# An Adaptive Multidisciplinary Conservation Aquaculture Plan for Endangered Kootenai River White Sturgeon

**Prepared by the Kootenai Tribe of Idaho**


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## EDITORS' NOTE

The editors understand that a conservation aquaculture program, no matter how adaptive or multidisciplinary, cannot be a successful surrogate for rehabilitation of altered habitat and ecological function. This hatchery management plan (Plan) is neither designed nor intended to divert needed attention from the restoration of habitat quality and ecological function compromised by anthropogenic changes to the Kootenai River ecosystem. This Plan simply acknowledges the empirical demographic bottleneck currently facing the endangered Kootenai River white sturgeon population. This Plan provides an interim management strategy to protect the Kootenai River white sturgeon population from otherwise inevitable extinction during the next 20 to 40 years, while carefully rebuilding demographic and genetic population components.

This document resulted from a series of steps to update the Kootenai River White Sturgeon Conservation Aquaculture Program in an adaptive fashion (Table 1). This Plan incorporates analysis of the most recent and most complete empirical data sets.

Table 1. Steps to develop and implement the updated Adaptive Conservation Aquaculture Program for the endangered Kootenai River white sturgeon population.

| Step | Task | Task Completed |
|---|---|---|
| 1. | Review Kincaid Plan in context of latest population demographic trends and rates. | 12/02 |
| 2. | Report findings to KTOI and Kootenai River White Sturgeon Recovery Team. | Spring 03 |
| 3. | Produce updated draft of qualitative Program elements, present to KTOI and Recovery Team for input and approval. | 5/12-13/03 |
| 4. | Produce final qualitative Program draft incorporating input and reviews from KTOI and Recovery Team, modify as needed for approval. | 5-10/03 |
| 5. | Incorporate input from Recovery Team Meeting (11/19/03) and from independent reviews; produce final quantitative draft. | 11-12/03 |
| 6. | Complete draft plan, submit to KTOI, Recovery Team, and additional outside independent reviewers. | 1-6/04 |
| 7. | Finalize plan and implement | 8/04 and beyond |

## Executive Summary

Aquaculture techniques were first applied to the Kootenai River white sturgeon population in northern Idaho in 1990 in response to concerns that missing year classes, failed recruitment, and skewed age class structure were threatening this population with extinction. An independently produced conservation breeding plan to preserve the population's remaining genetic variation was implemented in 1994 (Kincaid 1993). The population was listed as endangered under the Endangered Species Act (ESA 1973) in 1994 (USFWS 1994), due to unmitigated population decline and predominant recruitment failure on a decadal scale.

A Recovery Plan for the population was completed during 1999 (Duke et al. 1999; USFWS 1999). Subsequent concerns regarding duration, breadth, and magnitude of Kootenai River ecosystem degradation in Montana, Idaho, and British Columbia, and repeated failure to restore natural recruitment during the past decade suggested that a conservation hatchery program was warranted to preclude extinction. Empirical demographic modeling during 2002 revealed the increasingly imperiled condition of this population. Model simulations suggested that 90, 75, and 72% reductions in population abundance, biomass, and annually available spawners occurred from 1980 to 2002; population size was estimated to decrease by 50% every 7.4 years (Paragamian et al. in press). Recent capture of 659 juveniles (39 wild and 620 hatchery-reared) confirmed that wild recruitment of Kootenai River white sturgeon is very low (Paragamian et al. in press). The 2003 population abundance estimate for Kootenai River white sturgeon was approximately 600 fish (Paragamian et al. in press).

Without hatchery intervention, population extinction is certain during the next 20-40 years. With intervention, assuming ongoing natural recruitment failure, this hatchery program will contribute to demographic restoration and protection of remaining genetic variability during the next 30 to 50 years, while improvements in the Kootenai River ecosystem occur to collectively reestablish natural production and ecological function.

The Kootenai River White Sturgeon Conservation Aquaculture Program has greatly expanded since the initial implementation of the Kincaid Plan in 1994. Since then, the Program has: 1) produced, released, and monitored frequent year classes of captive-reared progeny from wild, native brood stock, 2) continued to preserve within-population genetic diversity, 3) minimized disease introduction and transmission, and 4) substantially contributed to the developing field of white sturgeon conservation aquaculture (Anders 1998; LaPatra et al. 1999; Ireland et al. 2002a, 2002b).

This new Plan has two goals, which are to: 1) Preserve the locally adapted Kootenai River white sturgeon genotypes, phenotypes, and associated life history traits; and 2) Restore age class structure to maximize future population viability and persistence. Fifteen new or modified operational guidelines are provided in this Hatchery Plan in response to the current population bottleneck, the need to preserve remaining genetic

diversity, continued failure of natural recruitment, and impending extinction without intervention. This Plan incorporates an Adaptive Management approach (Walters 1986; Walters 1997) and will be modified as necessary, following collection and analysis of the most recent and most complete empirical datasets. These datasets will then be used in updated ecosystem, demographic, and genetic models to guide the Program, and to maximize this Plan's effectiveness and success, in the broader context of Kootenai River ecosystem restoration.

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# I. Introduction

## *1. Background*

Aquaculture techniques were first applied to the Kootenai River white sturgeon population in northern Idaho in 1990 in response to concerns that missing year classes, failed recruitment, and skewed age class structure were threatening the population with extinction. From 1993 to 2003, operations of the Kootenai River White Sturgeon Conservation Aquaculture Program were guided by the "Breeding Plan to Preserve the Genetic Variability of Kootenai River White Sturgeon" (Kincaid 1993), subsequently referred to as the "Kincaid Plan". During this time the Kootenai Hatchery Program generally met the Kincaid Plan's objectives of reducing the threat of population extinction by: 1) providing frequent year classes from native brood stock; 2) representing inherent within-population genetic diversity in its brood stock and progeny; and 3) minimizing the introduction of disease into the recipient wild population (Ireland et al. 2002a). Many of the Kincaid Plan's objectives and recommendations remain relevant today, following an additional decade of failed natural recruitment since the Plan was first implemented. More detailed descriptions of Kootenai Hatchery operations, guidelines, and results can be found in Kincaid (1993), and Ireland et al. (2002a, 2002b), and the Kootenai Hatchery Genetics Management Plan (2000),

www.cbfwa.org/files/province/mtncol/subsum/KootenaiHGMP.doc

Effective population size ($N_e$) and production goals recommended by the Kincaid Plan (1993) were designed to compensate for missing or limited natural production of Kootenai River white sturgeon years classes from only 1973 to 1993. The Kincaid Plan recommended a mean annual $N_e$ of $\geq$ 10. This recommendation was because: "In light of the threatened status of Kootenai River white sturgeon, a random sample of 200 fish (100 males and 100 females) should be spawned to contribute progeny to the next generation over the next 20 years". The observed mean annual $N_e$ for all years of the program was (6.9) initially fell short of the recommended value of 10 due to challenges in the early years of the program with inadequate facilities. However, since 1995: 1) program performance greatly improved; 2) the facility was upgraded considerably; 3) the program annually approximated or exceeded the recommended mean annual $N_e$ of 10; and 4) a fail-safe back-up hatching and rearing facility was arranged within the Kootenay River Basin in British Columbia. The Kootenai River White Sturgeon Recovery Team (Recovery Team) subsequently incorporated the Kincaid Plan into its Recovery Plan, which was completed in 1999 (Duke et al. 1999; USFWS 1999).

Recent empirical population modeling and the ongoing natural recruitment failure suggested that more immediate and dire challenges currently face this endangered population than previously assumed (Duke et al. 1999; USFWS 1999; Paragamian et al. in press). Given this updated population condition, including more than 30 years of inadequate natural recruitment to maintain population persistence (Paragamian et al. in press), two important questions emerged:

> 1) Are Kincaid's $N_e$ goals and production numbers sufficient to adequately protect remaining genetic variability and to ensure population viability and persistence?

2) Given steady population decline, recruitment failure on decadal scales, and the failure of nearly 10 years of limited flow tests to reestablish natural recruitment to date, should the future Program focus on more rigorous population enhancement in addition to reducing the rate of population decline and loss of genetic variability as prescribed by the Kincaid Plan?

In addition to addressing these two questions, the purpose of this document is to: 1) Provide a brief, updated characterization of the Kootenai River white sturgeon population; and 2) Provide an updated and expanded Multidisciplinary Adaptive Conservation Aquaculture Program in response to most recent population characteristics (Paragamian et al. in press). This Plan resulted from collaborative efforts by members of an informal Kootenai Hatchery Review Team, composed of agency representatives and independent scientists, and was modified as necessary for endorsement and incorporation into an updated Recovery Plan by the Recovery Team.

*2. Updated population condition*

a. Demographic characteristics - Recent population simulations (Paragamian et al. in press) suggested that:

- The Kootenai River white sturgeon population declined by over 90% from 6,800 fish in 1980 to 630 in 2002, and total biomass declined by about 75% from 80 to 20 metric tons from 1980 to present.

- Current (2003) estimated population size is 600 individuals; population size is estimated to decrease by 50% every 7.4 years.

- Fewer than 500 adults from the existing wild population will remain by the year 2005, with fewer than 50 adult fish remaining by 2030.

- Estimated annual numbers of female spawners decreased from 270 per year in 1980 to about 77 in 2002.

- Fewer than 30 females are estimated to be spawning during any given year after 2015.

- With the advent of hatchery releases beginning in 1990, significant annual releases projected into the foreseeable future, and assuming no additional natural recruitment, significant numbers of hatchery-reared fish are expected to begin recruiting to the adult population after 2020.

- The adult population is expected to rapidly increase between 2020 and 2030, after which it is projected to stabilize to about 3,000 fish (depending on future stocking and survival rates), when the population reaches equilibrium (Figure 1).

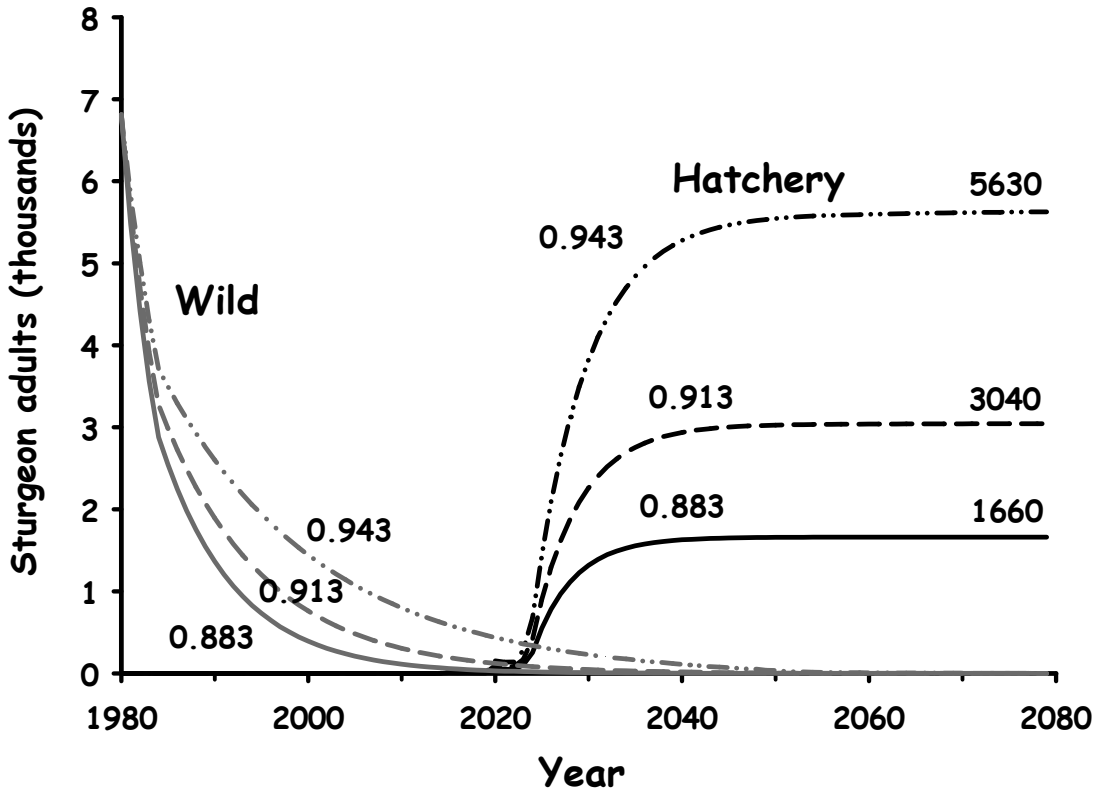


Figure 1. The empirically modeled demographic bottleneck in the endangered Kootenai River white sturgeon population, indicating population trajectories with and without intervention, releasing 1-2 year old fish with given survival rates (Figure 12 from Paragamian et al., in press.) Differences among the three trajectories represent ± 3% of average (91.3%) mortality rate.

