Kootenai River White Sturgeon Conservation Aquaculture Program

Post-release Survival Update and Recommendations for 2008

Kootenai Tribal Sturgeon Hatchery
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Administered by the Kootenai Tribe of Idaho through a contract from the Bonneville Power Administration (Project 198806400, Contract No. 00020490) as part of the Northwest Power and Conservation Council's Fish and Wildlife Program.

Program Overview

The Kootenai Tribe of Idaho proposed an experimental hatchery program to address the decline of the white sturgeon population in the Kootenai River. Since its inception in 1990, the Kootenai River White Sturgeon Conservation Aquaculture Program has continued to meet its objective of reducing the threat of extinction by providing annual year classes from native broodstock, representing inherent genetic variability in its broodstock and progeny groups, and minimizing the introduction or transmission of pathogens or disease to the wild (source) population.

By the late 1990s it became clear that non-hatchery efforts to restore recruitment were failing to counteract the extinction threat. This trend continues to the present (2008). In 2004 updated demographic analysis suggested that as few as 500 adults remained in the population, and triggered increased hatchery production for demographic and genetic conservation. In 2005, a report was prepared describing endangered Kootenai River white sturgeon population trends and causal factors of decline along with program history, protocols, and accomplishments during its first 15 years of operation (KTOI 2006).

Subsequent data analysis revealed newly reduced survival rates based on lower recapture frequencies of earlier life stages and release groups of smaller fish. Embryos and free-embryos (yolks-sac larvae) released during several years in the early 2000s have provided no evidence for post-release survival to date. Review of these analyses warranted an updated report to recommend and delineate 2008 operational changes for the program.

This report includes a brief program history for perspective, a summary of post-release survival analyses of early life stages released from the Kootenai Hatchery (Justice and Pyper 2007), and recommends program operational changes for 2008.

This report does not address hatchery operations beyond 2008 because the Program is currently involved in Step 1 of the Northwest Power and Conservation Council's 3-Step Hatchery Master Planning process. Recommendations regarding Program facility and operational changes beyond 2008 will be reported in future Master Planning documents.

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Brief Program Evolution

The Stage is Set: 1980-1987

The Kootenai River White Sturgeon Hatchery program (Program) began formally in 1990, growing out of a convergence of independent events during the preceding decades summarized below (modified from KTOI 2006). The Program has evolved in response to demonstrated successes, several hard lessons, and the increasing realization of the hatchery's significance to preventing extinction of Kootenai River white sturgeon. The stage was set for this program from 1980 to 1987, when consistent, decadal scale recruitment failure was confirmed in Idaho, Montana, and British Columbia waters of the Kootenai/y River (Andrusak 1980, Graham 1981, Partridge 1983). The Northwest Power Act of 1980 had recently been passed, mandating mitigation compensation for negative effects of the federal hydropower system, and significant developments in white sturgeon aquaculture were simultaneously occurring in California at UC Davis and in the Sacramento Valley. The combination of these events fueled the initial development of this Program.

An Experimental Program: 1988-1997

An experimental Kootenai Hatchery program was proposed by the Kootenai Tribe of Idaho (KTOI) and identified in the Northwest Power Planning Council's 1987 Columbia River Basin Fish and Wildlife Program. Funding was provided to the Tribe in 1988 by the Bonneville Power Administration to address critical uncertainties regarding Kootenai River white sturgeon recruitment. Key initial Program questions involved sturgeon gamete viability, whether natural recruitment failure occurred before or after spawning, and whether hatchery spawning and rearing of wild sturgeon might be a suitable tool for conservation and recovery of Kootenai River white sturgeon.

The first artificial spawning of wild Kootenai River white sturgeon occurred during 1990 in a makeshift set- up on the banks of the Kootenai River (Apperson and Anders 1991). Following initial success of the 1990 spawn under primitive field conditions, initial construction of a low cost experimental hatchery facility was completed on the KTOI reservation just outside Bonners Ferry in 1991. In 1993, a federal fish geneticist was contracted to provide a breeding plan tailored to the needs of the Kootenai sturgeon population (Kincaid 1993). Considerable progress in developing successful conservation aquaculture techniques and protocols occurred during this experimental Program phase, despite loss of the entire 1997 year class due to facility equipment failure in 1997. However, this loss of a year class of an endangered species expedited facility improvements.

