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White Sturgeon Program Summary Mainstem/Systemwide Province

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White Sturgeon Program Summary

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Purpose of Program

The Northwest Power Planning Council (NWPPC) system-wide goal in the 1994 Columbia River Basin Fish and Wildlife Program is a healthy Columbia Basin: "one that supports both human settlement and the long-term sustainability of native fish and wildlife species in native habitats where possible, while recognizing that where impacts have irrevocably changed the ecosystem, we must protect and enhance the ecosystem that remains" (NWPPC 1994). The overall vision in the NWPPC's 2000 Columbia Basin Fish and Wildlife Program (NWPPC 2000) is "a Columbia River ecosystem that sustains an abundant, productive, and diverse community of fish and wildlife, mitigating across the basin for the adverse effects to fish and wildlife caused by the development and operation of the hydrosystem and providing the benefits from fish and wildlife valued by the people of the region." Consistent with these themes, on a Columbia Basin scale, white sturgeon *Acipenser transmontanus* constitute an economically, ecologically, recreationally, and culturally valuable resource (Anders and Powell 1999).

The White Sturgeon Program seeks to ensure healthy populations of white sturgeon so that harvest opportunities for tribal and recreational fishers are sustained. To accomplish this, white sturgeon stocks in already productive areas will need to be intensively managed to maintain production, while depressed stocks in other areas will need to be rebuilt through a variety of measures. This program will address requirements for management of existing fisheries, research to determine factors limiting production in depressed stocks, and implementation of management activities resulting from research on methods to rebuild depressed stocks. Monitoring of stocks and evaluation of management actions are critical components of this program.

Background

Development of the Columbia River basin hydropower system has severely impacted populations of white sturgeon upstream from Bonneville Dam. The white sturgeon population in the Columbia River downstream from Bonneville Dam supports one of the most productive recreational and commercial sturgeon fisheries in the world (Craig and Hacker 1940; McCabe and Tracy 1994); however, populations impounded in Bonneville, The Dalles, and John Day reservoirs can support only limited recreational and tribal fisheries and are more vulnerable to over-fishing than the un-impounded population (Beamesderfer et al. 1995). Sturgeon populations upstream from McNary Dam can support only limited harvest or catch-and-release recreational fisheries. Fishing for white sturgeon has been prohibited upstream from Grand Coulee Dam, including all Canadian waters of the Columbia River. The white sturgeon population in the Kootenai River was listed as endangered in 1994 under the U. S. Endangered Species Act (USFWS 1994) and a recovery plan was completed in 1999 (USFWS 1999).

Extensive development of hydropower dams throughout the Columbia River Basin during the past century has severely fragmented free-flowing, large river habitats (National Research Council 1996) occupied by white sturgeon. Anadromous white sturgeon historically made migrations throughout the Columbia and Snake rivers for spawning and feeding, but are currently unable to use existing dam fishways for upstream passage (North et al. 1993). One important result of such river fragmentation for white sturgeon is the creation of a series of relatively isolated sub-populations (Jager et al. 2000; Secor et al. In press). This is especially critical for a migratory species like white sturgeon, where fragmentation by dams may artificially impose exclusively downstream gene flow. Altered seasonal river discharge and thermal regimes resulting from impoundment and dam operations may also alter migration, limit habitat availability, or affect timing, location or success of reproduction (Auer 1996; Cooke et al., In Press; Jager et al. In Press; Secor et al. In press; Holderman et al. submitted). Presence of dams and impoundments also severely restrict movements of two principal food sources for white sturgeon: eulachon *Thaleichthys pacificus* and Pacific lamprey *Lampetra tridentata*.

In addition to the effects of dams themselves, operation of the hydropower system has resulted in decreased productivity of many white sturgeon populations. Flow regimes have been altered and water depths increased, which have resulted in reduced water velocities over extensive areas (Parsley and Beckman 1994). In the Columbia River, white sturgeon spawning and egg incubation usually occur from April through July in the swiftest water available (Parsley et al. 1993), and the amount of spawning habitat for white sturgeon increases as discharge increases (Parsley and Beckman 1994). Hydropower production has reduced spring and summer discharges (Ebel et al. 1989), decreasing the amount of spawning habitat. During years of reduced river runoff, the lack of high-quality spawning habitat in impounded reaches may preclude successful reproduction by white sturgeon. As a result, many impounded white sturgeon populations are not as productive as they once were, and some populations in upper reaches of the Columbia River basin may already be facing extirpation.

In addition to poor spawning conditions, white sturgeon often experience year-class failures because of poor recruitment to young of the year in mainstem reservoirs (Parsley and Beckman 1994; Anders et al. In Press; Parsley et al. In Press). Although recent population estimates in John Day and The Dalles reservoirs (Ward 1998; Ward 1999) are higher than previous estimates (Beamesderfer et al. 1995), larval and juvenile fish have remained relatively scarce (Anders et al. In Press; Parsley et al. In Press).

Though hydroelectric development has reduced the availability of spawning habitat, it has increased the area physically suitable for young of the year and juvenile white sturgeon in impounded reaches (Parsley and Beckman 1994). Impoundment has increased water depths upstream from the dams; thus, because young sturgeon use the deeper water, the physical rearing habitat has increased. Spawning failures and low numbers of recruits to young of the year when spawning is successful have resulted in relatively few fish occupying this available habitat.

Concern about the effects of the hydropower system on white sturgeon led to a *White Sturgeon Research Needs* workshop in 1983 (Fickeisen et al. 1984), and eventually to the project now titled *White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers* in 1986. Overall goals of the program are to implement and evaluate measures to protect and restore white sturgeon populations and to mitigate for effects of the hydropower system on white sturgeon production in the Columbia and Snake rivers. Project 199902200, *Assessing Genetic Variation Among Columbia Basin White Sturgeon Populations*, is a preliminary step towards addressing critical uncertainties regarding fragmentation and isolation of white sturgeon populations. Comprehensive genetic research involving biparentally-inherited nuclear markers at an appropriate geographic scale will be required to characterize white sturgeon population structure and its underlying formative mechanisms. Such data can then be used to assess population-level effects of fragmentation on white sturgeon population structure, viability, and persistence.

Research Monitoring and Evaluation

Research, monitoring, and evaluation are important components of the Mainstem/ Systemwide Sturgeon Program. Research under the program supports sturgeon work at the geographic province level by developing and providing methods, techniques, and protocols for sampling and stock assessment. Research under this program will address uncertainties best approached from a broad perspective, such as contaminant effects on reproduction, passage, and the role of supplementation as an adaptive management tool. Research findings will have applicability at the geographic province level.

Monitoring under this program will provide information critical to the continuance of harvest opportunities by providing periodic updates on stock status. Monitoring at the mainstem/systemwide level should focus on issues such as geographic differences in population characteristics (growth, fecundity, etc.) so that monitoring at the province level has some criteria for comparison. Evaluation of management activities (some of which will result from new research) derived from research findings is crucial to determining effectiveness of approaches to maintain viable populations and rebuild depressed populations.

The need for further research is illustrated by the many gaps that still exist in the knowledge of factors influencing productivity of white sturgeon populations in the Columbia River. For example, water pollution may contribute to the poor reproductive success of white sturgeon in impoundments. The longevity, feeding habits, and delayed reproductive maturation of white sturgeon increases the exposure of individuals to persistent bio-accumulative pollutants such as PCBs, chlorinated pesticides, and chlorinated dioxins and furans that have been detected in environmental samples from the Columbia River (Foster et al. 1999, McCarthy and Gale 1999, US EPA 1992). These chemicals have been shown to adversely affect reproduction and development but the concentrations causing adverse effects in sturgeon are unknown. In addition, other types of water pollution, such as endocrine disrupting chemicals, have been shown to affect aquatic species in other river systems. Sources for these chemicals are in the Columbia Basin but have not been measured.

Scope of Program

Current program activities specifically affect white sturgeon in the Columbia River downstream from Priest Rapids Dam, and in the Snake River downstream from Lower Granite Dam. Project 198605000, *White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers*, includes work to mitigate for losses due to the hydropower system, evaluate the effects of mitigation actions, and investigate the potential of additional mitigation activities. Benefits may extend in the Columbia River upstream to Chief Joseph Dam if artificial propagation is used to restore populations in mid-Columbia River reservoirs suffering from extremely low productivity.

Work is very well coordinated with ongoing sturgeon projects in other areas of the basin. Project 198806400, *Kootenai River White Sturgeon Studies and Conservation*

Aquaculture; Project 198806500, *Kootenai River Fisheries Investigations*; Project 199700900, *Evaluate Potential Means of Rebuilding White Sturgeon Populations in the Snake River Between Lower Granite and Hells Canyon Dams*, and Project 199502700, *Assess Limiting Factors of the Lake Roosevelt White Sturgeon Population* are all designed to complete research needed to restore sturgeon populations outside the geographic scope of this project; therefore, these projects are all complementary.

All white sturgeon projects in the Columbia River Basin will benefit from the results of Project 199902200, *Assessing Genetic Variation Among Columbia Basin White Sturgeon Populations*. Effective conservation and management strategies for endemic fish populations require functional knowledge of historical and contemporary population structure of the managed species. Genetic techniques can generate valuable information concerning such structure, and provide a standardized, reproducible means of evaluation to complement ongoing biological and ecological investigation. Mitochondrial DNA (mtDNA) regions possess genetic markers that can provide information about historical population genetic structure and contemporary patterns of gene flow within and among areas, or populations (Avise 1994). The use of recently developed hyper-variable nuclear DNA markers is needed to enhance the picture of white sturgeon population structure, and its underlying mechanisms in the Columbia basin.

Geographic distribution and relatedness among white sturgeon mtDNA lineages can provide important insight into current and historical population structure, and mechanisms responsible for such structure. Such insight is currently incomplete, but remains crucial for successful white sturgeon conservation and management. Research using allozyme analyses (Bartley et al. 1985; Setter and Brannon 1992) and mtDNA sequencing (Brown et al. 1992) from a relatively limited number of samples and sampling locations suggested differences in white sturgeon allele and haplotype frequencies across geography.

The potential geographic scope for activities within the White Sturgeon Program should not be limited to that of current activities. Although certain activities have geographic constraints, such as limiting assessment activities that provide information for harvest management to only those areas where harvest currently occurs, the overall program should provide information that will be useful at various scales, including the geographic province level.