The following three paragraphs from Paragamian et al. (in press) summarize recent and future challenges for conservation and management of Kootenai River white sturgeon:

"Current numbers and population dynamics confirm that time has not yet run out for the Kootenai sturgeon but opportunities for effective intervention are rapidly dwindling. The long life span of sturgeon provides an extended period in which to identify and implement effective but somewhat contentious recovery measures. However, 35 and possibly 50 years of this window of opportunity have now passed for recovery of Kootenai white sturgeon. Consistent recruitment collapsed 15 to 30 years prior to the first systematic population surveys around 1980. Another 20 years have passed, during which the species was listed under the U.S. Endangered Species Act, a recovery plan was completed (Duke et al. 1999; USFWS 1999), a conservation hatchery program was developed (Ireland et al. 2002a, 2002b), and spring spawning flow measures have been implemented (Duke et al. 1999; USFWS 1999; Paragamian et al. 2001a, 2001b).

The next 5 to 20 years will be a critical period in the preservation of Kootenai sturgeon. A bottleneck in spawner numbers will occur as the wild population dwindles and hatchery-reared fish released beginning in 1992 are not yet recruited to the spawning population. Critically low fish numbers cannot be avoided by any action that has not yet been implemented. The die has been cast by the continued failure of natural production during past decades. Recovery measures implemented now cannot affect the depth or duration of the bottleneck.

It now appears likely that the next generation of Kootenai River white sturgeon will be produced primarily if not entirely by the conservation hatchery program. Post-release assessments revealed good condition, growth, and survival of hatchery juveniles, following increases after an initial post-release adjustment period (Ireland et al. 2002b). However, flow measures implemented to date have not been adequate to stimulate a significant year class although measures have fallen short of targets desired by some fish managers (B. Hallock, U.S. Fish and Wildlife Service, personal communication). Altered hydro operations involved water discharges that were generally small percentages of historical, natural hydrographs (Duke et al. 1999; USFWS 1999). Even the immediate restoration of suitable habitat conditions for recruitment (if possible) may not be sufficient to avoid adverse consequences of projected low population numbers. If fish managers had not initiated a conservation hatchery program during the 1990s as a contingency to habitat improvement measures (Kincaid 1993; Ireland et al. 2002a), it now appears likely that the current sturgeon generation would have been the last".

b. Genetic characteristics

Conservation aquaculture is simply what the term implies – use of aquaculture for conservation and recovery of endangered fish populations. It is not standard hatchery practices that have been used as a past baseline of evaluation. Conservation aquaculture involves incorporating the local gene pool and allowing sufficient migration of genes to allow allelic representation. This Plan is designed to mimic as much as possible natural reproductive attributes and gene flow models of wild white sturgeon. This requires careful selective breeding programs to provide sufficient diversity within a fish population of interest. It necessitates eliminating as much artificial conditioning as possible. When successful, it provides the increased population base on which natural selection can operate. As a result of its design, conservation aquaculture can reduce the commonly considered risks associated with hatchery production, such as competitive feeding behaviors, reduced growth rates, domestication selection, and increased incidence of disease. Finally, conservation aquaculture by no means presents the same risks associated with letting nature take its course when nature is no longer able to sustain a wild, native fish population.

Perhaps more than a specific set of culture techniques, conservation aquaculture is an adaptive, creative approach that prioritizes preservation of wild populations, along with their locally adapted gene pools and characteristic phenotypes and behaviors. Thus, the conservation aquaculture approach is in direct contrast to the ideology underlying more traditional hatchery supplementation programs, in which success was largely a function

of total numbers of fish released from a hatchery. Conservation aquaculture should be viewed as one component of multifaceted fish restoration and recovery programs, many of which include important habitat improvement efforts. Some supplementation programs have treated the symptom of declining fish populations in lieu of addressing serious issues of degraded and lost fish habitat, or other causal factors. In contrast, conservation aquaculture is designed to be implemented simultaneously with habitat improvement and watershed or ecosystem restoration activities. The goal of many traditional hatchery supplementation programs has been to create a harvestable surplus of fish. The goal of conservation aquaculture on the other hand is to conserve wild fish populations, along with their locally adapted gene pools and characteristic phenotypes and behaviors. The importance of this distinction between approaches cannot be over-emphasized. The fact that conservation aquaculture is not concerned with producing record numbers of fish for release alleviates many stress-mediated problems associated with high density fish rearing. In addition, due to the complementary nature of conservation aquaculture, commonly raised concerns that fish hatcheries "divert attention away from the real problems", or somehow usurp the need to address causal factors of fish population declines do not apply to conservation aquaculture.

Concerns and risks associated with aquaculture, including inbreeding fitness depression, domestication selection, manifestation of disease, and negative interactions between hatchery-reared and wild fish are often readily observable, and have been well documented (Krueger et al. 1981; Hynes et al. 1981; Kincaid 1983; Leary et al. 1985; Allendorf and Ryman 1987; Waples 1991; Ryman and Laikre 1991; Waples et al. 1992; Busack and Currens 1995). However, such observations may result from what Brannon (1993) referred to as "the perpetual oversight of hatchery programs" rather than from aquaculture per se. That is, when hatchery programs ignore the fact that fish populations are both the product of and an integral part of a complex ecosystem, their success is jeopardized. Brannon (1993) further suggested that if hatchery programs neglect the requirements of natural populations, and therefore the traits they possess that allow them to synchronize their life history with specific environmental constraints, failure is certain.

Low spawner numbers may also confound the ability to recognize suitable conditions for natural recruitment if they occur. Low spawner numbers also prompt decisions regarding whether mature fish are left in the river or removed to serve as brood stock. Finally, every reduction in numbers of available spawners increases the difficulty and cost of collecting ripe brood stock for the hatchery program, and simultaneously jeopardizes the success of all programs to restore demographic and genetic vigor to the population.

*3. Rationale for Conservation Aquaculture* - Recent empirical model simulations suggested that without hatchery intervention the Kootenai River white sturgeon population will be functionally extinct within 20 to 40 years (2020-2040; Figure 1). This assessment represents the current baseline for various management alternatives, and provides the impetus for this updated Hatchery Management Plan.

An increasing number of post-development ecosystems, like the Kootenai system, currently lack ecological structure and function necessary for natural recovery of some native fish populations (e.g. burbot and white sturgeon). In some cases, the time required for successful ecosystem restoration may exceed estimates of individual population persistence without intervention (Figure 1). In other cases, ecological structure and function necessary for natural recovery of native fish populations may have been irreversibly lost. Finally, in all cases, the success of ecosystem rehabilitation and its effects on recovering native fish population are not guaranteed (Anders 1998).

Altered post-development ecological conditions in the Kootenai River ecosystem and ongoing natural recruitment failure provide strong, complementary rationale for immediate implementation of a carefully designed conservation aquaculture program. In the Kootenai River, ecosystem alteration, including impoundment, has been frequently cited as a major cause of decline for taxa across trophic levels (Duke et al. 1999; USFWS 1999; Paragamian 2002; Anders et al. 2002, 2003). Given well documented empirical ecosystem perturbation for the Kootenai River, conservation aquaculture programs can provide a "population safety net" to protect, generate, and maintain abundance, age class structure, and genetic variability required for population viability and persistence (Ireland et al. 2002a). However, as with ecosystem restoration projects, the success of conservation aquaculture programs is not guaranteed.

*4. Program overview* - Rather than a specific set of culture techniques, the Kootenai White Sturgeon Conservation Aquaculture Program involves an adaptive, expanding suite of approaches that prioritize the preservation of the endangered white sturgeon population and its locally adapted genotypes, phenotypes and behaviors (Brannon 1993; Kincaid 1993; Anders 1998; Ireland et al. 2002a and 2002b). The goal of the Kincaid Plan (1993) was to: “Provide a systematic approach to preserve the Kootenai River white sturgeon gene pool, while management agencies work to restore river habitat conducive to natural spawning and larval survival”. This goal remains relevant today, and was supported by the following objectives:

1. Describe a long-term approach to preserve genetic variability.

2. Provide a multi-year breeding system to re-establish age structure.

3. Provide a breeding structure to create and maintain a “high” effective population size.

4. Describe “preservation stocking” methods to minimize potential detrimental effects of conventional supplemental stocking programs.

5. Describe small-lot culture procedures to reduce the risk of detrimental genetic effects commonly associated with intensive hatchery propagation.

6. Describe a marking system to maintain family identity throughout the life cycle.

The term “preservation stocking” was used in the Kincaid Plan to indicate that preservation of genetic variability was the primary program objective. Gradual demographic expansion of the wild white sturgeon population in the presence of failed natural recruitment was at that time (1993) a secondary, yet important objective.

*5. Program results to date* - Ireland et al. (2002a and 2002b) summarized the following pertinent results during the first 12 years (1999-2002) of the Kootenai River White Sturgeon Conservation Aquaculture Program:

- In 1990, a conservation program began to evaluate gamete viability and assess the feasibility of using aquaculture to aid in recovery of Kootenai River white sturgeon.

- Mature wild fish were captured prior to spawning and bred to produce four to 12 separate families per year to theoretically produce four to 10 adults per family at breeding age (assumed to be ~ Age 20 and older during the early 1990s).

- Over 40,000 age 1 to age 4 juvenile white sturgeon were released between 1992 to 2004.

- Average annual survival rates for hatchery-reared juveniles approximated 60% for the first year following release and 90% during all subsequent years.

- Growth rates and condition factors within 3 years after release were often poor as many hatchery fish adapted to natural conditions. Growth rates increased after the initial adjustment period.

- Relative weights of released juveniles were 88% of optimum at release, 78% of optimum at recapture, and increased with period at large.

- Empirical survival rate and condition values will provide a valuable empirical basis for adjusting release numbers of hatchery-reared fish consistent with the conservation goal of the hatchery program, quantified through future model simulation. Such results can also provide a baseline for comparison with the results of future monitoring to determine carrying capacity of the Kootenai River system for juvenile sturgeon.

## II. Adaptive Management and Conservation Aquaculture

Adaptive management (Walters 1986, 1997) is: "a process of 'learning by doing' that involves much more than simply better monitoring and response to unexpected management impacts. It has been repeatedly argued (Holling 1978, Walters 1986, Van Winkle et al. 1997) that adaptive management should begin with a concerted effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impacts of alternative policies. This modeling step is intended to serve three functions: (1) provide problem clarification and enhanced communication among scientists, managers, and other stakeholders, (2) policy screening to eliminate likely unsuccessful options, and (3) identify key knowledge gaps that make model predictions suspect". Typically, the design of management experiments then becomes a key second step in the process of adaptive management, and a new set of management issues arises about how to deal with the costs and risks of large-scale experimentation.

However, Walters (1997) also warned of the dangers associated with excessive reliance on modeling outcomes at the expense of empirical field research. Such dangers take the form of: (1) Cross-scale modeling (or prediction) problems, (i.e. erroneously substituting model outcomes for empirical outcomes); (2) Non-additivity of parameter and data effects in population dynamics analysis (e.g. projected population trajectories do not reflect empirical post-release survival); (3) Difficult or emergent properties plague adaptive management programs; and (4) Confounding effects in validation of historical data (e.g. estimated Kootenai River white sturgeon population abundance, viability, and persistence dropped considerably following recent quantitative modeling of empirical data; Paragamian et al. in press). Thus, adaptive management and conservation aquaculture share the premise of considerable uncertainty in the face of immediately needed restorative actions.

*1. Changing program roles for changing population needs* - Conservation aquaculture is well suited for the application of adaptive management because of the lack sufficient information to accurately predict ecological outcomes of particular management experiments. Thus, iterative adaptive management provides the underlying foundation for this multidisciplinary Adaptive Multidisciplinary Conservation Aquaculture Program.

Accordingly, this Program integrates results of empirical population modeling and iteratively evaluates and redesigns program attributes as necessary based on analyses of most recent empirical data. During the early 1990's, assumed stocking rates and survival rates were used in the Kincaid Plan due to the lack of empirical rates (Kincaid 1993). Since then, age-specific annual growth rates, survival rates, and condition factor values have been estimated using empirical data, demographic trends in the population with and without hatchery intervention have been modeled and reported, and the efficiency of various conservation hatchery practices has been documented and reviewed (Ireland et al.

2002 a, 2002b; Ireland and Anders in prep; Paragamian et al. in press; KHGMP 2000). This document addresses the changing roles and operations for the Kootenai River White Sturgeon Conservation Aquaculture Program in an adaptive, multidisciplinary fashion in response to changing population needs.

## III. Program Goals and Objectives

Program Goals

Two new goals of this Plan are to: 1) Preserve the locally adapted Kootenai River white sturgeon genotypes, phenotypes, and associated life history traits; and 2) Restore age class structure to maximize future demographic and genetic viability and persistence of the Kootenai River white sturgeon population.