Program Maturation: 1998-2005

As the experimental Program evolved, the original facility and equipment grew increasingly unable to meet the new objectives of the conservation aquaculture program as provided in the breeding plan (Kincaid 1993) and in the draft and final recovery plans (USFWS 1996 and 1999). In 1998, the KTOI sought funding for hatchery upgrades to bring the existing facility up to standard, as well as negotiating a cooperative agreement with British Columbia to provide a fail-safe facility for off-site hatching and rearing. With funding provided through the KTOI, the Ministry of Environment (now the Freshwater Fisheries Society of BC) developed facilities at the Kootenay Trout Hatchery in Fort Steele, B.C. to provide a backup rearing site to avoid repeated catastrophic loss that occurred at the Tribal facility in 1997.

Hatchery upgrades during this period provided the capability to meet recovery planning production objectives. Hatchery-produced fish were soon being collected in the monitoring and evaluation program. Analysis of mark-recapture data in 2001 confirmed excellent post-release survival rates of hatchery-reared fish in the river (mean survival ~60% first year at large, ~90% during all subsequent years; Ireland et al. 2002).

By the late 1990s it became evident that flow measures of the magnitudes implemented had failed to restore natural recruitment and that the next generation of Kootenai white sturgeon was going to be produced predominantly if not entirely by the hatchery program. This led to further refinements in hatchery objectives and protocols. These are reported in the Program's Adaptive Multidisciplinary Conservation Aquaculture Plan (KTOI 2004).

As a deliberate adaptive programmatic shift to reduce the duration in captivity before release and to empirically investigate factors limiting early life survival in the river, hatchery-reared sturgeon were released at increasingly early life stages during the early 2000s. Releases during these years included embryos (fertilized eggs), free embryos (yolk-sac larvae), and smaller fish (< 20 cm TL) compared to previous years.

Adaptive Management Phase: 2006–2008

Recent mark-recapture and survival analyses (Justice and Pyper 2007) indicated patterns of reduced survival estimates due to several factors, including size (age) at release. It now appears that the program should consider returning to releases of smaller numbers of older fish (yearling and Age 1) that demonstrated higher survival rates (Ireland et al. 2002). Program recommendations, including rearing and release strategies for 2008, are presented after the next section that summarizes the most comprehensive and updated post-release survival analyses.

2007 Summary of Post-release Survival Analysis

The following summary was provided by Justice and Pyper (2007): Declining survival rates during the first year following release appeared to coincide with increasing releases of hatchery fish in recent years (Figure 1a). This negative relationship between release numbers and survival suggests that density-dependent factors likely influenced mortality of juvenile sturgeon during their first year at large. However, there is little evidence suggesting density-dependent mortality after the first year at large, as indicated by the relatively stable survival rates for fish recaptured after two or more years following release (Figure 1b).

The inclusion of length covariates in mark-recapture models revealed strong positive relationships between size-at-release and survival during the first year at large. A comparison of first-year survival rates for small releases (i.e. length-at-release = 15cm) and large releases (i.e. length-at-release = 45cm) over time indicated that survival rates for small fish declined steeply in recent years while survival of larger fish was variable, but was generally higher (Figure 2). The low first-year survival estimate for large releases in 2003 was likely driven by low sample size in this year. The steep decline in first-year survival of small-sized releases suggests that the bottleneck for hatchery-produced juvenile sturgeon may be density-dependent mortality of relatively small fish during their first year at large.

Temporal variation in first-year growth did not provide strong evidence for density-dependent growth, although there was some indication of a negative decline in growth of fish released during spring (Figure 3). Unfortunately, limited numbers of recaptures from recent release groups reduced our ability to describe temporal trends in growth, particularly for autumn releases. In addition, the apparent decline in growth of spring releases was largely driven by unusually high growth for a single release group (i.e. 1995/1997 Spring KT), which may or may not have been related to low abundance in that year. Additional recaptures of recent releases in future years may provide valuable insight into the growth response of hatchery-reared juvenile sturgeon.