Accomplishments/Results

Project Histories

White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers

Project 198605000 began in 1986, based partly on findings and recommendations from the White Sturgeon Research Needs Workshop held in 1983 (Fickeisen et al. 1984). From 1986-88 methodologies were developed for habitat mapping and modeling, capture gears for various life stages, and marking and aging techniques. By 1992, results/findings included (1) dams limit movements of white sturgeon and have functionally isolated populations in mainstem Columbia River reservoirs; (2) population dynamics of white sturgeon are unique in each reservoir; (3) population productivity is 10-100 times higher downstream from Bonneville Dam than in Bonneville, The Dalles, or John Day reservoirs; (4) reduced flows and subsequent poor recruitment are the key factor limiting white sturgeon productivity in impoundments; (5) reservoirs provide large areas of suitable habitat for juvenile and adult white sturgeon, but compensatory population responses may reduce productivity if carrying capacity is exceeded;and (6) over-fishing had occurred in the three lowermost reservoirs of the Columbia. Appropriate exploitation rates under the reduced productivity resulting from the development and operation of the hydrosystem were described. By 1997, project accomplishments included (1) demonstration of increased abundance of white sturgeon in The Dalles and John Day reservoirs, which was attributable to intensive harvest management and reduced exploitation; (2) white sturgeon transplanted to The Dalles Reservoir demonstrated excellent survival and growth one and two years later; (3) completion of initial population estimates for white sturgeon in McNary, Ice Harbor, Little Goose, and Lower Monumental reservoirs, and the Hanford Reach.

Further accomplishments by 1998 included (1) development of habitat maps and flow-habitat models for the Columbia River up to Priest Rapids Dam; (2) completion of index sampling to develop initial descriptions of white sturgeon populations in Rock Island Reservoir, Lake Rufus Woods, and Lake Roosevelt; (3) documentation of presence of species-specific viral pathogens in wild Columbia River white sturgeon; (4) development of two indices of relative abundance for age-0 white sturgeon; (5) determination that white sturgeon larvae are susceptible to gas bubble trauma in laboratory experiments; and (6) determination that hydropeaking at The Dalles Dam displaces white sturgeon eggs and larvae from incubation areas.

Accomplishments since 1998 include progress in evaluating the feasibility of using hatchery-reared white sturgeon to supplement depressed populations. The first research-level release of hatchery-reared fish into the Columbia River will occur in 2002. The experimental release program will eventually include evaluation of the survival of three age groups of white sturgeon. The Kootenai River White Sturgeon Conservation Aquaculture Program (BPA 198806400) has been operating since the early 1990's and to date has accounted for virtually all of that population's production since then (Anders 1998; Duke et al. 1999).

Another recent accomplishment is the development of a discriminant function analysis model to predict white sturgeon sex and stage of maturity using blood plasma indicators, sex steroids and calcium, and fork length. Approximately 80% of the fish were correctly classified into two groups of sex (female or male) or four groups of sex and stage of maturity (immature female, immature male, maturing female, maturing male). Though error does exist in the classification of sex and stage of maturity of white sturgeon using blood plasma indicators, the technique currently has significant advantages over the more invasive biopsy method. Work is also proceeding on development of a non-invasive test to discriminate sex and stage of maturity in white sturgeon using mucus and/or urine. Preliminary results suggest that the development of such a test may be possible. In addition to these promising techniques, incorporation of molecular genetic approaches to white sturgeon sex identification is paramount.

Ongoing activities include (1) continued transplants of juvenile white sturgeon to The Dalles and John Day reservoirs, (2) continued periodic monitoring of population status in Bonneville, The Dalles, and John Day Reservoirs, and (3) continued monitoring of the relative abundance for age-0 white sturgeon. Effects of transplanting juvenile white sturgeon will be assessed in 2002. Although abundance of white sturgeon in reservoirs remains higher than prior to intensive harvest management and reduced exploitation, results indicate that regular monitoring is required to preclude over-exploitation. Annual monitoring of age-0 white sturgeon is required to develop a long-term database to evaluate relationships between hydropower system operations and recruitment to age 0 and older.

White Sturgeon Genetics

Results of two independent genetic analyses (protein electrophoresis) (Bartley et al. 1985; Setter and Brannon 1992) suggested that white sturgeon heterozygosity varied considerably across geography. The mean percentage of 29 polymorphic loci surveyed was lowest in the Kootenai River population (27.6%) compared with white sturgeon from the Snake (31.0%) and the mid-Columbia (44.8%) rivers, and Lake Roosevelt (55.2%, Setter and Brannon 1992). Kootenai River white sturgeon are believed to be a post-glacially isolated population of ancestral Columbia River stock; no unique alleles were found in Kootenai River fish relative to downstream populations (Setter and Brannon 1992). Setter and Brannon (1992) suggested that due to lower diversity and genetic distance estimates separating white sturgeon in the Kootenai system from other areas, the Kootenai River population constituted a stock within a species.

Most recently, Anders and Powell (in Prep) sequenced a hyper-variable 453 bp. segment of the A. transmontanus mitochondrial control region to: 1) characterize mitochondrial sequence diversity and divergence, population structure, and phylogenetic assemblages from a major portion of the species' geographic range; 2) quantify gene flow within and among major rivers across this range; and 3) assess whether population structure was best explained by isolation by distance, stepping stone, or by continent-island models of dispersal and gene flow, or alternative models. White sturgeon samples (n=260) were collected from 20 fish at 13 locations from six major rivers in western North America (Columbia, Snake, Kootenai, Fraser, Nechako, and Sacramento). Concordant results (AMOVA, Monte Carlo X^2, NCA, PHYLIP, PAUP, REAP, linear regression) including high F_{ST} and Nm values revealed that expansive gene flow over hundreds to thousands of kilometers best explained observed population structure. Observed population structure likely resulted from a potential mosaic of range expansions and contractions in conjunction with geographically and temporally variable gene flow over evolutionary time. Anders and Powell (in Prep) presented and discussed the "expansive gene flow model" (EGF) to explain observed population structure of white sturgeon in western North America. The EGF model was also strongly supported by independent empirical white sturgeon genetic, dispersal, life history, and reproductive data. from the Columbia and Fraser Rivers.

Adaptive Management Implications

White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers

Work to evaluate and mitigate the effects of the hydropower system on white sturgeon has been systematic, comprehensive, and beneficial. Efforts began with Project 198301200, White Sturgeon Workshop, which resulted in establishing research needs for white sturgeon. Project 198331600, Columbia River White Sturgeon Study, focused on the responses of young sturgeon to changes in temperature and flow, and addressed the potential for artificial propagation. Project 198506400, Develop Work Plan for Sturgeon Research, was the final step before funding of the comprehensive Project 198605000, Status and Habitat Requirements of White Sturgeon Populations in the Columbia River Downstream from McNary Dam. This project is now titled White Sturgeon Mitigation and Restoration in the Columbia and Snake rivers. Work from 1986-92 concentrated on determining the status and habitat requirements of white sturgeon in the Columbia River. Conclusions from this work led to recommendations for further work including (1) intensify management of fisheries for impounded populations, (2) evaluate whether augmented river discharge improves spawning and recruitment, (3) evaluate mitigation actions for impounded populations such as transplanting juvenile white sturgeon from below Bonneville Dam to The Dalles and John Day reservoirs, (4) investigate levels of contaminants in sturgeon tissue and constraints on population productivity, (5) quantify habitat available and evaluate constraints on enhancement, and (6) further refine and evaluate hatchery technology.

Management of and further research on white sturgeon in the lower Columbia and Snake rivers since 1992 has been based on these recommendations. Intensive management of fisheries in Bonneville, The Dalles, and John Day reservoirs is ongoing, as are annual transplants of up to 8,000 juvenile fish from below Bonneville Dam to The Dalles and John Day reservoirs. Response of populations to these activities is monitored. In addition, work to refine and evaluate hatchery technology has begun. Hatchery-reared white sturgeons will be released into Rock Island Reservoir at various ages, and survival will be compared among release (age) groups. Finally, general and specific operations of the hydropower system to enhance physical habitat conditions for white sturgeon have been identified. Success of spawning and survival of larval white sturgeon are monitored each year through sampling for age 0 fish in Bonneville, The Dalles, John Day, McNary, Lower Monumental, and Little Goose reservoirs.

Findings from the project will continue to be used in future management decisions. If artificial propagation is used in the future to supplement depleted populations of white sturgeon, results from hatchery release experiments will be used to determine the best age-at-release. Future decisions regarding harvest management of white sturgeon in the lower Columbia River will rely on continued population assessments. Information collected on white sturgeon recruitment may play a role in decisions regarding future operation of the hydropower system.

White Sturgeon Genetics

White sturgeon projects in the Columbia River Basin will benefit from the results of Project 199902200, *Assessing Genetic Variation Among Columbia Basin White Sturgeon*

Populations. Effective conservation and management strategies for endemic fish populations require functional knowledge of historical and contemporary population structure of the managed species. Genetic techniques can generate valuable information concerning such structure, and provide a standardized, reproducible means of evaluation to complement ongoing biological and ecological investigation. Geographic distribution and relatedness among white sturgeon mtDNA haplotypes provide important insight into current and historical population structure, and mechanisms responsible for such structure. Such insight is currently incomplete, but remains crucial for successful white sturgeon conservation and management.

Benefits to Fish and Wildlife

The White Sturgeon Program will contribute to the Northwest Power Planning Council's Fish and Wildlife Program vision of a Columbia River ecosystem that sustains an abundant, productive, and diverse community of fish and wildlife, mitigating across the basin for the adverse effects to fish and wildlife caused by the development and operation of the hydrosystem and providing the benefits from fish and wildlife valued by the people of the region. More specifically, the White Sturgeon Program addresses Fish and Wildlife Program objectives for biological performance related to resident fish losses: (1) complete assessments of resident fish losses throughout the basin resulting from the hydrosystem, expressed in terms of the various critical population characteristics of key resident fish species, (2) maintain and restore healthy ecosystems and watersheds, which preserve functional links among ecosystem elements to ensure continued persistence, health and diversity of all species including game fish species, non-game fish species, and other organisms, (3) protect and expand habitat and ecosystem functions as the means to significantly increase abundance, productivity, and life history diversity of resident fish, at least to extent they have been negatively affected by hydrosystem, development and operations; and (4) achieve population characteristics of these species within 100 years that, while fluctuating due to natural variability, represent on average full mitigation for losses of resident fish.

The Fish and Wildlife Program also calls for the continuation of existing measures until subbasin plans are adopted, the measure has been specifically repealed, or three years have elapsed, whichever comes first. Therefore, measures from the 1994 Fish and Wildlife Program addressing white sturgeon are still in effect.

White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers

Measure 10.4A calls for the study and evaluation of sturgeon populations: "The Council believes that studies and evaluations should be undertaken and completed quickly, and on-the-ground projects identified and completed as soon as possible to address the needs of this species. In addition, these studies should be coordinated to avoid redundant work and to increase the potential for learning." Measure 10.4A.2 further states that "Specific recommendations for the protection, mitigation, and enhancement of sturgeon may be submitted to the Council upon completion of these studies."

