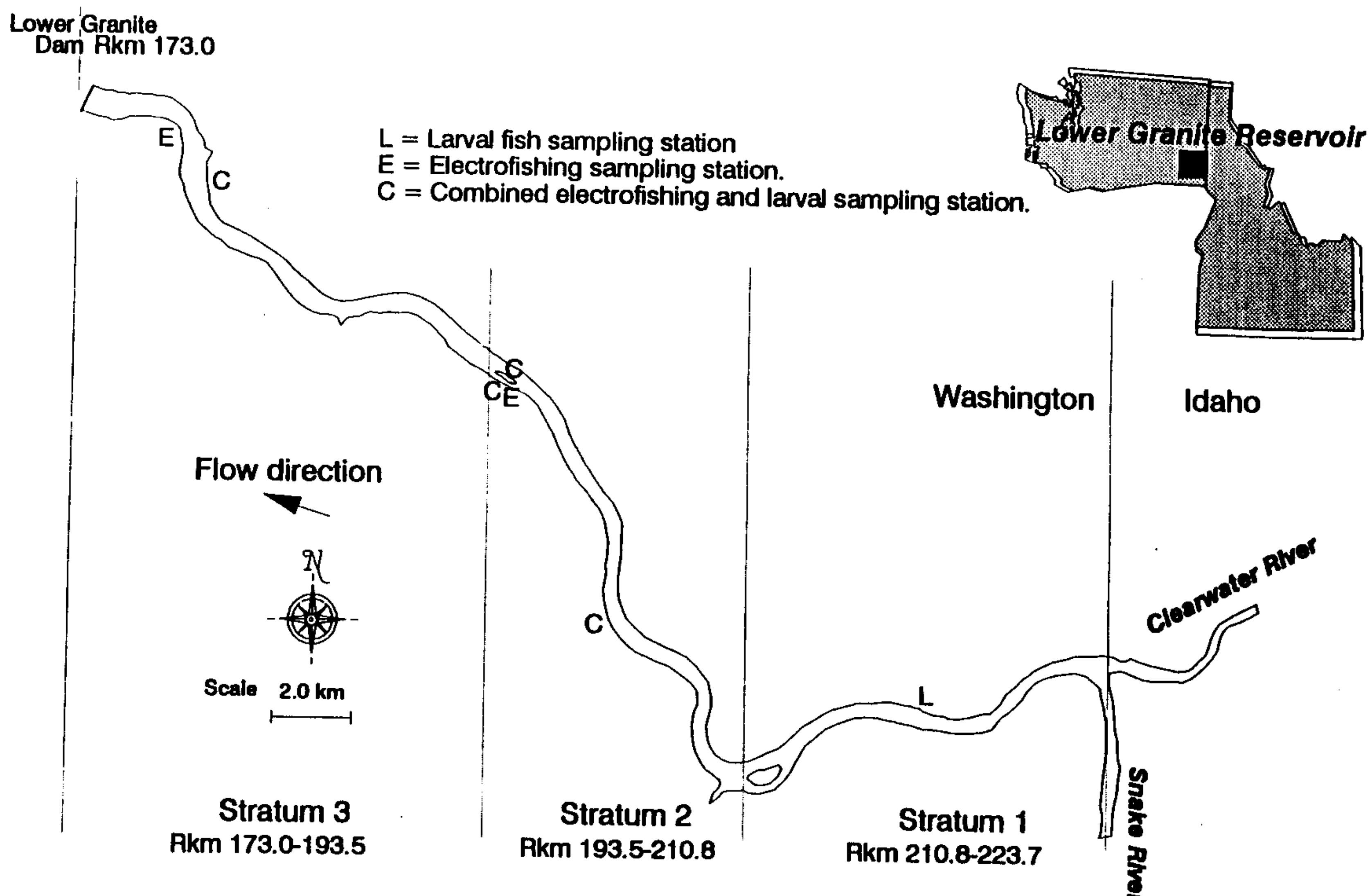

Figure 1. Lower Granite Reservoir showing standard sampling stations used from 1985-1993, and strata used for sample site selection in 1994 and 1995. Annual sampling designs are described in the text.

METHODS

Electrofishing Collections

Juvenile northern squawfish data were collected during October and November in 1985, 1987, and 1989 through 1995 by nighttime electrofishing surveys. Fall electrofishing captured juvenile northern squawfish in Lower Granite Reservoir more effectively than collection in other seasons or by other methods. Six stations were sampled by nighttime electrofishing in Lower Granite Reservoir from 1985 through 1993 (Figure 1). From 1985 through 1992, electrofishing was conducted at each station with three 5 minute passes/night whereas in 1993 a single 5 minute pass was completed at each station sampled.

Single pass electrofishing was used with a stratified random sampling design to sample monthly at 80 stations in 1994 and 60 stations in 1995. The number of 0.40 km stations electrofished in each of three strata (stratum 1; Rkm 210.8-223.7, stratum 2; Rkm 193.5-210.8, and stratum 3; Rkm 173.0-193.5; Figure 1) were selected with probability proportional to size (Scheaffer et al. 1990).

Six major habitat types were identified and quantified during the 1992 test drawdown of Lower Granite Reservoir, and consist of sand, talus, cobble, cliff, rip-rap, and embayments (Curet, 1994; rip-rap in Lower Granite Reservoir consists of intentionally placed angular rock ranging from 0.5 to 1.0 m in diameter). Specific sites electrofished within each stratum in 1994 and 1995 were chosen randomly with probability proportional to the availability of each habitat type within each stratum.

Larval Collections

Larval fishes were sampled with paired 0.5 m plankton nets and a custom built hand-drawn beam trawl (LaBolle et al. 1985). Plankton nets were towed at night approximately 1.5 m/sec. at the surface and 1 m depths for approximately 3 minutes at each depth. Three paired hauls were made at each station on each night sampled providing six samples/location/date. The beam trawl was pulled along the shoreline over a standard distance of 15.25 m during the daytime. Three such hauls were made along the shoreline in shallow (0.5 m) and deeper (1 m) water for a total of six hauls/location/date.

Larval fish sampling was conducted in 1989 through 1994 from late May or early June through August or mid-September, dependent upon year. In 1989 through 1993, larval fishes were sampled on either weekly or biweekly intervals at five stations (Figure 1). In 1994 larval fishes were sampled biweekly with plankton nets from 23-1.6 km sites randomly chosen throughout the reservoir in each biweekly interval, and also by hand beam trawl from all randomly selected sites except those with rip-rap or cliff shorelines.

In 1995 larval fish were collected biweekly by hand beam trawl from late May through early September in the upper reservoir (above Rkm 201) as larval northern squawfish were collected almost exclusively from the upper portion of Lower

Granite Reservoir in previous years (Bennett et al. 1994a), and larval fishes are often associated with nearshore areas (Scheidegger and Bain 1995). Larval fish sampling stations were stratified by habitat type in 1995. Seven to nine sites were randomly chosen for each biweekly interval in 1995 and included rip-rap (2-3), sand (2-3), cobble (1), talus (1), and embayment (1) habitats. Eight 15.25 m hauls each approximately 1.0 m in depth were taken at each site in 1995.

Data Analysis

Mean and cohort specific mortality rates of egg through larval, juvenile, and adult northern squawfish were examined through time. I considered the limiting stage as that when the highest mortality was experienced by the northern squawfish population.

Length at age data (observed and back-calculated) for northern squawfish in Lower Granite Reservoir were obtained from the Oregon Department of Fish and Wildlife (Clackamas, Oregon, unpublished data). MIX software (Ichthus Data Systems 1988) was used in conjunction with length at age data to proportion juvenile northern squawfish length data collected between 1985 and 1995 into age frequencies. Age frequencies for cohorts were combined, and catch curves (Ricker 1975) were used to estimate annual instantaneous mortality rates (Z). All electrofishing samples were considered simple random samples for my data analysis.

Total number of adult northern squawfish in Lower Granite Reservoir was calculated using combinations of gillnet (Bennett et al. 1991, 1993, 1994a, 1994b, 1995; Chandler 1993) and Sport Reward Program (Washington Department of Wildlife, Pullman, Washington, unpublished data) data with both Leslie and DeLury depletion estimators (Ricker 1975). The mean of seven abundance estimates was considered to be the population size of adult northern squawfish in Lower Granite Reservoir prior to known removals (1987). I assumed that the initial population size of adult northern squawfish was stable and that all removals resulted in a direct reduction of the adult population. Population of adult northern squawfish after 1987 was then determined to be the initial population size minus the sum of prior adult northern squawfish removals. Number of female northern squawfish was estimated as 56.3% of the total adult population (Oregon Department of Fish and Wildlife, Clackamas, Oregon, unpublished data).

Egg through larval mortality was estimated from total potential egg production by adult northern squawfish and estimates of total larval northern squawfish abundance in Lower Granite Reservoir from 1989 through 1995. Potential egg production was calculated using abundance of adult (> 250 mm) female northern squawfish multiplied by estimated mean fecundity (29,688 eggs/female) of northern squawfish in Columbia River reservoirs (Zimmerman et al. 1995). Abundance of larval northern squawfish was estimated using larval fish data collected from 1989 through 1995 (Bennett et al. 1991, 1993, 1994a, 1994b, 1995).

Total annual abundance of larval northern squawfish was estimated as the sum of the biweekly abundance estimates in each of nine strata. The upper (Rkm 210.8-224.9), middle (Rkm 193.1-210.8), and lower (Rkm 173.0-193.1) strata in Lower Granite Reservoir (Figure 1) were further subdivided into shallow nearshore (< 0.5 m deep), deep nearshore (0.5-1.0 m deep), and offshore (> 1.0 m deep) strata. Shallow hand beam trawls, deep hand beam trawls, and plankton net samples were used to represent shallow nearshore, deep nearshore, and offshore areas, respectively. Larval fish samples collected from each stratum were assumed to be randomly distributed within the stratum. I assumed that larval northern squawfish abundance in waters deeper than 1 m were not significant. Larval northern squawfish could not be identified at less than 18 mm (total length) and were found to recruit from larval sampling gear at approximately 27-28 mm. I assumed constant recruitment to and from the larval gears. Biweekly larval abundance was estimated as the sum of the mean density collected in each stratum multiplied by the volume of water within that stratum at a water level of 733' MSL (Batelle, Richland, Washington, unpublished data).

Instantaneous growth rates of northern squawfish were calculated as described by Ricker (1975). MIX software (Ichthus Data Systems 1988) was used to estimate mean length at age from electrofishing length frequencies. Mean length in consecutive years was then used to estimate annual instantaneous growth rates of juvenile northern squawfish age classes. I assumed that larval northern squawfish growth rates were reflected in the length of age 0 northern squawfish collected by fall electrofishing, and that northern squawfish hatched on June 15 at a length of 6 mm. The mean date of fall collections and mean size of age 0 northern squawfish collected were then used to estimate daily instantaneous growth for larval northern squawfish.

The degree that density dependent factors influence mortality of northern squawfish in Lower Granite Reservoir was examined using methods described by Varley and Gradwell (1968). Density dependence is assumed to be acting on the limited life stage if: 1) both regressions of final ($CPUE_{n+1}$) on initial ($CPUE_n$) density and initial on final density have slopes significantly different than one, and 2) both regression lines plot on the same side of the slope of unity. This approach ensures that variation around the two regressions is small because the regressions move closer together as the variation decreases (Dempster 1975).

I used key factor analysis (Morris 1963) to determine the relative importance of factor(s) potentially limiting the abundance of northern squawfish in Lower Granite Reservoir. Key factor analysis is a multiple regression technique that examines the role of both density dependent and density independent factors in controlling population change. The general model for key factor analysis is:

$$CPUE_{n+1} = a + CPUE_n(DD) + DI$$

where; $CPUE_{n+1}$ = Catch per unit of effort at time n+1,

$CPUE_n$ = Catch per unit of effort at time n,

DD = Density dependent factors,

DI = Density independent factors, and

a = y intercept of the model.

SAS statistical software was used to perform the multiple regression analysis. I considered all variables resulting in models with p-values less than 0.05 to be potentially important in limiting northern squawfish survival.

Habitat utilization by larval northern squawfish could not be assessed using key factor analysis although availability of suitable habitat to larval fish has been shown to be important in determining their survival (Scheidegger and Bain 1995; Bestgen and Williams 1994). Jacobs utilization index (Lechowicz 1982) was used to examine habitat preference of larval cyprinids collected from Lower Granite Reservoir in 1995. The Jacobs utilization index has a value of zero under random habitat use and varies for strongly preferred (+1) and strongly avoided (-1) habitats.

RESULTS

Egg-larval Northern Squawfish

To estimate annual egg production by northern squawfish in Lower Granite Reservoir, I estimated the pre-removal population size of adult northern squawfish as 4,195 (Table 1). Adult population estimates ranged from 3,669 to 5,076 (Table 1), and the 95% confidence interval for the mean estimate was from 2,984 to 7,205 adult northern squawfish.

Mean annual instantaneous mortality for northern squawfish in the egg through larval stage from 1989 through 1995 in Lower Granite Reservoir was 5.60 (0.37% survival; Figure 2). Annual instantaneous mortality estimates for northern squawfish in the egg through larval stage ranged from 1.39 (25% survival) to 15.35 (< 0.001% survival; Table 2).

I rejected the hypothesis that density dependent factors are acting on the egg through larval stage of northern squawfish in Lower Granite Reservoir. Slopes of the two necessary regressions (final on initial and initial on final density) were on opposite sides of unity, and only the slope (0.122) of final (ln # larvae) on initial (ln # eggs) density differed significantly from one ($P < 0.05$; Figure 3). The slope of initial on final density was 4.06 ($P > 0.05$).

Predictive modeling of northern squawfish survival in the egg through larval stage in Lower Granite Reservoir yielded 68 competing models with overlapping information (Appendix Table 1). Five of these models were significant ($P < 0.05$) in predicting egg through larval survival of northern squawfish

Table 1. Population estimates for adult northern squawfish (≥ 250 mm) in 1987 in Lower Granite Reservoir obtained using gillnet (1987-1995) and Sport Reward Program (1991-1995) data with Leslie and DeLury depletion estimators.

Data Analyzed[1]	Years Analyzed	Variables Regressed*	Initial Estimate	Prior Removals	Est. 1987 Population
Leslie Method					
Gillnet	1987-1994	GN CPUE/K_t	3,669	0	3,669
Gillnet	1987, 1989-1994	GN CPUE/K_t	5,076	0	5,076
Gillnet/SRP	1990-1993	GN CPUE/K_t	3,769	0	3,769
Gillnet/SRP	1991-1993	GN CPUE/K_t	3,969	0	3,969
Gillnet/SRP	1991-1993	SRP CPUE/K_t	4,510	0	4,510
SRP	1991-1993	SRP CPUE/K_t	3,608	859	4,467
DeLury Method					
SRP	1991-1993	SRP CPUE/E_t	3,266	641	3,907
				Mean Estimate	4,195

1 GN = Gillnet,
SRP = Sport Reward Program,
K_t = Cummulative catch,
E_t = Cummulative effort.

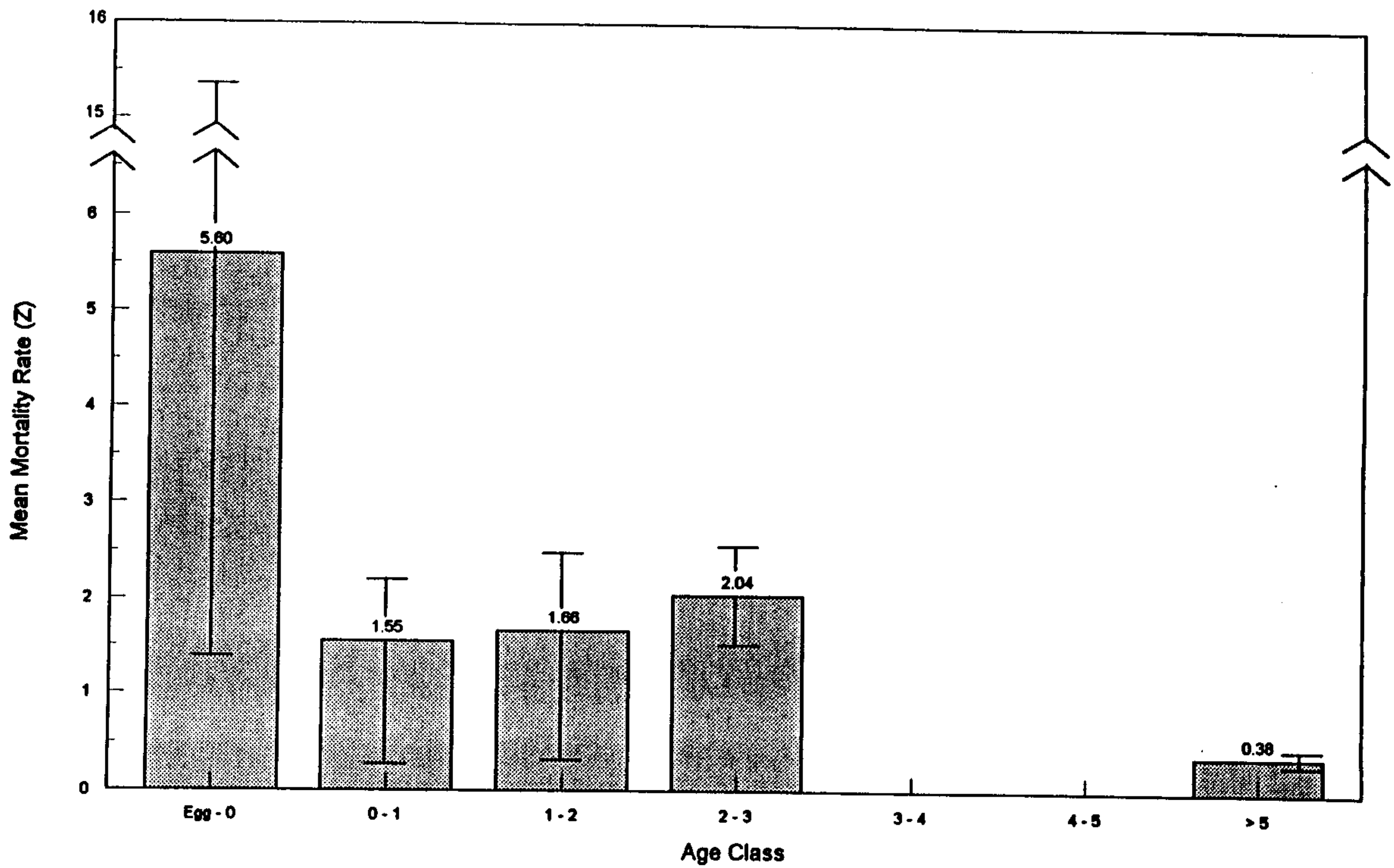

Figure 2. Mean instantaneous annual mortality rates by age class for northern squawfish in Lower Granite Reservoir. Lines indicate range of annual estimates by age class. Estimate for age > 5 taken from Chandler (1993).

Table 2. Estimated adult population size, egg production, larval production and egg through larval mortality estimates by year for northern squawfish in Lower Granite Reservoir.

Year	Prior Squawfish Removals	Population Estimate	Females	Fecundity[1]	Eggs Produced	Larvals Produced	Mortality (Z)
1987	0 [2]	4,195	2,362	29,866	70,537,071	----	----
1988	58 [2]	4,137	2,329	29,866	69,561,826	----	----
1989	71 [2]	4,066	2,289	29,866	68,367,993	1,991,694	3.54
1990	313 [2]	3,753	2,113	29,866	63,105,036	1,125,166	4.03
1991	199 [2]	3,554	2,001	29,866	59,758,939	14,955,092	1.39
1992	798 [3]	2,756	1,552	29,866	46,340,922	31,325	7.30
1993	1,748 [4]	1,008	568	29,866	16,949,074	105,177	5.08
1994	438 [4]	570	321	29,866	9,584,298	0	15.35
						Mean Mortality	5.60

1 Source: Zimmerman et al. 1995.
2 Source: Chandler 1993.
3 Source: Chandler 1993; Washington Department of Fish and Wildlife, unpublished data.
4 Source: Washington Department of Fish and Wildlife, unpublished data.