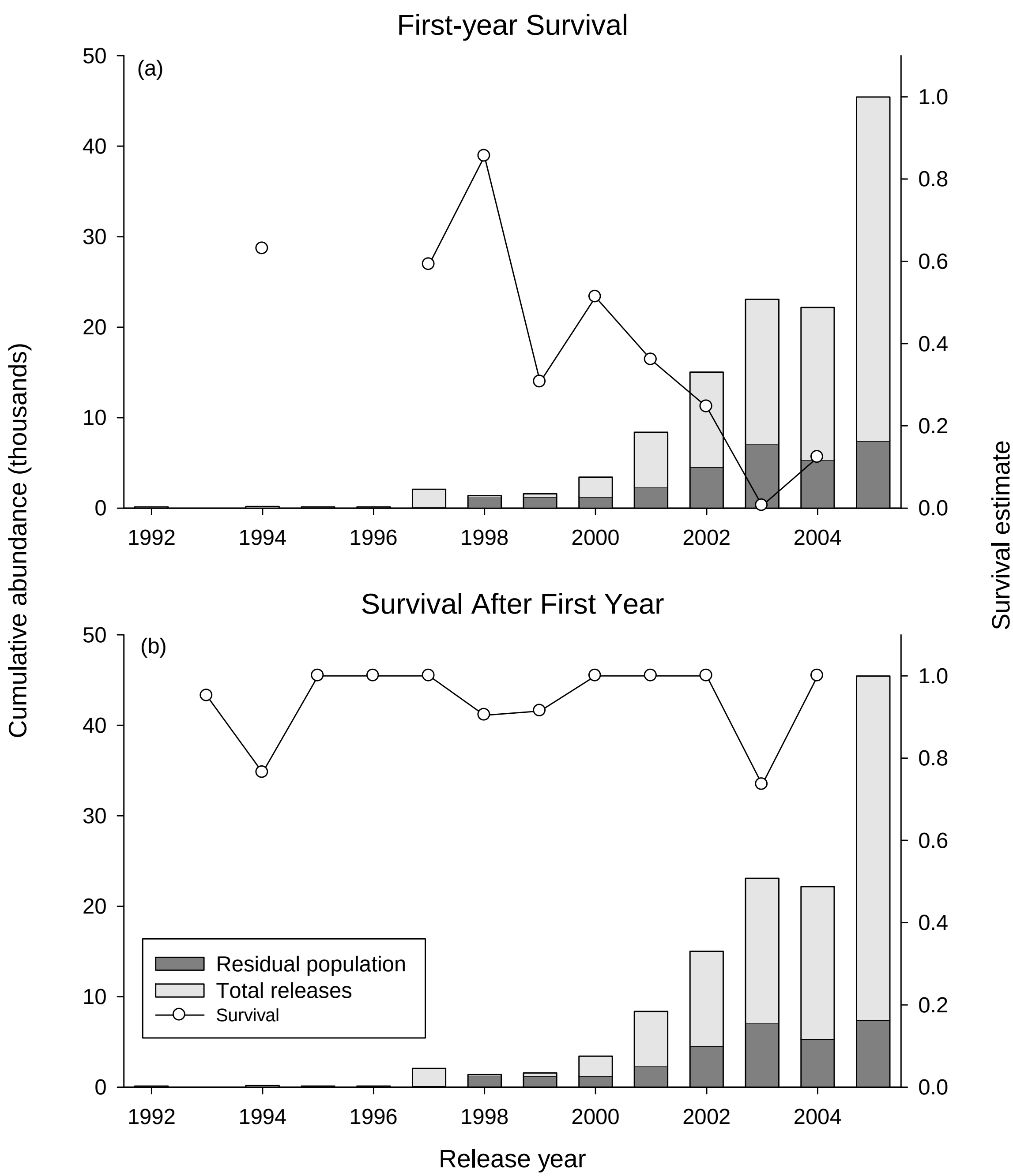

Figure 1. **Comparison of cumulative abundance (total releases + residual population) of hatchery-reared juvenile sturgeon and both (a) first-year survival rates and (b) survival rates after the first year at large by release year, 1992-2005. Survival estimates were derived from the best fitting mark-recapture model without length covariates included (model 6a). (Figure 22 in Justice and Pyper 2007).**