Work to address Measure 10.4A.2 (determine the impact of the hydrosystem on sturgeon) is nearly completed. Work to address Measure 10.4A.3 (evaluate potential means of rebuilding sturgeon populations between Bonneville Dam and the mouth of the

Snake River) is also nearly complete. Measure 10.4A.8 (development of an experimental white sturgeon facility for research on contaminants, reproduction, and genetics) is underway. Results will eventually address Measures 10.4A.2 (potential for artificial propagation), and 10.4A.3 (rebuilding sturgeon populations).

In addition to the Fish and Wildlife Program, recently completed subbasin summaries have recognized the need for white sturgeon protection and restoration. The list of fish and wildlife needs in the Columbia Plateau subbasin summary included (1) determine the hydropower system operation program that will maximize the productivity of white sturgeon in reservoirs while also supporting salmonid recovery in the Columbia River Basin, (2) determine appropriate stocks and mechanisms for supplementing white sturgeon populations in reservoirs, (3) develop both short term and long-term strategies for white sturgeon supplementation, and (4) develop, implement, and evaluate a management plan for white sturgeon in Columbia River reservoirs. Fish and wildlife needs from the Columbia Gorge subbasin summary included: investigate upstream passage for white sturgeon at Bonneville and The Dalles dams. Fish management needs listed in the Lower Columbia River subbasin summary included: assess the effects of transporting white sturgeon from the unimpounded lower Columbia River upstream to The Dalles and John Day reservoirs, including an accurate assessment of sub-legal, legal, over-legal, and broodstock populations.

White Sturgeon Genetics

Because genetic vigor or integrity is most often positively correlated to population size (demographic vigor), white sturgeon mitigation and restoration must include increasing the size of depressed sturgeon populations, and maintaining currently viable populations through recruitment, represented by all genetic components of the population. However, many Basin white sturgeon populations are plagued by limited or failed recruitment, usually due to several interacting and often un-quantified factors (Miller et al. 1995; Anders et al. In Press; Parsley et al. In Press). Such data gaps confound restoration in real time. Thus, successful white sturgeon mitigation and restoration should be based on determining and understanding the causes of demographic and subsequent genetic decay at relevant population-specific, and Basin-wide scales.

Regardless of specific causes of individual sturgeon population decline, all white sturgeon populations in the Columbia River basin require at least periodic recruitment for short-term sustainability and persistence. Reliable recruitment at longer time scales is also important to long-term population viability and persistence from demographic and genetic perspectives (Jager et al. 2001). Therefore, mitigation in the form of maintenance or reestablishment of sturgeon recruitment is critical (Gross et al., In Press) because genetic viability is positively correlated with population size, and demographic and genetic integrity, which are all in part recruitment-dependent. Sturgeon recruitment can result from natural or artificial production, or perhaps some carefully designed and implemented combination of both. Therefore, approaches to maximize the numbers of contributing breeders should be carefully evaluated, consistent with the goal of maintaining the proportional contributions of familial genetic characteristics to the subsequent generation used for restoration.

Program Funding to Date

Project 198605000, *White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers,* began in 1986 primarily as a research effort. Research findings have lead to management recommendations, many of which have been implemented. Current funding includes a few remaining research tasks, implementation of management activities that are made necessary by the impact of the hydropower system on white sturgeon, and evaluation of those management activities. Funding history for the project is summarized in Table 1.

Project 199902200, *Assessing Genetic Variation Among Columbia Basin White Sturgeon Populations*, became a project separate from 19860500 in 1999. Funding history since then has been: FY 1999: $137,763; FY 2000: $135,823; and FY 2001: $136,043.

Table 1. Funding history for Project 19860500, White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers.

Fiscal year	Approved budget	Carry over funds	New funds	Cumulative funds
1986	$400,044	$0	$400,044	$400,044
1987	$1,256,403	$0	$1,256,403	$1,656,477
1988	No new funds			
1989	$1,167,071	$120,000	$1,047,071	$2,703,518
1990	$1,177,143	$50,000	$1,127,143	$3,830,661
1991	$1,203,176	$0	$1,203,176	$5,033,837
1992	$681,200	$0	$681,200	$5,715,037
1993	$819,500	$0	$819,500	$6,534,537
1994	$1,489,302	$0	$1,489,302	$8,023,839
1995	$2,065,723	$69,800	$1,995,923	$10,019,762
1996	$2,454,200	$267,104	$2,187,096	$12,206,858
1997	$2,127,743	$75,686	$2,051,057	$14,257,915
1998	$2,023,562	$0	$2,023,562	$16,281,477
1999	$1,964,528	$650,000	$1,314,528	$17,596,005
2000	$1,934,266	$600,000	$1,334,266	$18,930,271
2001	$2,010,872	$400,000	$1,610,872	$20,541,143
2002	$1,907,980	$0	$1,907,980	$22,449,123

Reports and Technical Papers

Reports

Anders, P., and M. Powell. 2001. Assessing genetic variation among Columbia Basin white sturgeon. Final Report to the Bonneville Power Administration. Project 99-22. Portland, OR. In Prep.

Anders, P., C. Gelok, and M. Powell. 2001. Population structure and mitochondrial DNA diversity of North American white sturgeon (Acipenser transmontanus). *In*:

Proceedings of the Idaho Chapter of the American Fisheries Society, 2001 Annual Meeting. Boise, Idaho. February 22-24.

Anders, P., C. Gelok, and M. Powell. 2000a. Assessing genetic variation among Columbia Basin white sturgeon. 2000 Annual Report to the Bonneville Power Administration. Project 99-22. Portland, OR.

Anders, P., C. Gelok, and M. Powell. 2000b. An initial genetic evaluation of broodstock selection for the Kootenai River White Sturgeon Conservation Aquaculture Program. In: Kootenai River Fisheries Studies. Kootenai Tribe of Idaho. 2000 Annual Report to the Bonneville Power Administration. Project No. 88-64. Portland OR.

Anders, P., and M. Powell. 1999. Assessing genetic variation among Columbia Basin white sturgeon. 1999 Annual Report to the Bonneville Power Administration. Project 99-22. Portland, OR.

Anders, P. J, and M. S. Powell. 1999. Phylogeographic distribution of white sturgeon mtDNA haplotypes in the Columbia River Basin: Preliminary results. In: Proceedings of the Western Division of the American Fisheries Society, Annual Meeting. Moscow, ID, July 12-14, 1999.

Anders, P. J, and M. S. Powell. 1999. Conservation aquaculture: Theory behind the practice. In: Proceedings of the Western Division of the American Fisheries Society, Annual Meeting. Moscow, ID., July 12-14, 1999.

Anders, P. J. 1999. Conservation aquaculture: Theory behind the practice. In: Proceedings of the Oregon Chapter of the American Fisheries Society. 33rd Annual Meeting, Sunriver, Oregon. February 10-12, 1999. Pg. 8.

Anders, P. J. 1998/1999. Conservation genetics meets aquaculture: A merger for the new millennium. Idaho Aquaculture News. Winter 98/99.

Anders, P. J. 1998. Conservation: Another benefit of aquaculture. Idaho Aquaculture News. Winter 1998.

Anders, P., and M. Powell. 1998. Comprehensive management and conservation of Columbia Basin white sturgeon (Acipenser transmontanus): A zoogeographic approach. In: Proceedings of Ecosystem Based Management in the Upper Columbia River Basin: An International Conference and Workshop. Castlegar, British Columbia, Canada. April 27-30, 1998. Pp. 53-54.

Beamesderfer, R. C. and A. A. Nigro. 1993 . Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam: Final Report to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Beamesderfer, R. C. and A. A. Nigro. 1993. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and Determine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam. Annual Report (April 1992 – March 1993) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Beiningen, K. B. 1995. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and Determine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam. Annual Report (April 1993 – March 1994) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Beiningen, K. B. 1996. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and Determine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam. Annual Report (April 1994 – March 1995) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.Nigro. A. A. 1987. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Annual Report (July 1986 - March 1987) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Nigro. A. A. 1988. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Annual Report (July 1987 - March 1988) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Nigro. A. A. 1989. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Annual Report (April 1988 - March 1989) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Nigro. A. A. 1990. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Annual Report (April 1989 - March 1990) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Nigro. A. A. 1991. Status and habitat requirements of white sturgeon populations in the Columbia River downstream from McNary Dam. Annual Report (April 1990 - March 1991) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Rien, T. A., and K. B. Beiningen. 1997. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and Determine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam. Annual Report (April 1995 – March 1996) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Ward, D. L. 1998. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and Detrmine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam. Annual Report (April 1996 – March 1997) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Ward, D. L. 1999. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and Detrmine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam. Annual Report (April 1997 – March 1998) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Ward, D. L. 2000. White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers Upstream from Bonneville Dam. Annual Report (April 1998–March 1999) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Ward, D. L. 2001. White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers Upstream from Bonneville Dam. Annual Report (April 1999–March 2000) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Peer Review Articles

Anders, P. 1997. The need for objective assessment of conservation aquaculture. Fisheries, Vol. 22(5):46.

Anders, P. J. 2000. Ancient fish need modern protection. Fisheries. Vol. 25 (9):30.

Anders, P. J. 1999. Pursue integrated fisheries management. Fisheries Vol. 24 (11):36.

Anders, P.J. Conservation aquaculture and endangered species: Can objective science prevail over risk anxiety? 1998. Fisheries Vol. 23(11): 28-31.

Anders, P. J., C. Gelok., and M. S. Powell. 2001. Genetic population structure of white sturgeon Acipenser transmontanus, in western North America based on mitochondrial DNA sequence analysis. In: Proceedings of the 4th International Symposium on Sturgeon, Oshkosh, WI. July 8-13,2001.

Anders, P., and M. Powell. Population structure and mitochondrial DNA diversity of North American white sturgeon (*Acipenser transmontanus*): An empirical expansive gene flow model. In Preparation for Molecular Ecology.

Bayer, J. M. and T.D. Counihan. 2001. Length changes in white sturgeon larvae preserved in ethanol or formaldehyde. Collection Forum 15(1-2): 57-64.

Beamesderfer, R. C. 1991. MOCPOP 2.0: A flexible system for simulation of age-structured populations and stock related functions. Oregon Department of Fish and Wildlife Information Report 91-4.

Beamesderfer, R. C. 1993. A standard weight (Ws) equation for white sturgeon. California Fish and Game 79(2):63-69.