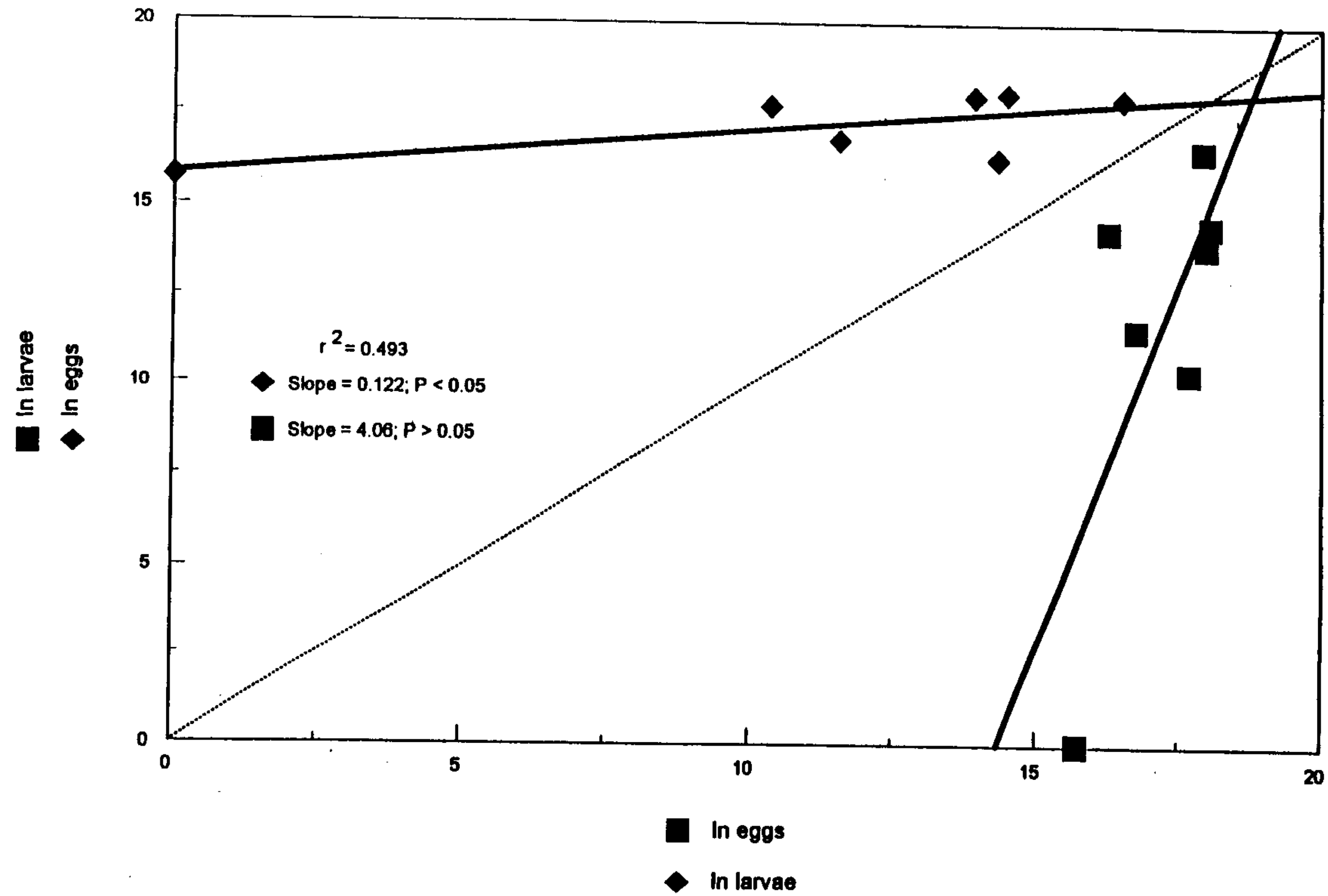

Figure 3. Plot used to test for density dependence acting on the egg-larval stages of development for the northern squawfish population in Lower Granite Reservoir.

(Table 3). Four significant models included variables related to Lower Granite Reservoir, including flow (1) and temperature (1) conditions, and water level fluctuations (2) and one significant model was related to temperature conditions in the Clearwater River. Significant predictive models for egg through larval survival of northern squawfish in Lower Granite Reservoir explained between 63% and 87% of the additional variance in egg through larval survival (variance in ln # larvae not explained by ln # eggs; $r^2 = 0.493$; Figure 3).

Models containing the median Julian date of flows ≥ 75 Kcfs ($P = 0.023$; $r^2 = 0.849$) and mean Julian date of temperatures ≥ 20^0C ($P = 0.017$; $r^2 = 0.869$) in Lower Granite Reservoir were significant predictors of egg through larval survival for northern squawfish. Water level fluctuations (forebay level variance) during June ($r^2 = 0.932$) and July ($r^2 = 0.815$) significantly affected ($P = 0.005$ and 0.034, respectively) egg through larval survival of northern squawfish in the reservoir. The model containing number of degree days > 10^0 C in the Clearwater River in July ($r^2 = 0.814$) was also significant ($P = 0.035$).

Because no larval northern squawfish were identified from larval fish collections from Lower Granite Reservoir in 1995, I examined habitat preference/avoidance larval cyprinids. A total of 430 larval cyprinids were collected by hand-drawn beam trawl in 1995. Cyprinid larvae were most frequently collected from sand habitats (Table 4) and most abundant in July.

Table 3. Variables included in significant ($P < 0.05$) predictive models for egg to larval survival of northern squawfish. Sample size (n) was 7 for all models.

Variable Included[1]	Correlation w/ Mortality	Model Significance	r^2	Period Represented
Lower Granite Reservoir				
MD ≥ 75 Kcfs	-	0.023	0.849	Annual
MN ≥ 20^{0}C	-	0.017	0.870	March 1 - Sept. 15
Forebay var. June	+	0.004	0.939	June
Forebay var. July	+	0.035	0.814	July
Clearwater River				
July Degree Days > 10^{0}C	+	0.035	0.813	July

1 MN = Mean julian date,
MD = Median julian date.

Table 4. Habitat availability, number of cyprinids collected, and Jacobs utilization index by habitat type for larval fish collections from Lower Granite Reservoir in 1995.

Habitat	Habitat Available (miles)	Habitat Proportion	Cyprinidae Collected	Cyprinidae Proportion	Jacobs D [1]
Sand	3.25	0.137	257	0.589	0.801
Talus	4.50	0.189	35	0.080	-0.456
Embayment	0.25	0.011	65	0.149	0.886
Rip-rap	14.75	0.621	49	0.112	-0.857
Cobble	1.00	0.042	30	0.069	0.254
Totals	23.75	1.000	436	1.000	

1 Jacobs D = $r_i - p_i / r_i + p_i - (2 r_i p_i)$

where: r_i = Relative number of cyprinids identified, and
p_i = Relative abundance of habitat in sample

Jacobs utilization index values (D) showed that larval cyprinids preferred embayment (D = 0.89), sand (D = 0.80), and cobble (D = 0.25) habitats in 1995 (Figure 4). Sand, embayment and cobble habitats make up approximately 19% of the area sampled above Rkm 201.2 in 1995 (Table 4). Larval cyprinids avoided rip-rap (D = -0.86), and talus habitats (D = -0.46; Figure 4) that comprise approximately 81% of habitat sampled upstream of Rkm 201.2 in 1995 (Table 4).

Juvenile Northern Squawfish

Mean annual instantaneous mortality for juvenile northern squawfish (ages 0 through 3) ranged from 1.55 (age 0 to 1) to 2.04 (age 2 to 3) with a weighted mean of 1.70 (Figure 2). Limited data precluded my estimating mortality rates for northern squawfish between 3 and 5 years of age.

I rejected the hypothesis that density dependent factors affect juvenile northern squawfish in Lower Granite Reservoir. The regressions of final on initial density (ln $CPUE_{n+1}$ on ln $CPUE_n$) and initial on final density (ln $CPUE_n$ on ln $CPUE_{n+1}$) had slopes less than unity, however only the slope of final on initial density (0.693) differed significantly from one ($P < 0.05$; Figure 5). The slope of initial on final density was 0.974 ($P > 0.10$; Figure 5).

Predictive modeling of juvenile northern squawfish survival in Lower Granite Reservoir yielded 38 competing models with overlapping information (Appendix Table 2). Seventeen models were significant ($P < 0.05$) in predicting

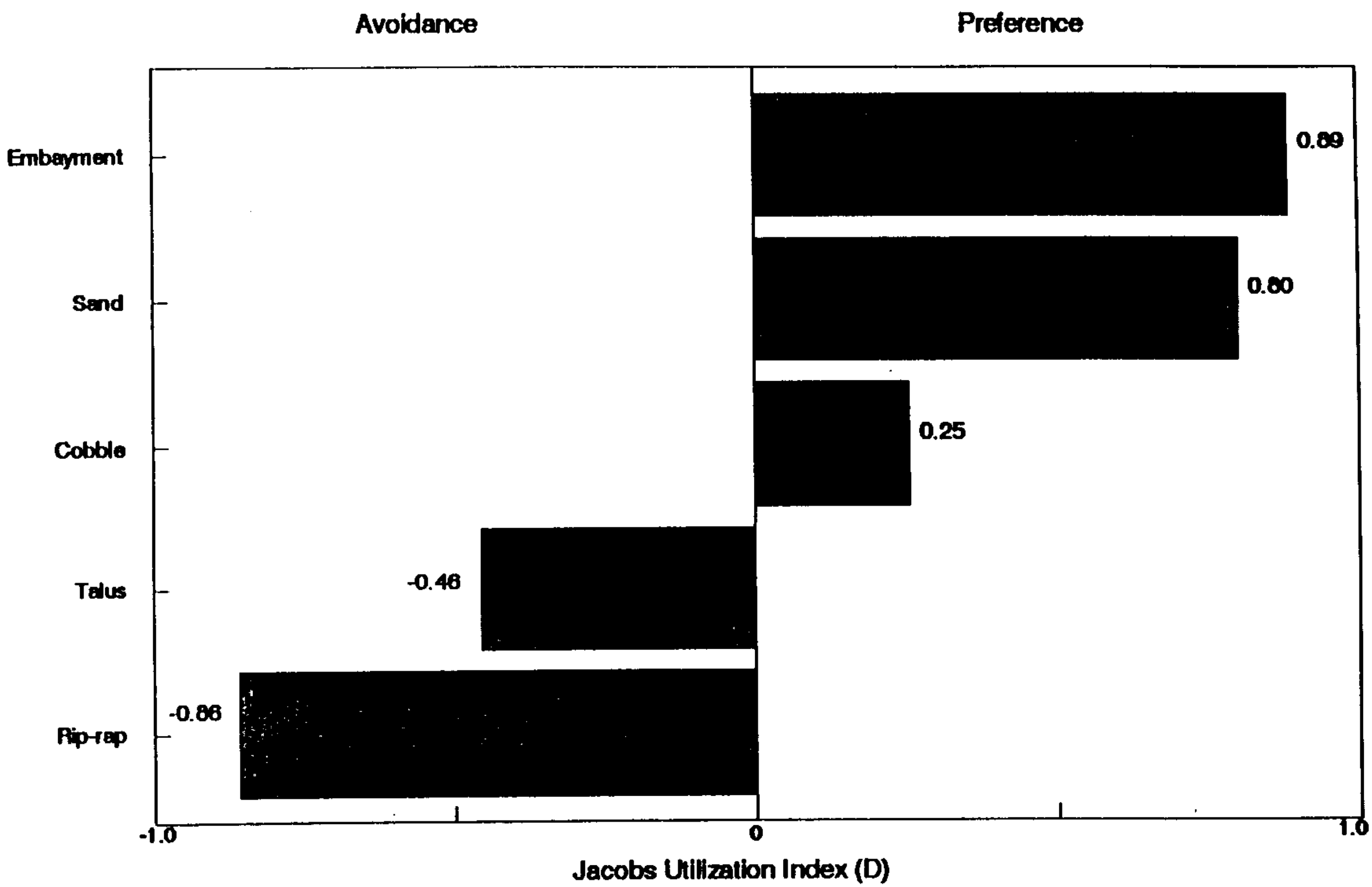

Figure 4. Jacobs utilization index values for larval cyprinidae collected from various habitats in Lower Granite Reservoir in 1995.

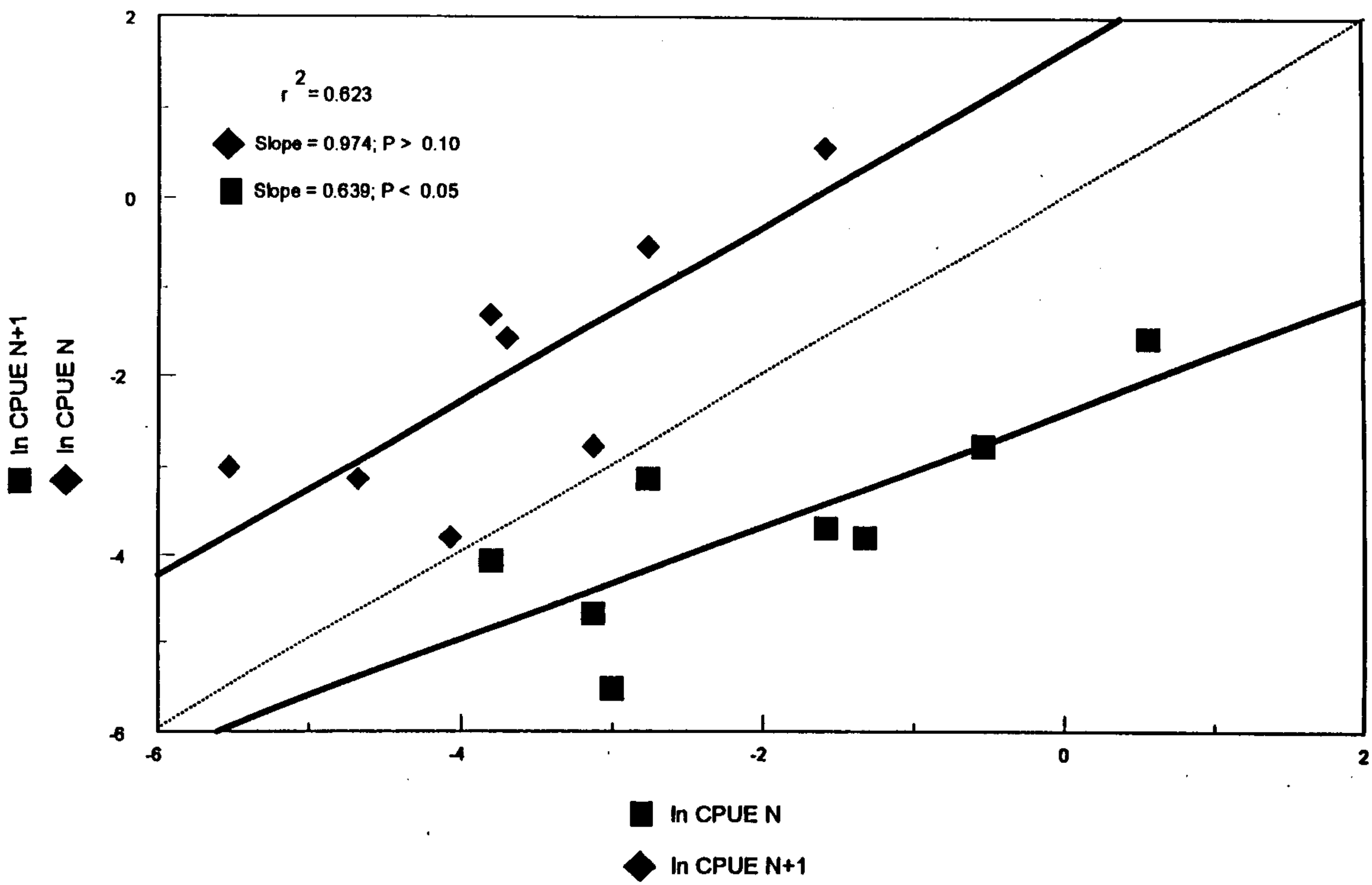

Figure 5. Plot used to test for density dependence acting on the juvenile northern squawfish population in Lower Granite Reservoir.

survival of juvenile northern squawfish (Table 5). Significant models included variables related to temperature duration and timing (8), growth rate of juvenile northern squawfish (1), forebay level and water level variance (4), flow conditions and timing (3), and turbidity conditions (1) in Lower Granite Reservoir. The model containing median Julian date of temperatures $\geq 10^0$ C had the highest predictive value ($r^2 = 0.810$) and explained approximately 50% of the additional variance in juvenile northern squawfish survival (variance in ln $CPUE_{n+1}$ not explained by ln $CPUE_n$; $r^2 = 0.623$; Figure 5). The model containing the number of days $\geq$ 75 Kcfs had the lowest predictive value ($r^2 = 0.706$) of significant models and explained approximately 22% of the additional variance in juvenile northern squawfish survival.

Eight models examining temperature duration and timing in Lower Granite Reservoir were significant ($P < 0.05$) in predicting juvenile northern squawfish survival. The coefficient of determination (r^2) for models containing median Julian date (MD) when reservoir temperatures equalled or exceeded various levels was 0.810 for 10^0 C ($P = 0.016$), 0.791 for 15^0 C ($P = 0.020$), and 0.760 for 20^0 C ($P = 0.028$; Table 5). Models including mean Julian date (MN) of temperatures $\geq$ 10^0, 15^0, and 20^0 C were significant and had coefficients of determination ranging from 0.744 ($P = 0.033$) to 0.791 ($P = 0.020$; Table 5). Annual duration (number of days) of water temperatures $\geq 15^0$ C also yielded a significant ($P = 0.030$) model for predicting juvenile northern squawfish survival (r^2

Table 5. Variables included in significant ($P < 0.05$) predictive models for juvenile northern squawfish survival. Sample size (n) was 8 for all models.

Variable Included[1]	Correlation w/ Mortality	Model Significance	r^2	Period Represented
Days ≥ 50 Kcfs	+	0.042	0.718	Annual
Days ≥ 75 Kcfs	+	0.047	0.706	Annual
MN ≥ 75 Kcfs	+	0.028	0.759	Annual
Days ≥ 15^{0}C	-	0.030	0.754	Annual
Winter Days ≥ 10^{0}C	-	0.040	0.723	Dec. 1 - Feb. 28
MN ≥ 20^{0}C	+	0.033	0.744	Annual
MN ≥ 15^{0}C	+	0.020	0.791	Annual
MN ≥ 10^{0}C	+	0.021	0.786	Annual
MD ≥ 20^{0}C	+	0.028	0.760	Annual
MD ≥ 15^{0}C	+	0.020	0.791	Annual
MD ≥ 10^{0}C	+	0.016	0.810	Annual
Mean secchi	-	0.045	0.712	March 1 - June 30
MOP forebay variance	+	0.033	0.744	April 15 - Sept. 30
Non-MOP forebay variance	-	0.019	0.797	Oct. 1 - April 14
Non-MOP forebay level	+	0.022	0.785	Oct. 1 - April 14
Winter forebay variance	-	0.031	0.750	Dec. 1 - Feb. 28
Instantaneous growth (G)	-	0.029	0.757	Annual

1 MN = Mean julian date,
MD = Median julian date.

= 0.754) as did the number of days in which temperatures equalled or exceeded 10^0 C from Dec. 1 through Feb. 28 (P = 0.040; r^2 = 0.723; Table 5).

Annual instantaneous growth rate was included in a significant (P = 0.029) predictive model of juvenile northern squawfish survival in Lower Granite Reservoir (r^2 = 0.757). Estimates of mean annual instantaneous growth for juvenile northern squawfish ranged from 0.22 (1993) to 0.61 (1990).

Three significant predictive models for juvenile northern squawfish survival examined the number of days that inflow to Lower Granite Reservoir was ≥ 50 Kcfs (r^2 = 0.718, P = 0.042), ≥ 75 Kcfs (r^2 = 0.706, P = 0.047), and the mean Julian date of flows ≥ 75 Kcfs (r^2 = 0.759, P = 0.028). Mean secchi measurement (March 1 through June 30) at Lower Granite Dam was also a significant predictor of juvenile northern squawfish survival (P = 0.045, r^2 = 0.712; Table 5).

Variance of forebay elevation under minimum pool (MOP) operations (May 1 - Sept. 30; r^2 = 0.744, P = 0.033), non-MOP operations (Oct. 1 - April 31; r^2 = 0.797, P = 0.019), and during winter (Dec. 1 - Feb. 28; r^2 = 0.750, P = 0.031) yielded significant ($P < 0.05$) models for predicting survival of juvenile northern squawfish. Mean forebay level during non-MOP operations was also significant (P = 0.021) in predicting juvenile northern squawfish survival (r^2 = 0.786). No models examining variation in forebay water level during individual months of MOP operations (May - September) were significant predictors of juvenile northern squawfish survival (Appendix Table 2).

Mortality of juvenile northern squawfish was positively correlated with timing of temperatures (mean and median Julian date ≥ 10⁰, 15⁰, and 20⁰ C) and flows (≥ 75 Kcfs), duration of flows (≥ 50 and 75 Kcfs), MOP forebay variance, and mean non-MOP forebay level (Table 5). Juvenile mortality was negatively correlated with duration of temperatures, annual instantaneous growth rate, mean secchi reading, and forebay variance under non-MOP and winter operations (Table 5).

The role of predation in annual mortality of juvenile northern squawfish has been assessed. Anglea (University of Idaho, Moscow, Idaho, unpublished data) estimated approximately 118,500 juvenile northern squawfish were consumed by smallmouth bass *Micropterus dolomieui* in Lower Granite Reservoir during 1995. Northern squawfish consumed had an average weight of approximately 9 g, corresponding to an average length of 105 mm (Bennett et al. 1983), and average age of 1+ (Oregon Department of Fish and Wildlife, Clackamas, Oregon, unpublished data).