Program Objectives

Population restoration

1. Implement annual multi-year breeding protocols to: a) maximize annual effective population numbers; b) re-establish age-class structure and population abundance; c) avoid further demographic and genetic bottlenecking; and d) contribute to long-term population viability and persistence.
2. Implement "demographic restoration" and "early life history research" stocking methods to maximize demographic and genetic vigor, and to address critical uncertainties overshadowing natural recruitment and population recovery.

Research, monitoring, and evaluation

1. Preserve and monitor genetic variability and diversity in the wild population and in the subset hatchery brood stock and progeny groups. (Variability refers to the relative composition of all genetic types within a sample, whereas diversity reflects the total number of different types). Use genetic analysis to avoid inbreeding in the hatchery whenever possible.
2. Implement and maintain a long-term database that incorporates all life stages, and is sensitive to individual- and family-level identity.
3. Evaluate program success and appropriateness of goals and objectives with an individual-based demographic and population genetic model.

Consistent with this Plan's goals and objective, fifteen specific operational guidelines were developed to preserve remaining genetic diversity, and to counteract the current population bottleneck, continued failure of natural recruitment, and impending extinction (see Section V, Specific Operation Guidelines). Because review of this Program is iterative and adaptive, the above objectives are subject to refinement at various stages of implementation following adequate monitoring and evaluation.

## IV. General Operational Guidelines

Like all Acipenserids, life history and reproductive attributes of white sturgeon (Table 2) resulted from local adaptation and dynamic natural selection pressures during their long evolutionary history (Birstein et al. 1997; Anders and Powell 2002; Gross et al. 2002; Secor et al. 2002). To the maximum extent possible, this Plan's breeding strategy is designed to mimic the natural mating system of white sturgeon, to result in the following benefits (Table 2).

Table 2. Benefits of white sturgeon life history and reproductive strategies.

| Life history or reproductive strategy | Benefits |
|---|---|
| Iteroparity, overlapping generations | Multiple opportunities to pass gametes on to subsequent generations within a single lifespan; enlarges intergenerational gene flow mosaic |
| | Enlarges intergenerational gene flow mosaic; naturally reduces probability of inbreeding |
| Differential, sex-specific age at first maturity | Reduces reproductive synchrony of male and female siblings and half-sib family members |
| Differential, sex-specific spawning periodicity | Reduces reproductive synchrony of male and female siblings and half-sib family members; |
| Communal, broadcast spawning | Enlarges intergenerational gene flow mosaic; reduces probability of inbred progeny |

Consistent with these white sturgeon life history and reproductive attributes, breeding matrices were designed to maximize effective population size ($N_e$), numbers of breeders ($N_b$), and within-population, inter-generational gene flow. By incorporating white sturgeon reproductive and mating system features into this Plan, resulting demographic and genetic processes should better resemble those of wild populations. For example, incorporation of this reproductive model minimizes the likelihood of inbreeding (spawning of full and half-sibs) in future generations. This Plan calls for the development of an empirical demographic and genetic model to calculate the probability of inbreeding, given a series of variable demographic, genetic, and reproductive attributes and process rates. Because all hatchery-reared progeny to date were marked individually and all future releases will be identified with family specific marks, inbreeding in the hatchery can and should be systematically minimized or prohibited. Thus, the greatest diversity of progeny, annually produced from the greatest diversity of parents, should provide the most efficient and empirically proven approach to preserve the population's genetic variability in the short-term. This approach also provides the raw material for the population's future evolutionary adaptive potential, assuming such genetic resources have not yet been lost from the wild population.

## V. Specific Operational Guidelines

*1. Annual brood stock numbers:* Beginning in 2004, attempt to double annual brood stock numbers (up to 12 females per year). Breed each female with as many different males as possible.

*Rationale:* Current practice seeks to spawn up to 6 females and 15 to 18 males. During the past three years, the annual average has been 15 broodstock per year. A total of 112 wild fish have been spawned in the hatchery from 1990 through 2003. Assuming at least 15 sturgeon will continue to be annually available during each of the next 15 to 20 years, and that wild recruitment will continue to fail, the founder population size for the next sturgeon generation will be only 340 to 410 fish. This number is substantially less than a generic population size guideline ($\geq$ 500) thought necessary to preserve key portions of existing genetic diversity (Meffe and Carroll 1994, 1997). The resulting founder effect risks loss of future population productivity at such time as natural recruitment conditions might be restored. In addition, it will become increasing difficult to obtain ripe females and males every year as the wild population continues to decline. Therefore, increasing annual brood stock numbers now and in the foreseeable future will help maximize the effective founding population size in the next generation, and provides a hedge for coming years when ripe spawners will be difficult to obtain. Modifications to brood stock collection efforts, release practices, and/or current hatchery facilities will be necessary to meet this Plan's brood stock doubling goal.

*2. Priority for use of available brood stock*: The hatchery gets first priority for any suitable brood stock that can be collected during the next 20 years. Any ripe sturgeon not appropriate or needed for the hatchery, as determine by Hatchery Program personnel, may be released in upstream areas where incubation and rearing habitat may be more suitable. Natural spawning opportunities in the current spawning reach will still be afforded the balance of the wild population not needed for the hatchery conservation or experimental set and jet programs. However, natural spawning during the past 30 or more years has resulted in negligible recruitment, which is the most immediate and dangerous threat to this population.

*Rationale:* This is the California condor question: When does a captive breeding program supercede hopes for restoration of natural spawning? With the continued failure of natural recruitment, it is apparent that the hatchery provides the only immediately successful prospects for conservation of Kootenai sturgeon. Even if natural recruitment does occur, it is likely to be sporadic such that existing population diversity will not be preserved. *The hatchery is top priority for any ripe fish that is available (up to the hatchery capacity) even if it means that no ripe fish are available to spawn in the wild or for the upstream transport experiment.* This is because natural spawning during the past 30 or more years has resulted in negligible recruitment, which is the most immediate and dangerous threat to this population. This priority may be revisited if the upstream transplant experiment proves successful. In practice, fish are expected to continue to be available for both hatchery and transport experiment purposes for the foreseeable future because not all ripe fish are suitable for hatchery spawning (for instance, because of collection timing, sperm sample availability, maturation stage or size, or other logistical concerns). It is also practically impossible to catch every ripe fish

during any year. Therefore, at least some fish are expected to be available to take advantage of favorable natural recruitment conditions should they occur. However, for prioritization purposes, natural recruitment during the past several decades has done little or nothing to improve population status and reduce the extinction risk.

*3.* *Kootenay Hatchery:* Rear unique families at the KTOI and Kootenay hatcheries.

*Rationale:* The Kootenay Hatchery in Canada was developed as a backup facility to rear duplicate family groups in case of unforeseen disasters at the KTOI facility. The Kootenay Hatchery has facilities to rear 5 families separately. Hatchery enhancements and staff expertise have minimized chances of problems that could result in loss of all or a portion of the annual production at either facility. Rearing different families at each facility maximizes the numbers of brood stock that can be used, thus helping maximize founder population sizes.

*4.* *Release numbers:* Rear more fish from each family (up to 10,000 Age 0 fish per family, possible more as larvae), and release them at smaller sizes and younger ages.

*Rationale:* Past targets for release were up to 1,500 fish from each family group to a size suitable for PIT tagging (~30 g). However, the hatcheries have the capacity to raise greater numbers of each family especially if fish are released at smaller sizes. Release group numbers were previously limited in an attempt to avoid swamping naturally-produced spawners. However, since it now appears that the next generation will be composed almost entirely of hatchery produced fish, larger release group numbers are appropriate to ensure that: 1) the existing genetic diversity of each parent is represented in all recombinant permutations of offspring, and 2) sufficient numbers of each family will be available to survive for 20-plus years to reach maturity and produce viable subsequent generations. Increasing release numbers helps ameliorate the risk of genetically and demographically whittling down the sturgeon population with every succeeding generation. In an ideal world, we would back-calculate appropriate release numbers from the desired population size needed to sustain genetic and demographic viability and from sturgeon densities scaled to the capacity of the system. However, uncertainties in expected survival and maturation points make this exercise fruitless. For instance, just a ± 3% difference in expected mortality rate produces a 3-fold difference in expected equilibrium numbers (Figure 1). Instead, an adaptive approach is proposed where increased release numbers accompanied by monitoring will ultimately determine appropriate population sizes and densities. Future release numbers should be adjusted when monitoring detects a significant, multi-year, density-dependent reduction in survival, growth, or condition. However, care must be exercised not to mistake density-dependent growth reduction from inter-annual variation or density-independent growth inhibition. Figure 2 and Table 3 illustrate modeled population trajectories resulting from various stocking regimes and current empirical survival rates. Appendix 1 provides Age 0 release survival trajectories, given several survival rate scenarios. Future recaptures of fish released at Age 0 will provide empirical survival rate estimates, which will help to better define release numbers of Age 0 fish.

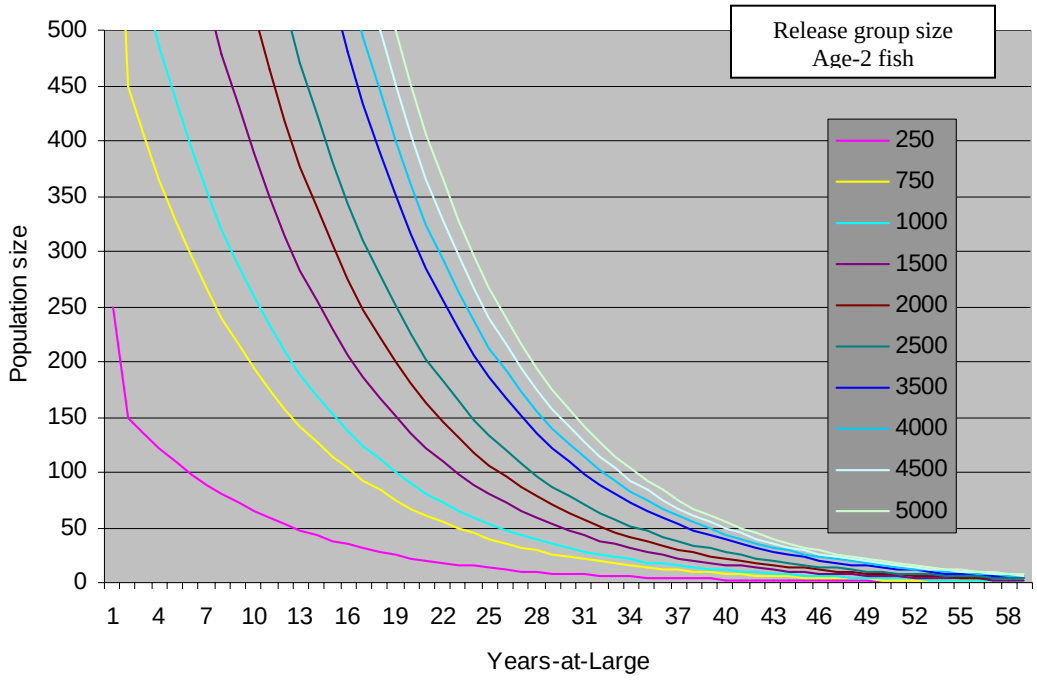


Figure 2. Post-release white sturgeon survival trajectories for a range of release group sizes from the Kootenai Hatchery using empirical annual survival rates (60% during release year, 90% during all subsequent years).