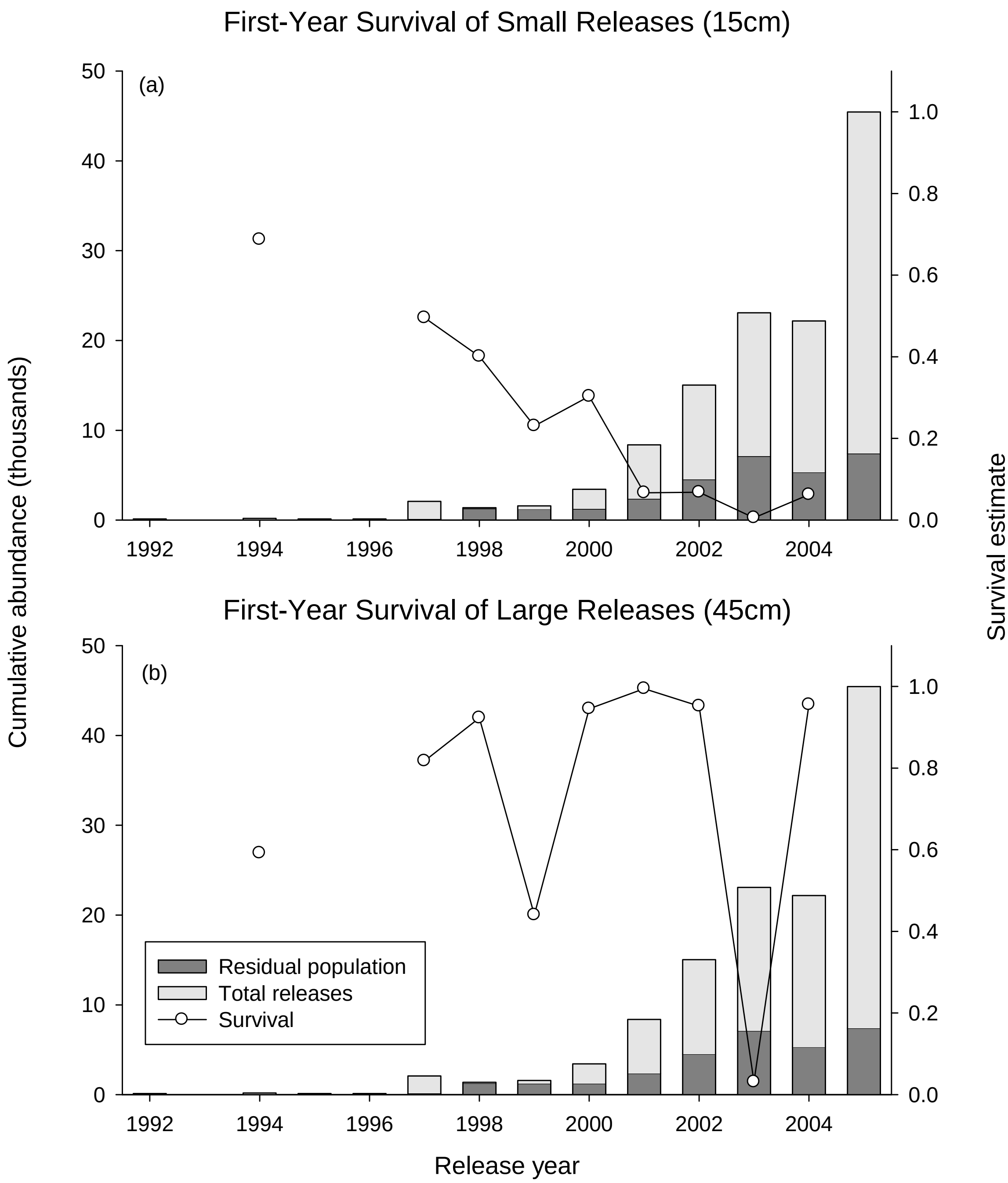

Figure 2. **Comparison of cumulative abundance (total releases + residual population) of hatchery-reared juvenile sturgeon and first-year survival rates of both (a) small releases (15cm), and (b) large releases (45cm) by release year, 1992-2005. Survival estimates were derived from the best fitting mark-recapture covariate model (model 4b), where length-at-release was fixed at 15cm and 45cm for small releases and large releases respectively. (Figure 23 in Justice and Pyper 2007).**