Beamesderfer, R. C. P., T. A. Rien, and A. A. Nigro. 1995. Dynamics and potential production of white sturgeon populations in three Columbia River reservoirs Transactions of the American Fisheries Society 124:857-872.

Counihan, T. D., and C. N. Frost. 1999. Influence of externally attached transmitters on the swimming performance of juvenile white sturgeon. Transactions of the American Fisheries Society 128:965-970.

Counihan, T. D., A. I. Miller, M. G. Mesa, and M. J. Parsley. 1998. The effects of dissolved gas supersaturation on white sturgeon larvae. Transactions of the American Fisheries Society 127:316-322.

Counihan, T. D., A. I. Miller, and M. J. Parsley. 1999. Indexing the relative abundance of age-0 white sturgeon in an impoundment of the lower Columbia River from highly skewed trawling data. North American Journal of Fisheries Management 19:520-529.

Counihan, T. D., and M. J. Parsley. *Provisionally accepted*. Effects of hydropower peaking dam operations on white sturgeon eggs and larvae in the Columbia River. North American Journal of Fisheries Management.

Counihan, T. D, J. D.DeVore, and M. J.Parsley. *Provisionally accepted*. The effect of river discharge and water temperature on the year-class strength of Columbia River white stugeon. Transactions of the American Fisheries Society.

DeVore, J. D., B. W. James, C. A. Tracy, and D. A. Hale. 1995. Dynamics and potential production of white sturgeon in the Columbia River downstream from Bonneville Dam. Transactions of the American Fisheries Society 124:845-856.

Elliott J. C. and R. C. Beamesderfer. 1990. Comparison of efficiency and selectivity of three gears used to sample white sturgeon in a Columbia River reservoir. California Fish and Game 76(3):174-180.

Ireland, S. C., P. J. Anders, and J. T. Siple. *In Press.* Conservation aquaculture: An adaptive approach to prevent extinction of an endangered white sturgeon population (*Acipenser transmontanus*). *In*: W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Press

.McCabe, G. T., Jr. 1993. Prevalence of the parasite *Cystoopsis acipenseri* (Nematoda) in juvenile white sturgeons in the lower Columbia River. Journal of Aquatic Animal Health 5(4):313-316.

McCabe, G. T., Jr. and L. G. Beckman. 1990. Use of an artificial substrate to collect white sturgeon eggs. California Fish and Game 76(4):248-250.

McCabe, G. T., Jr., R. L. Emmett, and S. A. Hinton. 1993. Feeding ecology of juvenile white sturgeon (*Acipenser transmontanus*) in the Lower Columbia River. Northwest Science 67(3):170-180.

McCabe, G. T., Jr. and C. A. Tracy 1994. Spawning and early life history of white sturgeon, *Acipenser transmontanus*, in the lower Columbia River. Fishery Bulletin 92:760-772.

Miller, A. I., and L. G. Beckman. 1996. First record of predation on white sturgeon eggs by sympatric fishes. Transactions of the American Fisheries Society 125:338-340.

Muir, W. D., G. T. McCabe Jr., M. J. Parsley, and S. A. Hinton. 2000. Diet of first-feeding larval and young-of-the-year white sturgeon in the Lower Columbia River. Northwest Science 74(1):25-33.

North, J. A., R. C. Beamesderfer, and T. A. Rien. 1993. Distribution and movements of white sturgeon in three lower Columbia River reservoirs. Northwest Science 67(2):105-111.

Parsley, M. J., and L. G. Beckman. 1994. White sturgeon spawning and rearing habitat in the Lower Columbia River. North American Journal of Fisheries Management 14:812-827.

Parsley, M. J., L. G. Beckman, and G. T. McCabe, Jr. 1993. Spawning and rearing habitat use by white sturgeons in the Columbia River downstream from McNary Dam. Transactions of the American Fisheries Society 122(2):217-227.

Parsley, M. J. and K. K. Kappenman. 2000. White sturgeon spawning areas in the lower Snake River. Northwest Science 74:192-201.

Parsley, M. J., P. J. Anders. A. I. Miller, L. G. Beckman, and G. T McCabe Jr. *In Press*. Recovery of white sturgeon populations through natural production: Understanding the influence of abiotic and biotic factors on spawning and subsequent recruitment. *In*: W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Press.

Rien, T. A., and R. C. Beamesderfer. 1994. Accuracy and precision in age estimates of white sturgeon from pectoral fin rays. Transactions of the American Fisheries Society 123(2):255-265.

Rien, T. A., R. C. P. Beamesderfer, and C. A. Foster. 1994. Retention, recognition, and effects on survival of several tags and marks on white sturgeon. California Fish and Game 80(4):161-170.

Rien, T. A., and J. A. North. *In Press*. White sturgeon transplants within the Columbia River. *In*: W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Press.

Warren, J. J. and L. G. Beckman. 1993. Fishway use by white sturgeon to bypass mainstem Columbia River dams. U.S. Fish and Wildlife Service Sea Grant Extension Project, Columbia River Series WSG-AG 93-02.

Relationship to Regional Programs

In addition to the Fish and Wildlife Program, actions to protect and restore populations and mitigate for effects of the hydrosystem on productivity of white sturgeon have been called for in the “Columbia River Fish Management Plan” (*US v. Oregon*), in the “Multi-Year Implementation Plan” of the CBFWA, and in “Wy-Kan-Ush-Mi Wa-Kish-Wit” (the anadromous fish restoration plan of the Nez Perce, Umatilla, Warm Springs and Yakama tribes). Recommended actions from earlier work are described in “A Review of Alternatives for the Restoration and Management of White Sturgeon Populations and Fisheries in the Columbia River Between Bonneville and McNary Dams (Zone 6)” (DeVore et al. 1998). These recommendations are being implemented and assessed *Basin*

White Sturgeon under this project as specific measures that can protect and restore populations and mitigate for effects of the hydropower system on productivity of white sturgeon in the three-pool area between Bonneville and McNary dams.

The White Sturgeon Program addresses goals of the "White Sturgeon Research Program Implementation Plan" developed by BPA in cooperation with state and federal fishery agencies, tribes, universities, and the private sector, and approved by the Northwest Power Planning Council in 1985. The earlier phases of white sturgeon research focused on high priority information needs conducted in high priority areas, as designated in this plan. The Program also addresses research priorities described in the White Sturgeon Management Framework completed by the Pacific States Marine Fisheries Commission in 1992.

Although this Program concentrates on white sturgeon projects in the lower Columbia and Snake rivers, work is well coordinated with ongoing sturgeon projects in other areas of the basin. Project 198806400, *Kootenai River White Sturgeon Studies and Conservation Aquaculture*; Project 198806500, *Kootenai River Fisheries Investigations*; Project 199700900, *Evaluate Potential Means of Rebuilding White Sturgeon Populations in the Snake River Between Lower Granite and Hells Canyon Dams*, and Project 199502700, *Assess Limiting Factors of the Lake Roosevelt White Sturgeon Population* are all designed to study and restore sturgeon populations outside the geographic scope of this project; therefore, these projects are all complementary.

All white sturgeon projects in the Columbia River Basin will benefit from the work of Project 199902200, *Assessing Genetic Variation Among Columbia Populations*. Results from this project will provide guidelines for the transportation of juvenile sturgeon from the area downstream from Bonneville Dam to upstream reservoirs. Results should also provide guidelines for the release of artificially propagated juveniles and the monitoring and evaluation of their effects on recipient wild populations.

In addition to ensuring that all white sturgeon work in the Columbia River basin is coordinated and complimentary, sturgeon workers regularly organize a comprehensive meeting to discuss issues and share findings. In December 1997, the Oregon Department of Fish and Wildlife organized a meeting consisting of (1) a white sturgeon genetics roundtable, and (2) a white sturgeon summit meeting. In 2000, the Nez Perce Tribe organized and hosted a white sturgeon research coordination meeting. Such periodic regional meetings are expected to occur in the future, with consideration given to producing formal proceedings to foster effective regional information sharing.

The White Sturgeon Program also addresses goals and priorities specified in the Action Agencies (BPA, USACE, USBR) Five-year Implementation Plan for anadromous and resident fish. Goal 1 of the Implementation Plan is to “avoid jeopardy and assist in meeting recovery standards for Columbia Basin salmon, steelhead, bull trout, sturgeon, and other aquatic species that are affected by the FCRPS.” Furthermore, the Implementation Plan states that, “our goal is to achieve the greatest gains in survival, as quickly as possible while acknowledging that unlimited resources are not available to the Action Agencies. For example, actions that can be quickly implemented, can be accomplished with available resources, and provide a significant and measurable survival benefit would be implemented first.”

Goal 3 of the Implementation Plan is to “Assure tribal fishing rights and provide non-tribal fishing opportunities.” Protection and restoration of white sturgeon populations to facilitate tribal and non-tribal fisheries are critical components of the White sturgeon Program.

The White Sturgeon Program also addresses Goal 4 of the Implementation Plan, which is to balance other needs in the Columbia River basin. The Implementation Plan seeks to ensure that (1) salmon, steelhead, sturgeon, and bull trout conservation measures are integrated with the NWPPC Fish and Wildlife Program and balanced with the needs of other native fish and wildlife species, (2) salmon, steelhead, sturgeon, and bull trout conservation measures are balanced with human needs, including FCRPS project purposes, and (3) resources important to maintaining the traditional culture of basin tribes are preserved.

Relationship of Program to USFWS/NMFS Biological Opinion -- RPA's

Although white sturgeon throughout most of the Columbia River basin are not listed under the Endangered Species Act, findings from the White Sturgeon Program will be helpful in the recovery of listed Kootenai white sturgeon. For example, the status of white sturgeon in the lower Columbia River allows for greater, although prudent, levels of hatchery experimentation, particularly in areas that evaluate the efficacy of different release sizes and densities. Findings may be particularly useful to the recovery of Kootenai River white sturgeon. Results from genetics work may also benefit listed white sturgeon.

Future Needs

The consequences to white sturgeon are severe if Program needs are not addressed. Without intensive management and supporting research where needed, current levels of harvest cannot be maintained, and potential future increases will be precluded. Production of white sturgeon in most reservoirs will remain extremely limited, and abundance of severely depressed populations will continue to decline from critically low levels. Production will be limited by operation of the hydrosystem, and abundance will remain low if depressed reservoir populations are not supplemented. White sturgeon are a species of historic commercial, recreational, and tribal importance, and loss of these populations is significant and unacceptable. Closure of fisheries would likely result in litigation; therefore, annual funding is essential to maintain and increase current harvest levels.