Table 3. Modeled survival of Age 1-2 Kootenai River White Sturgeon Hatchery Progeny assuming 60% survival during first year-at-large, followed by 90% annual survival during all subsequent years (Ireland et al. 2002a).

| | **Release Numbers per family** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age** | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 |
| 2 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 |
| 3 | 600 | 900 | 1200 | 1500 | 1800 | 2100 | 2400 | 2700 |
| 4 | 540 | 810 | 1080 | 1350 | 1620 | 1890 | 2160 | 2430 |
| 5 | 486 | 729 | 972 | 1215 | 1458 | 1701 | 1944 | 2187 |
| 6 | 437 | 656 | 875 | 1094 | 1312 | 1531 | 1750 | 1968 |
| 7 | 394 | 590 | 787 | 984 | 1181 | 1378 | 1575 | 1771 |
| 8 | 354 | 531 | 709 | 886 | 1063 | 1240 | 1417 | 1594 |
| 9 | 319 | 478 | 638 | 797 | 957 | 1116 | 1275 | 1435 |
| 10 | 287 | 430 | 574 | 717 | 861 | 1004 | 1148 | 1291 |
| 11 | 258 | 387 | 517 | 646 | 775 | 904 | 1033 | 1162 |
| 12 | 232 | 349 | 465 | 581 | 697 | 814 | 930 | 1046 |
| 13 | 209 | 314 | 418 | 523 | 628 | 732 | 837 | 941 |
| 14 | 188 | 282 | 377 | 471 | 565 | 659 | 753 | 847 |
| 15 | 169 | 254 | 339 | 424 | 508 | 593 | 678 | 763 |

| | Release Numbers per family | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age** | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 |
| 16 | 153 | 229 | 305 | 381 | 458 | 534 | 610 | 686 |
| 17 | 137 | 206 | 275 | 343 | 412 | 480 | 549 | 618 |
| 18 | 124 | 185 | 247 | 309 | 371 | 432 | 494 | 556 |
| 19 | 111 | 167 | 222 | 278 | 334 | 389 | 445 | 500 |
| 20 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 |
| 21 | 90 | 135 | 180 | 225 | 270 | 315 | 360 | 405 |
| 22 | 81 | 122 | 162 | 203 | 243 | 284 | 324 | 365 |
| 23 | 73 | 109 | 146 | 182 | 219 | 255 | 292 | 328 |
| 24 | 66 | 98 | 131 | 164 | 197 | 230 | 263 | 295 |
| 25 | 59 | 89 | 118 | 148 | 177 | 207 | 236 | 266 |
| 26 | 53 | 80 | 106 | 133 | 160 | 186 | 213 | 239 |
| 27 | 48 | 72 | 96 | 120 | 144 | 168 | 191 | 215 |
| 28 | 43 | 65 | 86 | 108 | 129 | 151 | 172 | 194 |
| 29 | 39 | 58 | 78 | 97 | 116 | 136 | 155 | 174 |
| 30 | 35 | 52 | 70 | 87 | 105 | 122 | 140 | 157 |
| 31 | 31 | 47 | 63 | 79 | 94 | 110 | 126 | 141 |
| 32 | 28 | 42 | 57 | 71 | 85 | 99 | 113 | 127 |
| 33 | 25 | 38 | 51 | 64 | 76 | 89 | 102 | 114 |
| 34 | 23 | 34 | 46 | 57 | 69 | 80 | 92 | 103 |
| 35 | 21 | 31 | 41 | 52 | 62 | 72 | 82 | 93 |
| 36 | 19 | 28 | 37 | 46 | 56 | 65 | 74 | 83 |
| 37 | 17 | 25 | 33 | 42 | 50 | 58 | 67 | 75 |
| 38 | 15 | 23 | 30 | 38 | 45 | 53 | 60 | 68 |
| 39 | 14 | 20 | 27 | 34 | 41 | 47 | 54 | 61 |
| 40 | 12 | 18 | 24 | 30 | 36 | 43 | 49 | 55 |
| 41 | 11 | 16 | 22 | 27 | 33 | 38 | 44 | 49 |
| 42 | 10 | 15 | 20 | 25 | 30 | 34 | 39 | 44 |
| 43 | 9 | 13 | 18 | 22 | 27 | 31 | 35 | 40 |
| 44 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 |
| 45 | 7 | 11 | 14 | 18 | 22 | 25 | 29 | 32 |
| 46 | 6 | 10 | 13 | 16 | 19 | 23 | 26 | 29 |
| 47 | 6 | 9 | 12 | 15 | 17 | 20 | 23 | 26 |
| 48 | 5 | 8 | 10 | 13 | 16 | 18 | 21 | 24 |
| 49 | 5 | 7 | 9 | 12 | 14 | 16 | 19 | 21 |
| 50 | 4 | 6 | 8 | 11 | 13 | 15 | 17 | 19 |
| 51 | 4 | 6 | 8 | 10 | 11 | 13 | 15 | 17 |
| 52 | 3 | 5 | 7 | 9 | 10 | 12 | 14 | 15 |
| 53 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 |
| 54 | 3 | 4 | 6 | 7 | 8 | 10 | 11 | 13 |
| 55 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 11 |
| 56 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 10 |
| 57 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 58 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 59 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 7 |

| | Release Numbers per family | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Age** | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 |
| 60 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 61 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 62 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 5 |
| 63 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 64 | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 |
| 65 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |

5. *Marking requirements:* Hatchery fish may be batch-marked with coded-wire-tags (CWTs) rather than individually coded PIT tags.

*Rationale:* All hatchery fish have been marked with individually numbered PIT tags and year-specific scute removal patterns to distinguish hatchery and wild fish, and to provide family and release group-specific mark-recapture information suitable for estimating survival and growth. Analysis of 10 years of PIT tag data provided excellent data on survival and growth of hatchery fish and more of the same type of data from future release groups will provide diminishing returns in information value. CWTs in combination with scute removal can be used to batch mark individual family groups so that hatchery and wild fish can continue to be distinguished. Electronic wands can detect the presence of a CWT but unlike the PIT tag cannot decipher the tag code. However, individual identity of hatchery progeny in the future should be available from microsatellite DNA assignment or exclusion testing. In addition, the size of the PIT tag requires raising fish to 30 g, which may require 2 years for some individuals. The corresponding need to maintain overlapping generations in the hatchery constrains the numbers of family groups that may be reared. This, in turn limits numbers of wild fish that can be spawned to produce the next generation. Thus, CWTs allow fish to be tagged and released at smaller sizes, which frees up hatchery space to produce more family groups and preserve more of the existing population's diversity. Finally, PIT tags are costly and use of CWTs will substantially reduce tagging costs. PIT tags should continue to be used on 500 fish subsamples of appropriate release groups for monitoring and research purposes. In addition, other batch marking alternatives such as tetracycline, calcein, or micro-elemental analysis should continue to be investigated.

6. *Size at release:* Release fish at smaller sizes and younger ages (10-15 g in fall at age 0+ or spring at age 1 rather than at 30 g at age 1+ or 2).

*Rationale:* Eliminating the PIT tag requirement provides the flexibility to release fish at smaller sizes and ages, which opens up space for more family groups in the hatchery. All the fish from any brood year can be released by the time space is needed for rearing the next brood year. Actual size at release will now depend on first year growth in each facility. Upon release, smaller fish are expected to survive at similar annual rates to those observed in previous groups although an extra year of natural mortality means that slightly fewer fish from any release group would be expected to survive to a given age than if they would have been released a year later. However, increased release numbers allowed by this change in space utilization is designed to more than offset this effect. Minimizing time in the hatchery also minimizes opportunities for hatchery selection

effects and unforeseen rearing catastrophes, such as disease outbreak or equipment failure. Future releases can occur in spring or fall and unequal numbers of some family groups can be released during each season. This decision should be made based on how best to maximize numbers of fish that can be produced from each family group. For instance, fall releases of a portion of each family might clear sufficient space to allow rearing the balance of the group through spring.

*7. Release locations:* Release fish throughout British Columbia, Idaho, and Montana (downstream from Kootenai Falls) portions of the river (Figure 3).

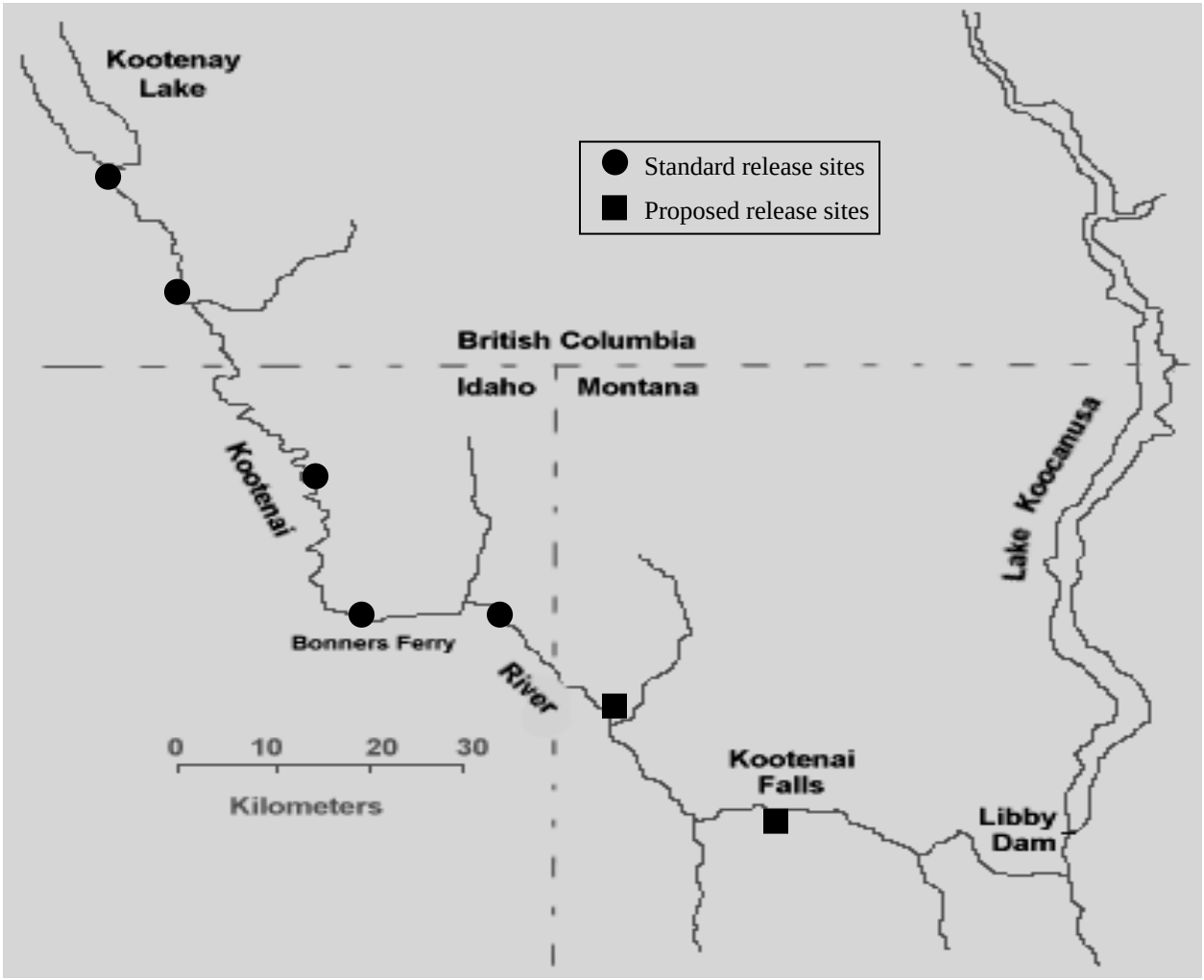


Figure 3. Locations of standard and proposed release sites for hatchery reared Kootenai River white sturgeon.

*Rationale:* Release of fish throughout much of the Kootenai River downstream from Kootenai Falls (Figure 3) is designed to allow fish to colonize all suitable habitats, and to reduce risks from concentrating fish in small areas where they could outstrip available habitat and food resources. Analysis of past fish movements indicated that released fish gradually dispersed from release sites, and distributed naturally into suitable habitats. Reasonable attempts should be made to distribute each family group among multiple release sites. Proposed fish release sites have been expanded upriver to include Montana waters of the Kootenai River downstream from Kootenai Falls to take advantage of habitat throughout the historic range, and to provide opportunities for potential imprinting to upstream areas where more favorable spawning and rearing conditions may exist. In addition, releases directly to Kootenay Lake should be immediately discontinued to reflect the potential that this practice could lead to impaired imprinting, should it occur. Further reflecting imprinting uncertainties, consideration should be given to releasing representatives from all family groups at all sites, acknowledging logistical limitations may prohibit all combinations. Similar treatment between the families will help ensure that none are severely compromised as adults in the event that strongly localized imprinting is a factor. With each hatchery rearing different family groups, this will complicate transboundary transport because it implies release of both Canadian- and U.S.-reared fish at multiple sites. This issue may be of greater concern for Canadian-reared families, since they are reared on groundwater in the absence of any cues that could imprint them to the Kootenai River.

This stratified systematic release strategy is recommended due to: 1) uncertainty associated with inter- and intraspecific competition and the distribution, quality, and suitability of white sturgeon rearing habitats in the post-development Kootenai River system, and 2) assumed variable and differential survival and adaptability within and among families. This release strategy:

- assumes no pre-conceived spatial distribution of habitat suitability for juvenile white sturgeon;
- allows volitional colonization and habitat use across a large area of the river and its habitat types;
- provides empirical information on performance and behaviors associated with stocking across habitat types, and among family release groups;
- allows for maximum potential habitat colonization, and access to the widest range of resources, and
- minimizes the probability of artificially increasing negative interaction and density-dependence growth reductions for post-release juvenile white sturgeon in the Kootenai River.

Release protocols include up to 7 standardized release sites for consideration during an initial 3-5 year period (2 in Montana, 3 in Idaho, and 2 in BC) This Plan recommends release sites in: Montana: 1) sturgeon hole, 2) Yaak River confluence; Idaho: 3) Above Hemlock Bar, 4) Kootenai Hatchery, 5) Rock Creek, and British Columbia: 6) Creston boat launch, 7) Kootenay River delta).

8. *Family equalization:* Allow for release of family groups of varying numbers.