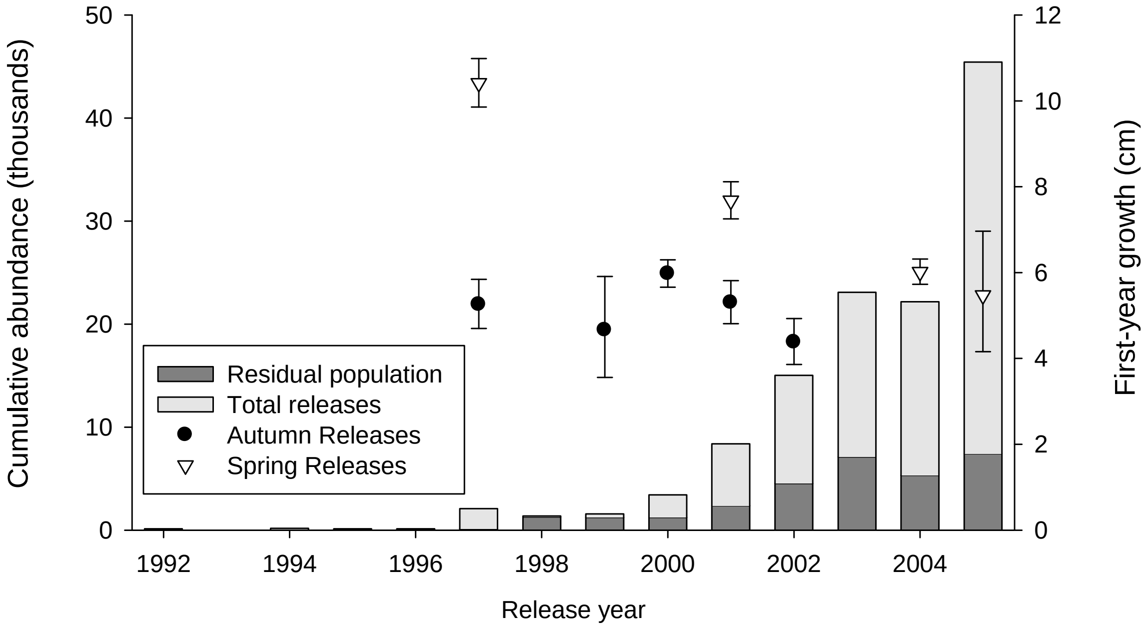

Figure 3. **Comparison of first-year growth (cm) (averaged across rearing facilities) for autumn and spring releases and cumulative abundance of juvenile sturgeon by release year, 1992-2005. Growth rates were derived from a linear model with sqrt(growth) as the response variable, and release group, sqrt(days-at-large), and sqrt(length-at-release (cm)) as explanatory variables. Growth estimates were based on fish with a fixed fork length of 20 cm and days-at-large fixed at 365 days. Error bars represent 95% confidence intervals. (Figure 24 in Justice and Pyper 2007).**

Recommendations for 2008

Spawning Matrix

To maximize genetic diversity, effective population number, and within parental and lineage contribution within and among hatchery-produced progeny groups, as stated in the most recent Kootenai Hatchery Plan (KTOI 2004):

- Maintain a minimum long-term average annual effective population number (N_e) of 10 for all year classes to reduce the probability of future inbreeding depression (Table 1).
- Spawn up to 12 females and spawn with as many different males as available or possible. (At a minimum, spawn at 1:1 male:female ratios).
- Use PIT tag numbers to prohibit spawning of previously paired spawners.

Release strategy

Release strategy details for 2008 are presented in the following table, followed by addition bulleted release strategy information.