DISCUSSION

My abundance and density estimates of adult northern squawfish (4,195; 1.16/hectare; Table 1) are notably lower than those for John Day Reservoir (85,316/4.4 per hectare; Beamesderfer and Rieman 1991), however I believe that they are accurate. Ward et al. (1995) also found abundance in Lower Granite Reservoir to be much lower than that in John Day Reservoir. Northern squawfish sampling efforts throughout the reservoir by the Oregon Department of Fish and Wildlife have largely been unsuccessful (S. Smith, Washington Department of Wildlife, Pullman, Washington, personal communication) attesting to their low abundance. Highest abundance is in the upstream reaches (Ward et al. 1995) especially the Snake River arm (G. Naughton, University of Idaho, Moscow, Idaho, personal communication).

Mean annual egg through larval mortality of northern squawfish is considerably higher than that of juveniles or adults in Lower Granite Reservoir (Figure 2), and therefore probably has the greatest limiting effect on northern squawfish abundance. Variable mortality estimates in egg through larval and juvenile stages (Figure 2) suggest juvenile mortality is probably also important in limiting abundance of some year classes of northern squawfish.

Actual egg through larval mortality is probably higher than I have estimated because I assumed a stable adult population size. Removals of adult northern squawfish from Lower Granite Reservoir from 1987 through 1995 (4,330 fish;

Chandler 1993; Washington Department of Wildlife, Pullman, Washington, unpublished data) have exceeded my population estimate suggesting that immigration may have occurred or my population estimate was low. In June and July of 1995 we sampled 445 gillnet hours in various habitats throughout the reservoir, collecting only six northern squawfish providing further support for low population abundance in Lower Granite Reservoir. Underestimating adult population size would also underestimate the number of eggs produced, and subsequently underestimate the egg through larval mortality rate. I do not believe that this had a measurable effect on modeling results, as relative mortality rates across years would still be similar to my estimates.

My data suggests that density independent factors are most important in controlling both egg through larval and juvenile survival of northern squawfish in Lower Granite Reservoir. Data on both stages yielded only one regression (initial on final density or final on initial density) having a slope significantly ($P < 0.05$) different from 1 (Figure 3; Figure 5). Egg through larval data yielded regressions with slopes on opposite sides of the slope of unity (Figure 3).

I considered all variables resulting in models with p-values less than 0.05 to be potentially important in limiting northern squawfish survival. However, type I error rates of the models were higher than reported due to my use of competing models. Interrelationship of modeled variables prevented my adjusting p-values accordingly and therefore, reported p-values of the models cannot be interpreted as significance. This affects only reported p-values for competing models, and not those pertaining to tests of density dependence or correlations between modeled variables.

Temperature conditions in Lower Granite Reservoir probably, in part, limit northern squawfish abundance. Timing (mean and median Julian date) is probably more important than duration of temperatures in predicting juvenile northern squawfish survival (Table 5), and delayed warming of the reservoir contributes to higher mortality in both the egg through larval (Table 3) and juvenile (Table 5) stages. Under poor runoff conditions in 1992, Lower Granite Reservoir warmed to 10^0C on March 20, and 20^0C on June 19. In contrast, under high spring runoff in 1993, the reservoir did not reach 10^0C until April 25, and 20^0C until August 19. Annual spring temperature conditions in Lower Granite Reservoir are more variable than summer or fall temperature conditions (Figure 6) and therefore probably have the greatest effect on both timing and duration of temperature conditions.

Significance of degree days > 10^0 C in the Clearwater River during July in predicting egg through larval survival of northern squawfish (Table 3) was unclear. Other models examining accumulation of degree days (> 10, 15, and 20^0C) during May, June, and July in the Snake and Clearwater rivers were not significant ($0.11 \leq P \leq 0.26$) predictors of egg through larval mortality (Appendix Table 1). Water temperatures are undoubtedly important in determining rates of

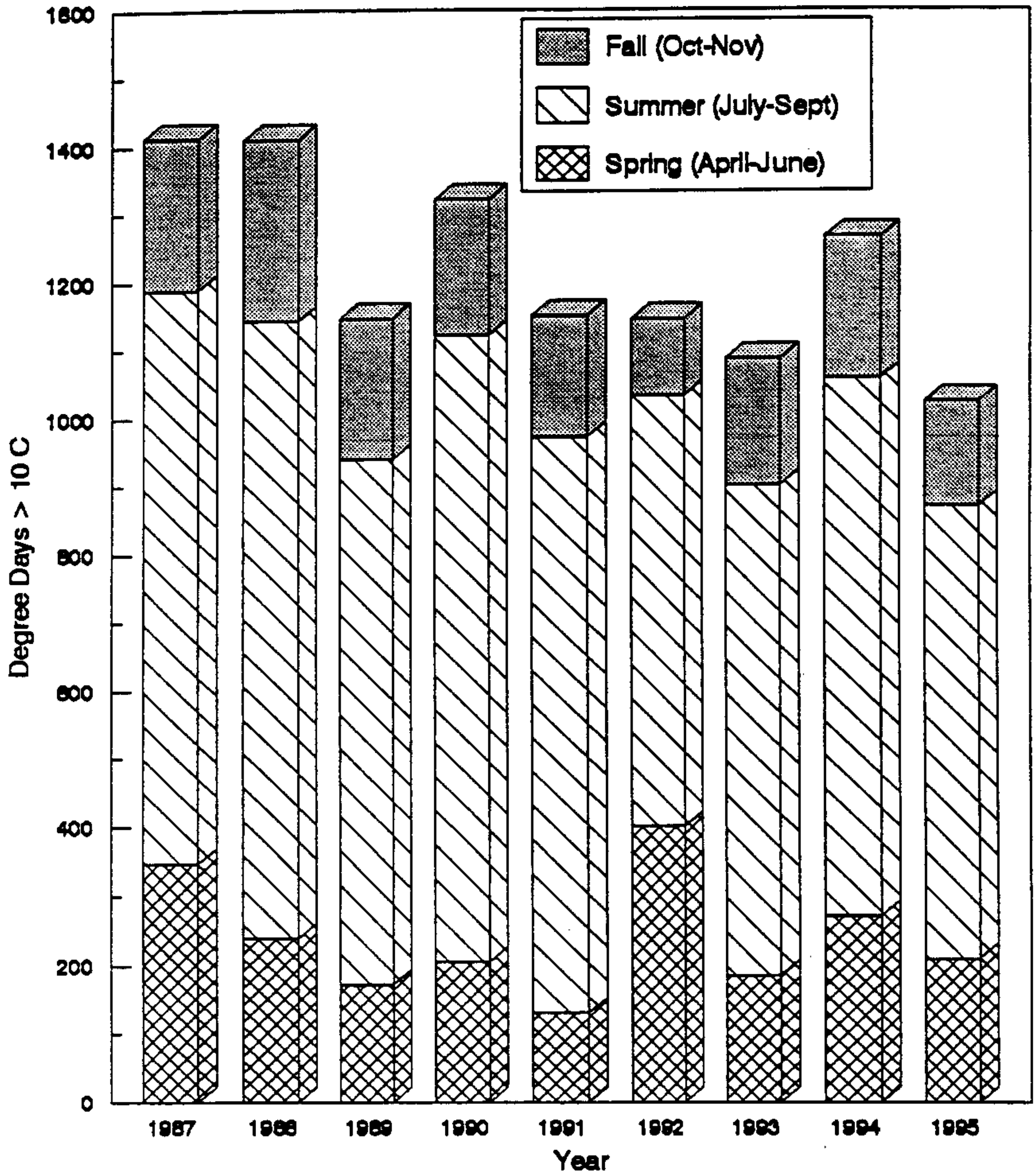

Figure 6. Degree days > 10^{0}C by season in Lower Granite Reservoir from 1987 through 1995.

development and survival of larval fishes (Bestgen and Williams 1994; Wang and Eckmann 1994; Kroll et al. 1992; Pepin 1991), but riverine temperatures were not highly significant in my modeling of egg through larval survival.

Consumption rate of fishes increases with water temperature (Vigg and Burley 1991; Niimi and Beamish 1974). Larval fishes are an important dietary item of juvenile fall chinook salmon *Oncorhynchus tshawytscha* (Curet 1994) and resident fishes (M. Davis, University of Idaho, Moscow, Idaho, personal communication) in Lower Granite Reservoir. Juvenile northern squawfish in Lower Granite Reservoir are probably most affected by predation from smallmouth bass (S. Anglea, University of Idaho, Moscow, Idaho, unpublished data), and predation by other species is probably negligible (M. Davis, University of Idaho, Moscow, Idaho, personal communication). Based on my abundance and mortality estimates, less than 2.5% of juvenile northern squawfish in Lower Granite Reservoir are consumed annually by smallmouth bass, compared to mean annual mortality of 82% ($Z = 1.70$). The influence of predation on annual mortality of larval northern squawfish is unknown. However, predation is probably not a significant component of annual mortality for juvenile northern squawfish in Lower Granite Reservoir.

Warmer temperatures generally benefit survival of fishes unless temperatures exceed optimal levels (Kroll et al. 1992; Brett 1979). Increased survival at a larger body size has been well documented for fishes (Wang and Eckmann 1994; Pepin

1993 and 1991; Rice et al. 1993; Buijse and Houthuijzen 1992), and abundance of juvenile northern squawfish in Lower Granite Reservoir is limited, in part, by growth rates. Juvenile growth is negatively correlated with mortality (Table 5). Later reservoir warming probably leads to a decreased length of growing season available to juvenile northern squawfish. Although not significant, I found negative correlations between juvenile growth rate and mean ($P = 0.51$) and median ($P = 0.45$) Julian date of temperatures $\geq 10^0$ C (Table 6).

A negative correlation of juvenile growth rate with duration of temperatures $\geq 20^0$ C ($P < 0.05$; Appendix Table 3) suggests that growth of juvenile northern squawfish may be inhibited at high temperatures. My data suggest that earlier occurrence of high temperatures ($\geq 20^0$ C) also reduces survival of larval northern squawfish (Table 3). Many fish exhibit growth inhibition at temperatures beyond some optimum level (Tacon and Cowey 1985; Ursin 1979), including the Colorado squawfish *Ptychocheilus lucius* (Bestgen and Williams 1994). The upper lethal temperature for northern squawfish is 29.3^0 C (Black 1953). Preferred temperature for most fishes is between 9.5^0 C (larval or age 0) and 13^0 C (adults) below their lethal temperature (Clark 1969), and optimal temperatures for growth are normally within $\pm$ 2^0C of preferred temperatures (Kellogg and Gift 1983). Mean water temperatures in July and August normally exceed 20^0C and have the greatest predictable effect on growth rate of juvenile northern squawfish (Table 7), with higher temperatures resulting in

Table 6. Correlation between variables included in significant ($P < 0.05$) predictive models for juvenile northern squawfish survival. Values in bold indicate significant ($P < 0.05$) correlations (Page 1 of 2).

Variable Included[1]	D 50 Kcfs	D 75 Kcfs	MN 75 Kcfs	D15C	Winter D10C	MD20C	MD15C	MD10C
Sample size (n)	11	11	11	10	10	10	10	10
Days ≥ 50 Kcfs	1.00	**0.92**	-0.00	-0.56	0.20	0.49	0.57	0.21
Days ≥ 75 Kcfs		1.00	-0.32	-0.48	0.20	0.29	0.36	0.09
MN ≥ 75 Kcfs*			1.00	-0.34	0.18	0.51	0.54	0.28
Days ≥ 15C				1.00	-0.29	-0.39	-0.53	0.01
Winter days ≥ 10C					1.00	0.14	0.43	0.54
MD ≥ 20C						1.00	**0.84**	0.59
MD ≥ 15C							1.00	**0.70**
MD ≥ 10C								1.00
MN ≥ 20C								
MN ≥ 15C								
MN ≥ 10C								
Mean secchi								
MOP forebay variance								
Winter forebay variance								
Non-MOP forebay variance								
Mean Non-MOP forebay level								
Instantaneous growth rate (G)								

Table 6. Correlation between variables included in significant ($P < 0.05$) predictive models for juvenile northern squawfish survival. Values in bold indicate significant ($P < 0.05$) correlations (Page 2 of 2).

Variable Included[1]	MN20C	MN15C	MN10C	Mean Secchi	MOP FB VAR.	Winter FB VAR.	Non-MOP FB VAR.	Non-MOP FB LEV.	Growth (G)
Sample size (n)	10	10	10	10	10	8	8	8	8
Days ≥ 50 Kcfs	0.26	0.41	0.24	**-0.92**[2]	0.55[2]	-0.08[3]	-0.44[3]	0.43[3]	0.49
Days ≥ 75 Kcfs	0.11	0.19	0.16	**-0.94**[2]	0.60[2]	0.18[3]	-0.40[3]	0.31[3]	0.57
MN ≥ 75 Kcfs	0.42	0.54	0.31	0.18[2]	-0.04[2]	-0.39[3]	-0.28[3]	0.44[3]	-0.16
Days ≥ 15C	-0.17	-0.32	-0.18	0.54	-0.28	0.29	0.41	-0.42	-0.16
Winter days≥10C	0.56	0.57	0.56	-0.32	**0.69**	-0.05	-0.63	0.58	-0.48
MD ≥ 20C	**0.84**	**0.79**	0.60	-0.37	0.18	-0.64	**-0.71**	**0.84**	0.16
MD ≥ 15C	0.61	**0.95**	**0.74**	-0.45	0.22	-0.67	**-0.84**	**0.90**	0.15
MD ≥ 10C	0.31	**0.82**	**0.96**	-0.21	0.34	-0.46	**-0.85**	**0.85**	-0.31
MN ≥ 20C	1.00	0.62	0.34	-0.08	0.31	-0.66	-0.58	**0.74**	0.45
MN ≥ 15C		1.00	**0.84**	-0.27	0.09	**-0.72**	**-0.85**	**0.91**	0.09
MN ≥ 10C			1.00	-0.27	0.35	-0.40	**-0.90**	**0.89**	-0.27
Mean secchi				1.00[2]	**-0.70**[2]	-0.11[3]	0.54[3]	-0.47[3]	-0.38
MOP forebay variance					1.00[2]	0.54[3]	-0.58[3]	0.48[3]	-0.57
Winter forebay variance						1.00[3]	0.22[3]	-0.38[3]	-0.43[4]
Non-MOP forebay variance							1.00[3]	**-0.96**[3]	0.05[4]
Mean Non-MOP forebay level								1.00[3]	0.02[4]
Instantaneous growth rate (G)									1.00

1 MN = Mean julian date, MD = Median julian date
2 Sample size (n) = 11
3 Sample size (n) = 9
4 Sample size (n) = 7

Table 7. Predictable effect (r^2) of monthly temperature conditions (1987-1994) on growth rates of larval and juvenile northern squawfish in Lower Granite Reservoir.

	Larval (n=7)		Juvenile (n=8)	
Month	Mean Temp. Vs. Growth	Max Temp. Vs. Growth	Mean Temp. Vs. Growth	Max Temp. Vs. Growth
April	----	----	0.02	0.01
May	----	----	0.05	0.10
June	0.00	0.00	0.06	0.18
July	0.07	0.02	0.50	0.30
August	0.03	0.04	0.36	0.04
September	0.00	0.00	0.20	0.27
October	----	----	0.00	0.03
November	----	----	0.23	0.05

decreased growth. Although growth of larval northern squawfish does not appear to be inhibited at high temperatures (Table 7), larval development may be impeded (Bestgen and Williams 1994).

Egg through larval development and juvenile growth are acting in a density independent fashion on the northern squawfish population in Lower Granite Reservoir and are apparently regulated by temperature conditions. This interpretation is supported by my earlier rejection of the hypothesis that density dependent factors are significant in determining survival of northern squawfish during these stages in Lower Granite Reservoir.

My analysis showed that increased water level fluctuations in Lower Granite Reservoir during June and July are negatively related to survival of larval northern squawfish (Table 3). Water level fluctuation has been hypothesized (Rieman and Beamesderfer 1990; Bennett et al. 1994a) but not demonstrated to affect survival of northern squawfish. Larval northern squawfish are most abundant in Lower Granite Reservoir during June and July (Bennett et al. 1991, 1993a, 1993b, 1994b, 1995), and rear in shallow low gradient areas where they may be subject to stranding on the shore or in nearshore vegetation when water levels decline (Bennett et al. 1994a). Wave action and low motility due to their small size may also contribute to stranding of larval northern squawfish.

The influence of water level fluctuation on mortality of juvenile northern squawfish is less clear. Forebay mean water levels (non-MOP conditions) and variation (MOP, non-MOP, and winter conditions) were significant predictors of juvenile northern squawfish survival in Lower Granite Reservoir. Water level variations in individual months of MOP conditions (May - September) were not. Juvenile northern squawfish normally inhabit shallow (< 1 m) water only until their first winter (Beamesderfer 1983), and those older than age 0 are probably sufficiently mobile to avoid the effect of water level fluctuations. Forebay levels and variations appear to be collinear with the timing of reservoir temperatures (Table 6), providing additional support for the importance of timing of reservoir temperatures in limiting the abundance of juvenile northern squawfish in Lower Granite Reservoir.

Increased duration of flows ≥ 50 or 75 Kcfs and later mean Julian date of flows ≥ 75 Kcfs coincides with higher mortality of juvenile northern squawfish in Lower Granite Reservoir (Table 5). Mean secchi disc readings were significant predictors of juvenile northern squawfish survival and are significantly ($P < 0.001$) negatively correlated with annual duration of flows ≥ 50 and ≥ 75 Kcfs (Table 6). Mean secchi reading is also negatively related ($P = 0.36$) to growth of juvenile northern squawfish. Increased turbidity may inhibit feeding success and growth of juvenile northern squawfish, and the effect of flow on northern squawfish survival is probably realized through its effect on turbidity and temperature conditions in Lower Granite Reservoir.

The importance of earlier median Julian date (MD) $\geq$ 75 Kcfs in reducing egg-larval survival of northern squawfish (Table 3) is unclear because of its collinearity with water level fluctuations in June ($P = 0.02$) and July ($P = 0.07$; Table 8). Discharge has been suggested as a possible spawning cue for Colorado squawfish (Tyus 1990; Nesler et al. 1988). My data indicate that MD $\geq$ 75 Kcfs occurs shortly before the probable spawning time (June) of northern squawfish (Bratovich 1984) in Lower Granite Reservoir. Earlier flows $\geq$ 75 Kcfs may result in earlier spawning and subsequent exposure of eggs and larvae to less favorable conditions, possibly through food limitation.

My data suggest that larval mortality is probably more important in limiting abundance of northern squawfish than spawning or hatching success. The significant predictive models for egg through larval survival of northern squawfish generally relate to environmental conditions in Lower Granite Reservoir, and explain the majority of the variation in survival ($r^2 > 0.81$; Table 3). Relative abundance of unidentifiable larval cyprinids (< 18 mm) is much higher than those of identifiable size, suggesting that abundance of northern squawfish in Lower Granite Reservoir is probably limited by mortality during the early larval stage of development. Further work should more closely evaluate mortality between egg and late larval (> 18 mm) stages for

Table 8. Correlation between variables included in significant ($P < 0.05$) predictive models for egg through larval survival of northern squawfish. Values in bold indicate significant ($P < 0.05$) correlations.

Variable Included[1]	MD 75 Kcfs	MN20C	FB Var. June	FB Var. July	CWR July DD>10C
Sample size (n)	11	11	11	11	11
Lower Granite Reservoir					
MD ≥ 75 Kcfs	1.00	0.09	-0.69	-0.57	0.33
MN ≥ 20^0 C		1.00	-0.56	-0.21	-0.35
June FB Variance			1.00	0.48	0.27
July FB Variance				1.00	0.26
Clearwater River					
July DD > 10^0 C					1.00

1 MD = Median Julian date,
MN = Mean Julian date,
FB = Forebay,
DD = Degree days.

northern squawfish in mainstem reservoirs to better define the limited life history stage. As fish collections in Lower Granite Reservoir continue, the importance of unexplained (or additional) variables in limiting abundance of northern squawfish may become more clear. Low power may have obscured significance of some variables due to regressing on a limited number of data points for egg through larval (7) and juvenile (8) models. Low power was evidenced by wide confidence intervals for estimated parameters in non-significant models (± 2 times the parameter estimate or greater) that included zero (Appendix Table 5; Appendix Table 6). Low power may also have affected significance of correlations between modeled variables, and further data may strengthen interpretations that I based on these correlations.

My data indicate that reservoir management practices may be important in determining survival of northern squawfish in Lower Granite Reservoir. Larval cyprinids prefer those habitats least available (embayment, sand, and cobble) upstream of Rkm 201.2 in Lower Granite Reservoir (Figure 4). Increases in availability of preferred rearing habitats (particularly sand and cobble) above Rkm 201.2 due to natural reservoir shallowing or in-water disposal of dredged materials may enhance survival of larval cyprinids including northern squawfish.