*Rationale:* Because of variation in spawning success and survival, family groups may vary in size from a few hundred to several thousand fish. Given the acute nature of the demographic risk to the Kootenai sturgeon population, it is currently more important to maximize release numbers, within limits, from each family group to ensure a next generation than it is to try to equalize release numbers from each family in an attempt to balance the genetic contributions of hatchery fish in the generation after the next generation. For instance, it is not appropriate to cull the large family groups down to the size of the smallest family group. This concern would be significant if some families were orders of magnitude different from the average (e.g. 100,000 vs. 10,000). Furthermore, normal variation about the desired release numbers (3,000-4,500) is not a major concern, due to compensation and variability from empirical white sturgeon reproductive and gene flow models (Table 2). Note that natural recruitment can no longer be counted on in the absence of the hatchery to adequately propagate the existing population into the next generation. Given 40 years of recruitment failure, it is unlikely that consistently favorable conditions will be immediately restored during multiple, consecutive years. If successful natural recruitment does occur, it will likely only involve a few fish in one year or another, and would be beneficially additive, better representing natural models of white sturgeon reproduction and gene flow.

*Background* - Equalization of family group size at release has been reported as a way to reduce or minimize selection associated with hatcheries, based on the notion that differential early life selection pressures occur in the hatchery relative than in the wild (Allendorf 1993; Kincaid 1993; Smith et al. 2002). However, this concern is more applicable to semelparous salmon species than to sturgeon (Anders in review). This is so because progeny groups of any species that survive well in the hatchery may not survive equally well in the wild, and vice versa. However, few published empirical evaluations comparing performance and survival of variable and equalized family release groups currently exist in the literature to support or refute such claims (Hedrick and Hedgecock 1994).

Equalizing the number of individuals among all family groups at release has also been recommended as a way to reduce inbreeding in subsequent generations. This recommendation is based on the assumption that equalizing family release group size will minimize over- and under-representation of hatchery-reared fish after they mature and reproduce in the wild. However, when this argument is applied to white sturgeon, it is based on two faulty assumptions: 1) equal post-release survival until sexual maturation, and 2) equal reproductive contribution among progeny from all release groups. Furthermore, failure of the first assumption greatly increases the probability of violating the second. In addition to faulty assumptions, Kootenai River white sturgeon typically require 20 or more years (30 for females) between release and maturation. Therefore, the need to equalize group size for sturgeon hatchery programs is not a major concern (Anders in review).

Currently, none of the salmon conservation aquaculture programs in the Columbia River basin equalize the size of release groups (Paul Kline, Idaho Department of Fish and Game; Madison Powell University of Idaho, personal communication, 2003). However, these programs do adamantly require equal fish numbers from all progeny groups if these

groups are used to create captive brood stock populations. In both cases (release groups and founding of captive brood stock populations) the common objective is to represent progeny from as many lineages and families within the population as possible (Table 2), because in both cases surviving hatchery progeny are needed to contribute to future generations.

9. *Brood stock reuse:* Minimize reuse of brood stock in the same or different years where alternatives are available, but reuse brood stock as necessary to fully utilize the available hatchery space and minimize extinction risks.

*Rationale*: As the wild Kootenai River white sturgeon population continues to decline, it will become increasingly difficult to collect brood stock every year. As more and more fish from the shrinking population are used for brood stock, previously used brood stock will comprise an increasing proportion of the annual brood stock catch. Ideally, only new individuals would be used for brood stock until every remaining fish had the opportunity to contribute via the hatchery to the next generation. If there is a choice, new brood stock should be preferentially used over previously used fish. Practically, there will be times when only previously used brood stock will be available. It is better to reuse brood stock to maximize numbers in the next generation and hedge against demographic risks than to leave hatchery space unused and further risk extinction. Use DNA data from all previously used brood stock to help make spawning matrix decisions.

10. *Half-sib family use:* Use of half-sib families is appropriate.

*Rationale:* As with brood stock reuse, there will be times when there are not enough males or females to produce unique family groups. It is typically easier to get males than females; so one female may be spawned with several different males to provide the opportunity for all available males to contribute.

11. *Failsafe population:* Develop a failsafe sturgeon population by release of additional hatchery fish in a natural water body where attendant risks to the current wild population and other sensitive species is minimal.

*Rationale:* Establishing a second Kootenai sturgeon population is designed to reduce acute extinction risk for the current population. A failsafe population can be established with hatchery fish produced in excess of current hatchery rearing capacity. Each family typically includes many more eggs and larvae than can be feasibly raised in the hatchery (because bigger fish require more space than smaller fish). Libby Reservoir is one potential site for establishing an experimental, non-essential population of Kootenai River white sturgeon. However, additional work is needed to resolve historical range and interstate regulation questions.

The Endangered Species Act (1992) provides for the creation of "Experimental" populations: "The Secretary may authorize the release of an endangered species or threatened species outside the current range of such species if the Secretary determines that such release will further the conservation of such species" (ESA, Section 10 (j)(2)(A)). Such populations can be listed as essential or non-essential under the ESA. If listed as non-essential, such a population would have no critical habitat designated (ESA, Section 10(j) (2) (B)).

Further rationale for establishing an experimental population (essential or non-essential) is that extinction probabilities decline exponentially when populations contain several sub populations, compared to modeled persistence of a single population, due largely to the effects stochastic events on persistence (Meffe and Carroll 1994, 1997; Dr. Oz Garton, University of Idaho, personal communication). Such population structuring also increases recovery probabilities due to the low probability of all sub-populations being simultaneously and lethally affected in different locations by the same or different stochastic factors.

Therefore, in the interest of population preservation and reduction of extinction probability for Kootenai River white sturgeon, this Plan recommends consideration of Lake Koocanusa (and other suitable sites, preferably within the Kootenai/y Basin) as a potential site to establish an experimental population of Kootenai River white sturgeon.

12. *Hatchery modifications:* Additional hatchery facilities are required to ensure conservation of current genetic diversity and expansion plans (e.g. NPCC 3-Step Hatchery Evaluation Process should be initiated immediately).

*Rationale:* Even with recommended changes to brood stock use and juvenile rearing strategies, projected fish numbers will fall short of minimums required to confidently assure conservation of existing genetic diversity. Additional adult holding and juvenile rearing space is required to preserve additional families. Temperature regulation in the adult holding facility would also provide the opportunity to hold males at the hatchery and to bring them into spawning condition, as females are ready. The current practice of relying on males spawned at capture will become increasingly chancy as the population continues to decline. In such cases, it will become increasingly likely that spawning opportunities will be lost when females are ripe but no males are available. Water temperature regulation in the juvenile rearing facilities could increase growth and survival. Considerations of hatchery capital expenditures require review in the NPPC 3-step planning process. This process needs to be initiated immediately to provide the needed facilities before the remaining wild population disappears completely.

13. *Monitoring & Adjustments:* Continue to implement an annual scientific monitoring and evaluation plan with flexibility to adapt activities to critical questions that change over the course of implementing this Plan.

*Rationale:* Uncertainty in the effectiveness of recovery over various time scales, and the experimental nature of recovery activities place a high premium on an effective and adaptive monitoring and evaluation programs. Monitoring and evaluation components of this Plan and its adaptive management framework will provide critical guidance for program implementation. Conservation efforts and the research and monitoring program will need to evolve as efforts continue to unfold. An effective balance will need to be struck between implementation actions needed to preserve the population in the near term and experimental designs to facilitate research. When push comes to shove, immediate preservation actions trump strict research protocols designed to better understand critical uncertainties that threaten short- and long-term recovery.

*14. Stocking Measures*

In order to adaptively meet changing program needs in response to increasingly threatening demographic conditions for this population, two new stocking strategies are recommended to update the Program's past preservation stocking strategy:

- Demographic restoration stocking
- Early life research stocking

*Demographic restoration stocking* – Demographic restoration stocking is designed to establish and maintain abundance, age class and population genetic structures required for population viability and persistence. Demographic restoration stocking is proposed to ensure that the duration of the demographic bottleneck (Figure 1) is not increased. Demographic restoration stocking is refined from the past preservation stocking strategy (Kincaid 1993) by incorporating most recent empirical population demographic and annual survival estimates (Ireland et al 2002a; Paragamian et al. in press), but continues to address the initial program goal of protecting genetic variability and rebuilding demographic vigor. Effects of production and stocking numbers will be evaluated with the individual-based empirical model, and incorporated into this Plan (See Section V.4 "Release numbers" for more details).

*Early life research stocking* - Early life research stocking allows focused empirical research on specific critical uncertainties currently jeopardizing short- or long-term population recovery. ELR stocking *is not* to be used to increase release numbers above demographic restoration stocking goals. Rather, research stocking is designed to address specific experiments where researchers and managers propose a release group or set of release groups to test particular hypotheses, or to collect empirical data from early life stages unavailable without hatchery production. (e.g. empirical diet studies of YOY or age-0 fish). Based on most recent empirical recapture rates, it is assumed that significant proportions of research stocking groups can be removed as part of any proposed study design. (Estimated mean annual capture probabilities averaged 10-15% over the last 8 years (1994-2002), ranged from < 1-22%; Paragamian et al. in press)

*Early life research stocking – release numbers:* Release numbers of fish under research stocking protocols will be determined by sampling efficiencies and sample size requirements to answer specific research questions. Decisions regarding implementation of research involving fish stocking, and its legitimacy will be made through a simple proposal-and-review process facilitated by the Recovery Team and the KTOI Fisheries Program Director, Hatchery Manager, and other appropriate fisheries managers. Proposing entities are encouraged to solicit independent scientific review of their proposals. Stocking protocols under research stocking will be determined based on their scientific and design merits, their probability of success, and their consistency with goals and objectives of this Plan.

*15.* "*Excess Fish" Policy* – This policy deals with fish that are produced in excess of all stocking goals for all purposes at the Kootenai Hatchery in Idaho. Alternatively, sturgeon at the Kootenay Trout Hatchery near Fort Steele, BC produced in excess of agreed-upon restoration and research-stocking purposes, as well as the following uses, will be humanely euthanized. Recommended fish uses under this Plan's Excess Fish Policy include: 1) use in establishment of experimental non-essential population, 2) applied research, and 3) public information and education. These uses may coincide temporally.

1) Establishment of experimental, non-essential population for conservation of Kootenai River white sturgeon under ESA, Section 10-J (See Section V.11. "Failsafe population" for more details).

2) Applied research may involve various aspects of embryonic, larval, or juvenile performance, survival, or behavior that apply to issues of this Program and population recovery. Examples have included laboratory contaminant uptake (Kruse and Scarnecchia 2002), embryo survival studies (J. Congleton, University of Idaho, personal communication), and fish pathology research (Cain and Drennan 2002).

3) Use of endangered Kootenai River white sturgeon for public information and education purposes is allowed under Section 10 of the ESA, and is strongly encouraged by the Program. Such activities provide the valuable and necessary function of informing the public; public support of the Program is an important, tangible Program asset. Examples of such activities include presentations or displays of preserved sturgeon eggs, larvae, and juveniles in public places and in schools.

# VI. Annual Monitoring and Evaluation Programs

Five monitoring and evaluation (M&E) programs are included within the Kootenai Conservation Aquaculture Program:

1) Genetics
2) Fish health
3) Post-release performance, behavior, and survival
4) Gamete cryopreservation
5) Hatchery water quality

*1. Genetics M&E Plan*

A population genetics Monitoring and Evaluation Plan is essential to guide and track the success of any conservation aquaculture program. The Genetic M&E Program uses newly developed white sturgeon microsatellite primers (Rodzen et al. 2004; McQuown et al. 2000) to characterize: 1) the wild population, 2) the hatchery brood stock population, and 3) representative progeny groups (n=60). The Genetics M&E Plan will also: 4) annually track genetic diversity and variability, and 5) maintain diversity & variability over time at levels initially encountered in the investigation. Inter-annual changes in variability estimates are expected due to within-year small-sample bias. However, it is the intent of this Plan to preclude long-term reductions in genetic variability and diversity. Annually monitoring variability and diversity trajectories is designed to achieve this goal.

Microsatellite DNA markers have become popular as the optimal marker systems for many applications, due to their high resolution and highly variable nature. Nine white sturgeon microsatellite primer sets have been developed, tested, and described in terms of their inheritance patterns at nine highly variable, polymorphic microsatellite loci (McQuown et al. 2000; Rodzen and May 2002). These primers will be used to evaluate individual, familial and population genetic aspects of the Kootenai Hatchery Program. These markers are particularly well suited for the wild population and the subset brood stock sample groups, as needed for evaluating genetic aspects of this Program, due to their high variability and individual discriminating power. Because white sturgeon are suspected of having a polyploid derivative genome, one cannot assume that a given locus will fit the assumptions of Mendelian inheritance for a single disomic locus. There is evidence that a large amount of genome duplication has occurred, and the species is suspected of being octaploid derived (Blacklidge and Bidwell 1993). Comparisons of DNA content and chromosome number across sturgeon species in the order Acipenseriformes worldwide show that genomes vary from 4N (e.g. Birstein et al. 1993, Fontana 1976) to possibly 16N (Birstein et al. 1993, Blacklidge and Bidwell 1993), with most appearing to be 4N (Birstein et al. 1997). Nine tetramer motif $[GATA]_n$ microsatellite loci were developed for use in the white sturgeon (Rodzen and May 2002). These authors reported inheritance patterns for these nine systems, which ranged from one possible disomic system to tetrasomy and octosomy. Due to the complex modes of

inheritance underlying these systems and the highly duplicated nature of the genome, we proposed each allele be scored as its own dominant marker, similar to amplified fragment length polymorphisms (AFLPs) or restriction fragment length polymorphisms (RAPDs) (J. Rodzen, UC Davis, personal communication). The utility of this method has been validated by the observation that individual alleles within a microsatellite system generally fit the expectation for independent transmission and fit the expected transmission frequency for single copy nuclear markers (Rodzen and May 2002). Finally, this suite of nine microsatellite loci could be used to assign or exclude unmarked juveniles captured in the river to or from the hatchery produced progeny groups.