Project Recommendations

White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers

The consequences to white sturgeon are severe if project 198605000 is not continued. Without intensive management, current levels of harvest cannot be maintained, and potential future increases will be precluded. Production of white sturgeon in most reservoirs will remain extremely limited, and abundance of severely depressed populations will remain critically low. Production will be limited by operation of the hydropower system, and abundance will remain low because depressed reservoir populations will not be supplemented. White sturgeon is a species of historic commercial, recreational, and tribal importance, and loss of these populations is significant and unacceptable. Closure of fisheries would likely result in litigation; therefore, annual funding is essential to maintain and increase current harvest levels.

White Sturgeon Genetics

Success of all population and evolutionary processes is ultimately dependent on populations' underlying genetic integrity. Thus, research contributing to the understanding of white sturgeon population genetics, with resolution and sample representation appropriate for local and regional management and conservation is crucial for the species' viability and persistence. Determination of desired population genetic condition for currently fragmented groups of white sturgeon within the Columbia Basin, comparison of such conditions with those existing, and innovative research and management strategies to improve the latter stand to provide great benefit to the species, and to the ecological communities in which they exist.

Higher resolution white sturgeon nuclear DNA (nDNA) genetic research is needed to provide more informative and comprehensive evaluation of the species at the Basin scale. A three-year white sturgeon genetics study is being completed (Anders and Powell, In prep). The first 2 years of this study involved strictly mitochondrial DNA. When this research was proposed (1998), no primers were available or developed to perform genetic analysis of nuclear microsatellite regions (nDNA) in octaploid (8N) white sturgeon. By the third year of this research, primers were available. However, one year's data analysis has proved inadequate to comprehensively address white sturgeon genetic diversity, variation, and population structure with high-resolution bi-parentally inherited nDNA markers. Such resolution is required for: 1) informed decisions regarding local and regional conservation and management issues of wild populations; 2) genetic monitoring of increasingly abundant progeny from conservation aquaculture programs; 3) providing tools to evaluate effects of these progeny on various population genetic parameters in wild, recipient Basin white sturgeon populations. To address these and other relevant issues of applied white sturgeon population genetics, more representative microsatellite analysis, and the development of single nucleotide polymorphisms (SNP's) are urgently needed.

Needed Future Actions

Maturation Status Model

Sustainable harvest levels of white sturgeon in the Columbia River are based on population models and fecundity estimates (Beamesderfer and Rieman 1988; Beamesderfer et al. 1995; DeVore et al. 1995). A key element of these models is spawning frequency, which is currently unknown for the populations of sturgeon in the Columbia River basin. A preliminary discriminant function model developed at OSU suggests that female white sturgeon may be distinguished by stage of maturity (pre-vitellogenic, early vitellogenic, mid-vitellogenic, and migratory nucleus) using plasma testosterone, estradiol, and 11-ketotestosterone. The development of this model and a similar model for male sturgeon would be extremely useful to management agencies: if sturgeon can be distinguished by stage of maturity and time to spawning, fisheries managers may accurately estimate spawning frequency and the percentage of the population that will spawn in any given year, thus allowing for the calibration of the current population models. To increase the predictive value and sensitivity of the preliminary discriminant function model for females and develop such a model for males, a larger number of paired gonad and blood samples from maturing sturgeon at various stages of development must be collected and analyzed. In addition, knowledge of the maturation cycle is required (e.g. the length of time required for vitellogenesis) which can be gained through measuring gonadal development in the marked oversize fish below Bonneville Dam. Collection of a larger data set (paired gonad and blood samples) from oversize fish will also increase the sensitivity and accuracy of the current sex and stage of maturity model that includes all size classes of sturgeon (Webb et al. in press). Understanding the white sturgeon maturation cycle and further development of the models to accurately predict individual fish maturational status will assist Bonneville Power Administration in the creation of a critical tool for assessing the impact of hydropower system development and operation on white sturgeon, and for monitoring future mitigation and management activities on sustainability of sturgeon populations in the Columbia River basin.

White Sturgeon Passage

From population genetics and demographic perspectives, historical (pre-dam) levels of white sturgeon gene flow have been greatly reduced and altered by impoundment of the Basin (NRC 1996; Anders and Powell In Prep), making mitigation for artificially reduced gene flow paramount. Studies should be done to develop fishway design criteria for white sturgeon to complement ongoing efforts to develop criteria for Pacific lamprey. It is not surprising that white sturgeon seldom ascend the existing fishways at the dams because they were designed for salmonids. Although little is known about white sturgeon swimming performance, research on other sturgeons has demonstrated that the swimming abilities of sturgeons are substantially different from those of salmonids. In general, sturgeons are poorer swimmers, particularly at burst swimming speeds. Sturgeons also generate greater drag than salmonids while swimming and have a less efficient tail, resulting in greater energy expenditure while swimming in higher velocity areas typical of fishways.

Adult and juvenile white sturgeon are capable of moving downstream through dams, although their route of passage is unknown. 97% of tagged sturgeons recaptured in a different reservoir than where they were tagged in had moved downstream through one or more dams versus upstream. It is unknown if fish pass through spill gates or turbines. Navigation locks at dams may provide another possible passage route (upstream and downstream) for fish, but use of navigation locks by white sturgeon has not been confirmed.

Objectives of a project to develop fishway design criteria for white sturgeon should include:

1 Identify ways to enhance access to fishways or reduce delay by describing the distribution and movements of white sturgeon in dam fishways and in adjacent areas including fish ladder entrances and exits, navigation locks, and immediate tailrace and forebay areas.

2. Determine if fallback occurs for fish that ascend fishways.
3. Relate swim performance of white sturgeon to fishway design to provide criteria that can be used in designing fishways.

Adaptive Management of White Sturgeon

Develop an adaptive management tool to answer the question: "What combination of supplementation, broodstock management, and harvest policies lead to improved viability of white sturgeon in all river sections?" This could be done by expanding an existing population viability analysis model that has been developed for the middle Snake River through the combined efforts of Idaho Power, the Electric Power Research Institute, and Oak Ridge National Laboratory. The expanded analysis should include white sturgeon populations in the lower Snake River and in the Columbia River reservoirs.

The goal would be to integrate information on white sturgeon population status and genetic diversity with information on habitat availability for the isolated populations to quantify the costs and benefits of alternative adaptive strategies. Information on white sturgeon population size structure, age composition, population estimates, and habitat data from a larger number of river segments should permit the development of relationships relating individual growth and maturation to temperature and habitat availability.

Work needs to be done to address the question: "How can population monitoring information be used to design adaptive policies for supplementation and harvest management that will enable Columbia River Basin white sturgeon populations to thrive?" Expanding the application of an existing population viability model and addressing these two objectives could find the answer to this question:

Objective 1. Integrate basin-wide information on white sturgeon habitat, growth and status for use in a Population Viability Analysis model.

Objective 2. Use the model to design adaptive policies (e.g., supplementation and harvest management) that raise long-term population densities of white sturgeon in the Columbia River basin.

Meeting these objectives would also answer several corollary questions:

1. To what extent can longitudinal differences in maturation and growth of female white sturgeon in the Columbia and Snake Rivers be explained by variables that summarize water temperature on an annual basis?
2. What levels of downstream and upstream migration do the regional genetic analysis and the model indicate?
3. How significant are each of the three risks associated with supplementation and under what conditions are they of concern?
4. What types of population monitoring data and what time intervals for monitoring are needed to provide policy makers with feedback?

Evaluate the Effect of Chemical Contaminants on White Sturgeon Productivity

Recent studies have collected one of the largest data sets on white sturgeon for organochlorines and reproductive physiology. However, several questions need to be addressed concerning the effects of environmental contaminants on the reproductive physiology of white sturgeon in the Columbia River and the influence of the hydroelectric system on chemical concentrations in sediments, water, and tissue.

The work to date has centered on reproductively immature white sturgeon collected from the commercial harvest. This was an appropriate method for initial data collection but information is necessary on older reproductively cycling white sturgeon in order to fully assess the potential effects of these environmental contaminants on sturgeon at all phases of reproductive development. Work similar to that conducted on the reproductively immature sturgeon should be conducted on larger reproductively maturing sturgeon. Data collection should continue with the reproductively immature white sturgeon to expand the list of potential contaminant effects and to assist in directing areas of inquiry for reproductively mature sturgeon. Studies of mature and immature sturgeon should evaluate contaminant concentrations in tissues important for reproduction and development of sturgeon. Biological endpoints should be measured in these and other tissues important for reproduction and development to assess reproductive status and effects of environmental contaminants on reproductive physiology.

More information is needed on the potential effects of contaminants on sturgeon energetics. There is evidence from other river systems that endocrine disrupting chemicals could be interacting with micronutrients and energetics to affect growth, reproduction, and development. The results to date show correlative evidence linking environmental contaminants and condition factor but additional information on a possible mechanism is needed. Such studies will provide information for determining if environmental contaminants are causing reduced condition factor in sturgeon from some locations or if other factors are playing a primary role. An area of little understanding is the role of ocean access has on micronutrient uptake and the importance for growth, reproduction, and development.

Data need to be collected on the concentrations of environmental contaminants in sediments and water from the Columbia River basin and their relation to tissue concentrations in sturgeon. The effect of the hydroelectric system on the fate and transport of these chemicals needs to be understood to be able to address the role of hydroelectric system on accumulation of these chemicals by sturgeon.

The following is a detailed summary of recent studies:

A cooperative study was initiated between Oregon Department of Environmental Quality, Oregon State University, Pacific University, and U.S. Geological Survey Biological Resources Division investigating the occurrence of chlorinated pesticides and PCBs and their effect on reproductive physiology in white sturgeon. Samples from sturgeon were collected from tissues and analyzed for chlorinated pesticides and PCBs as well as physiological, molecular, and biochemical measures of reproductive physiology. Specifically, chlorinated pesticides and PCBs were measured in samples from white sturgeon gonads in 1996; livers in 1997; and livers, gonads, and cheeks in 2000 and 2001. Biological endpoint samples were collected for plasma reproductive steroids in 1996, 1997, 2000, and 2001; condition factor and liver enzymes in 1997, 2000, and 2001; and plasma triacylglycerides and free fatty acids in 2000 and 2001. Gonad histology was performed for all years.

The chlorinated pesticide DDT and its metabolites DDE and DDD were frequently detected in livers and gonads of reproductively immature Columbia River white sturgeon with concentrations for DDE>DDD>DDT. Organochlorine concentrations varied between tissues with gonad>liver>cheek. Data from 1996 indicated higher levels of DDE in gonads of fish from The Dalles Pool but the 1997 data showed no differences between Columbia River locations (Foster et al. 2001a, Foster et al. 2001b). Organochlorine data for year 2000 collected samples show higher levels in gonads of fish from Bonneville Pool (Feist et al. 2001).