Flow augmentation used in recent years to facilitate smolt outmigration results in increased duration of higher flows and later reservoir warming. I found that both conditions reduced survival of juvenile northern squawfish (Table 5), although cooler water temperatures in Lower Granite Reservoir may enhance survival of larval northern squawfish (Table 3). My results suggested that water temperatures decrease duration of high temperatures (> 20^0 C) that may adversely affect development of larval northern squawfish. Management of Lower Granite Reservoir at MOP conditions through June and July enhances survival of larval northern squawfish (Table 3), probably by reducing stranding of larvae on the shore. Stable water levels may also increase survival of juvenile northern squawfish (Table 5) although the relationship is less clear. I believe that summer water level fluctuations of 1-2 feet, particularly during June and July, may have a pronounced negative impact on their survival and should be more closely examined as an alternative to predator management.

SUMMARY

1) Northern squawfish abundance in Lower Granite Reservoir is limited by highest mortality in the egg through larval stages of development, however juvenile (ages 0+ through 3+) mortality is also important in limiting the abundance of some year classes.

2) I found no evidence of density dependent mortality in either the egg through larval or juvenile stages of development.

3) Water level fluctuations are most important in predicting egg through larval survival of northern squawfish;

4) Although density dependent factors are not significant in determining overall egg through larval mortality rates, the availability of preferred or suitable rearing habitat, at least in part, limits survival of larval northern squawfish in Lower Granite Reservoir.

5) Survival of juvenile northern squawfish in Lower Granite Reservoir is limited by growth rates. Growth rates were related to timing of temperature conditions. Earlier reservoir warming provides a longer growing season that results in increased growth.

REFERENCES

Beamesderfer, R.C. and B.E. Rieman. 1991. Abundance and distribution of northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:439-447.

Beamesderfer, R.C. 1983. Reproductive biology, early life history, and microhabitat of northern squawfish (*Ptychocheilus oregonensis*) in the St. Joe River, Idaho. Masters's thesis. University of Idaho, Moscow.

Bennett, D.H., P.M. Bratovich, W. Knox, D. Palmer, and H. Hansel. 1983. Status of the warmwater fishery and the potential of improving warmwater fish habitat in the lower Snake reservoirs. Completion Report. U.S. Army Corps of Engineers, Walla Walla Washington.

Bennett, D.H., and F.C. Shrier. 1986. Effects of sediment dredging and in-water disposal on fishes in Lower Granite Reservoir, Idaho-Washington. Completion Report. U.S. Army Corps of Engineers, Walla Walla Washington.

Bennett, D.H., L.K. Dunsmoor, and J.A. Chandler. 1988. Fish and benthic community abundance at proposed in-water disposal sites, Lower Granite Reservoir. Completion Report. U.S. Army Corps of Engineers, Walla Walla Washington.

Bennett, D.H., L.K. Dunsmoor, J.A. Chandler, and T. Barila. 1989. Use of dredged material to enhance fish habitat in Lower Granite Reservoir, Idaho-Washington. Proceedings of the Symposium on the effects of dredging on anadromous fishes in the Pacific Northwest. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Bennett, D.H., J.A. Chandler, and L.K. Dunsmoor. 1990. Lower Granite Reservoir in-water disposal test: Results of the fishery, benthic, and habitat monitoring program-Year 1 (1988). Completion Report. U.S. Army Corps of Engineers, Walla Walla, Washington.

Bennett, D.H., J.A. Chandler, and G. Chandler. 1991. Lower Granite Reservoir in-water disposal test: Results of the fishery, benthic and habitat monitoring program-Year 2 (1989). Completion Report. U.S. Army Corps of Engineers, Walla Walla, Washington.

Bennett, D.H., T.J. Dresser, Jr., T.S. Curet, K.B. Lepla, and M.A. Madsen. 1993a. Lower Granite Reservoir in-water disposal test: Results of monitoring the fish community activity at disposal and reference sites in Lower Granite Reservoir, Idaho-Washington-Year 3 (1990). Completion Report. U.S. Army Corps of Engineers, Walla Walla, Washington.

Bennett, D.H., T.J. Dresser, Jr., T.S. Curet, K.B. Lepla, and M.A. Madsen. 1993b. Lower Granite Reservoir in-water disposal test: Results of monitoring the fish community activity at disposal and reference sites in Lower Granite Reservoir, Idaho-Washington-Year 4 (1991). Completion Report. U.S. Army Corps of Engineers, Walla Walla, Washington.

Bennett, D.H., T.J. Dresser, Jr., and M.A. Madsen. 1994a. Effects of reservoir operations at minimum pool and regulated inflows of low temperature water on resident fishes in Lower Granite Reservoir, Idaho-Washington. Completion Report. U.S. Army Corps of Engineers, Walla Walla, Washington.

Bennett, D.H., T.J. Dresser, Jr., and M.A. Madsen. 1994b. Evaluation of the effects of the 1992 test drawdown on the fish communities in Lower Granite and Little Goose reservoirs, Washington. Completion Report. U.S. Army Corps of Engineers, Walla Walla Washington.

Bennett, D.H., T.J. Dresser, Jr., and M.A. Madsen. 1995. Monitoring fish community activity at disposal and reference sites in Lower Granite Reservoir, Idaho-Washington year 6 (1993). Draft Report. U.S. Army Corps of Engineers, Walla Walla Washington.

Bestgen, K.R. and M.A. Williams. 1994. Effects of fluctuating and constant temperatures on early development and survival of Colorado squawfish. Transactions of the American Fisheries Society 123:574-579.

Black, E.C. 1953. Upper lethal temperatures of some British Columbia freshwater fishes. Journal of the Fisheries Research Board of Canada 10(4):196-210.

Bratovich, P.M. 1985. Reproduction and early life histories of selected resident fishes in lower Snake River reservoirs. Master's thesis. University of Idaho, Moscow.

Brett, J.R. 1979. Environmental factors and growth. Pages 599-675 *in* W.S. Hoar, D.J. Randall and J.R. Brett, ed. Fish physiology, Volume VIII. Academic Press, Inc. New York.

Buijse, A.D. and R.P. Houthuijzen. 1992. Piscivory, growth, and size-selective mortality of age 0 pikeperch (*Stizostedion lucioperca*). Canadian Journal of Fisheries and Aquatic Sciences 49:894-902.

Carlander, K.D. 1969. Handbook of freshwater fishery biology. Volume 1. The Iowa State University Press. Ames, Iowa.

Casey, O.E. 1962. The life history of the northern squawfish in Cascade Reservoir. Master's thesis. University of Idaho, Moscow.

Chandler, J.A. 1993. Consumption rates and estimated total loss of juvenile salmonids by northern squawfish in Lower Granite Reservoir, Washington. Master's thesis. University of Idaho, Moscow.

Clark, J.R. 1969. Thermal pollution and aquatic life. Scientific American 220(3):19-27.

Curet, T. 1994. Habitat use, food habits and the influence of predation on subyearling chinook salmon in Lower Granite and Little Goose reservoirs. Master's thesis. University of Idaho, Moscow.

Dempster, J.P. 1975. Animal population ecology. Academic Press. New York.

Falter, C.M. 1969. Digestive rates and daily rations of northern squawfish in the St. Joe River, Idaho. Doctoral dissertation. University of Idaho, Moscow.

Funk, W.H., C.M. Falter and A.J. Lingg. 1985. Limnology of an impounded series in the lower Snake River. Final Report. United States Corps of Engineers, Walla Walla, Washington.

Ichthus Data Systems. 1988. MIX, an interactive program for fitting mixtures of distributions. Ichthus Data Systems. Hamilton, Ontario.

Kellogg, R.L. and J.J. Gift. 1983. Relationship between optimum temperatures for growth and preferred temperatures for the young of four fish species. Transactions of the American Fisheries Society 112:424-430.

Kroll, K.J., K.P. Van Eenennaam, S.I. Doroshov, J.E. Hamilton, and T.R. Russell. 1992. Effect of water temperature and formulated diets on growth and survival of larval paddlefish. Transactions of the American Fisheries Society 121:538-543.

LaBolle, L.D., Jr., H.W. Li, and B.C. Mundy. 1985. Comparison of two samplers for quantitatively collecting larval fishes in upper littoral habitats. Journal of Fish Biology 26 (2):139-146.

Lechowicz, J.J. 1982. The sampling characteristics of electivity indices. Oecologia (Berl.) 52:22-30.

Morris, R.F. 1963. Predictive population equations based on key factors. Pages 250-255 *in* R.H. Tamarin, ed. Population regulation. Dowden, Hutchinson & Ross, Inc. Stroudsburg, Pennsylvania.

Nesler, T.P., R.T. Muth and A.F. Wasowicz. 1988. Evidence for baseline flow spikes as spawning cues for Colorado squawfish in the Yampa River, Colorado. American Fisheries Society Symposium 5:68-79.

Niimi, A.J. and F.W.H. Beamish. 1974. Bioenergetics and growth of largemouth bass (*Micropterus salmoides*) in relation to body weight and temperature. Canadian Journal of Zoology 52:447-456.

Patten B.G., and D.T. Rodman. Reproductive behavior of the northern squawfish *Ptychocheilus oregonensis*. Transactions of the American Fisheries Society 98(1):108-111.

Pepin, P. 1993. An appraisal of the size-dependent mortality hypothesis for larval fish: Comparison of a multispecies study with an empirical review. Canadian Journal of Fisheries and Aquatic Sciences 50:2166-2174.

Pepin, P. 1991. Effect of temperature and size on development, mortality, and survival rates of the pelagic early life history stages of marine fish. Canadian Journal of Fisheries and Aquatic Sciences 48:503-518.

Rice, J.A., and 6 co-authors. 1993. Growth rate variation and larval survival: Inferences from an individual-based size-dependent predation model. Canadian Journal of Fisheries and Aquatic Sciences 50:133-142.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin 191. Fisheries Research Board of Canada, Department of the Environment, Fisheries and Marine Service. Ottawa.

Ried, G.E. 1971. Life history of the northern squawfish Ptychocheilus oregonensis (Richardson), in the St. Joe River, Idaho. Master's Thesis. University of Idaho, Moscow.

Rieman, B.E. and R.C. Beamesderfer. 1990. Dynamics of a northern squawfish population and the potential to reduce predation on juvenile salmonids in a Columbia River reservoir. North American Journal of Fisheries Management 10:228-241.

Rieman, B.E., R.C. Beamesderfer, S. Vigg and T.P. Poe. 1991. Estimated loss of juvenile salmonids to predation by northern squawfish, walleyes, and smallmouth bass in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:448-458.

Scheaffer, R.L., W. Mendenhall, and L. Ott. 1990. Elementary survey sampling, fourth edition. Duxbury Press, Belmont, California.

Scheidegger, K.J. and M.B. Bain. 1995. Larval fish distribution and microhabitat use in free-flowing and regulated rivers. Copeia 1:125-135.

Simpson, J.C. and R.L. Wallace. 1982. Fishes of Idaho, second edition. University of Idaho Press, Moscow.

Tabor, R.A., R. S. Shively, and T.P. Poe. 1993. Predation on juvenile salmonids in the Columbia River near Richland, Washington. North American Journal of Fisheries Management 13:831-838.

Tacon, A.G.J., and C.B. Cowey. 1985. Protein and amino acid requirements. Pp 155-184 *in* P. Tytler and P. Calow. Fish energetics: New perspectives. The Johns Hopkins University Press. Baltimore.

Tyus, H.M. 1990. Potamodromy and reproduction of Colorado squawfish in the Green River basin, Colorado and Utah. Transactions of the American Fisheries Society 119:1035-1047.

Ursin, E. 1979. Principles of growth in fishes. Pp 63-87 *in* P.J. Miller, ed. Fish phenology: Anabolic adaptiveness in teleosts. Symposia of the Zoological Society of London, No. 44.

Varley, G.C. and G.R. Gradwell. 1968. Population models for the Winter Moth. Pp 132-142 *in* T.R.E. Southwood, ed. Insect Abundance. Blackwell Scientific Publications, Oxford.

Vigg, S. and C.C. Burley. 1991. Temperature-dependent maximum daily consumption of juvenile salmonids by northern squawfish (*Ptychocheilus oregonensis*) from the Columbia River. Canadian Journal of Fisheries and Aquatic Sciences 48:2491-2498.

Vigg, S., T.P. Poe, L.A. Prendergast, and H.C. Hansel. 1991. Rates of consumption of juvenile salmonids and alternative prey fish by northern squawfish, walleyes, smallmouth bass, and channel catfish in John Day Reservoir, Columbia River. Transactions of the American Fisheries Society 120:421-438.

Wang, N. and R. Eckmann. 1994. Effects of temperature and food density on egg development, larval survival and growth of perch (*Perca fluviatilis* L.). Aquaculture 122:323-333.

Ward, D.L., J.H. Petersen, and J.J. Loch. 1995. Index of predation on juvenile salmonids by northern squawfish in the lower and middle Columbia River and in the lower Snake River. Transactions of the American Fisheries Society 124:321-334.

Zimmerman, M.P., C. Knutsen, D.L. Ward, and K. Anderson. 1995. Development of a systemwide predator control program: Indexing and fisheries evaluation. Pages 357-429 *in* C.F. Willis and D.L.Ward, ed. Development of a systemwide predator control program: stepwise implementation of a predation index, predator control fisheries, and evaluation plan in the Columbia River basin. Volume 2. Contract DE-BI79-90BP07084. Annual report to Bonneville Power Administration. Portland.

Appendix Table 1. Model significance and coefficient of variation of competing models for predicting egg-larval survival of northern squawfish. Sample size (n) was 7 for all models unless noted (Page 1 of 2).
Model: ln(# Larvae) = ln(# Eggs) + Variable

Variable[1]	Model Significance	r^2	Period Examined
Lower Granite Reservoir			
Days ≥ 50 Kcfs	0.18	0.57	Annual
Days ≥ 75 Kcfs	0.21	0.54	Annual
Days ≥ 100 Kcfs	0.14	0.62	Annual
MN ≥ 50 Kcfs	0.23	0.52	Annual
MN ≥ 75 Kcfs	0.21	0.54	Annual
MD ≥ 50 Kcfs	0.13	0.64	Annual
MD ≥ 75 Kcfs	0.02	0.85	Annual
June DD ≥ 20°C	0.23	0.52	June
June DD ≥ 15°C	0.23	0.52	June
June DD ≥ 10°C	0.22	0.53	June
July DD ≥ 20°C	0.21	0.54	July
July DD ≥ 15°C	0.19	0.57	July
July DD ≥ 10°C	0.19	0.57	July
August DD ≥ 20°C	0.20	0.56	August
August DD ≥ 15°C	0.20	0.55	August
August DD ≥ 10°C	0.20	0.55	August
Sept. DD ≥ 20°C	0.16	0.60	September
Sept. DD ≥ 15°C	0.12	0.65	September
Sept. DD ≥ 10°C	0.12	0.65	September
MN ≥ 20°C	0.02[2]	0.87	March 1 - Sept. 15
MN ≥ 15°C	0.18	0.57	March 1 - Sept. 15
MN ≥ 10°C	0.17	0.59	March 1 - Sept. 15
MD ≥ 20°C	0.12[2]	0.66	March 1 - Sept. 15
MD ≥ 15°C	0.19	0.56	March 1 - Sept. 15
MD ≥ 10°C	0.17	0.58	March 1 - Sept. 15
Mean secchi	0.20	0.56	March 1 - June 30
Days secchi ≥ 1.5'	0.13	0.63	March 1 - June 30
Days secchi ≥ 2.0'	0.15	0.61	March 1 - June 30
MOP Forebay var.	0.06	0.75	April 15-Sept. 30
Forebay var. May	0.12	0.65	May
Forebay var. June	0.00	0.94	June
Forebay var. July	0.03	0.81	July
Forebay var. August	0.22	0.53	August
Forebay var. Sept.	0.22	0.53	September
Clearwater River			
Days ≥ 20 Kcfs	0.17	0.59	Annual
Days ≥ 30 Kcfs	0.23	0.53	Annual
May DD ≥ 10°C	0.16	0.60	May
June DD ≥ 20°C	0.16	0.59	June
June DD ≥ 15°C	0.21	0.54	June
June DD ≥ 10°C	0.23	0.52	June
July DD ≥ 20°C	0.22	0.53	July

Appendix Table 1. Model significance and coefficient of variation of competing models for predicting egg-larval survival of northern squawfish. Sample size (n) was 7 for all models unless noted (Page 2 of 2).
Model: ln(# Larvae) = ln(# Eggs) + Variable

Variable[1]	Model Significance	r^2	Period Examined
Clearwater River			
July DD $\geq$ 15^{0}C	0.10	0.68	July
July DD $\geq$ 10^{0}C	0.04	0.81	July
MN $\geq$ 20^{0}C	0.82	0.13	March 1 - Sept. 15
MN $\geq$ 15^{0}C	0.16	0.60	March 1 - Sept. 15
MN $\geq$ 10^{0}C	0.22	0.53	March 1 - Sept. 15
MD $\geq$ 20^{0}C	0.77	0.16	March 1 - Sept. 15
MD $\geq$ 15^{0}C	0.17	0.59	March 1 - Sept. 15
MD $\geq$ 10^{0}C	0.21	0.55	March 1 - Sept. 15
Snake River			
Days $\geq$ 50 Kcfs	0.19	0.57	Annual
Days $\geq$ 75 Kcfs	0.15	0.61	Annual
May DD $\geq$ 15^{0}C	0.20	0.55	May
May DD $\geq$ 10^{0}C	0.23	0.52	May
June DD $\geq$ 20^{0}C	0.20	0.55	June
June DD $\geq$ 15^{0}C	0.23	0.52	June
June DD $\geq$ 10^{0}C	0.22	0.53	June
July DD $\geq$ 20^{0}C	0.17	0.59	July
July DD $\geq$ 15^{0}C	0.19	0.57	July
July DD $\geq$ 10^{0}C	0.19	0.57	July
MN $\geq$ 20^{0}C	0.23	0.52	March 1 - Sept. 15
MN $\geq$ 15^{0}C	0.21	0.53	March 1 - Sept. 15
MN $\geq$ 10^{0}C	0.18	0.57	March 1 - Sept. 15
MD $\geq$ 20^{0}C	0.22	0.53	March 1 - Sept. 15
MD $\geq$ 15^{0}C	0.22	0.53	March 1 - Sept. 15
MD $\geq$ 10^{0}C	0.19	0.56	March 1 - Sept. 15
Instantaneous growth (G)	0.20	0.55	Annual

1 MN = Mean Julian date, MD = Median Julian date, DD=Degree days
2 Sample size (n) = 6

Appendix Table 2. Model significance and coefficient of variation (r^2) of competing models for predicting juvenile northern squawfish survival. Sample size (n) was 8 for all models.
Model: $\ln(CPUE_{n+1}) = \ln(CPUE_n) + \text{Variable}$

Variable[1]	Model Significance	r^2	Period Examined
Days ≥ 20 Kcfs	0.09	0.62	June 1 - May 31
Days ≥ 25 Kcfs	0.09	0.63	June 1 - May 31
Days ≥ 35 Kcfs	0.08	0.64	June 1 - May 31
Days ≥ 50 Kcfs	0.04	0.72	Annual
Days ≥ 75 Kcfs	0.05	0.71	Annual
Days ≥ 100 Kcfs	0.07	0.65	Annual
MN ≥ 50 Kcfs	0.06	0.68	Annual
MN ≥ 75 Kcfs	0.03	0.76	Annual
MD ≥ 50 Kcfs	0.07	0.65	Annual
MD ≥ 75 Kcfs	0.07	0.67	Annual
Days ≥ 20°C	0.08	0.64	Annual
Days ≥ 15°C	0.03	0.75	Annual
Days ≥ 10°C	0.06	0.68	Annual
Winter Days ≥ 10°C	0.04	0.72	Dec. 1-Feb. 28
MN ≥ 20°C	0.03	0.74	Annual
MN ≥ 15°C	0.02	0.79	Annual
MN ≥ 10°C	0.02	0.79	Annual
MD ≥ 20°C	0.03	0.76	Annual
MD ≥ 15°C	0.02	0.79	Annual
MD ≥ 10°C	0.02	0.81	Annual
DD > 20°C	0.07	0.66	Annual
DD > 15°C	0.07	0.65	Annual
DD > 10°C	0.09	0.63	Annual
Mean secchi	0.05	0.71	March 1-June 30
Days secchi ≥ 1.5'	0.05	0.69	March 1-June 30
Days secchi ≥ 2.0'	0.07	0.66	March 1-June 30
MOP Forebay variance	0.03	0.74	April 15-Sept. 30
Forebay var. May	0.05	0.70	May
Forebay var. June	0.05	0.69	June
Forebay var. July	0.06	0.69	July
Forebay var. August	0.07	0.66	August
Forebay var. Sept.	0.08	0.65	September
Winter forebay var.	0.03	0.75	Dec. 1-Feb. 28
Winter forebay level	0.08	0.63	Dec. 1-Feb. 28
Non-MOP forebay var.	0.02	0.80	Oct. 1-April 14
Non-MOP forebay level	0.02	0.79	Oct. 1-April 14
Sampling effort	0.08	0.64	Annual
Instantaneous growth (G)	0.03	0.76	Annual

1 MN = Mean julian date,
MD = Median julian date,
DD = Degree Days.

Appendix Table 3. Coefficient of variation (r^2) between variables examined in predictive models for juvenile northern squawfish survival (Page 1 of 9).