Consideration should also be given to pre-spawning genotyping of all brood stock in the hatchery each year. Recently, such genetic data have been successfully and routinely used in salmon conservation aquaculture programs to develop "desirability" or "dissimilarity" (genetic distance) matrices to minimize inbreeding in the hatchery. Although white sturgeon hatcheries have much less control over brood stock availability, much less flexibility in spawner timing, and spawn very few fish compared to salmon hatcheries, this genotyping could occur quickly, and could provide benefits under certain situations for the Program. Such information can facilitate intentional outbreeding (the breeding of more distantly related individuals) and the reduction of unintentional inbreeding. Outbreeding depression is the reduction in fitness in progeny from distantly related individuals. However, the isolated nature of the Kootenai River white sturgeon population, including total lack of gene flow from outside populations since retreat of the last glacial period (~10,000 years ago) suggests that outbreeding depression poses little or no risk to this population.

*2. Fish Health M&E Plan*

*Background* - A primary objective of any aquaculture program is to minimize introduction and transmission of pathogens in cultured and wild populations (Ireland et al. 2002a). Although asymptomatic infection can be widely distributed within and among wild populations, maintenance of controlled rearing conditions (optimal densities, temperature regimes, water quality conditions) can reduce or prevent stress-induced outbreaks of disease in the hatchery setting (LaPatra et al. 1994, 1999). Development, refinement, and strict implementation of the Program's disease testing protocols for white sturgeon produced in the Kootenai River White Sturgeon Conservation Aquaculture Facility will continue to minimize potential disease outbreaks and disease transmission to the wild population.

Kootenai Hatchery upgrades completed in 1999 (new water intake system, improved water temperature control for incubation and hatching, sediment filtration systems, pathogen control (UV sterilization), and added rearing capacity) appear to have contributed to increased hatching success and survival of early life stages, and minimized disease outbreak and fish loss (Ireland 1999; Ireland and Anders in preparation; Ireland et al. 2003). The addition of a "fail-safe" facility and collaboration with biologists and fish culturists in British Columbia, Canada have contributed further to program success**.**

From 1992 through 1996, white sturgeon produced from the Program were periodically tested for the presence of white sturgeon iridovirus (WSIV). Testing was mandatory when disease mediated fish loss occurred in the hatchery. From 1997 through 2004, all brood stock and at least 30 progeny from each spawning year were annually tested for the presence of pathogens. Fish health monitoring included parasitology, bacteriology, virology and histopathology examinations. Since 1997, ovarian fluid and male and female gametes were also sampled and tested for viral pathogens (WSIV, *Herpes* viruses 1 and 2). Disease testing results have been reviewed by relevant state, provincial, federal and tribal management agencies. Generally fish with no diagnostic signs of disease symptoms were approved for release (LaPatra et al. 1999).

Disease testing Protocols - At a minimum, the following protocols, from Idaho and British Columbia hatcheries will be followed regarding fish health testing for white sturgeon in the program hatcheries:

***Disease Testing Protocol for Release of Hatchery Reared White Sturgeon into the Kootenai River – Kootenai Tribe of Idaho***

Approved in 1997 by all members of the White Sturgeon Recovery Team and respective pathologists from USFWS, IDFG, MFWP, BC Ministry of Fisheries and CA DFO.

The permittee shall examine 30 hatchery sturgeon to verify disease free status prior to release. A report of this examination shall accompany the written proposal to release sturgeon submitted under 8 (c) above. The protocols are as follows:

*Virology:* Using normal sturgeon cell lines and epidermal tissue methods recommended by Dr. Ron Hedrick, test 30 sturgeon. It would be preferable to use 2 fish per pooled sample rather than 5 fish.

*Histology:* Evaluation by a competent histologist of 20 fish. The following tissues should be processed: gills, heart, brain, liver, kidney (anterior, mid, and posterior), gastro-intestinal tract, spleen, gonad, skin, muscle, and semi-circular canal/skull area (to check for *M. cerebralis*).

*Bacteriology:* Culture of kidney tissue from 30 fish, using media suitable for the isolation of myxobacteria, mycobacteria, and *Yersinia spp*.

*Parasitology:* Gill and skin wet mounts from 10 fish checking for bacteria and parasites.

Freshwater Fisheries
Society *of* BC

# Pathology testing protocols for Kootenai Sturgeon 2003

An extensive Pathology testing program has been implemented on the Kootenai sturgeon program by the Freshwater Fishery Society of BC (FFSBC) in order to meet transplant approval requirements regulated by the Introductions and Transfers Committee (ITC). The ITC is a group of representatives from all governing bodies with an interest in fish movements entering, leaving and within British Columbia. Equal representative positions are appointed from the federal level from the Department of Fisheries and Oceans (DFO) and at the provincial level from the Ministry of Water, Air and Land Protection (WLAP) and Ministry of Agriculture, Fisheries and Foods (MAFF). This committee is responsible for approving all permits related to fish movements within BC and also to assess all risks and mandate any quarantine measures to any species of fish being introduced into BC waters.

The Kootenai River system is a transboundary river system stemming from its headwaters located in Canada, through Lake Koocanusa, looping down through Montana and Idaho and crossing back up across the 49$^{th}$ parallel border to empty into Kootenay Lake BC. The brood stock for the Kootenai white sturgeon are captured in the Kootenai river around the Libby dam area in Idaho and are spawned at the Kootenai Tribes of Idaho Hatchery. As part of the recovery conservation initiative, a portion of disinfected fertilized eggs is transported up across the border to be reared in the FFSBC's Kootenay Sturgeon Conservation Hatchery.

Historically the tributary waters feeding into the Kootenai River in Idaho were at one time stocked with fish known to carry a fish virus know as Infectious Pancreatic Necrosis Virus (IPNV). This virus can cause devastating mortalities in hatcheries rearing salmonids and can be detrimental to some freshwater species such as Rainbow trout and Brook trout. There is not much documented in the literature as to whether sturgeon can be carriers of salmonid diseases however there was paper cited from France, which indicated that IPNV had been detected in a sturgeon species, form the wild. It should also be noted that to date IPNV has not been detected I any fish within the waters of the Province of British Columbia. Since the original proposal was to bring sturgeon eggs across the border into BC and the sturgeon brood came from historically potential IPNV water the ITC assessed it as a moderate to high risk introduction an imposed strict quarantine guidelines and an intensive Fish Health Monitoring program. Quarantine measures included sentinel salmonid fish reared in discharge effluent (the thought being

that if sturgeon were shedding virus (in particular IPNV) the salmonids would pick it up and the virus could be isolated from them), and ozonation of effluent plus intensive sampling of individual family groups during the first 120 days of rearing. We have managed to get some modifications to the sampling schedule over the past two years as test results have come up consistently negative for pathogens of concern. All Canadian reared Kootenai sturgeon are tested at the FFSBC Fish Health Unit, located in Nanaimo, BC. The current testing protocol is as follows:

| Sample type | Submission time | Number of fish per submission | Histology performed Y/N | Comments |
|---|---|---|---|---|
| Sentinel RBT | Pre-test 6 weeks in advance | 60 fish | N | Done prior to fish entering into sentinel tank 6 weeks prior to receipt of first egg shipment |
| Family 1 | 30 dph<br>60 dph | 30 fish<br>60 dph | Y<br>Y | dph: days post hatch |
| Family 2 | 30 dph<br>60 dph | 30 fish<br>30 fish | Y<br>Y | dph: days post hatch |
| Family 3 | 30 dph<br>60 dph | 30 fish<br>30 fish | Y<br>Y | dph: days post hatch |
| Family 4 | 30 dph<br>60 dph | 30 fish<br>30 fish | Y<br>Y | dph: days post hatch |
| Family 5 | 30 dph<br>60 dph | 30 fish<br>30 fish | Y<br>Y | dph: days post hatch |
| Pooled sample Pre-release | 60 days prior to release | 60 fish | Y | 1 Pooled sample of all families |

All submitted samples are tested using virus protocols laid out in the Fish Health Protection regulations Manual of Compliance. Homogenized samples used for sturgeon are generally done in pools of three fish each and include the following extracted tissue:

- 1 operculum
- 1 set of gills
- barbels /skin
- 1 pectoral fin
- small piece of spleen
- small piece of liver
- small piece of pyloric ceaca
- and kidney tissue

Samples are homogenized in Hank's balanced salt solution using a Polytron Homogenizer. The samples are then diluted to a 2% concentration, centrifuged, filtered through a 0.45 um filter paper and inoculated onto the following cell lines:

- EPC (best line for IHNV)
- CHSE-214 (salmonid cell line of choice for detection of IPNV)
- WSS-2 (white sturgeon spleen cell line)
- WSSK (white sturgeon skin cell line)
- WSG (white sturgeon gill cell line)

The sturgeon are monitored for the following known fish viruses:

- IPNV (Infectious Pancreatic Necrosis) Salmonid virus
- IHNV (Infectious Hematopoietic Necrosis) Salmonid virus
- WSIV (White Sturgeon Iridovirus) sturgeon virus
- WSHV-1 (White sturgeon herpesvirus type 1)
- WSHV-2 (White sturgeon herpesvirus type 2)
- Adenovirus (White sturgeon Adenovirus) (detectable by histology using intestine tissue, not isolated on cell lines)

Sturgeon viruses are very difficult to isolate on cell lines so we use Histology sections of gill and pectoral fin as a back up measure to try and detect some of the viruses. To date all virology samples and histology samples have been negative.

In 2003 we had to apply to the ITC to make changes to our effluent treatment. In order to reduce time required to ozonate effluent we had to ensure ITC brood fish would test negative for IPNV prior to the ozone being turned off. We introduced the PCR test for IPNV to check adults. Reproductive fluids are collected at time of spawn and shipped to the FFSBC Fish Health lab for testing for IPNV using the IPNV PCR test.

*3. Post-release performance M&E Plan*

A post-release monitoring program was first implemented in 1993 to annually recapture hatchery-reared Kootenai River white sturgeon in the Kootenai River, using experimental mesh gill nets, hoop nets, and angling (Marcuson 1994; Paragamian et al. 1997; Ireland 1997; Ireland et al. 2002a). Mark-and-recapture techniques were successfully used to estimate annual growth and survival of these fish. An ultrasonic telemetry study was implemented in 1999 to determine juvenile white sturgeon habitat use, relative to depth, velocity, substrate and cover. Average post-stocking survival rates for the first year and condition factors ($W_r$; Beamesderfer 1993) for each release group were estimated.

The following larval and juvenile white sturgeon sampling methods were provided by, and will be implemented by the Idaho Department of Fish and Game. This work will simultaneously target naturally and hatchery-reared larvae and juveniles.

*Larval white sturgeon sampling (IDFG)* - Larval white sturgeon sampling will be conducted using ½ m nets at mid-water column depths and at the surface, and d-ring nets fished on the Kootenai River substrate. Lead weights ranging from 2.7-9.1 kg (6-20 lbs) will be attached to mid-column and bottom nets in order to effectively sample desired depths. Flow meters will be attached to the mouth of each net to measure current velocity, which together with total sampling time and net mouth dimensions provide the total volume of water sampled. Larval sampling will be conducted at various times of day in ten predetermined locations between rkm 220.0 and 244.5. Because white sturgeon larvae are effectively planktonic during early developmental stages (sampled as drift items), sampling will occur at river channel constrictions, where current is directed toward a bank or structure, and in areas adjacent to and downstream from known spawning sites. Sampling day and location will be randomized (with replacement), and sites will have equal probabilities of being sampled on a given day. Studies suggest that sturgeon larvae drift primarily at night (Kempinger 1996). Future monitoring and evaluation efforts should incorporate night sampling.

*Juvenile white sturgeon sampling (IDFG)*

*Gillnetting* - Five sizes of weighted multifilament gill nets (1.5, 2, 3, 4, and 6-inch stretch mesh) will be used to sample juvenile and young-of-the-year (YOY) sturgeon according to methods reported by Paragamian et al. (1996) and Fredericks and Fleck (1996). Gill net sampling will be conducted at one of 12 predetermined index sites located between rkm 192.0 and 230.5. Gill nets will be set during the day and checked every hour. All juvenile sturgeon will be processed by methods reported by Paragamian et al. (1996). Seventy five percent of the sampling will be conducted at five locations (index sites) that are thought to represent prime juvenile sturgeon habitat. The remaining 25 percent of the effort will occur at seven locations thought to be marginal juvenile habitat. As with larval sampling juvenile sampling site selection will be randomized, with replacement. All sampling performed by the IDFG will be coordinated with the British Columbia Ministry of Water, Land, and Air Protection (MWLAP) and Kootenai Tribe of Idaho (KTOI) programs.