2008	Embryos	Age 1 Fish
Release group size	Remainder of embryos collected with reasonable hand-stripping effort following collection of all eggs needed for annual family production	Up to 1,500 fish per family
Release locations	Standard embryo release sites (IDFG,KTOI provide information)	Distribute among standard fish release sites
Release timing	At night just after collection with each spawning	Spring, Summer or Fall, depending on fish size

- Release up to 1,500 Age 1+ (~18 mo.) fish per family in 2008 to mitigate the declining trend in survival and growth among small fish (mean TL ~ 15 cm) during their first year at large, compared to larger fish (mean TL 30-45 cm) revealed by recent analysis (Figures 1 and 2).
- Releasing 1,500 Age 1+ fish given empirical survival rates yields approximately 50 remaining fish at age 30; release groups of 750 would yield approximately 25 fish at age 30 (Table 3)
- Equalize family sizes within reason to maximize diversity and minimize potential dominance of progeny groups at release. However, do not equalize down to the lowest release groups size if the number of fish per family in the majority of families greatly exceeds the number of individuals in the smallest family.
- Recent analysis of fall vs. spring releases revealed that size of fish in the fall releases over time has been associated with a steady post-release growth rate trend, whereas releases of younger (smaller) fish appeared to exhibit a declining trend in growth rate over time (Figure 3). However, release time can vary depending on fish size.

Table 1. Effective population size (N_e) is calculated using the equation, $N_e = (4N_fN_m / N_f + N_m)$. This equation does not take into account variation in family size at release. Bold values in the shaded cells meet or exceed he recommended mean annual N_e value of 10 (Kincaid 1993). For comparison, all values in bold text correspond to the recommended annual effective population sizes and recommended mating combinations for cultured Atlantic (*Acipenser oxyrhynchus*; Pierre et al., 1996) and lake sturgeon (*Acipenser fulvescens*) stocking programs (2008).

Effective Population Size	Number of Female Parents											
Number of Male Parents	1	2	3	4	5	6	7	8	9	10	11	12
1	2.0	2.7	3.0	3.2	3.3	3.4	3.5	3.6	3.6	3.6	3.7	3.7
2	2.7	4.0	4.8	5.3	5.7	6.0	6.2	6.4	6.5	6.7	6.8	6.9
3	3.0	4.8	6.0	6.9	7.5	8.0	8.4	8.7	9.0	9.2	9.4	9.6
4	3.2	5.3	6.9	**8.0**	8.9	9.6	10.2	10.7	11.1	11.4	11.7	12.0
5	3.3	5.7	7.5	**8.9**	**10.0**	10.9	11.7	12.3	12.9	13.3	13.8	14.1
6	3.4	6.0	**8.0**	**9.6**	**10.9**	**12.0**	12.9	13.7	14.4	15.0	15.5	16.0
7	3.5	6.2	**8.4**	**10.2**	**11.7**	**12.9**	**14.0**	14.9	15.7	16.5	17.1	17.7
8	3.6	6.4	**8.7**	**10.7**	**12.3**	**13.7**	**14.9**	**16.0**	16.9	17.8	18.5	19.1
9	3.6	6.5	**9.0**	**11.1**	**12.9**	**14.4**	**15.7**	**16.9**	**18.0**	19.0	19.8	20.6
10	3.6	6.7	**9.2**	**11.4**	**13.3**	**15.0**	**16.5**	**17.8**	**19.0**	**20.0**	21.0	21.8
11	3.7	6.8	**9.4**	**11.7**	**13.8**	**15.5**	**17.1**	**18.5**	**19.8**	**20.6**	**22.0**	23.0
12	3.7	6.9	**9.5**	**12.0**	**14.1**	**16.0**	**17.7**	**19.1**	**20.6**	**21.8**	**23.0**	**24.0**
13	3.7	6.9	**9.8**	**12.2**	**14.4**	**16.4**	**18.2**	**19.8**	**21.3**	**22.6**	**23.8**	**25.0**
14	3.7	7.0	**9.9**	**12.4**	**14.7**	**16.8**	**18.7**	**20.4**	**21.9**	**23.3**	**24.6**	**25.8**
15	3.8	7.1	**10.0**	**12.6**	**15.0**	**17.1**	**19.1**	**20.9**	**22.5**	**24.0**	**25.4**	**26.7**
16	3.8	7.1	**10.1**	**12.8**	**15.2**	**17.5**	**19.5**	**21.3**	**23.0**	**24.6**	**26.1**	**27.4**
17	3.8	7.2	**10.2**	**13.0**	**15.5**	**17.7**	**19.8**	**21.8**	**23.5**	**25.2**	**26.7**	**28.1**
18	3.8	7.2	**10.3**	**13.1**	**15.7**	**18.0**	**20.2**	**22.2**	**24.0**	**25.7**	**27.3**	**28.8**
19	3.8	7.2	**10.4**	**13.2**	**15.8**	**18.2**	**20.5**	**22.5**	**24.4**	**26.2**	**27.9**	**29.4**
20	3.8	7.3	**10.4**	**13.3**	**16.0**	**18.5**	**20.7**	**22.9**	**24.8**	**26.7**	**28.4**	**30.0**
21	4.1	8.1	**11.8**	**15.2**	**18.3**	**21.1**	**23.7**	**26.1**	**28.3**	**30.4**	**32.3**	**34.1**
22	4.2	8.3	**12.1**	**15.6**	**18.8**	**21.8**	**24.5**	**27.0**	**29.3**	**31.5**	**33.5**	**35.4**
23	4.3	8.5	**12.4**	**16.0**	**19.4**	**22.5**	**25.3**	**27.9**	**30.3**	**32.6**	**34.7**	**36.6**
24	4.3	8.7	**12.7**	**16.5**	**20.0**	**23.2**	**26.1**	**28.9**	**31.4**	**33.7**	**35.9**	**37.9**
25	4.4	8.8	**13.0**	**16.9**	**20.5**	**23.8**	**26.9**	**29.8**	**32.4**	**34.8**	**37.1**	**39.2**