Variable Included[1]	D 50 Kcfs	D 75 Kcfs	D 100 Kcfs	MN 50 Kcfs	MN 75 Kcfs
Sample size (n)	11	11	11	11	11
Days ≥ 50 Kcfs	1.00	**0.92**	**0.87**	-0.29	-0.00
Days ≥ 75 Kcfs		1.00	**0.95**	-0.50	-0.44
Days ≥ 100 Kcfs			1.00	-0.46	-0.32
MN ≥ 50 Kcfs				1.00	**0.84**
MN ≥ 75 Kcfs					1.00
MD ≥ 50 Kcfs					
MD ≥ 75 Kcfs					
Days ≥ 20°C					
Days ≥ 15°C					
Days ≥ 10°C					
MN ≥ 20°C					
MN ≥ 15°C					
MN ≥ 10°C					
MD ≥ 20°C					
MD ≥ 15°C					
MD ≥ 10°C					
DD ≥ 20°C					
DD > 15°C					
DD > 10°C					
MN Secchi					
Days Secchi ≥ 1.5'					
Days Secchi ≥ 2.0'					
MOP forebay variance					
Forebay var. May					
Forebay var. June					
Forebay var. July					
Forebay var. August					
Forebay var. Sept.					
Winter forebay var.					
Winter forebay level					
Non-MOP forebay var.					
Non-MOP forebay level					
Days ≥ 20 Kcfs					
Days ≥ 25 Kcfs					
Days ≥ 35 Kcfs					
Winter days ≥ 10°C					
Sampling effort					
Instantaneous growth rate (G)					

Appendix Table 3. Coefficient of variation (r^2) between variables examined in predictive models for juvenile northern squawfish survival (Page 2 of 9).

Variable Included[1]	MD50 Kcfs	MD75 Kcfs	D20C	D15C	D10C
Sample size (n)	11	11	10	10	10
Days ≥ 50 Kcfs	0.16	-0.50	-0.27	-0.56	-0.59
Days ≥ 75 Kcfs	0.33	-0.59	-0.11	-0.48	-0.45
Days ≥ 100 Kcfs	0.38	**-0.73**	-0.12	-0.32	-0.33
MN ≥ 50 Kcfs	0.03	0.62	-0.12	-0.23	-0.24
MN ≥ 75 Kcfs	-0.26	0.42	-0.05	-0.34	-0.31
MD ≥ 50 Kcfs	1.00	0.02	0.08	-0.05	0.05
MD ≥ 75 Kcfs		1.00	0.10	-0.24	-0.19
Days ≥ 20°C			1.00	0.11	0.53
Days ≥ 15°C				1.00	**0.75**
Days ≥ 10°C					1.00
MN ≥ 20°C					
MN ≥ 15°C					
MN ≥ 10°C					
MD ≥ 20°C					
MD ≥ 15°C					
MD ≥ 10°C					
DD ≥ 20°C					
DD > 15°C					
DD > 10°C					
MN Secchi					
Days Secchi ≥ 1.5'					
Days Secchi ≥ 2.0'					
MOP forebay variance					
Forebay var. May					
Forebay var. June					
Forebay var. July					
Forebay var. August					
Forebay var. Sept.					
Winter forebay var.					
Winter forebay level					
Non-MOP forebay var.					
Non-MOP forebay level					
Days ≥ 20 Kcfs					
Days ≥ 25 Kcfs					
Days ≥ 35 Kcfs					
Winter days ≥ 10°C					
Sampling effort					
Instantaneous growth rate (G)					

Appendix Table 3. Coefficient of variation (r^2) between variables examined in predictive models for juvenile northern squawfish survival (Page 3 of 9).

Variable Included[1]	MN20C	MN15C	MN10C	MD20C	MD15C
Sample size (n)	10	10	10	10	10
Days ≥ 50 Kcfs	0.26	0.41	0.24	0.49	0.57
Days ≥ 75 Kcfs	0.11	0.19	0.16	0.29	0.36
Days ≥ 100 Kcfs	0.10	0.07	0.06	0.27	0.22
MN ≥ 50 Kcfs	0.35	0.31	0.10	0.38	0.31
MN ≥ 75 Kcfs	0.42	0.54	0.31	0.51	0.54
MD ≥ 50 Kcfs	0.11	0.17	0.03	0.15	0.24
MD ≥ 75 Kcfs	0.20	0.51	0.37	0.27	0.45
Days ≥ 20⁰C	-0.37	0.16	0.56	-0.19	0.04
Days ≥ 15⁰C	-0.17	-0.32	-0.18	-0.39	-0.53
Days ≥ 10⁰C	-0.59	-0.40	-0.17	**-0.65**	-0.56
MN ≥ 20⁰C	1.00	0.62	0.34	**0.84**	0.61
MN ≥ 15⁰C		1.00	**0.84**	**0.79**	**0.95**
MN ≥ 10⁰C			1.00	0.60	**0.74**
MD ≥ 20⁰C				1.00	**0.84**
MD ≥ 15⁰C					1.00
MD ≥ 10⁰C					
DD ≥ 20⁰C					
DD > 15⁰C					
DD > 10⁰C					
MN Secchi					
Days Secchi ≥ 1.5'					
Days Secchi ≥ 2.0'					
MOP forebay variance					
Forebay var. May					
Forebay var. June					
Forebay var. July					
Forebay var. August					
Forebay var. Sept.					
Winter forebay var.					
Winter forebay level					
Non-MOP forebay var.					
Non-MOP forebay level					
Days ≥ 20 Kcfs					
Days ≥ 25 Kcfs					
Days ≥ 35 Kcfs					
Winter days ≥ 10⁰C					
Sampling effort					
Instantaneous growth rate (G)					

Appendix Table 3. Coefficient of variation (r^2) between variables examined in predictive models for juvenile northern squawfish survival (Page 4 of 9).

Variable Included[1]	MD10C	DD>20	DD>15	DD>10
Sample size (n)	10	11	11	11
Days ≥ 50 Kcfs	0.21	-0.24	-0.40	-0.59
Days ≥ 75 Kcfs	0.09	-0.07	-0.21	-0.38
Days ≥ 100 Kcfs	0.02	-0.18	-0.27	-0.37
MN ≥ 50 Kcfs	0.05	0.00	-0.10	-0.17
MN ≥ 75 Kcfs	0.28	-0.10	-0.18	-0.29
MD ≥ 50 Kcfs	0.02	0.34	0.19	0.15
MD ≥ 75 Kcfs	0.31	0.44	0.33	0.24
Days ≥ 20°C	0.53	**0.86**[2]	**0.98**[2]	**0.92**[2]
Days ≥ 15°C	0.01	-0.33[2]	0.04[2]	0.38[2]
Days ≥ 10°C	-0.00	0.27[2]	0.51[2]	**0.76**[2]
MN ≥ 20°C	0.31	-0.31[2]	-0.32[2]	-0.40[2]
MN ≥ 15°C	**0.82**	0.26[2]	0.17[2]	-0.05[2]
MN ≥ 10°C	**0.96**	0.48[2]	0.53[2]	0.33[2]
MD ≥ 20°C	0.59	-0.08[2]	-0.16[2]	-0.34[2]
MD ≥ 15°C	**0.70**	0.25[2]	0.07[2]	-0.21[2]
MD ≥ 10°C	1.00	0.39[2]	0.49[2]	0.36[2]
DD > 20°C		1.00	**0.92**	**0.78**
DD > 15°C			1.00	**0.94**
DD > 10°C				1.00
MN Secchi				
Days Secchi ≥ 1.5'				
Days Secchi ≥ 2.0'				
MOP forebay variance				
Forebay var. May				
Forebay var. June				
Forebay var. July				
Forebay var. August				
Forebay var. Sept.				
Winter forebay var.				
Winter forebay level				
Non-MOP forebay var.				
Non-MOP forebay level				
Days ≥ 20 Kcfs				
Days ≥ 25 Kcfs				
Days ≥ 35 Kcfs				
Winter days ≥ 10°C				
Sampling effort				
Instantaneous growth rate (G)				

Appendix Table 3. Coefficient of variation (r^2) between variables examined in predictive models for juvenile northern squawfish survival (Page 5 of 9).

Variable Included[1]	MN Secchi	Secchi ≥ 1.5'	Secchi ≥ 2.0'	MOP FB Var.
Sample size (n)	11	11	11	11
Days ≥ 50 Kcfs	**-0.92**	**0.86**	**0.89**	0.55
Days ≥ 75 Kcfs	**-0.94**	**0.97**	**0.96**	0.60
Days ≥ 100 Kcfs	**-0.86**	**0.95**	**0.96**	**0.66**
MN ≥ 50 Kcfs	0.45	-0.57	**-0.61**	-0.21
MN ≥ 75 Kcfs	0.18	-0.36	-0.37	-0.04
MD ≥ 50 Kcfs	-0.11	0.20	0.19	0.16
MD ≥ 75 Kcfs	0.50	**-0.74**	**-0.75**	-0.43
Days ≥ 20^{0}C	0.11[2]	-0.06[2]	-0.13[2]	0.38[2]
Days ≥ 15^{0}C	0.54[2]	-0.41[2]	-0.32[2]	-0.28[2]
Days ≥ 10^{0}C	0.53[2]	-0.37[2]	-0.34[2]	-0.03[2]
MN ≥ 20^{0}C	-0.08[2]	0.04[2]	0.04[2]	0.31[2]
MN ≥ 15^{0}C	-0.27[2]	0.03[2]	0.05[2]	0.09[2]
MN ≥ 10^{0}C	-0.27[2]	0.07[2]	0.07[2]	0.35[2]
MD ≥ 20^{0}C	-0.37[2]	0.17[2]	0.21[2]	0.18[2]
MD ≥ 15^{0}C	-0.45[2]	0.18[2]	0.21[2]	0.22[2]
MD ≥ 10^{0}C	-0.21[2]	-0.01[2]	0.05[2]	0.34[2]
DD > 20^{0}C	0.10	-0.13	-0.21	0.14
DD > 15^{0}C	0.24	-0.21	-0.28	0.10
DD > 10^{0}C	0.43	-0.34	-0.39	-0.01
MN Secchi	1.00	**-0.89**	**-0.93**	**-0.70**
Days Secchi ≥ 1.5'		1.00	**0.97**	0.59
Days Secchi ≥ 2.0'			1.00	**0.63**
MOP forebay variance				1.00
Forebay var. May				
Forebay var. June				
Forebay var. July				
Forebay var. August				
Forebay var. Sept.				
Winter forebay var.				
Winter forebay level				
Non-MOP forebay var.				
Non-MOP forebay level				
Days ≥ 20 Kcfs				
Days ≥ 25 Kcfs				
Days ≥ 35 Kcfs				
Winter days ≥ 10^{0}C				
Sampling effort				
Instantaneous growth rate (G)				

Appendix Table 3. Coefficient of variation (r^2) between variables examined in predictive models for juvenile northern squawfish survival (Page 6 of 9).

Variable Included[1]	May FB Var.	June FB Var.	July FB Var.	August FB Var.
Sample size (n)	11	11	11	11
Days ≥ 50 Kcfs	0.11	0.28	0.43	-0.04
Days ≥ 75 Kcfs	0.19	0.37	0.35	-0.05
Days ≥ 100 Kcfs	0.38	0.42	0.40	-0.24
MN ≥ 50 Kcfs	-0.30	-0.57	-0.24	0.38
MN ≥ 75 Kcfs	-0.43	-0.38	0.17	0.32
MD ≥ 50 Kcfs	0.01	-0.29	-0.27	0.17
MD ≥ 75 Kcfs	-0.59	**-0.69**	-0.57	**0.70**
Days ≥ 20^{0}C	-0.36[2]	0.08[2]	**0.81**[2]	0.41[2]
Days ≥ 15^{0}C	0.24[2]	-0.08[2]	0.04[2]	**-0.70**[2]
Days ≥ 10^{0}C	0.16[2]	0.23[2]	0.40[2]	-0.26[2]
MN ≥ 20^{0}C	-0.34[2]	-0.70[2]	-0.38[2]	-0.13[2]
MN ≥ 15^{0}C	**-0.69**[2]	-0.66[2]	0.19[2]	0.45[2]
MN ≥ 10^{0}C	-0.60[2]	-0.42[2]	0.57[2]	0.44[2]
MD ≥ 20^{0}C	-0.26[2]	-0.53[2]	-0.09[2]	0.14[2]
MD ≥ 15^{0}C	-0.58[2]	-0.53[2]	0.10[2]	0.51[2]
MD ≥ 10^{0}C	-0.49[2]	-0.40[2]	0.60[2]	0.28[2]
DD > 20^{0}C	-0.44	-0.09	-0.05	**0.75**
DD > 15^{0}C	-0.40	-0.08	0.08	0.52
DD > 10^{0}C	-0.24	-0.05	0.03	0.26
MN Secchi	-0.18	-0.43	-0.40	-0.00
Days Secchi ≥ 1.5'	0.27	0.52	0.47	-0.18
Days Secchi ≥ 2.0'	0.35	0.52	0.45	-0.27
MOP forebay var.	0.35	0.54	**0.61**	0.07
Forebay var. May	1.00	**0.64**	0.00	-0.60
Forebay var. June		1.00	0.48	-0.26
Forebay var. July			1.00	-0.14
Forebay var. August				1.00
Forebay var. Sept.				
Winter forebay var.				
Winter forebay level				
Non-MOP forebay var.				
Non-MOP forebay level				
Days ≥ 20 Kcfs				
Days ≥ 25 Kcfs				
Days ≥ 35 Kcfs				
Winter days ≥ 10^{0}C				
Sampling effort				
Instantaneous growth rate (G)				

Appendix Table 3. Coefficient of variation (r^2) between variables examined in predictive models for juvenile northern squawfish survival (Page 7 of 9).

Variable Included[1]	Sept. FB Var.	Winter FB Var.	Winter FB Lev.	Non-MOP FB Var.
Sample size (n)	11	9	9	9
Days ≥ 50 Kcfs	0.33	-0.08	0.38	-0.44
Days ≥ 75 Kcfs	0.25	0.18	0.04	-0.40
Days ≥ 100 Kcfs	0.31	0.29	0.10	-0.28
MN ≥ 50 Kcfs	-0.03	-0.43	0.45	-0.01
MN ≥ 75 Kcfs	-0.06	-0.39	0.56	-0.28
MD ≥ 50 Kcfs	0.09	0.06	-0.36	-0.12
MD ≥ 75 Kcfs	-0.02	-0.64	-0.01	-0.13
Days ≥ 20^{0}C	-0.43[2]	0.35[4]	**-0.80**[4]	-0.40[4]
Days ≥ 15^{0}C	-0.01[2]	0.29[4]	-0.20[4]	0.41[4]
Days ≥ 10^{0}C	-0.40[2]	0.53[4]	-0.66[4]	0.40[4]
MN ≥ 20^{0}C	0.46[2]	-0.66[4]	**0.72**[4]	-0.58[4]
MN ≥ 15^{0}C	0.29[2]	**-0.72**[4]	0.30[4]	**-0.85**[4]
MN ≥ 10^{0}C	0.20[2]	-0.40[4]	-0.06[4]	**-0.90**[4]
MD ≥ 20^{0}C	**0.69**[2]	-0.64[4]	0.62[4]	**-0.71**[4]
MD ≥ 15^{0}C	0.37[2]	-0.67[4]	0.37[4]	**-0.84**[4]
MD ≥ 10^{0}C	0.31[2]	-0.46[4]	0.01[4]	**-0.85**[4]
DD > 20^{0}C	-0.31	-0.01	**-0.75**	-0.31
DD > 15^{0}C	-0.32	0.11	**-0.81**	-0.31
DD > 10^{0}C	-0.31	0.21	**-0.82**	-0.10
MN Secchi	-0.37	-0.11	-0.17	0.54
Days Secchi ≥ 1.5'	0.15	0.36	0.00	-0.31
Days Secchi ≥ 2.0'	0.31	0.30	0.08	-0.32
MOP forebay variance	0.27	0.54	-0.12	-0.58
Forebay var. May	0.39	0.41	0.18	0.63
Forebay var. June	-0.11	**0.76**	-0.23	0.37
Forebay var. July	-0.25	0.40	-0.05	-0.36
Forebay var. August	-0.29	-0.37	-0.31	-0.34
Forebay var. Sept.	1.00	-0.43	0.55	-0.26
Winter forebay var.		1.00	-0.52	0.22
Winter forebay level			1.00	-0.01
Non-MOP forebay var.				1.00
Non-MOP forebay level				
Days ≥ 20 Kcfs				
Days ≥ 25 Kcfs				
Days ≥ 35 Kcfs				
Winter days ≥ 10^{0}C				
Sampling effort				
Instantaneous growth rate (G)				

Appendix Table 3. Coefficient of variation (r^2) between variables examined in predictive models for juvenile northern squawfish survival (Page 8 of 9).

Variable Included[1]	Non-MOP FB Lev.	Winter Days≥20 Kcfs	Winter Days≥25 Kcfs	Winter Days>35 Kcfs
Sample size (n)	9	9	9	9
Days ≥ 50 Kcfs	0.43	**0.86**	**0.87**	0.60
Days ≥ 75 Kcfs	0.31	**0.78**	**0.86**	0.58
Days ≥ 100 Kcfs	0.21	0.62	**0.74**	0.49
MN ≥ 50 Kcfs	0.20	-0.41	-0.52	-0.39
MN ≥ 75 Kcfs	0.44	-0.14	-0.31	-0.32
MD ≥ 50 Kcfs	0.04	-0.00	0.02	-0.14
MD ≥ 75 Kcfs	0.21	-0.15	-0.36	-0.33
Days ≥ 20°C	0.25[4]	0.26	0.12	-0.30
Days ≥ 15°C	-0.42[4]	**-0.69**	**-0.67**	-0.45
Days ≥ 10°C	-0.53[4]	-0.51	-0.58	**-0.67**
MN ≥ 20°C	**0.74**[4]	0.56	0.11	0.39
MN ≥ 15°C	**0.91**[4]	0.57	0.27	0.11
MN ≥ 10°C	**0.89**[4]	0.56	0.32	0.06
MD ≥ 20°C	**0.84**[4]	0.47	0.40	0.23
MD ≥ 15°C	**0.90**[4]	0.58	0.43	0.14
MD ≥ 10°C	**0.85**[4]	0.38	0.20	-0.09
DD > 20°C	0.16	0.52	0.37	-0.16
DD > 15°C	0.16	0.28	0.16	-0.27
DD > 10°C	-0.05	-0.09	-0.17	-0.46
MN Secchi	-0.47	**-0.91**	**-0.89**	-0.48
Days Secchi ≥ 1.5'	0.20	**0.72**	**0.86**	0.64
Days Secchi ≥ 2.0'	0.23	**0.73**	**0.83**	0.53
MOP forebay variance	0.48	0.60	0.45	-0.15
Forebay var. May	-0.60	-0.19	-0.11	-0.14
Forebay var. June	-0.51	0.36	0.38	0.08
Forebay var. July	0.28	0.58	0.48	0.06
Forebay var. August	0.30	0.49	0.30	0.01
Forebay var. Sept.	0.38	0.49	0.34	-0.10
Winter forebay var.	-0.38	-0.12[5]	0.06[5]	-0.15[5]
Winter forebay level	0.24	-0.31[5]	-0.46[5]	-0.17[5]
Non-MOP forebay var.	**-0.96**	-0.75[5]	-0.60[5]	-0.19[5]
Non-MOP forebay level	1.00	0.64[5]	0.47[5]	0.11[5]
Days ≥ 20 Kcfs		1.00	**0.93**	0.47
Days ≥ 25 Kcfs			1.00	**0.71**
Days ≥ 35 Kcfs				1.00
Winter days ≥ 10°C				
Sampling effort				
Instantaneous growth rate (G)				

Appendix Table 3. Coefficient of variation (r^2) between variables examined in predictive models for juvenile northern squawfish survival (Page 9 of 9).