The following juvenile white sturgeon sampling sections were provided by and will be implemented by the BC Ministry of Water. Land, and Air Protection, in cooperation with the KTOI and the IDFG:

# Kootenay/Kootenai River White Sturgeon Juvenile Sampling Plan (BC WLAP)

## Introduction

This sampling program for juvenile white sturgeon (*Acipenser transmontanus*) in the Kootenay/Kootenai River (spelled "Kootenay" in Canada) between the Kootenay River delta at the south end of Kootenay Lake and Bonners Ferry Idaho is intended to establish long-term juvenile white sturgeon sampling locations and methods that are consistent between years and among all members of the Kootenai River White Sturgeon Recovery Team. The objectives for the sampling program are to:

1) Index natural recruitment events in the Kootenay/Kootenai River;

2) Collect DNA and WSIV tissue samples from all wild juveniles;

3) Determine the age distribution of both wild and hatchery-produced juveniles;

4) Describe population trends related to growth rate, size, distribution, survival and abundance of both hatchery and wild juvenile white sturgeon; and

5) Determine large scale habitat preferences of wild and hatchery-produced juveniles.

## Methodology

*Sampling Gear* - Juvenile white sturgeon will be captured using multi-strand nylon gill nets of 150 ft. by 6 ft. Previous juvenile sturgeon sampling programs on the Kootenay River in Canada have exclusively used 2 inch stretched measure nets (Vandenbos and Spence 2001). These nets had proven the most effective size for capturing juvenile YOY white sturgeon in previous work on the lower Columbia River (Burner et al. 2000). Two inch stretch measure nets have been successful in capturing nearly all age classes of sturgeon in the Kootenay River in Canada and the USA (Vandenbos and Spence 2001; Neufeld and Spence 2002). Although, it is probable the use of a single mesh size in previous sampling programs has resulted in size selectivity biases in sturgeon catch. Size selectivity of gill nets by mesh size is widely recognized (McCombie and Berst 1969, Hamley 1975 and references therein, Hilborn and Walters 1992). However, the scutes that line the lateral and dorsal surface of juvenile sturgeon often result in tangle captures, thus diluting the effect of gill net size selectivity. Juvenile sturgeon may not experience the extent of gill net selectivity that many other fish encounter; however, selectivity is still present. On the Kootenay River in 2001, 1-inch stretch measure nets were used on

an experimental basis to capture smaller juvenile sturgeon resulting from larval releases in the spring of 2000 and possible natural recruitment events. No young-of-the-year (YOY) sturgeon from either of these scenarios were captured, comparisons of capture data for larger juveniles captured in these sets showed a significant difference in capture efficiencies, with catch per unit effort in 2 inch nets twice as high as in 1 inch nets (Neufeld and Spence 2002). This was primarily a comparison of 1999 brood year capture efficiency (25-45cm) because 95% of the catch during 2001 was from this brood year. These results further illustrated size selectivity in gill nets, similar to the work of Burner et al. (2000) from the lower Columbia River which showed 2 inch stretch measure nets captured sturgeon <35cm more efficiently than two other mesh sizes.

Juvenile sampling programs on the lower Columbia River have focused on YOY recruitment indexing, and therefore 2 inch stretch measure nets were ideal. However, although the primary objective of sampling on the Kootenay/Kootenai River is to index natural recruitment events, other objectives of this program are diverse and include measures to identify growth, condition, survival and distribution of a variety of juvenile sturgeon sizes. Given that different mesh sizes account for size selectivity in many fish species including sturgeon and that the age structure of the juvenile population will continue to expand with additional hatchery releases and time at large, multiple gill net mesh sizes will be used for juvenile sturgeon sampling on the Kootenay/Kootenai River. Two, 4 and 6 inch stretch measure nets will be used for juvenile sampling. Gill net size will be selected randomly for each set and will not correspond with the expected catch at any given sampling site. Because the primary objective of this sampling program is to index natural recruitment, crews will fish two 2 inch nets and only one each of the 4 and 6 inch nets. The target length of sets will be one hour, with an acceptable range of between 45 and 120 minutes.

*Sample Period and Location* - Juvenile white sturgeon sampling will begin in late June and continue until early September; the period of highest empirical capture efficiencies. Approximately 24 net sets will be completed at index sites while approximately 12 will be completed in secondary sampling locations. Index and secondary sites have been determined by IDFG and MWLAP staff and will be used annually, including 17 sites in Canada (Figure 4, Table 4). Index site selection was based on previous sampling programs (highest capture efficiencies), and on sites, which were fishable during high flow events. Secondary sampling locations will include back channel habitat and areas of suitable habitat that are only fishable during low flows.

Table 4. Juvenile white sturgeon gill net sampling sites (site code and location).

| Index Site Code | Location (RKM) | Site Type |
|---|---|---|
| KRGCrw | 77 | Index |
| KRGed | 120 | Index |
| KRGwd | 121 | Index |
| KRG123 | 123 | Secondary |
| KRG130 | 130 | Index |
| EsCh | 132.5 | Secondary |
| KRG134 | 133.7 | Index |
| KRG137 | 137.4 | Index |
| KRG141 | 141.5 | Secondary |
| KRG145 | 144.8 | Index |
| KRG150 | 150 | Secondary |
| FrSl | 150 | Secondary |
| KRG157 | 157.3 | Secondary |
| KRG161 | 161.4 | Index |
| KRG163 | 163 | Secondary |
| KRG165 | 165 | Index |
| KRG167 | 167 | Secondary |

*Sampling Protocols* - Captured white sturgeon will be brought into the boat for sampling. Smaller juveniles will be placed in a plastic container filled with water. Larger juveniles and all adults will be placed in a waterproof stretcher, with enough water to allow for respiration. The following procedure will be employed to sample juvenile sturgeon, after which they will be released once normal respiration, orientation and swimming behavior are established. Items 4, 5 and 6 need not be completed for fish that are recaptures:

Pit Tag

- Read pit tag and record number on scale envelope (Scale envelope becomes the container for other samples e.g. DNA and WSIV tissue sample).
- If no tag is present, sterilize tag and injector with Germaphine and inject tag on right side under the dorsal fin

Length

- Measure both fork and total length (nearest cm)

Scute Mark

- Record all scute marks
- If fish is wild/unmarked, remove L2 scute

Fin Ray

- If fish is wild/unmarked, take a pectoral fin ray sample

Genetic Tissue

- If fish is wild/unmarked, clip tip of any fin, place in solution of ethanol and place sample vial in scale envelope

WSIV

- If fish is wild/unmarked, use hole punch to take tissue from both the caudal and pectoral fins to sample for white sturgeon iridovirus. Use WSIV storage solution provided by IDFG to preserve samples and place vial in scale envelope.

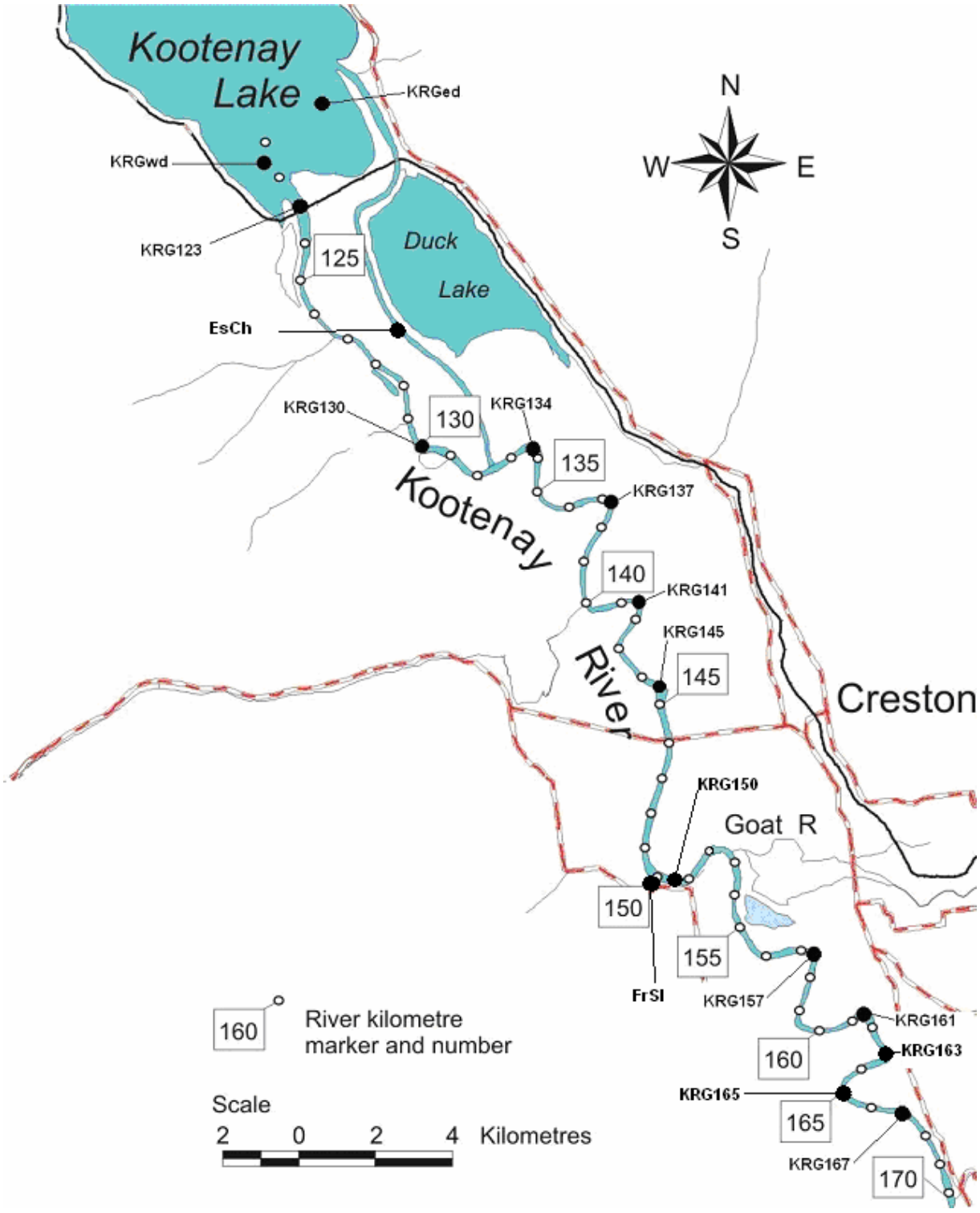


Figure 4. Juvenile white sturgeon gill net index and secondary sampling site locations used by BC MWLAP.

Growth, survival, habitat use and movement data will be collected to evaluate effects of the Program's release strategy. Systematic evaluation of post-release fish (see above sampling sections) and a subset marked with transmitters (e.g. Vemco tags) is recommended to more efficiently evaluate the success of release strategy components. Historic habitat use by rearing, maturing, and reproducing white sturgeon in the Kootenai/y system is uncertain. Whether Kootenai River white sturgeon exhibit homing or spawning site fidelity is also unknown, other than the fact that since the early 1990s spawning has generally occurred in a river reach from Shorty's Island (~ rkm 238) upstream to near the town of Bonners Ferry (~ rkm 245). Given such uncertainties, the release strategy is designed for fish to volitionally reestablish habitat use patterns across most of the system. Statistical analyses will be used to compare post-release habitat and reach use data by release group. Adjustments to the release protocols will be made when supported by systematic, replicated empirical data collected during an initial 3 to 5 year standardized M&E schedule (See above larval and juvenile sampling sections).

*4. Cryopreservation Plan* – A research plan for development of cryopreservation techniques for white sturgeon gametes will be developed and included in this Program, in cooperation with Dr. Joseph Cloud, University of Idaho, and members of the Upper Columbia White Sturgeon Recovery Team. Recent progress in cryopreservation techniques may enable this program to further contribute to inter-generational gene flow and incorporation of genetic material to further advance genetic restoration of the Kootenai River white sturgeon population.

*5. Hatchery Water Quality M&E Plan* - A plan for monitoring and evaluating Kootenai Hatchery water quality parameters will be developed and included in this Program.

## VII. Program Coordination

The existing program for white sturgeon is consistent with and complementary to relevant Northwest Power and Conservation Council policies, National Marine Fisheries Service and US Fish and Wildlife recovery plans, Biological Opinions, and other fishery management plans, watershed plans, and activities. More specific empirical information concerning this successful model program can be found in the Program's Kootenai Hatchery Genetics Management Plan (2000), Ireland et al. (2003, 2002a, 2002b), Ireland and Anders (in preparation), LaPatra et al. (1999), Anders (1998), and at http://www.nwcouncil.org/fw/stories/kootenai.htm.