Table 2. Survivorship data of six release group sizes (n= 250 to 1,500) of hatchery-reared fish released at age 1 applying empirical survival rates of 60% during first year at large and 90% during all subsequent years to age 50 (Ireland et al. 2002).

Age	Number of Fish per Release Group					
1	**250**	**500**	**750**	**1000**	**1250**	**1500**
2	150	300	450	600	750	900
3	135	270	405	540	675	810
4	122	243	365	486	608	729
5	109	219	328	437	547	656
6	98	197	295	394	492	590
7	89	177	266	354	443	531
8	80	159	239	319	399	478
9	72	143	215	287	359	430
10	65	129	194	258	323	387
11	58	116	174	232	291	349
12	52	105	157	209	262	314
13	47	94	141	188	235	282
14	42	85	127	169	212	254
15	38	76	114	153	191	229
16	34	69	103	137	172	206
17	31	62	93	124	154	185
18	28	56	83	111	139	167
19	25	50	75	100	125	150
20	23	45	68	90	113	135
21	20	41	61	81	101	122
22	18	36	55	73	91	109
23	16	33	49	66	82	98
24	15	30	44	59	74	89
25	13	27	40	53	66	80
26	12	24	36	48	60	72
27	11	22	32	43	54	65
28	10	19	29	39	48	58
29	9	17	26	35	44	52
30	8	16	24	31	39	47
31	7	14	21	28	35	42
32	6	13	19	25	32	38
33	6	11	17	23	29	34
34	5	10	15	21	26	31
35	5	9	14	19	23	28
36	4	8	13	17	21	25
37	4	8	11	15	19	23
38	3	7	10	14	17	20
39	3	6	9	12	15	18
40	3	5	8	11	14	16
41	2	5	7	10	12	15
42	2	4	7	9	11	13
43	2	4	6	8	10	12
44	2	4	5	7	9	11
45	2	3	5	6	8	10
46	1	3	4	6	7	9
47	1	3	4	5	7	8
48	1	2	4	5	6	7
49	1	2	3	4	5	6
50	1	2	3	4	5	6

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