Variable Included[1]	Winter D10C	Sampling Effort	Growth (G)
Sample size (n)	10	9	8
Days ≥ 50 Kcfs	0.20	0.49	0.49
Days ≥ 75 Kcfs	0.20	0.47	0.57
Days ≥ 100 Kcfs	0.14	**0.70**	0.38
MN ≥ 50 Kcfs	0.14	0.10	-0.23
MN ≥ 75 Kcfs	0.18	0.19	-0.16
MD ≥ 50 Kcfs	0.30	0.10	-0.07
MD ≥ 75 Kcfs	0.35	-0.47	-0.15
Days ≥ 20°C	0.57	-0.67	**-0.78**
Days ≥ 15°C	-0.29	0.17	-0.16
Days ≥ 10°C	-0.01	-0.42	-0.63
MN ≥ 20°C	-0.31	**0.78**	0.45
MN ≥ 15°C	0.41	0.27	0.09
MN ≥ 10°C	0.61	0.07	-0.27
MD ≥ 20°C	0.14	0.68	0.16
MD ≥ 15°C	0.43	0.27	0.15
MD ≥ 10°C	0.54	0.18	-0.31
DD ≥ 20°C	0.59	**-0.74**	-0.68
DD > 15°C	0.48	**-0.68**	**-0.77**
DD > 10°C	0.27	-0.61	**-0.79**
MN Secchi	-0.32	-0.34	-0.38
Days Secchi ≥ 1.5'	0.08	0.46	0.62
Days Secchi ≥ 2.0'	0.09	0.55	0.52
MOP forebay variance	**0.69**	0.09	-0.57
Forebay var. May	-0.24	0.32	-0.11
Forebay var. June	-0.05	-0.23	-0.29
Forebay var. July	0.49	0.06	-0.67
Forebay var. August	**0.67**	-0.64	-0.28
Forebay var. Sept.	-0.01	**0.67**	0.17
Winter forebay var.	-0.06[4]	-0.24[5]	-0.43[5]
Winter forebay level	-0.37[4]	**0.88**[5]	0.64[5]
Non-MOP forebay var.	-0.63[4]	-0.22[5]	0.05[5]
Non-MOP forebay level	0.58[4]	0.37[5]	0.02[5]
Days ≥ 20 Kcfs	0.43[3]	-0.48[5]	0.03[5]
Days ≥ 25 Kcfs	0.17[3]	-0.21[5]	0.29[5]
Days ≥ 35 Kcfs	-0.27[3]	0.31[5]	0.73[5]
Winter days ≥ 10°C	1.00	-0.42[4]	-0.48
Sampling effort		1.00	0.42[5]
Instantaneous growth rate (G)			1.00

1 MN=Mean julian date, MD=Median julian date, DD=Degree days
2 Sample size (n) = 10
3 Sample size (n) = 9
4 Sample size (n) = 8
5 Sample size (n) = 7

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 1 of 21).

Variable Included[1]	D 50 Kcfs	D 75 Kcfs	D 100 Kcfs	MN 50 Kcfs	MN 75 Kcfs
Sample size (n)	11	11	11	11	11
Lower Granite Reservoir					
Days ≥ 50 Kcfs	1.00	**0.92**	**0.87**	-0.29	-0.00
Days ≥ 75 Kcfs		1.00	**0.95**	-0.50	-0.44
Days ≥ 100 Kcfs			1.00	-0.46	-0.32
MN ≥ 50 Kcfs				1.00	**0.84**
MN ≥ 75 Kcfs					1.00
MD ≥ 50 Kcfs					
MD ≥ 75 Kcfs					
June DD ≥ 20°C					
June DD ≥ 15°C					
June DD ≥ 10°C					
July DD ≥ 20°C					
July DD ≥ 15°C					
July DD ≥ 10°C					
August DD ≥ 20°C					
August DD ≥ 15°C					
August DD ≥ 10°C					
Sept. DD ≥ 20°C					
Sept. DD ≥ 15°C					
Sept. DD ≥ 10°C					
MN ≥ 20°C					
MN ≥ 15°C					
MN ≥ 10°C					
MD ≥ 20°C					
MD ≥ 15°C					
MD ≥ 10°C					
Mean secchi					
Days secchi ≥ 1.5'					
Days secchi ≥ 2.0'					
MOP Forebay var.					
Forebay var. May					
Forebay var. June					
Forebay var. July					
Forebay var. August					
Forebay var. Sept.					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 2 of 21).

Variable Included[1]	MD 50 Kcfs	MD 75 Kcfs	DD>20^0 June	DD>15^0 June	DD>10^0 June
Sample size (n)	11	11	11	11	11
Lower Granite Reservoir					
Days $\geq$ 50 Kcfs	0.16	-0.50	**-0.72**	**-0.60**	-0.49
Days $\geq$ 75 Kcfs	0.33	-0.59	**-0.64**	-0.33	-0.24
Days $\geq$ 100 Kcfs	0.38	**-0.73**	-0.50	-0.19	-0.09
MN $\geq$ 50 Kcfs	0.03	0.62	-0.01	-0.41	-0.53
MN $\geq$ 75 Kcfs	-0.26	0.42	-0.20	**-0.63**	-0.67
MD $\geq$ 50 Kcfs	1.00	0.02	-0.10	-0.01	-0.09
MD $\geq$ 75 Kcfs		1.00	0.13	-0.26	-0.43
June DD $\geq$ 20^{0}C			1.00	**0.77**	**0.67**
June DD $\geq$ 15^{0}C				1.00	**0.96**
June DD $\geq$ 10^{0}C					1.00
July DD $\geq$ 20^{0}C					
July DD $\geq$ 15^{0}C					
July DD $\geq$ 10^{0}C					
August DD $\geq$ 20^{0}C					
August DD $\geq$ 15^{0}C					
August DD $\geq$ 10^{0}C					
Sept. DD $\geq$ 20^{0}C					
Sept. DD $\geq$ 15^{0}C					
Sept. DD $\geq$ 10^{0}C					
MN $\geq$ 20^{0}C					
MN $\geq$ 15^{0}C					
MN $\geq$ 10^{0}C					
MD $\geq$ 20^{0}C					
MD $\geq$ 15^{0}C					
MD $\geq$ 10^{0}C					
Mean secchi					
Days secchi $\geq$ 1.5'					
Days secchi $\geq$ 2.0'					
MOP Forebay var.					
Forebay var. May					
Forebay var. June					
Forebay var. July					
Forebay var. August					
Forebay var. Sept.					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 3 of 21).

Variable Included[1]	DD>20⁰ July	DD>15⁰ July	DD>10⁰ July	DD>20⁰ August	DD>15⁰ August
Sample size (n)	11	11	11	11	11
Lower Granite Reservoir					
Days ≥ 50 Kcfs	-0.21	-0.20	-0.20	-0.17	-0.22
Days ≥ 75 Kcfs	-0.14	-0.06	-0.06	-0.01	-0.05
Days ≥ 100 Kcfs	-0.27	-0.18	-0.18	-0.13	-0.17
MN ≥ 50 Kcfs	-0.15	-0.28	-0.28	0.10	0.02
MN ≥ 75 Kcfs	-0.08	-0.17	-0.17	-0.05	-0.16
MD ≥ 50 Kcfs	-0.37	-0.18	-0.18	0.54	0.46
MD ≥ 75 Kcfs	0.30	0.15	0.15	0.48	0.51
June DD ≥ 20⁰C	0.17	0.27	0.27	-0.01	0.09
June DD ≥ 15⁰C	0.18	0.29	0.29	-0.02	0.07
June DD ≥ 10⁰C	0.02	0.14	0.14	-0.23	-0.14
July DD ≥ 20⁰C	1.00	**0.88**	**0.88**	0.45	0.57
July DD ≥ 15⁰C		1.00	**1.00**	0.61	0.68
July DD ≥ 10⁰C			1.00	0.61	0.68
August DD ≥ 20⁰C				1.00	0.96
August DD ≥ 15⁰C					1.00
August DD ≥ 10⁰C					
Sept. DD ≥ 20⁰C					
Sept. DD ≥ 15⁰C					
Sept. DD ≥ 10⁰C					
MN ≥ 20⁰C					
MN ≥ 15⁰C					
MN ≥ 10⁰C					
MD ≥ 20⁰C					
MD ≥ 15⁰C					
MD ≥ 10⁰C					
Mean secchi					
Days secchi ≥ 1.5'					
Days secchi ≥ 2.0'					
MOP Forebay var.					
Forebay var. May					
Forebay var. June					
Forebay var. July					
Forebay var. August					
Forebay var. Sept.					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 4 of 21).

Variable Included[1]	DD>10^0 August	DD>20^0 Sept.	DD>15^0 Sept.	DD>10^0 Sept.	MN≥20^0
Sample size (n)	11	11	11	11	11
Lower Granite Reservoir					
Days ≥ 50 Kcfs	-0.21	-0.20	-0.17	-0.17	-0.05
Days ≥ 75 Kcfs	-0.05	0.03	-0.09	-0.09	-0.10
Days ≥ 100 Kcfs	-0.17	0.05	-0.07	-0.07	-0.01
MN ≥ 50 Kcfs	0.02	-0.03	0.19	0.19	0.24
MN ≥ 75 Kcfs	-0.16	-0.20	0.18	0.18	0.14
MD ≥ 50 Kcfs	0.46	**0.65**	0.30	0.30	0.61
MD ≥ 75 Kcfs	0.51	0.15	0.21	0.21	0.09
June DD ≥ 20^{0}C	0.09	0.31	0.25	0.25	0.08
June DD ≥ 15^{0}C	0.07	0.33	0.12	0.12	-0.11
June DD ≥ 10^{0}C	-0.14	0.15	-0.04	-0.04	-0.09
July DD ≥ 20^{0}C	0.57	0.23	0.20	0.17	-0.67
July DD ≥ 15^{0}C	**0.68**	0.46	0.32	0.32	-0.53
July DD ≥ 10^{0}C	**0.68**	0.46	0.31	0.31	-0.53
August DD ≥ 20^{0}C	**0.96**	**0.78**	0.49	-0.01	0.10
August DD ≥ 15^{0}C	**1.00**	**0.71**	0.36	0.36	-0.04
August DD ≥ 10^{0}C	1.00	**0.71**	0.36	0.36	-0.04
Sept. DD ≥ 20^{0}C		1.00	**0.80**	**0.80**	0.32
Sept. DD ≥ 15^{0}C			1.00	**1.00**	0.31
Sept. DD ≥ 10^{0}C				1.00	0.31
MN ≥ 20^{0}C					1.00
MN ≥ 15^{0}C					
MN ≥ 10^{0}C					
MD ≥ 20^{0}C					
MD ≥ 15^{0}C					
MD ≥ 10^{0}C					
Mean secchi					
Days secchi ≥ 1.5'					
Days secchi ≥ 2.0'					
MOP Forebay var.					
Forebay var. May					
Forebay var. June					
Forebay var. July					
Forebay var. August					
Forebay var. Sept.					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 5 of 21).

Variable Included[1]	MN≥15⁰	MN≥10⁰	MD≥20⁰	MD≥15⁰	MD≥10⁰
Sample size (n)	11	11	11	11	11
Lower Granite Reservoir					
Days ≥ 50 Kcfs	0.48	0.46	0.38	0.49	0.34
Days ≥ 75 Kcfs	0.35	0.34	0.29	0.42	0.22
Days ≥ 100 Kcfs	0.18	0.23	0.22	0.25	0.12
MN ≥ 50 Kcfs	0.33	0.22	0.28	0.30	0.09
MN ≥ 75 Kcfs	0.45	0.39	0.24	0.34	0.25
MD ≥ 50 Kcfs	0.18	0.13	0.26	0.26	0.03
MD ≥ 75 Kcfs	0.45	0.29	0.34	0.40	0.32
June DD ≥ 20⁰C	-0.57	-0.26	-0.40	**-0.68**	-0.08
June DD ≥ 15⁰C	**-0.78**	-0.58	-0.54	**-0.73**	-0.43
June DD ≥ 10⁰C	**-0.88**	**-0.64**	-0.59	**-0.82**	-0.50
July DD ≥ 20⁰C	0.23	0.05	-0.05	0.24	0.20
July DD ≥ 15⁰C	0.12	0.00	-0.32	0.09	0.07
July DD ≥ 10⁰C	0.12	0.00	-0.33	0.09	0.07
August DD ≥ 20⁰C	0.43	0.16	0.06	0.46	0.11
August DD ≥ 15⁰C	0.36	0.10	0.04	0.42	0.13
August DD ≥ 10⁰C	0.36	0.10	0.04	0.42	0.13
Sept. DD ≥ 20⁰C	0.17	0.21	0.05	0.14	0.18
Sept. DD ≥ 15⁰C	0.34	0.51	0.27	0.20	0.47
Sept. DD ≥ 10⁰C	0.34	0.51	0.27	0.20	0.47
MN ≥ 20⁰C	-0.01	0.15	0.22	-0.08	0.14
MN ≥ 15⁰C	1.00	**0.83**	**0.74**	**0.94**	**0.73**
MN ≥ 10⁰C		1.00	**0.75**	**0.66**	**0.92**
MD ≥ 20⁰C			1.00	**0.75**	**0.77**
MD ≥ 15⁰C				1.00	0.56
MD ≥ 10⁰C					1.00
Mean secchi					
Days secchi ≥ 1.5'					
Days secchi ≥ 2.0'					
MOP Forebay var.					
Forebay var. May					
Forebay var. June					
Forebay var. July					
Forebay var. August					
Forebay var. Sept.					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 6 of 21).

Variable Included[1]	Mean Secchi	Secchi ≥ 1.5'	Secchi ≥ 2.0'	FB Var. MOP	FB Var. May
Sample size (n)	11	11	11	11	11
Lower Granite Reservoir					
Days ≥ 50 Kcfs	**-0.92**	**0.86**	**0.89**	0.55	0.11
Days ≥ 75 Kcfs	**-0.94**	**0.97**	**0.96**	0.60	0.19
Days ≥ 100 Kcfs	**-0.86**	**0.95**	**0.96**	**0.66**	0.38
MN ≥ 50 Kcfs	0.45	-0.57	**-0.61**	-0.21	-0.51
MN ≥ 75 Kcfs	0.18	-0.36	-0.37	-0.04	-0.30
MD ≥ 50 Kcfs	-0.11	0.20	0.19	0.16	0.01
MD ≥ 75 Kcfs	0.50	**-0.74**	**-0.75**	-0.43	-0.59
June DD ≥ 20°C	**0.62**	-0.57	-0.53	-0.08	0.13
June DD ≥ 15°C	0.42	-0.18	-0.19	-0.05	0.41
June DD ≥ 10°C	0.31	-0.07	-0.06	-0.06	0.50
July DD ≥ 20°C	0.02	-0.11	-0.17	0.15	-0.19
July DD ≥ 15°C	0.00	-0.01	-0.09	0.26	-0.30
July DD ≥ 10°C	0.00	-0.01	-0.09	0.26	-0.30
August DD ≥ 20°C	0.10	-0.12	-0.20	0.07	-0.50
August DD ≥ 15°C	0.09	-0.16	-0.21	0.12	-0.37
August DD ≥ 10°C	0.09	-0.16	-0.21	0.12	-0.37
Sept. DD ≥ 20°C	0.11	-0.01	-0.07	0.20	-0.30
Sept. DD ≥ 15°C	0.17	-0.09	-0.16	0.03	-0.53
Sept. DD ≥ 10°C	0.17	-0.09	-0.16	0.03	-0.53
MN ≥ 20°C	0.22	-0.22	-0.13	-0.20	-0.14
MN ≥ 15°C	-0.42	0.19	0.16	0.17	-0.59
MN ≥ 10°C	-0.43	0.20	0.22	0.26	-0.55
MD ≥ 20°C	-0.35	0.12	0.17	0.07	-0.19
MD ≥ 15°C	-0.48	0.26	0.23	0.23	-0.40
MD ≥ 10°C	-0.36	0.08	0.16	0.24	-0.42
Mean secchi	1.00	**-0.89**	**-0.93**	**-0.70**	-0.18
Days secchi ≥ 1.5'		1.00	**0.97**	0.59	0.27
Days secchi ≥ 2.0'			1.00	**0.63**	0.35
MOP Forebay var.				1.00	0.35
Forebay var. May					1.00
Forebay var. June					
Forebay var. July					
Forebay var. August					
Forebay var. Sept.					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 7 of 21).

Variable Included[1]	FB Var. June	FB Var. July	FB Var. August	FB Var. Sept.	CWR D 20 Kcfs
Sample size (n)	11	11	11	11	11
Lower Granite Reservoir					
Days ≥ 50 Kcfs	0.28	0.43	-0.04	0.33	**0.92**
Days ≥ 75 Kcfs	0.37	0.35	-0.05	0.25	**0.77**
Days ≥ 100 Kcfs	0.42	0.40	-0.24	0.31	**0.72**
MN ≥ 50 Kcfs	-0.57	-0.24	0.38	-0.28	-0.10
MN ≥ 75 Kcfs	-0.38	0.17	0.32	-0.06	0.19
MD ≥ 50 Kcfs	-0.29	-0.27	0.17	0.09	0.17
MD ≥ 75 Kcfs	**-0.69**	-0.57	**0.70**	-0.02	-0.41
June DD ≥ 20°C	-0.10	0.02	-0.23	-0.06	**-0.84**
June DD ≥ 15°C	0.29	-0.04	-0.41	-0.16	**-0.74**
June DD ≥ 10°C	0.38	0.01	**-0.60**	-0.13	**-0.62**
July DD ≥ 20°C	0.27	0.10	0.54	-0.14	-0.29
July DD ≥ 15°C	0.31	0.34	0.54	-0.44	-0.26
July DD ≥ 10°C	0.31	0.34	0.54	-0.44	-0.26
August DD ≥ 20°C	-0.21	-0.15	**0.79**	-0.36	-0.09
August DD ≥ 15°C	-0.12	-0.21	**0.79**	-0.26	-0.21
August DD ≥ 10°C	-0.12	-0.21	**0.79**	-0.26	-0.21
Sept. DD ≥ 20°C	-0.24	0.04	0.34	-0.18	-0.22
Sept. DD ≥ 15°C	-0.47	0.16	0.22	-0.06	-0.14
Sept. DD ≥ 10°C	-0.47	0.16	0.22	-0.06	-0.14
MN ≥ 20°C	-0.56	-0.21	-0.23	0.19	0.07
MN ≥ 15°C	-0.41	-0.02	**0.70**	0.22	0.50
MN ≥ 10°C	-0.52	0.16	0.36	0.40	0.37
MD ≥ 20°C	-0.50	-0.37	0.22	**0.74**	0.29
MD ≥ 15°C	-0.24	-0.16	**0.70**	0.26	0.50
MD ≥ 10°C	-0.45	0.07	0.26	0.60	0.20
Mean secchi	-0.43	-0.40	-0.00	-0.37	**-0.75**
Days secchi ≥ 1.5'	0.52	0.47	-0.18	0.15	**0.73**
Days secchi ≥ 2.0'	0.52	0.45	-0.27	0.31	**0.72**
MOP Forebay var.	0.54	**0.61**	0.07	0.27	0.33
Forebay var. May	**0.64**	0.00	-0.60	0.39	-0.06
Forebay var. June	1.00	0.48	-0.26	-0.11	0.17
Forebay var. July		1.00	-0.14	-0.25	0.39
Forebay var. August			1.00	-0.29	0.04
Forebay var. Sept.				1.00	0.10

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 8 of 21).

Variable Included[1]	CWR D 30 Kcfs	CWR DD>10^0 May	CWR DD>20^0 June	CWR DD>15^0 June	CWR DD>10^0 June
Sample size (n)	11	11	11	11	11
Lower Granite Reservoir					
Days ≥ 50 Kcfs	**0.74**	**-0.67**	-0.51	**-0.75**	**-0.72**
Days ≥ 75 Kcfs	**0.73**	-0.57	-0.48	-0.60	-0.54
Days ≥ 100 Kcfs	0.55	-0.42	-0.33	-0.43	-0.41
MN ≥ 50 Kcfs	-0.09	-0.01	0.04	-0.17	-0.32
MN ≥ 75 Kcfs	0.11	-0.09	-0.25	-0.39	-0.51
MD ≥ 50 Kcfs	0.36	-0.12	-0.03	-0.07	-0.07
MD ≥ 75 Kcfs	-0.05	0.01	-0.06	-0.08	-0.10
June DD ≥ 20^0C	-0.87	**0.86**	0.46	**0.91**	**0.88**
June DD ≥ 15^0C	**-0.72**	**0.74**	0.50	**0.90**	**0.93**
June DD ≥ 10^0C	**-0.68**	**0.68**	0.50	**0.86**	**0.91**
July DD ≥ 20^0C	**-0.05**	0.13	-0.13	0.05	0.08
July DD ≥ 15^0C	0.01	0.25	-0.14	0.16	0.20
July DD ≥ 10^0C	0.01	0.25	-0.14	0.16	0.20
August DD ≥ 20^0C	0.37	-0.01	-0.20	-0.09	-0.06
August DD ≥ 15^0C	0.26	0.06	-0.10	0.01	0.03
August DD ≥ 10^0C	0.26	0.06	-0.10	0.01	0.03
Sept. DD ≥ 20^0C	0.09	0.34	-0.23	0.20	0.24
Sept. DD ≥ 15^0C	0.03	0.29	-0.51	0.01	0.05
Sept. DD ≥ 10^0C	0.03	0.29	-0.51	0.01	0.05
MN ≥ 20^0C	0.06	0.15	-0.02	0.07	0.07
MN ≥ 15^0C	**0.71**	-0.59	**-0.74**	**-0.84**	**-0.82**
MN ≥ 10^0C	0.45	-0.30	**-0.84**	**-0.62**	-0.58
MD ≥ 20^0C	0.40	-0.39	-0.60	**-0.60**	-0.58
MD ≥ 15^0C	0.77	**-0.61**	**-0.66**	**-0.84**	**-0.84**
MD ≥ 10^0C	0.27	-0.13	**-0.74**	-0.44	-0.39
Mean secchi	**-0.69**	0.49	0.57	**0.63**	**0.59**
Days secchi ≥ 1.5'	**0.60**	-0.48	-0.41	-0.48	-0.42
Days secchi ≥ 2.0'	0.57	-0.42	-0.40	-0.45	-0.39
MOP Forebay var.	0.27	0.09	-0.28	-0.15	-0.22
Forebay var. May	-0.34	0.19	0.56	0.38	0.30
Forebay var. June	0.02	0.08	0.23	0.13	0.12
Forebay var. July	0.11	0.10	-0.26	-0.07	-0.10
Forebay var. August	0.44	-0.29	-0.29	-0.41	-0.43
Forebay var. Sept.	-0.01	-0.03	-0.22	-0.16	-0.16

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 9 of 21).