The Kootenai Tribe of Idaho will administer and operate this Program, and will conduct and oversee associated monitoring and evaluation studies in cooperation with the following agencies. Hatchery monitoring and evaluation will be closely integrated with concurrent Kootenai River fisheries and the ecosystem research being performed by the Idaho Department of Fish and Game, Montana Department of Fish Wildlife and Parks, British Columbia Ministry of Water, Land and Air Protection and the Freshwater Fisheries Society of British Columbia. Data generated from this program and associated monitoring is provided to the IDFG cooperative database manager. The KTOI also has collaborations with the University of Idaho (U of I), College of Southern Idaho, University of California at Davis, Clear Springs Foods (Research Division), Idaho Department of Fish and Game, U. S. Fish and Wildlife Service, U. S. Geological Survey, the Freshwater Fisheries Society of British Columbia, S. P. Cramer and Associates, J-U-B Engineers, Free Run Aquatic Research and other specialized consulting firms, academics, or private subcontractors for technical services, including but not limited to: fish pathology, genetic, brood stock program design, implementation, monitoring and evaluation, research, database management, and facility support. Furthermore, this Program will be effectively and beneficially incorporated in larger-scale international management and research groups involved in multi-species, community, and ecosystem recovery programs and issues (e.g. IKERT (International Kootenai/y River Ecosystem Rehabilitation Team) and the USFWS Kootenai River White Sturgeon Recovery Team).

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# IX. APPENDIX 1: Post-release family survival trajectories of hatchery-reared Kootenai River white sturgeon under two survival rate scenarios.

**Survival scenario 1: Year of release 30% survival, year 2 post release 60% survival, all subsequent years, 90% survival**

| Age | Initial release number and annual numbers surviving | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 | 10000 |
| 1 | 900 | 1200 | 1500 | 1800 | 2100 | 2400 | 2700 | 3000 |
| 2 | 540 | 720 | 900 | 1080 | 1260 | 1440 | 1620 | 1800 |
| 3 | 486 | 648 | 810 | 972 | 1134 | 1296 | 1458 | 1620 |
| 4 | 437 | 583 | 729 | 875 | 1021 | 1166 | 1312 | 1458 |
| 5 | 394 | 525 | 656 | 787 | 919 | 1050 | 1181 | 1312 |
| 6 | 354 | 472 | 590 | 709 | 827 | 945 | 1063 | 1181 |
| 7 | 319 | 425 | 531 | 638 | 744 | 850 | 957 | 1063 |
| 8 | 287 | 383 | 478 | 574 | 670 | 765 | 861 | 957 |
| 9 | 258 | 344 | 430 | 517 | 603 | 689 | 775 | 861 |
| 10 | 232 | 310 | 387 | 465 | 542 | 620 | 697 | 775 |
| 11 | 209 | 279 | 349 | 418 | 488 | 558 | 628 | 697 |
| 12 | 188 | 251 | 314 | 377 | 439 | 502 | 565 | 628 |
| 13 | 169 | 226 | 282 | 339 | 395 | 452 | 508 | 565 |
| 14 | 153 | 203 | 254 | 305 | 356 | 407 | 458 | 508 |
| 15 | 137 | 183 | 229 | 275 | 320 | 366 | 412 | 458 |
| 16 | 124 | 165 | 206 | 247 | 288 | 329 | 371 | 412 |
| 17 | 111 | 148 | 185 | 222 | 259 | 296 | 334 | 371 |
| 18 | 100 | 133 | 167 | 200 | 233 | 267 | 300 | 334 |
| 19 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 |
| 20 | 81 | 108 | 135 | 162 | 189 | 216 | 243 | 270 |
| 21 | 73 | 97 | 122 | 146 | 170 | 195 | 219 | 243 |
| 22 | 66 | 88 | 109 | 131 | 153 | 175 | 197 | 219 |
| 23 | 59 | 79 | 98 | 118 | 138 | 158 | 177 | 197 |
| 24 | 53 | 71 | 89 | 106 | 124 | 142 | 160 | 177 |
| 25 | 48 | 64 | 80 | 96 | 112 | 128 | 144 | 160 |
| 26 | 43 | 57 | 72 | 86 | 101 | 115 | 129 | 144 |
| 27 | 39 | 52 | 65 | 78 | 90 | 103 | 116 | 129 |
| 28 | 35 | 47 | 58 | 70 | 81 | 93 | 105 | 116 |
| 29 | 31 | 42 | 52 | 63 | 73 | 84 | 94 | 105 |
| 30 | 28 | 38 | 47 | 57 | 66 | 75 | 85 | 94 |
| 31 | 25 | 34 | 42 | 51 | 59 | 68 | 76 | 85 |
| 32 | 23 | 31 | 38 | 46 | 53 | 61 | 69 | 76 |
| 33 | 21 | 27 | 34 | 41 | 48 | 55 | 62 | 69 |
| 34 | 19 | 25 | 31 | 37 | 43 | 49 | 56 | 62 |
| 35 | 17 | 22 | 28 | 33 | 39 | 45 | 50 | 56 |
| 36 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 37 | 14 | 18 | 23 | 27 | 32 | 36 | 41 | 45 |
| 38 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 41 |
| 39 | 11 | 15 | 18 | 22 | 26 | 29 | 33 | 36 |
| 40 | 10 | 13 | 16 | 20 | 23 | 26 | 30 | 33 |
| 41 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 |
| 42 | 8 | 11 | 13 | 16 | 19 | 21 | 24 | 27 |
| 43 | 7 | 10 | 12 | 14 | 17 | 19 | 22 | 24 |
| 44 | 6 | 9 | 11 | 13 | 15 | 17 | 19 | 22 |
| 45 | 6 | 8 | 10 | 12 | 14 | 16 | 17 | 19 |
| 46 | 5 | 7 | 9 | 10 | 12 | 14 | 16 | 17 |
| 47 | 5 | 6 | 8 | 9 | 11 | 13 | 14 | 16 |
| 48 | 4 | 6 | 7 | 8 | 10 | 11 | 13 | 14 |
| 49 | 4 | 5 | 6 | 8 | 9 | 10 | 11 | 13 |
| 50 | 3 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 51 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 52 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 9 |
| 53 | 3 | 3 | 4 | 5 | 6 | 7 | 8 | 8 |
| 54 | 2 | 3 | 4 | 5 | 5 | 6 | 7 | 8 |
| 55 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 7 |
| 56 | 2 | 2 | 3 | 4 | 4 | 5 | 5 | 6 |
| 57 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 |
| 58 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 59 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4 |
| 60 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 |
| 61 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 4 |
| 62 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 |
| 63 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 |
| 64 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 |
| 65 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| 66 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| 67 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| 68 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 69 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 70 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Survival Scenario 2: 40% survival year of release, 90% survival all subsequent years.**

| Age | Initial release number and annual numbers surviving | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | 3000 | 4000 | 5000 | 6000 | 7000 | 8000 | 9000 | 10000 |
| 1 | 1200 | 1600 | 2000 | 2400 | 2800 | 3200 | 3600 | 4000 |
| 2 | 1080 | 1440 | 1800 | 2160 | 2520 | 2880 | 3240 | 3600 |
| 3 | 972 | 1296 | 1620 | 1944 | 2268 | 2592 | 2916 | 3240 |
| 4 | 875 | 1166 | 1458 | 1750 | 2041 | 2333 | 2624 | 2916 |
| 5 | 787 | 1050 | 1312 | 1575 | 1837 | 2100 | 2362 | 2624 |
| 6 | 709 | 945 | 1181 | 1417 | 1653 | 1890 | 2126 | 2362 |
| 7 | 638 | 850 | 1063 | 1275 | 1488 | 1701 | 1913 | 2126 |
| 8 | 574 | 765 | 957 | 1148 | 1339 | 1531 | 1722 | 1913 |
| 9 | 517 | 689 | 861 | 1033 | 1205 | 1377 | 1550 | 1722 |
| 10 | 465 | 620 | 775 | 930 | 1085 | 1240 | 1395 | 1550 |
| 11 | 418 | 558 | 697 | 837 | 976 | 1116 | 1255 | 1395 |
| 12 | 377 | 502 | 628 | 753 | 879 | 1004 | 1130 | 1255 |
| 13 | 339 | 452 | 565 | 678 | 791 | 904 | 1017 | 1130 |
| 14 | 305 | 407 | 508 | 610 | 712 | 813 | 915 | 1017 |
| 15 | 275 | 366 | 458 | 549 | 641 | 732 | 824 | 915 |
| 16 | 247 | 329 | 412 | 494 | 576 | 659 | 741 | 824 |
| 17 | 222 | 296 | 371 | 445 | 519 | 593 | 667 | 741 |
| 18 | 200 | 267 | 334 | 400 | 467 | 534 | 600 | 667 |
| 19 | 180 | 240 | 300 | 360 | 420 | 480 | 540 | 600 |
| 20 | 162 | 216 | 270 | 324 | 378 | 432 | 486 | 540 |
| 21 | 146 | 195 | 243 | 292 | 340 | 389 | 438 | 486 |
| 22 | 131 | 175 | 219 | 263 | 306 | 350 | 394 | 438 |
| 23 | 118 | 158 | 197 | 236 | 276 | 315 | 355 | 394 |
| 24 | 106 | 142 | 177 | 213 | 248 | 284 | 319 | 355 |
| 25 | 96 | 128 | 160 | 191 | 223 | 255 | 287 | 319 |
| 26 | 86 | 115 | 144 | 172 | 201 | 230 | 258 | 287 |
| 27 | 78 | 103 | 129 | 155 | 181 | 207 | 233 | 258 |
| 28 | 70 | 93 | 116 | 140 | 163 | 186 | 209 | 233 |
| 29 | 63 | 84 | 105 | 126 | 147 | 167 | 188 | 209 |
| 30 | 57 | 75 | 94 | 113 | 132 | 151 | 170 | 188 |
| 31 | 51 | 68 | 85 | 102 | 119 | 136 | 153 | 170 |
| 32 | 46 | 61 | 76 | 92 | 107 | 122 | 137 | 153 |
| 33 | 41 | 55 | 69 | 82 | 96 | 110 | 124 | 137 |
| 34 | 37 | 49 | 62 | 74 | 87 | 99 | 111 | 124 |
| 35 | 33 | 45 | 56 | 67 | 78 | 89 | 100 | 111 |
| 36 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 37 | 27 | 36 | 45 | 54 | 63 | 72 | 81 | 90 |
| 38 | 24 | 32 | 41 | 49 | 57 | 65 | 73 | 81 |
| 39 | 22 | 29 | 36 | 44 | 51 | 58 | 66 | 73 |
| 40 | 20 | 26 | 33 | 39 | 46 | 53 | 59 | 66 |
| 41 | 18 | 24 | 30 | 35 | 41 | 47 | 53 | 59 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 42 | 16 | 21 | 27 | 32 | 37 | 43 | 48 | 53 |
| 43 | 14 | 19 | 24 | 29 | 34 | 38 | 43 | 48 |
| 44 | 13 | 17 | 22 | 26 | 30 | 34 | 39 | 43 |
| 45 | 12 | 16 | 19 | 23 | 27 | 31 | 35 | 39 |
| 46 | 10 | 14 | 17 | 21 | 24 | 28 | 31 | 35 |
| 47 | 9 | 13 | 16 | 19 | 22 | 25 | 28 | 31 |
| 48 | 8 | 11 | 14 | 17 | 20 | 23 | 25 | 28 |
| 49 | 8 | 10 | 13 | 15 | 18 | 20 | 23 | 25 |
| 50 | 7 | 9 | 11 | 14 | 16 | 18 | 21 | 23 |
| 51 | 6 | 8 | 10 | 12 | 14 | 16 | 19 | 21 |
| 52 | 6 | 7 | 9 | 11 | 13 | 15 | 17 | 19 |
| 53 | 5 | 7 | 8 | 10 | 12 | 13 | 15 | 17 |
| 54 | 5 | 6 | 8 | 9 | 11 | 12 | 14 | 15 |
| 55 | 4 | 5 | 7 | 8 | 9 | 11 | 12 | 14 |
| 56 | 4 | 5 | 6 | 7 | 9 | 10 | 11 | 12 |
| 57 | 3 | 4 | 5 | 7 | 8 | 9 | 10 | 11 |
| 58 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 59 | 3 | 4 | 4 | 5 | 6 | 7 | 8 | 9 |
| 60 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 |
| 61 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 |
| 62 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 6 |
| 63 | 2 | 2 | 3 | 3 | 4 | 5 | 5 | 6 |
| 64 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 |
| 65 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 66 | 1 | 2 | 2 | 3 | 3 | 3 | 4 | 4 |
| 67 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 |
| 68 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 |
| 69 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 |
| 70 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 |