Plasma testosterone and 11-ketotestosterone were negatively correlated with DDE in reproductively immature males (Foster et al. 2001a) suggesting a potential connection between impaired reproduction and contaminant body burden. Preliminary data indicates that a cytochrome P450 involved in steroid metabolism may be induced by DDE and could be a mechanism for plasma androgen reductions. This cytochrome P450 could also be involved in the metabolism of reproductive maturation factors. Hepatic EROD activity, an indicator of another cytochrome P450, was elevated in sturgeon from Bonneville and The Dalles pools but was not correlated with chlorinated pesticides or PCBs indicating exposure of sturgeon to other Ah-receptor agonists, such as PAHs, chlorinated dioxins, or chlorinated furans.

Condition factor for fish from Bonneville pool was lower than those from other locations and triacylglycerides were lower in fish from Bonneville Pool (Feist et al. 2001). Condition factor was negatively correlated with total liver PCBs. Many factors could be affecting condition factor but Ah-receptor agonists have been shown to adversely affect energetics.

Vitellogenin, the egg yolk protein precursor, is naturally expressed in vitellogenic females but has been shown to occur in males and nonvitellogenic females exposed to xenoestrogens. Some plasma samples from males and reproductively immature females had elevated levels of plasma vitellogenin indicating exposure to estrogenic chemicals. Gonad histology showed some fish with intersex gonads and others with striated muscle intrusion (Feist et al. 2001). The occurrence of this type of gonad histology may indicate exposure and effect from environmental contaminants.

These data indicate contaminant effects on plasma androgen concentrations and the induction of liver enzymes. Contaminants may also be involved with reduced condition factor and altered gonad development. The contribution of contaminant stress to the poor reproductive success of Columbia River white sturgeon is unknown, but remains a distinct possibility, and may represent another component added to other factors such as nutritional status and habitat quality that are working together to decrease the reproductive success of white sturgeon in the Columbia River above Bonneville Dam. Thus, understanding the relative contribution of contaminant stress to white sturgeon reproduction will provide important information for white sturgeon management and restoration efforts in the Columbia River Basin.

Understanding the Influence of Abiotic and Biotic Factors on Spawning and Subsequent Recruitment

Recovery or maintenance of white sturgeon populations through natural production in perturbed river systems such as the Columbia River Basin requires adequate knowledge of the abiotic and biotic factors that influence spawning and cause mortality of embryonic, larval, and juvenile life stages. Although it is known that the year-class strength of white sturgeon is determined within 2-3 months after spawning, little is known about specific causes of mortality to early life stages during this period. Initial spawning success is critical in the development of a strong year-class, and maximized recruitment may be dependent upon water temperature and the availability of optimal in-river habitat. Analyses have shown that increased river discharge combined with suitable water temperatures during spawning, egg incubation, yolk-sac larvae dispersal, and first exogenous feeding result in greater recruitment. However, little is known about the importance of other variables that influence year class strength, such as food availability or losses due to predation. Two recent papers provide insight into pre- and post-spawning recruitment failure mechanisms (Anders et al. In Press; Parsley et al. In Press).

The Columbia River and its watershed have been drastically altered by human activities that undoubtedly have influenced population size and recruitment success of many fish species including white sturgeon. Construction and operation of hydroelectric dams, agriculture, logging, mining, stream channelization, flood control operations, water pollution, and harvest histories have allowed some native and introduced fish species to flourish, while other native species have declined. Fish adapted to riverine conditions, such as white sturgeon, have suffered most. In general, current population trends and sizes can be characterized as stable at a relatively high population size in the lower Columbia River, stable or variable at low to moderate population sizes in middle reaches, and stable at extremely low to negligible population sizes in upper reaches of the basin.

Some areas where population productivity is high experience inter-annual variations in recruitment, while other areas have low recruitment that precludes harvest opportunities*, and some areas have had a virtual lack of recruitment for several decades.* The latter case led to listing the Kootenai River population of white sturgeon as an endangered species by the U.S. Fish and Wildlife Service in 1994 under the Endangered Species Act. Fishery management responses to declines in white sturgeon populations have generally been to protect spawning stocks by restricting harvest through minimum and maximum size limits, imposing daily and annual harvest limits, and closing seasons and areas. This management approach of protecting spawning stock to maintain production has been relatively successful in the lower Columbia River as evidenced by the maintenance of harvest opportunities. However, populations are still declining in other areas of the Columbia River Basin despite decades of restrictions on harvest that have included catch and release fishing only or complete elimination of fishing for white sturgeon. Thus, environmental effects on stock-recruitment relations for white sturgeon differ among areas and among years within areas, further confounding management efforts.

Effective management of self-sustaining white sturgeon populations or recovery of declining populations through natural production will be achieved only through an understanding of the factors affecting reproduction and early life history. A major source of uncertainty in fisheries management and a central problem of fishery science is a lack of understanding of recruitment variability. The causes of variability or failure in recruitment of white sturgeon to age-0 among areas or among years within an area are largely unknown. Once the dynamics of the recruitment process are better known, defensible decisions can be made to implement a variety of alternatives ranging from regulating harvest to altering hydropower system operations or constructing artificial spawning areas to benefit natural production in white sturgeon populations.

Carrying Capacities of Reservoirs

Information is needed on how hydropower system development and operation has affected availability of food (quality and quantity) for white sturgeon. Food availability and carrying capacity may vary in each Columbia and Snake river reservoir. Efforts to recover populations through harvest management and supplementation will fail if the biological environment resulting from hydropower system construction and operation will not sustain the additional production desired.

Questions to be addressed through mainstem/systemwide research include:

1. Does the current environment provide nutritionally suitable forage in a timely manner and in adequate amounts to sustain production or allow additional production? How do prey quantities and types vary throughout the system?
    a. Are foods currently consumed by larval, juvenile, and adult white sturgeon meeting their nutritional needs? For instance, introduced *Corbicula* spp. are consumed in large quantities, but do these provide the essential nutrients and meet the caloric needs of white sturgeon?
    b. Altered thermal regimes due to hydropower system operation may have increased metabolic needs for white sturgeon during winter. What are the metabolic requirements of various sizes of white sturgeon? Do the reservoir environments provide adequate forage during all seasons?
2. Do introduced biota (most of which have benefited from hydropower system operation) compete for space or food with white sturgeon? Is the potential production that could be realized for white sturgeon instead going into other organisms?
3. Is there intra-specific competition for food? If food is limiting, will stocking or other measures to increase juvenile abundance influence growth rates of adults, and thus offset any gains in productivity?

Genetic Contribution of Individual White Sturgeon

Information regarding the degree of genetic contribution made to the next generation by individual broodstock females and males in a given spawning season for a given reservoir is urgently required. Management staff from both states and tribes continually stresses the need for maximum broodstock escapement to maximize recruitment for population and fisheries stability over the long-term. This strategy is consistent with conservation programs that seek to maximize the expansion of depressed or declining stocks in order to decrease risks associated with demographic and environmental stochasticity. Stock assessment surveys do not estimate the numbers of broodstock sized sturgeon in any one pool due to the lack of recruitment of these fish to the sampling gear. Using a re-designed sampling procedure to assess the numbers of broodstock will likely be too expensive and still may not give precise information. Additionally, the handling of these fish via a concentrated population assessment effort could result in increased mortality rates of these fish. Recent advancements in molecular techniques and technology may provide useful alternatives. Genetic investigations could address broodstock contribution and numbers issue by non-lethal tissue sampling of young of year sturgeon during the regularly scheduled monitoring that is already in place.

Specifically, a pelvic or anal fin section could be collected from each young of year sturgeon collected during the regular monitoring process. All samples would be stored in a lysis buffer solution that is non-toxic and has long term storage capability and requires a fairly small sample (~2 paper hole sized punches). Analysis is straight-forward, mechanized and is fairly inexpensive (max. cost of $40/sample). When a sufficient amount of samples have been collected (~ 100 or more for all pools sampled), the analysis could be conducted and a plot of the different parental contributions could be produced. Given the high degree of variability between water years this proposal would have a fairly long time span (e.g. 10-20 years) and would be viewed as an additional long-term monitoring tool to estimate both instantaneous and overall effective population size of populations with managed fisheries. Additionally it would provide useful information on the numbers and time necessary to enhance or restore depressed populations in the upper Columbia River reservoirs.

The uniqueness of this proposed approach is that there are essentially no additional costs except for laboratory analysis and genetic interpretation. Field supplies are very inexpensive and the procedure is minimally invasive to the fish. A standardized long-term monitoring process is already in place and will likely continue for some time to come. This program will not answer all of the questions related to broodstock abundance and egg per recruit contributions, but it will certainly start answering questions regarding effective population size and genetic contributions. Similar programs of this nature are already underway for Redfish Lake sockeye and Salmon River Chinook salmon (Powell and Faler 2001).

Develop a Comprehensive Integrated White Sturgeon Management Plan

Currently, reference to white sturgeon "populations" is simply a convenient way to describe groups of fish in particular geographic areas. Although biological, genetic, and ecological data needed to accurately define white sturgeon populations and putative population structure are being collected and analyzed, critical uncertainties remain. Ongoing white sturgeon genetic research is providing much needed information about white sturgeon population structure (Anders and Powell 1999; Anders et al. 2000a, b; Anders and Powell, In Prep.). These data, along with extensive data and information collected, analyzed, and published by ongoing BPA 86-50 cooperators (see above citation lists) form the basis for a much needed Plan. The proposed mechanism to organize and prioritize existing information and critical uncertainties is a comprehensive, integrated Columbia Basin White Sturgeon Conservation and management Plan.

Because white sturgeon research, management, and recovery activities have proliferated in the Columbia Basin, the need has never been greater for a cooperative, multi-agency Plan. This approach and supporting rationale for the Plan are consistent with the fact that as a species, white sturgeon functionally exist at the Columbia Basin scale. Thus, white sturgeon management and required underlying research at considerably smaller geographic scales appears inadequate to successfully conserve and manage

Columbia Basin white sturgeon at the relevant Basin-wide (species) scale, as mandated by the NWPPC's Fish and Wildlife Program (NWPPC 1994; 2000).