Variable Included[1]	CWR DD>20⁰ July	CWR DD>15⁰ July	CWR DD>10⁰ July	CWR MN≥20⁰	CWR MN≥15⁰
Sample size (n)	11	11	11	10	11
Lower Granite Reservoir					
Days ≥ 50 Kcfs	-0.54	-0.43	-0.21	0.55	0.45
Days ≥ 75 Kcfs	-0.55	-0.40	-0.19	0.50	0.29
Days ≥ 100 Kcfs	-0.56	-0.47	-0.25	0.52	0.25
MN ≥ 50 Kcfs	0.60	0.15	0.09	0.09	0.28
MN ≥ 75 Kcfs	0.40	0.13	0.11	0.08	0.29
MD ≥ 50 Kcfs	0.08	-0.11	-0.06	0.59	0.04
MD ≥ 75 Kcfs	0.65	0.46	0.33	-0.17	0.09
June DD ≥ 20⁰C	0.24	0.39	0.29	-0.63	**-0.66**
June DD ≥ 15⁰C	0.04	0.19	0.10	-0.49	**-0.64**
June DD ≥ 10⁰C	-0.20	0.00	-0.07	-0.39	-0.56
July DD ≥ 20⁰C	0.53	**0.73**	**0.70**	**-0.66**	-0.33
July DD ≥ 15⁰C	0.49	**0.83**	**0.80**	**-0.69**	**-0.67**
July DD ≥ 10⁰C	0.49	**0.83**	**0.80**	**-0.69**	**-0.67**
August DD ≥ 20⁰C	**0.66**	**0.65**	0.60	-0.06	-0.34
August DD ≥ 15⁰C	**0.66**	**0.73**	**0.71**	-0.25	-0.37
August DD ≥ 10⁰C	**0.66**	**0.73**	**0.71**	-0.25	-0.37
Sept. DD ≥ 20⁰C	0.41	0.39	0.35	-0.04	-0.46
Sept. DD ≥ 15⁰C	0.31	0.18	0.09	0.10	-0.22
Sept. DD ≥ 10⁰C	0.31	0.18	0.09	0.10	-0.22
MN ≥ 20⁰C	-0.10	-0.32	-0.35	0.61	0.17
MN ≥ 15⁰C	0.20	0.07	0.13	0.36	0.46
MN ≥ 10⁰C	-0.10	-0.11	-0.04	0.32	0.35
MD ≥ 20⁰C	-0.07	-0.36	-0.28	**0.67**	**0.78**
MD ≥ 15⁰C	0.24	0.06	0.15	0.45	0.56
MD ≥ 10⁰C	-0.09	-0.05	0.03	0.23	0.35
Mean secchi	0.53	0.30	0.06	-0.39	-0.35
Days secchi ≥ 1.5'	-0.58	-0.40	-0.22	0.39	0.18
Days secchi ≥ 2.0'	**-0.67**	-0.45	-0.23	0.44	0.24
MOP Forebay var.	-0.07	0.19	0.43	-0.03	-0.09
Forebay var. May	-0.27	-0.27	-0.13	0.01	0.10
Forebay var. June	-0.17	0.14	0.27	-0.32	-0.24
Forebay var. July	-0.19	0.16	0.26	-0.47	-0.41
Forebay var. August	**-0.70**	**0.67**	**0.65**	-0.19	-0.08
Forebay var. Sept.	-0.35	-0.45	-0.30	0.46	**0.66**

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 10 of 21).

Variable Included[1]	CWR MN≥10⁰	CWR MD≥20⁰	CWR MD≥15⁰	CWR MD≥10⁰
Sample size (n)	11	10	11	11
Lower Granite Reservoir				
Days ≥ 50 Kcfs	**0.81**	0.52	**0.63**	**0.82**
Days ≥ 75 Kcfs	**0.70**	0.44	0.35	**0.72**
Days ≥ 100 Kcfs	0.55	0.45	0.22	**0.62**
MN ≥ 50 Kcfs	-0.21	0.20	0.35	-0.47
MN ≥ 75 Kcfs	0.06	0.18	**0.63**	-0.08
MD ≥ 50 Kcfs	-0.08	0.56	-0.23	-0.19
MD ≥ 75 Kcfs	-0.17	-0.08	0.14	-0.41
June DD ≥ 20⁰C	**-0.71**	**-0.70**	**-0.70**	-0.52
June DD ≥ 15⁰C	**-0.66**	-0.57	**-0.91**	-0.45
June DD ≥ 10⁰C	**-0.61**	-0.49	**-0.87**	-0.36
July DD ≥ 20⁰C	0.13	-0.62	-0.01	0.22
July DD ≥ 15⁰C	0.01	**-0.67**	-0.12	0.15
July DD ≥ 10⁰C	0.01	**-0.67**	-0.12	0.15
August DD ≥ 20⁰C	-0.05	0.00	-0.10	-0.15
August DD ≥ 15⁰C	-0.09	-0.19	-0.13	-0.14
August DD ≥ 10⁰C	-0.09	-0.19	-0.13	-0.14
Sept. DD ≥ 20⁰C	-0.21	0.01	-0.47	-0.20
Sept. DD ≥ 15⁰C	0.00	0.09	-0.28	-0.05
Sept. DD ≥ 10⁰C	0.00	0.09	-0.28	-0.05
MN ≥ 20⁰C	-0.25	0.56	-0.19	-0.29
MN ≥ 15⁰C	**0.69**	0.41	**0.68**	0.46
MN ≥ 10⁰C	0.59	0.29	0.49	0.45
MD ≥ 20⁰C	0.50	**0.65**	0.24	0.30
MD ≥ 15⁰C	**0.62**	0.51	**0.66**	0.39
MD ≥ 10⁰C	0.52	0.17	0.37	0.47
Mean secchi	**-0.70**	-0.33	-0.52	**-0.78**
Days secchi ≥ 1.5'	**-0.64**	0.34	0.25	**0.72**
Days secchi ≥ 2.0'	**0.61**	0.35	0.26	**0.73**
MOP Forebay var.	0.18	-0.10	0.28	0.39
Forebay var. May	-0.24	-0.05	-0.23	-0.03
Forebay var. June	0.03	-0.34	0.02	0.33
Forebay var. July	0.25	-0.53	0.24	0.49
Forebay var. August	0.19	-0.08	0.40	-0.01
Forebay var. Sept.	0.24	0.36	0.15	0.27

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 11 of 21).

Variable Included[1]	SR D 50 Kcfs	SR D 75 Kcfs	SR DD>15⁰ May	SR DD>10⁰ May	SR DD>20⁰ June
Sample size (n)	11	11	10	10	10
Lower Granite Reservoir					
Days ≥ 50 Kcfs	**0.94**	**0.79**	-0.53	**-0.76**	-0.54
Days ≥ 75 Kcfs	**0.98**	**0.90**	-0.48	-0.56	-0.38
Days ≥ 100 Kcfs	**0.96**	**0.98**	-0.35	-0.43	-0.22
MN ≥ 50 Kcfs	-0.48	-0.46	-0.00	-0.19	-0.22
MN ≥ 75 Kcfs	-0.29	-0.38	-0.30	-0.49	-0.54
MD ≥ 50 Kcfs	0.27	0.48	-0.14	-0.06	0.01
MD ≥ 75 Kcfs	**-0.63**	**-0.75**	-0.08	-0.03	-0.20
June DD ≥ 20⁰C	**-0.62**	-0.40	0.35	0.62	0.53
June DD ≥ 15⁰C	-0.34	-0.08	0.50	**0.84**	**0.74**
June DD ≥ 10⁰C	-0.22	0.01	0.53	**0.79**	**0.74**
July DD ≥ 20⁰C	-0.19	-0.33	-0.16	0.26	-0.01
July DD ≥ 15⁰C	-0.15	-0.21	-0.19	0.19	0.02
July DD ≥ 10⁰C	-0.15	-0.21	-0.19	0.19	0.02
August DD ≥ 20⁰C	-0.15	-0.11	-0.25	0.03	-0.13
August DD ≥ 15⁰C	-0.16	-0.16	-0.17	0.11	-0.02
August DD ≥ 10⁰C	-0.16	-0.16	-0.17	0.11	-0.02
Sept. DD ≥ 20⁰C	-0.08	0.15	-0.33	0.18	-0.07
Sept. DD ≥ 15⁰C	-0.18	-0.00	-0.56	-0.03	-0.41
Sept. DD ≥ 10⁰C	-0.18	-0.00	-0.56	-0.03	-0.41
MN ≥ 20⁰C	-0.10	0.10	-0.36	-0.22	-0.46
MN ≥ 15⁰C	0.30	0.09	**-0.76**	**-0.75**	**-0.85**
MN ≥ 10⁰C	0.32	0.18	**-0.89**	**-0.78**	**-0.88**
MD ≥ 20⁰C	0.31	0.19	-0.59	-0.50	**-0.65**
MD ≥ 15⁰C	0.38	0.16	**-0.66**	**-0.65**	**-0.74**
MD ≥ 10⁰C	0.24	0.08	**-0.81**	-0.60	**-0.77**
Mean secchi	**-0.95**	**-0.77**	0.60	**0.68**	0.51
Days secchi ≥ 1.5'	**0.95**	**0.91**	-0.38	-0.44	-0.26
Days secchi ≥ 2.0'	**0.98**	**0.91**	-0.40	-0.46	-0.28
MOP Forebay var.	**0.63**	**0.61**	-0.43	-0.40	-0.23
Forebay var. May	0.30	0.42	0.53	0.38	0.61
Forebay var. June	0.41	0.37	0.26	0.21	0.38
Forebay var. July	0.35	0.37	-0.34	-0.36	-0.25
Forebay var. August	-0.14	-0.31	-0.33	-0.31	-0.36
Forebay var. Sept.	0.37	0.31	-0.28	-0.22	-0.25

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 12 of 21).

Variable Included[1]	SR DD>15^0 June	SR DD>10^0 June	SR DD>20^0 July	SR DD>15^0 July	SR DD>10^0 July
Sample size (n)	10	10	10	10	10
Lower Granite Reservoir					
Days $\geq$ 50 Kcfs	-0.60	-0.59	-0.35	-0.44	-0.44
Days $\geq$ 75 Kcfs	-0.33	-0.30	-0.27	-0.28	-0.28
Days $\geq$ 100 Kcfs	-0.23	-0.24	-0.46	-0.44	-0.44
MN $\geq$ 50 Kcfs	-0.49	-0.54	-0.22	-0.30	-0.18
MN $\geq$ 75 Kcfs	**-0.74**	**-0.79**	-0.20	-0.33	-0.30
MD $\geq$ 50 Kcfs	0.07	0.10	-0.05	0.04	0.04
MD $\geq$ 75 Kcfs	-0.17	-0.12	0.37	0.32	0.32
June DD $\geq$ 20^{0}C	**0.67**	0.62	-0.04	0.15	0.15
June DD $\geq$ 15^{0}C	**0.92**	**0.89**	0.04	0.25	0.25
June DD $\geq$ 10^{0}C	**0.88**	**0.85**	0.01	0.19	0.19
July DD $\geq$ 20^{0}C	0.31	-0.30	0.42	0.54	0.54
July DD $\geq$ 15^{0}C	0.36	0.34	0.46	**0.63**	**0.63**
July DD $\geq$ 10^{0}C	0.36	0.34	0.46	**0.64**	**0.64**
August DD $\geq$ 20^{0}C	0.12	0.14	0.50	0.61	0.61
August DD $\geq$ 15^{0}C	0.22	0.25	0.46	0.59	0.59
August DD $\geq$ 10^{0}C	0.22	0.25	0.46	0.59	0.59
Sept. DD $\geq$ 20^{0}C	0.32	0.30	0.20	0.39	0.39
Sept. DD $\geq$ 15^{0}C	-0.01	-0.05	0.10	0.19	0.19
Sept. DD $\geq$ 10^{0}C	-0.01	-0.05	0.10	0.19	0.19
MN $\geq$ 20^{0}C	-0.35	-0.29	-0.03	-0.18	-0.18
MN $\geq$ 15^{0}C	**-0.75**	**-0.71**	0.04	-0.06	-0.06
MN $\geq$ 10^{0}C	**-0.69**	**-0.66**	-0.19	-0.25	-0.25
MD $\geq$ 20^{0}C	-0.57	-0.52	-0.28	-0.40	-0.40
MD $\geq$ 15^{0}C	**-0.69**	**-0.64**	-0.01	-0.11	-0.11
MD $\geq$ 10^{0}C	-0.51	-0.47	-0.16	-0.21	-0.21
Mean secchi	0.47	0.44	0.36	0.38	0.38
Days secchi $\geq$ 1.5'	-0.21	-0.22	-0.30	-0.29	-0.29
Days secchi $\geq$ 2.0'	-0.23	-0.22	-0.35	-0.36	-0.36
MOP Forebay var.	-0.21	-0.27	-0.62	-0.48	-0.48
Forebay var. May	0.37	0.32	-0.60	-0.53	-0.53
Forebay var. June	0.30	0.25	-0.20	-0.11	-0.11
Forebay var. July	-0.20	-0.28	-0.26	-0.19	-0.19
Forebay var. August	-0.30	-0.27	0.37	0.39	0.39
Forebay var. Sept.	-0.24	-0.21	-0.58	**-0.64**	**-0.64**

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 13 of 21).

Variable Included[1]	SR MN≥20°	SR MN≥15°	SR MN≥10°	SR MD≥20°	SR MD≥15°
Sample size (n)	10	10	10	10	10
Lower Granite Reservoir					
Days ≥ 50 Kcfs	0.53	0.61	0.32	0.62	**0.65**
Days ≥ 75 Kcfs	0.30	0.36	0.16	0.39	0.38
Days ≥ 100 Kcfs	0.31	0.34	0.11	0.37	0.36
MN ≥ 50 Kcfs	0.45	0.51	0.33	0.35	0.32
MN ≥ 75 Kcfs	**0.67**	**0.76**	0.54	0.58	0.54
MD ≥ 50 Kcfs	-0.13	-0.04	-0.16	-0.10	-0.17
MD ≥ 75 Kcfs	-0.01	-0.01	0.16	-0.03	-0.13
June DD ≥ 20°C	-0.46	-0.59	-0.14	-0.54	**-0.69**
June DD ≥ 15°C	**-0.66**	**-0.80**	-0.47	**-0.72**	**-0.79**
June DD ≥ 10°C	-0.61	**-0.78**	-0.46	**-0.64**	**-0.64**
July DD ≥ 20°C	-0.33	-0.24	-0.23	-0.36	-0.63
July DD ≥ 15°C	-0.44	-0.28	-0.21	-0.46	**-0.71**
July DD ≥ 10°C	-0.44	-0.28	-0.21	-0.46	**-0.71**
August DD ≥ 20°C	-0.32	-0.12	-0.19	-0.33	-0.52
August DD ≥ 15°C	-0.38	-0.24	-0.27	-0.36	-0.58
August DD ≥ 10°C	-0.38	-0.24	-0.27	-0.36	-0.58
Sept. DD ≥ 20°C	-0.29	-0.18	-0.03	-0.39	**-0.66**
Sept. DD ≥ 15°C	0.07	0.17	0.40	-0.12	-0.36
Sept. DD ≥ 10°C	0.07	0.17	0.40	-0.12	-0.36
MN ≥ 20°C	0.36	0.26	0.40	0.31	0.34
MN ≥ 15°C	0.53	**0.68**	0.55	0.53	0.40
MN ≥ 10°C	0.62	**0.64**	**0.85**	0.57	0.39
MD ≥ 20°C	0.61	0.51	0.55	0.60	0.48
MD ≥ 15°C	0.53	**0.63**	0.38	0.55	0.42
MD ≥ 10°C	0.53	0.46	**0.73**	0.50	0.27
Mean secchi	-0.49	-0.47	-0.31	-0.59	-0.52
Days secchi ≥ 1.5'	0.23	0.30	0.09	0.30	0.32
Days secchi ≥ 2.0'	0.29	0.29	0.13	0.38	0.38
MOP Forebay var.	0.42	0.38	0.22	0.46	0.18
Forebay var. May	-0.04	-0.22	-0.45	0.03	0.07
Forebay var. June	-0.13	-0.15	-0.49	-0.04	-0.06
Forebay var. July	0.24	0.38	0.27	0.20	0.10
Forebay var. August	0.01	0.21	0.08	0.02	-0.13
Forebay var. Sept.	0.51	0.23	0.33	0.55	0.43

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 14 of 21).

Variable Included[1]	SR MD≥10⁰	Growth (G)
Sample size (n)	10	7
Lower Granite Reservoir		
Days ≥ 50 Kcfs	0.42	-0.69
Days ≥ 75 Kcfs	0.28	-0.68
Days ≥ 100 Kcfs	0.26	-0.50
MN ≥ 50 Kcfs	0.17	0.69
MN ≥ 75 Kcfs	0.10	-0.04
MD ≥ 50 Kcfs	0.02	**0.82**
MD ≥ 75 Kcfs	0.11	0.54
June DD ≥ 20⁰C	-0.03	0.43
June DD ≥ 15⁰C	-0.36	0.36
June DD ≥ 10⁰C	-0.38	0.10
July DD ≥ 20⁰C	-0.03	0.09
July DD ≥ 15⁰C	-0.16	-0.05
July DD ≥ 10⁰C	-0.17	-0.05
August DD ≥ 20⁰C	-0.16	0.45
August DD ≥ 15⁰C	-0.15	0.48
August DD ≥ 10⁰C	-0.15	0.48
Sept. DD ≥ 20⁰C	0.06	0.50
Sept. DD ≥ 15⁰C	0.39	0.08
Sept. DD ≥ 10⁰C	0.39	0.08
MN ≥ 20⁰C	0.51	0.17
MN ≥ 15⁰C	0.58	-0.06
MN ≥ 10⁰C	**0.88**	-0.32
MD ≥ 20⁰C	**0.75**	0.09
MD ≥ 15⁰C	0.41	0.14
MD ≥ 10⁰C	**0.93**	-0.36
Mean secchi	-0.42	0.67
Days secchi ≥ 1.5'	0.18	**-0.76**
Days secchi ≥ 2.0'	0.27	**-0.77**
MOP Forebay var.	0.32	-0.25
Forebay var. May	-0.20	0.17
Forebay var. June	-0.43	-0.31
Forebay var. July	0.16	-0.68
Forebay var. August	-0.00	0.36
Forebay var. Sept.	0.71	-0.06

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 15 of 21).

Variable Included[1]	CWR D 20 Kcfs	CWR D 30 Kcfs	CWR DD>10^0 May	CWR DD>20^0 June	CWR DD>15^0 June
Sample size (n)	11	11	11	11	11
Clearwater River					
Days $\geq$ 20 Kcfs	1.00	**0.82**	**-0.77**	-0.46	**-0.82**
Days $\geq$ 30 Kcfs		1.00	**-0.73**	**-0.64**	**-0.88**
May DD $\geq$ 10^{0}C			1.00	0.28	**0.84**
June DD $\geq$ 20^{0}C				1.00	**0.68**
June DD $\geq$ 15^{0}C					1.00
June DD $\geq$ 10^{0}C					
July DD $\geq$ 15^{0}C					
July DD $\geq$ 10^{0}C					
MN $\geq$ 20^{0}C					
MN $\geq$ 15^{0}C					
MN $\geq$ 10^{0}C					
MD $\geq$ 20^{0}C					
MD $\geq$ 15^{0}C					
MD $\geq$ 10^{0}C					
Snake River					
Days $\geq$ 50 Kcfs					
Days $\geq$ 75 Kcfs					
May DD $\geq$ 20^{0}C					
May DD $\geq$ 15^{0}C					
May DD $\geq$ 10^{0}C					
June DD $\geq$ 20^{0}C					
June DD $\geq$ 15^{0}C					
June DD $\geq$ 10^{0}C					
July DD $\geq$ 20^{0}C					
July DD $\geq$ 15^{0}C					
July DD $\geq$ 10^{0}C					
MN $\geq$ 20^{0}C					
MN $\geq$ 15^{0}C					
MN $\geq$ 10^{0}C					
MD $\geq$ 20^{0}C					
MD $\geq$ 15^{0}C					
MD $\geq$ 10^{0}C					
Growth					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 16 of 21).