In addition to white sturgeon population genetic data (Anders and Powell 1999; Anders et al. 2000a, b; Anders and Powell, In Prep.), empirical movement and migration data have confirmed the species' ability to migrate in excess of 2,500 km within, between, and among major river systems of western North America (Rien and Beiningen 1997; DeVore et al. 1999). Although white sturgeon migrations involve the marine environment, all sturgeons spawn exclusively in freshwater (Bemis and Kynard 1997). Unfortunately, extensive development of hydropower dams throughout the Columbia River Basin during the past century has severely fragmented free-flowing, large river habitats (National Research Council 1996) occupied by white sturgeon. One important result of such river fragmentation for white sturgeon is the creation of a series of relatively isolated sub-populations (Secor et al. In press; Jager et al. 2000;). This is especially critical for a migratory species like white sturgeon, where fragmentation by dams may artificially impose exclusively downstream gene flow, creating fragmented sub-populations. Such a scenario may likely jeopardize or eliminate functional mechanisms of population and evolutionary biology responsible for long-term viability and persistence. Altered seasonal river discharge and thermal regimes resulting from impoundment and dam operations can also alter migration and limit availability of spawning, rearing, feeding and migratory habitats (Auer 1996; Cooke et al., In Press; Jager et al. In Press; Secor et al. In press). Furthermore, various reservoirs within the Basin may currently lack suitable habitat for successful completion of all lifestages. Due to such post-impoundment limitation, organized, Basin-wide biological information to facilitate management and conservation, in the form of the Plan, is recommended. Such an approach would provide information needed to assess, monitor, and evaluate population restoration options for Basin white sturgeon.

Such a plan is also recommended to address and prioritize the diverse set of research and management needs for white sturgeon, which vary considerably across the Columbia Basin. This array of research and management needs results largely from spatial variability of white sturgeon status across the Basin, as briefly summarized: Miller et al. (1995) and Parsley et al. (In Press) described white sturgeon population sizes and trends as high and generally stable in the lower Columbia River, low to moderate, and relatively stable in the middle reaches, and low to negligible in upper reaches of the Basin, where population trends were either unknown or generally declining. The Kootenai population, occupying British Columbia, Idaho, and historically Montana waters of the upper Columbia River Basin was federally listed as endangered under the US Endangered Species Act in 1994 (USFWS 1994). Proactive research and management to be provided and implemented under the Plan are proposed as a preferred alternative to subsequent listings.

The development of such a comprehensive plan is predicated on the need to gather, evaluate, integrate, and make available all white sturgeon biological, ecological, and genetic data from the Columbia Basin. Therefore, it is recommended that prior to the Plan's development, a comprehensive document representing the "State of the Science for Columbia Basin White Sturgeon" be produced. First, this document would provide a comprehensive summary white sturgeon biological, ecological, and genetic information from the Basin. In doing so, this document should: 1) identify and prioritize, by specific location, white sturgeon research, management and conservation needs throughout the Basin; 2) identify and prioritize data gaps, also by specific location, that need to be addressed for successful management and conservation, and 3) facilitate innovative, science-based solutions to management and conservation issues which transcend agency boundaries. Secondly, it should provide all Columbia Basin white sturgeon researchers, managers, regulatory personnel, and scientific reviewers with a comprehensive, accessible source of white sturgeon biological, ecological, and genetic information and techniques. This provision would allow definition and incorporation of the "best available science" concerning white sturgeon research, management and legal status definition into all planning, review, implementation and evaluation activities.

Finally, several additional issues warrant future attention in the Council's Program regarding Columbia Basin white sturgeon: 1) Incorporation of biological, ecological, demographic, and genetic data into population viability and persistence models to help prioritize white sturgeon research, management and conservation activities, and evaluate their probabilities of success, and cost-effectiveness. 2) Provide opportunities to develop and evaluate artificial white sturgeon spawning habitats in conjunction with Russian sturgeon researchers and their proven techniques. Such techniques have been successfully employed for decades to restore natural sturgeon production in Russian rivers where access to historical sturgeon spawning habitat has eliminated, or habitats have been severely degraded (Personal communication, D. Pavlov, Russian Academy of Sciences, Moscow, Russia). This is particularly relevant to upriver Basin populations (Duke et al. 1999; USFWS 1999; Holderman et al., submitted).

White Sturgeon Fish Health Needs

The White Sturgeon Iridovirus (WSIV) has been documented from sturgeon in the Kootenai River, the Snake River, and the mainstem of the Columbia River. Since presence of this virus has been recorded from very few sites in the basin, its full geographical range within the basin is not known. The virus can cause mortalities as high as 95% among juvenile sturgeon (age 0+) raised in hatcheries. Knowledge is lacking about its impact upon juvenile sturgeon in the wild. Presence of this pathogen in the wild may explain some of the recruitment failure in mainstem pools on the Columbia River. This pathogen may present a serious problem for future propagation of sturgeon for restoration and mitigation programs. Very little is known about the transmission of this pathogen, either horizontally within the hatchery environs or vertically from parent to offspring during spawning.

Broodstock for propagation projects are drawn almost exclusively from fish captured in the wild. These fish are not screened for the presence of WSIV at the time of spawning and as a result there have been severe outbreaks of WSIV among progeny. A rapid and sensitive screening test is needed to provide appropriate risk assessment capabilities for white sturgeon propagation projects. Research is also desperately needed in areas of disease treatment and management in order to minimize the impact of potential outbreaks during propagation procedures.

White Sturgeon Supplementation Plan

Currently managers involved in the white sturgeon program are focusing on a strategy that uses natural production, intensive harvest management and in river supplementation of white sturgeon from below Bonneville Reservoir to rebuild depressed populations in John Day, The Dalles and Bonneville reservoirs. The goal of this management strategy is to rebuild the populations in these reservoirs while allowing a commercial and sport harvest, with the ultimate goal of stabilizing the population, and possibly increasing the level of production of each reservior in the future. These management activities are being evaluated and the success of each strategy and it's potential future as a strategy will be determined as time and data accumulation allows. Population surveys are currently being conducted that will evaluate the success of restricted harvest management and in river supplementation with much of this information becoming available in 2003.

Meanwhile, there is a need to develop a plan that would investigate the use of hatchery supplementation to rebuild white sturgeon populations in Lower Columbia River reservoirs, should current management activities prove unsuccessful at reaching the goal of rebuilding the populations in these reservoirs. Such a plan would investigate and address the potential of using wild white sturgeon broodstock to spawn and produce offspring that would be hatchery reared and used to rebuild wild populations, supplement current harvest levels, and/or potentially increase future harvest levels. The initial stages of this plan would allow for the use of hatchery reared white sturgeon to be released in reservoirs above Bonneville Dam for supplementation research evaluation, proceeding much as the current in river supplementation project in use now. The development of this plan would investigate other white sturgeon hatchery supplementation programs and facilities and determine their applicability to the Lower Columbia River populations. It would also investigate and identify possible tribal, state, and federal partnerships and potential locations for developing a hatchery facility should the need for such a facility be determined.

References

Anders, P. J. 1998. Conservation aquaculture and endangered species: Can objective science prevail over risk anxiety? Fisheries 23: 28-31

Anders, P., and M. Powell. 1999. Assessing genetic variation among Columbia Basin white sturgeon. 1999. Annual Report to the Bonneville Power Administration. Project 99-22. Portland, OR.

Anders, P., and M. Powell. Population structure and mitochondrial DNA diversity of North American white sturgeon (*Acipenser transmontanus)*: An empirical expansive gene flow model. *In Preparation.*

Anders, P. J., D. L. Richards, M. S. Powell. *In Press.* The First Endangered White Sturgeon Population (*Acipenser transmontanus*): Repercussions in an Altered Large River-floodplain Ecosystem. *In*: W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Press, Bethesda, MD.

Anders, P., C. Gelok, and M. Powell. 2000a. Assessing genetic variation among Columbia Basin white sturgeon. 2000 Annual Report to the Bonneville Power Administration. Project 99-22. Portland, OR.

Anders, P., C. Gelok, and M. Powell. 2000b. An initial genetic evaluation of broodstock selection for the Kootenai River White Sturgeon Conservation Aquaculture Program. In: Kootenai River Fisheries Studies. Kootenai Tribe of Idaho. 2000 Annual Report to the Bonneville Power Administration. Project No. 88-64. Portland OR.

Auer, N. A. 1996. Response of spawning lake sturgeons to change in hydroelectric facility operation. Transactions of the American Fisheries Society 125:66-77.

Avise, J. C. 1994. Molecular Markers, Natural History and Evolution. Sinauer Associates, Sunderland, MA. USA.

Bartley, D. M., G. A. E. Gall, and B. Bentley. 1985. Preliminary description of the genetic structure of white sturgeon, *Acipenser transmontanus* in the Pacific Northwest. *In*: F. P. Binkowski and S. E. Dorshov (eds.) North American Sturgeons. W. Junk Publishers, Dordrecht, The Netherlands.

Beamesderfer, R. C. and B. E. Rieman. 1988. Size selectivity and bias in estimates of population statistics of smallmouth bass, walleye, and northern squawfish in a Columbia River reservoir. North American Journal of Fisheries Management 8:505-510.

Beamesderfer, R. C. P., T. A. Rien, and A. A. Nigro. 1995. Differences in the dynamics and potential production of impounded and unimpounded white sturgeon populations in the lower Columbia River. Transactions of the American Fisheries Society 124:857-872.

Bemis, W. E., and B. Kynard. 1977. Sturgeon rivers: an introduction to Acipenseriform biogeography and life history. Environmental Biology of Fishes 48:167-183.

Brown, J. B., A. T. Beckenbach, and M. J. Smith. 1992. Influence of Pleistocene glaciations and human intervention upon mitochondrial DNA diversity in white sturgeon (*Acipenser transmontanus*) populations. Canadian Journal of Fisheries and Aquatic Sciences (49) 358-367.

Cooke, D. W., S. D. Leach, and J. J. Isely. *In Press*. Behavior and lack of upstream passage of shortnose sturgeon at a hydroelectric facility/navigation lock complex. *In*: W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Press.

Craig, J. A., and R. L. Hacker. 1940. Sturgeon fishery of Columbia River Basin. Bulletin of the Bureau of Fisheries 49:204-208.

DeVore, D., B. James, and R. Beamesderfer. 1999. Lower Columbia River white sturgeon current stock assessment and management implications. Washington Department of Fish and Wildlife. Report No. SS 99-08.

DeVore, J. D., B. W. James, C. A. Tracy, and D. A. Hale. 1995. Dynamics and potential production of white sturgeon in the unimpounded lower Columbia River. Transactions of the American Fisheries Society 124:845-856.

DeVore, J. D., B. Parker, R. C. P. Beamesderfer, and T. A. Rien. 1998. A review of alternatives for the restoration and management of white sturgeon populations and fisheries in the Columbia River between Bonneville and McNary dams. Washington Department of Fish and Wildlife, Olympia, WA.

Duke, S., P. Anders, G. Ennis, R. Hallock, J. Hammond, S. Ireland, J. Laufle, L. Lockard, B. Marotz, V. Paragamian, and R. Westerhof. 1999. Recovery plan for Kootenai River white sturgeon (*Acipenser transmontanus)*. Journal of Applied Ichthyology (15):157-163.