Variable Included[1]	CWR DD>10⁰ June	CWR DD>20⁰ July	CWR DD>15⁰ July	CWR DD>10⁰ July	CWR MN≥20⁰
Sample size (n)	11	11	11	11	10
Clearwater River					
Days ≥ 20 Kcfs	**-0.81**	-0.40	-0.42	-0.26	**0.66**
Days ≥ 30 Kcfs	**-0.81**	-0.14	-0.14	-0.03	0.58
May DD ≥ 10⁰C	0.81	0.24	0.38	0.30	-0.45
June DD ≥ 20⁰C	0.58	0.20	0.13	0.09	-0.39
June DD ≥ 15⁰C	0.98	0.15	0.27	0.17	-0.56
June DD ≥ 10⁰C	1.00	0.05	0.22	0.11	-0.53
July DD ≥ 20⁰C		1.00	**0.79**	**0.70**	-0.39
July DD ≥ 15⁰C			1.00	**0.96**	**-0.73**
July DD ≥ 10⁰C				1.00	**-0.65**
MN ≥ 20⁰C					1.00
MN ≥ 15⁰C					
MN ≥ 10⁰C					
MD ≥ 20⁰C					
MD ≥ 15⁰C					
MD ≥ 10⁰C					
Snake River					
Days ≥ 50 Kcfs					
Days ≥ 75 Kcfs					
May DD ≥ 20⁰C					
May DD ≥ 15⁰C					
May DD ≥ 10⁰C					
June DD ≥ 20⁰C					
June DD ≥ 15⁰C					
June DD ≥ 10⁰C					
July DD ≥ 20⁰C					
July DD ≥ 15⁰C					
July DD ≥ 10⁰C					
MN ≥ 20⁰C					
MN ≥ 15⁰C					
MN ≥ 10⁰C					
MD ≥ 20⁰C					
MD ≥ 15⁰C					
MD ≥ 10⁰C					
Growth					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 17 of 21).

Variable Included[1]	CWR MN≥15^0	CWR MN≥10^0	CWR MD≥20^0	CWR MD≥15^0	CWR MD≥10^0
Sample size (n)	11	11	10	11	11
Clearwater River					
Days ≥ 20 Kcfs	0.47	**0.79**	**0.69**	**0.69**	**0.73**
Days ≥ 30 Kcfs	0.40	**0.69**	0.62	**0.61**	0.55
May DD ≥ 10^{0}C	-0.56	**-0.81**	-0.53	**-0.63**	-0.56
June DD ≥ 20^{0}C	-0.32	**-0.61**	-0.36	-0.43	-0.53
June DD ≥ 15^{0}C	**-0.65**	**-0.83**	-0.62	**-0.82**	**-0.61**
June DD ≥ 10^{0}C	**-0.66**	**-0.76**	-0.61	**-0.89**	-0.54
July DD ≥ 20^{0}C	-0.28	-0.36	-0.27	-0.01	-0.45
July DD ≥ 15^{0}C	-0.64	-0.32	**-0.67**	-0.03	-0.22
July DD ≥ 10^{0}C	-0.55	-0.20	-0.61	0.11	-0.07
MN ≥ 20^{0}C	**0.74**[2]	0.34[2]	**0.98**	0.22[2]	0.18[2]
MN ≥ 15^{0}C	1.00	0.47	**0.76**	0.53	0.27
MN ≥ 10^{0}C		1.00	0.36	**0.63**	**0.90**
MD ≥ 20^{0}C			1.00	0.30[2]	0.16[2]
MD ≥ 15^{0}C				1.00	0.51
MD ≥ 10^{0}C					1.00
Snake River					
Days ≥ 50 Kcfs					
Days ≥ 75 Kcfs					
May DD ≥ 20^{0}C					
May DD ≥ 15^{0}C					
May DD ≥ 10^{0}C					
June DD ≥ 20^{0}C					
June DD ≥ 15^{0}C					
June DD ≥ 10^{0}C					
July DD ≥ 20^{0}C					
July DD ≥ 15^{0}C					
July DD ≥ 10^{0}C					
MN ≥ 20^{0}C					
MN ≥ 15^{0}C					
MN ≥ 10^{0}C					
MD ≥ 20^{0}C					
MD ≥ 15^{0}C					
MD ≥ 10^{0}C					
Growth					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 18 of 21).

Variable Included[1]	SR D 50 Kcfs	SR D 75 Kcfs	SR DD>15^0 May	SR DD>10^0 May	SR DD>20^0 June
Sample size (n)	11	11	10	10	10
Clearwater River					
Days ≥ 20 Kcfs	**0.78**	**0.65**	-0.44	-0.74	-0.56
Days ≥ 30 Kcfs	**0.66**	0.47	-0.60	**-0.69**	**-0.65**
May DD ≥ 10^{0}C	-0.54	-0.33	0.19	0.58	0.39
June DD ≥ 20^{0}C	-0.43	-0.26	**0.97**	**0.70**	**0.93**
June DD ≥ 15^{0}C	-0.57	-0.32	**0.63**	**0.84**	**0.80**
June DD ≥ 10^{0}C	-0.53	-0.29	0.56	**0.84**	**0.75**
July DD ≥ 20^{0}C	**-0.60**	-0.55	0.14	0.27	0.12
July DD ≥ 15^{0}C	-0.45	-0.50	0.03	0.20	0.13
July DD ≥ 10^{0}C	-0.22	-0.29	-0.06	0.05	0.07
MN ≥ 20^{0}C	0.50[2]	0.54[2]	-0.39[3]	-0.49[3]	-0.50[3]
MN ≥ 15^{0}C	0.36	0.20	-0.24	-0.42	-0.45
MN ≥ 10^{0}C	**0.68**	0.45	-0.60	**-0.73**	**-0.68**
MD ≥ 20^{0}C	0.44[2]	0.46[2]	-0.33[3]	-0.47[3]	-0.49[3]
MD ≥ 15^{0}C	0.38	0.08	-0.46	**-0.86**	**-0.68**
MD ≥ 10^{0}C	**0.74**	**0.53**	-0.54	-0.59	-0.54
Snake River					
Days ≥ 50 Kcfs	1.00	**0.91**	-0.44	-0.56	-0.35
Days ≥ 75 Kcfs		1.00	-0.29	-0.33	-0.14
May DD ≥ 15^{0}C			1.00	**0.75**	**0.85**
May DD ≥ 10^{0}C				1.00	**0.93**
June DD ≥ 20^{0}C					1.00
June DD ≥ 15^{0}C					
June DD ≥ 10^{0}C					
July DD ≥ 20^{0}C					
July DD ≥ 15^{0}C					
July DD ≥ 10^{0}C					
MN ≥ 20^{0}C					
MN ≥ 15^{0}C					
MN ≥ 10^{0}C					
MD ≥ 20^{0}C					
MD ≥ 15^{0}C					
MD ≥ 10^{0}C					
Growth					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 19 of 21).

Variable Included[1]	SR DD>15^0 June	SR DD>10^0 June	SR DD>20^0 July	SR DD>15^0 July	SR DD>10^0 July
Sample size (n)	10	10	10	10	10
Clearwater River					
Days ≥ 20 Kcfs	**-0.68**	**-0.67**	-0.16	-0.30	-0.30
Days ≥ 30 Kcfs	-0.61	-0.55	0.16	0.05	0.05
May DD ≥ 10^{0}C	0.57	0.51	-0.12	0.06	0.06
June DD ≥ 20^{0}C	0.62	0.58	-0.00	0.06	0.06
June DD ≥ 15^{0}C	**0.86**	**0.81**	0.02	0.20	0.20
June DD ≥ 10^{0}C	**0.91**	**0.88**	0.16	0.33	0.33
July DD ≥ 20^{0}C	0.10	0.05	0.22	0.29	0.29
July DD ≥ 15^{0}C	0.24	0.21	0.34	0.48	0.48
July DD ≥ 10^{0}C	0.13	0.10	0.14	0.30	0.30
MN ≥ 20^{0}C	-0.58[3]	-0.56[3]	-0.25[3]	-0.44[3]	-0.44[3]
MN ≥ 15^{0}C	-0.62	-0.57	-0.32	-0.54	-0.54
MN ≥ 10^{0}C	-0.61	-0.58	0.00	-0.15	-0.15
MD ≥ 20^{0}C	-0.62[3]	-0.60[3]	-0.16[3]	-0.37[3]	-0.37[3]
MD ≥ 15^{0}C	-0.92	**-0.91**	-0.21	-0.39	-0.39
MD ≥ 10^{0}C	-0.41	-0.39	-0.07	-0.16	-0.16
Snake River					
Days ≥ 50 Kcfs	-0.35	-0.34	-0.39	-0.41	-0.41
Days ≥ 75 Kcfs	-0.14	-0.15	-0.47	-0.43	-0.43
May DD ≥ 15^{0}C	**0.64**	0.61	0.10	0.13	0.13
May DD ≥ 10^{0}C	**0.91**	**0.88**	0.26	0.38	0.38
June DD ≥ 20^{0}C	**0.84**	**0.80**	0.05	0.18	0.18
June DD ≥ 15^{0}C	1.00	**0.99**	0.29	0.47	0.47
June DD ≥ 10^{0}C		1.00	0.38	0.53	0.53
July DD ≥ 20^{0}C			1.00	**0.96**	**0.96**
July DD ≥ 15^{0}C				1.00	**1.00**
July DD ≥ 10^{0}C					1.00
MN ≥ 20^{0}C					
MN ≥ 15^{0}C					
MN ≥ 10^{0}C					
MD ≥ 20^{0}C					
MD ≥ 15^{0}C					
MD ≥ 10^{0}C					
Growth					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 20 of 21).

Variable Included[1]	SR MN≥20^0	SR MN≥15^0	SR MN≥10^0	SR MD≥20^0	SR MD≥15^0
Sample size (n)	10	10	10	10	10
Clearwater River					
Days ≥ 20 Kcfs	0.49	**0.68**	0.24	0.57	**0.69**
Days ≥ 30 Kcfs	0.35	0.52	0.20	0.44	0.44
May DD ≥ 10^{0}C	-0.23	-0.45	-0.07	-0.32	-0.56
June DD ≥ 20^{0}C	-0.58	-0.58	**-0.75**	-0.53	-0.34
June DD ≥ 15^{0}C	-0.62	**-0.77**	-0.46	**-0.67**	**-0.72**
June DD ≥ 10^{0}C	**-0.70**	**-0.86**	-0.45	**-0.74**	**-0.78**
July DD ≥ 20^{0}C	-0.16	-0.00	-0.24	-0.23	-0.40
July DD ≥ 15^{0}C	-0.32	-0.20	-0.24	-0.33	-0.57
July DD ≥ 10^{0}C	-0.18	-0.08	-0.19	-0.15	-0.43
MN ≥ 20^{0}C	0.60[3]	0.61[3]	0.29[3]	0.61[3]	**0.74**[3]
MN ≥ 15^{0}C	**0.66**	0.54	0.32	**0.70**	**0.79**
MN ≥ 10^{0}C	0.40	0.58	0.36	0.44	0.52
MD ≥ 20^{0}C	0.58[3]	0.65[3]	0.23[3]	0.58[3]	**0.74**[3]
MD ≥ 15^{0}C	**0.73**	0.83	0.47	**0.81**	**0.82**
MD ≥ 10^{0}C	0.31	0.44	0.23	0.38	0.39
Snake River					
Days ≥ 50 Kcfs	0.37	0.39	0.18	0.47	0.47
Days ≥ 75 Kcfs	0.24	0.27	0.06	0.28	0.28
May DD ≥ 15^{0}C	-0.61	-0.61	**-0.77**	-0.58	-0.33
May DD ≥ 10^{0}C	**-0.74**	**-0.82**	**-0.74**	**-0.79**	**-0.73**
June DD ≥ 20^{0}C	**-0.73**	**-0.77**	**-0.80**	**-0.70**	-0.56
June DD ≥ 15^{0}C	**-0.87**	**-0.92**	**-0.72**	**-0.88**	**-0.86**
June DD ≥ 10^{0}C	**-0.89**	**-0.97**	**-0.72**	**-0.88**	**-0.85**
July DD ≥ 20^{0}C	**-0.64**	-0.47	-0.38	-0.61	-0.49
July DD ≥ 15^{0}C	**-0.76**	-0.60	-0.44	**-0.74**	**-0.70**
July DD ≥ 10^{0}C	**-0.76**	-0.60	-0.44	**-0.74**	**-0.70**
MN ≥ 20^{0}C	1.00	**0.90**	**0.76**	**0.97**	**0.85**
MN ≥ 15^{0}C		1.00	**0.67**	**0.86**	**0.79**
MN ≥ 10^{0}C			1.00	**0.68**	0.53
MD ≥ 20^{0}C				1.00	**0.90**
MD ≥ 15^{0}C					1.00
MD ≥ 10^{0}C					
Growth					

Appendix Table 4. Coefficient of variation (r^2) between variables examined in predictive models for egg-larval survival of northern squawfish (Page 21 of 21).

Variable Included[1]	SR MD≥10⁰	Growth (G)
Sample size (n)	10	7
Clearwater River		
Days ≥ 20 Kcfs	0.22	-0.73
Days ≥ 30 Kcfs	0.14	-0.33
May DD ≥ 10⁰C	-0.09	0.38
June DD ≥ 20⁰C	-0.65	0.46
June DD ≥ 15⁰C	-0.37	0.36
June DD ≥ 10⁰C	-0.35	0.23
July DD ≥ 20⁰C	-0.29	0.70
July DD ≥ 15⁰C	-0.27	0.27
July DD ≥ 10⁰C	-0.15	0.19
MN ≥ 20⁰C	0.30[3]	-0.12
MN ≥ 15⁰C	0.40	0.02
MN ≥ 10⁰C	0.52	-0.72
MD ≥ 20⁰C	0.20[3]	0.04
MD ≥ 15⁰C	0.34	-0.42
MD ≥ 10⁰C	0.48	**-0.85**
Snake River		
Days ≥ 50 Kcfs	0.34	-0.63
Days ≥ 75 Kcfs	0.24	-0.41
May DD ≥ 15⁰C	**-0.73**	0.46
May DD ≥ 10⁰C	-0.61	0.51
June DD ≥ 20⁰C	**-0.68**	0.46
June DD ≥ 15⁰C	-0.52	0.37
June DD ≥ 10⁰C	-0.51	0.34
July DD ≥ 20⁰C	-0.45	-0.03
July DD ≥ 15⁰C	-0.49	0.05
July DD ≥ 10⁰C	-0.49	0.05
MN ≥ 20⁰C	**0.63**	-0.28
MN ≥ 15⁰C	0.51	-0.28
MN ≥ 10⁰C	**0.81**	-0.41
MD ≥ 20⁰C	0.59	-0.33
MD ≥ 15⁰C	0.40	-0.44
MD ≥ 10⁰C	1.00	-0.39
Growth		1.00

1 MN = Mean Julian date, MD = Median Julian date, DD = Degree days, CWR = Clearwater River, SR = Snake River
2 Sample size (n) = 10
3 Sample size (n) = 9

Appendix Table 5. Parameter estimates and associated 95% confidence limits for variables included in non-significant predictive models for egg-larval survival of northern squawfish. Sample size (n) was 7 for all models (Page 1 of 2).

Variable[1]	Parameter Estimate	95% Confidence Limits Lower	Upper
Lower Granite Reservoir			
Days ≥ 50 Kcfs	-0.035	-0.177	0.107
Days ≥ 75 Kcfs	-0.039	-0.269	0.191
Days ≥ 100 Kcfs	-0.110	-0.415	0.195
MN ≥ 50 Kcfs	0.041	-0.531	0.613
MN ≥ 75 Kcfs	-0.083	-0.638	0.472
MD ≥ 50 Kcfs	0.130	-0.175	0.435
June DD ≥ 20°C	-0.710	-8.899	7.479
June DD ≥ 15°C	-0.002	-0.199	0.195
June DD ≥ 10°C	-0.006	-0.134	0.121
July DD ≥ 20°C	-0.064	-0.480	0.352
July DD ≥ 15°C	-0.030	-0.155	0.095
July DD ≥ 10°C	-0.030	-0.155	0.095
August DD ≥ 20°C	0.037	-0.141	0.215
August DD ≥ 15°C	0.032	-0.135	0.199
August DD ≥ 10°C	0.032	-0.135	0.199
Sept. DD ≥ 20°C	0.180	-0.347	0.707
Sept. DD ≥ 15°C	0.048	-0.063	0.159
Sept. DD ≥ 10°C	0.048	-0.063	0.159
MN ≥ 15°C	0.190	-0.587	0.967
MN ≥ 10°C	0.270	-0.618	1.158
MD ≥ 20°C	0.150	-0.183	0.483
MD ≥ 15°C	0.170	-0.552	0.892
MD ≥ 10°C	0.250	-0.611	1.111
Mean secchi	1.300	-4.807	7.407
Days secchi ≥ 1.5'	-0.260	-0.871	0.351
Days secchi ≥ 2.0'	-0.090	-0.359	0.179
MOP Forebay var.	-8.050	-19.848	3.748
Forebay var. May	-4.240	-14.012	5.532
Forebay var. August	1.940	-17.659	21.539
Forebay var. Sept.	0.810	-5.408	7.028
Clearwater River			
Days ≥ 20 Kcfs	-0.078	-0.336	0.180
Days ≥ 30 Kcfs	0.042	-0.485	0.569
May DD ≥ 10°C	-0.170	-0.697	0.357
June DD ≥ 20°C	-0.150	-0.650	0.350
June DD ≥ 15°C	-0.023	-0.184	0.138
June DD ≥ 10°C	-0.001	-0.101	0.099
July DD ≥ 20°C	-0.079	-0.801	0.643
July DD ≥ 15°C	-0.056	-0.167	0.055

Appendix Table 5. Parameter estimates and associated 95% confidence limits for variables included in non-significant predictive models for egg-larval survival of northern squawfish. Sample size (n) was 7 for all models (Page 2 of 2).

Variable[1]	Parameter Estimate	95% Confidence Limits Lower	Upper
Clearwater River			
MN ≥ 20°C	0.076	-0.369	0.521
MN ≥ 15°C	0.220	-0.474	0.914
MN ≥ 10°C	0.075	-0.702	0.852
MD ≥ 20°C	0.080	-0.334	0.494
MD ≥ 15°C	-0.300	-1.327	0.727
MD ≥ 10°C	-0.087	-0.587	0.413
Snake River			
Days ≥ 50 Kcfs	-0.038	-0.196	0.120
Days ≥ 75 Kcfs	-0.110	-0.443	0.223
May DD ≥ 15°C	-0.160	-1.021	0.701
May DD ≥ 10°C	0.007	-0.168	0.182
June DD ≥ 20°C	-0.200	-1.227	0.827
June DD ≥ 15°C	0.001	-0.140	0.143
June DD ≥ 10°C	0.010	-0.140	0.124
July DD ≥ 20°C	0.072	-0.170	0.314
July DD ≥ 15°C	0.033	-0.103	0.169
July DD ≥ 10°C	0.033	-0.103	0.169
MN ≥ 20°C	-0.060	-0.921	0.801
MN ≥ 15°C	-0.150	-1.177	0.877
MN ≥ 10°C	0.260	-0.767	1.287
MD ≥ 20°C	-0.089	-0.783	0.605
MD ≥ 15°C	0.160	-1.034	1.354
MD ≥ 10°C	0.290	-0.987	1.567
Growth	443.810	-2008.425	2896.045

1 MN = Mean Julian date,
MD = Median Julian date,
DD = Degree days.

Appendix Table 6. Parameter estimates and associated 95% confidence limits for variables included in non-significant predictive models for juvenile northern squawfish survival. Sample size (n) was 8 for all models.

Variable[1]	Parameter Estimate	95% Confidence Limits Lower	95% Confidence Limits Upper
Days ≥ 20 Kcfs	-0.000	-0.013	0.012
Days ≥ 25 Kcfs	-0.001	-0.016	0.014
Days ≥ 35 Kcfs	-0.013	-0.080	0.054
Days ≥ 100 Kcfs	-0.012	-0.058	0.034
MN ≥ 50 Kcfs	-0.050	-0.184	0.084
MD ≥ 50 Kcfs	-0.021	-0.103	0.061
MD ≥ 75 Kcfs	-0.030	-0.128	0.068
Days ≥ 20°C	-0.006	-0.034	0.022
Days ≥ 10°C	0.025	-0.042	0.092
DD > 20°C	-0.003	-0.013	0.008
DD > 15°C	-0.001	-0.006	0.004
DD > 10°C	-0.000	-0.006	0.005
Days secchi ≥ 1.5'	-0.045	-0.153	0.063
Days secchi ≥ 2.0'	-0.013	-0.057	0.031
Forebay var. May	0.647	-0.867	2.167
Forebay var. June	1.286	-1.872	4.452
Forebay var. July	-1.883	-6.713	2.953
Forebay var. August	-0.582	-2.611	1.451
Forebay var. Sept.	-0.175	-1.003	0.643
Winter forebay level	-0.324	-2.505	1.865
Sampling effort	-0.000	-0.001	0.001

1 MN = Mean julian date,
MD = Median julian date,
DD = Degree Days.