Ebel, W. J., C. D. Becker, J. W. Mullan, and H. L. Raymond. 1989. The Columbia River – toward a holistic understanding. Canada Special Publication of Fisheries and Aquatic Sciences 106:205-219.

Feist, G. W., M. S. Fitzpatrick, E. P. Foster, D. T. Gundersen, M. A. H. Webb, A. G. Maule, W. L. Gale, and C. B. Schreck. 2001. Endocrine disrupting chemicals and reproduction in white sturgeon. 4th International Sturgeon Symposium. July 8-13, 2001.

Fickeisen, D. H., D. A. Neitzel, and D. D. Dauble. 1984. White sturgeon research needs: workshops results. Division of Fish and Wildlife, Bonneville Power Administration, U. S. Department of Energy, Portland, OR.

Foster E. P., D. Drake, and R. Farlow. 1999. Polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran congener profiles in fish, crayfish, and sediment collected near a wood treating facility and a bleached kraft pulp mill. Bull. Environ. Contam. Toxicol.. 62: 239-246.

Foster, E. P., M. S. Fitzpatrick, G. W. Feist, C. B. Schreck, J. Yates, J. M. Spitsbergen, and J. Heidel. 2001a. Altered reproductive physiology, EROD induction, reduced condition factor, and the occurrence of organochlorine pollutants in white sturgeon (*Acipenser transmontanus*) from the Columbia River. Arch. Environ. Contam. Toxicol. 41(2):182-191.

Foster, E. P., M. S. Fitzpatrick, G. W. Feist, C. B. Schreck, and J. Yates. 2001b. Gonad organochlorine concentrations and plasma sex steroid levels in white sturgeon (*Acipenser transmontanus*) from the Columbia River, USA. Bull. Environ. Contam. Toxicol. 67:239-245.

Gross, M. R., J. Repka, C. T. Roberstson, D. H Secor, and W. VanWinkle. *In Press*. Sturgeon conservation:Insights from elasticity analysis. *In*: W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Press.

Holderman, C. E., P. J. Anders, and B. Shafii. A preliminary *in situ* embryo incubation experiment to investigate natural recruitment failure in an endangered white sturgeon population (*Acipenser transmontanus*). *Submitted to Transactions of the American Fisheries Society (12/01).*

Jager, H. I., K. LePla, J. Chandler, P. Bates, W. VanWinkle. 2000. Population viability analysis of white sturgeon and other riverine fishes. Environmental Science and Policy 3:S483-S489.

Jager, H. I., J. A Chandler, K. B. LePla, and W. Van Winkle. 2001. A theoretical study of river fragmentation by dams and its effects on white sturgeon. Environmental Biology of Fishes 60:347-361.

Jager, H. I., VanWinkle, W., J. A. Chandler, K. B. LePla, P. Bates, and T. D. Counihan. In Press. A simulation study of factors controlling white sturgeon recruitment in the Snake River. *In*: W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Press.

McCabe, G. T., Jr. and C. A. Tracy 1994. Spawning and early life history of white sturgeon, *Acipenser transmontanus*, in the lower Columbia River. Fishery Bulletin 92:760-772.

McCarthy K. A., and R. W. Gale. 1999. Investigation of the distribution of organochlorine and polycyclic aromatic hydrocarbon compounds in the lower Columbia River using semipermeable membrane devices. Water-Resources Investigations Report 99-4051. U.S. Geological Survey, Portland, OR

Miller, A. I., T. D. Counihan, M. J Parsley, and L. G Beckman. 1995. Columbia River Basin white sturgeon. Pages 154-157 *in*: E. T. La Roe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac eds. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service. Washington, D.C. 530 pp.

National Research Council (NRC). 1996. Upstream: Salmon and society in the Pacific Northwest. National Academy Press, Washington D.C.

Northwest Power Planning Council (NWPPC). 1994. Columbia Basin Fish and Wildlife Program. Portland, OR.

Northwest Power Planning Council (NWPPC). 2000. Columbia Basin Fish and Wildlife Program. Portland, OR.

North, J. A., R. C. Beamesderfer, and T. A. Rien. 1993. Distribution and movements of white sturgeon in three lower Columbia River reservoirs. Northwest Science 67(2):105-111.

Parsley, M. J., P. J. Anders. A. I. Miller, L. G. Beckman, and G. T McCabe Jr. *In Press*. Recovery of white sturgeon populations through natural production: Understanding the influence of abiotic and biotic factors on spawning and subsequent recruitment. *In*: W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Press.

Parsley, M. J., and L. G. Beckman. 1994. White sturgeon spawning and rearing habitat in the Lower Columbia River. North American Journal of Fisheries Management 14:812-827.

Parsley, M. J., L. G. Beckman, and G. T. McCabe, Jr. 1993. Spawning and rearing habitat use by white sturgeons in the Columbia River downstream from McNary Dam. Transactions of the American Fisheries Society 122(2):217-227.

Powell M. and J.C. Faler 2001. Genetic analysis of Redfish Lake sockeye and Salmon river chinook salmon 2001. Annual Report to the Bonneville Power Administration. Project 93-00. Portland, OR.

Rien, T. A., and K. B. Beiningen. 1997. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and Determine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam. Annual Report (April 1995 – March 1996) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Secor, D. H., P. J. Anders, W. Van Winkle, and D. A. Dixon. *In Press.* Can We Study Sturgeons to Extinction? What We Do and Don't Know about the Conservation of North American Sturgeons. *In*: W. VanWinkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Press.

Setter, A. and E. Brannon. 1992. A summary of stock identification research on white sturgeon of the Columbia River (1985-1990). Project No. 89-44. Final Report to the Bonneville Power Administration, Portland OR.

U.S. Environmental Protection Agency (EPA). 1992. National study of chemical residues in fish, Vol. II. EPA 823-R-92-008b. U.S. Environmental Protection Agency, Washington, DC.

USFWS (U.S. Department of Interior, Fish and Wildlife Service). 1994. Determination of endangered status for the Kootenai River white sturgeon population. Federal Register 59(171) 45989.

USFWS (U.S. Department of Interior, Fish and Wildlife Service). 1999. Recovery plan for the white sturgeon (*Acipenser transmontanus*): Kootenai River population. U.S. Fish and Wildlife Service, Portland, Oregon.

Ward, D. L. 1998. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and Detrmine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam. Annual Report (April 1996 – March 1997) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Ward, D. L. 1999. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and Detrmine the Status and Habitat Requirements of White Sturgeon Populations in the Columbia and Snake Rivers Upstream From McNary Dam. Annual Report (April 1997 – March 1998) to Bonneville Power Administration, Contract No. DE-A179-86BP63584.

Webb, M. A. H., G. W. Feist, C. B. Schreck, E. P. Foster, and M. S. Fitzpatrick. *In Press*. Potential classification of sex and stage of gonadal maturity of wild white sturgeon using blood plasma indicators. Transactions of the American Fisheries Society.

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Appendix A. Hatchery and Genetic Management Plan: White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers

Columbia River Inter-tribal Fish Commission
729 N.E. Oregon, Suite 200,
Portland, Oregon 97232
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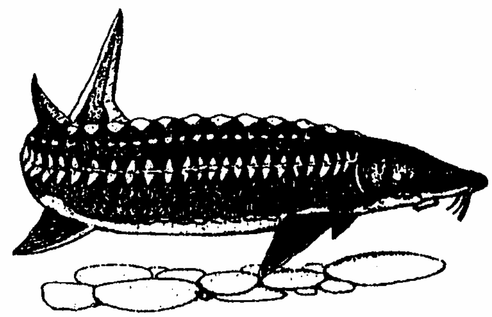

HATCHERY AND GENETIC MANAGEMENT PLAN

White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers

A portion of the material in this plan was derived from the Kootenai Tribe of Idaho's White Sturgeon Hatchery and Genetics Plan written for the NWPPC Mountain Columbia Provincial Rolling Review - December 2000.

Hatchery Program:
White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers

Species or Hatchery Population/Strain:
White Sturgeon

Agency Operator:
Columbia River Inter-Tribal Fish Commission

Watershed and Region:
Mainstem / Systemwide

Date Submitted: 2/15/02

Date Last Updated: 2/15/02

SECTION 1. GENERAL PROGRAM DESCRIPTION

1.1) Name of hatchery or program.
White Sturgeon Mitigation and Restoration in the Columbia and Snake Rivers Upstream From Bonneville Dam

1.2) Species and population (or strain) under propagation, ESA/population status.
White sturgeon (*Acipenser transmontanus*); Not listed

1.3) Responsible organization and individuals

Name (and title): *Blaine Parker Project Leader (lead contact)*
Agency or Tribe: *Columbia River Inter-Tribal Fish Commission*
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Name (and title): *John Holmes (on-site operations lead)*
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Email: *John_Holmes@r1.fws.gov*

Other agencies, Tribes, co-operators, or organizations involved, including contractors, and extent of involvement in the program:

Development of artificial propagation techniques and protocols is one task under the larger program titled "White sturgeon mitigation and restoration in the Columbia and Snake rivers upstream from Bonneville Dam". The purpose of the propagation task is research – to identify how to most effectively use artificial propagation to restore white sturgeon populations.

The Oregon Department of Fish and Wildlife (ODFW) administers the overall program. The Columbia River Inter-Tribal Fish Commission (CRITFC) is the lead agency on the artificial propagation task. Juvenile white sturgeon are reared at the Abernathy Fish Technology Center (AFTC), operated by the U.S. Fish and Wildlife Service (USFWS). All activities are reviewed by agencies involved in the overall program, which include ODFW, the Washington Department of Fish and Wildlife (WDFW), CRITFC, USFWS, and the U. S. Geological Survey (USGS).

1.4) Funding source, staffing level, and annual hatchery program operational costs.

The Bonneville Power Administration funds the overall program, including the specific artificial propagation task described here. Cost sharing for this task is also provided by CRITFC and the USFWS.

Current staff includes the project leader (1.0 FTE) and project biologist (1.0 FTE) from CRITFC, and a project biologist (0.5 FTE), fish culturist (0.25 FTE), and hatchery technician (1.0 FTE) from the USFWS.

Estimated costs of the propagation task (Table 1), as well as previous task developments and investments (Table 2) are summarized below. The purpose of propagation is limited to research and existing facilities are being used; therefore, costs are relatively low. Planning and design were completed prior to FY2002. Broodstock collection began in FY1999 and will continue through FY2003. Limited releases of hatchery-reared fish will occur from FY2002 through FY2006. Evaluation of the effectiveness of various release strategies (age of fish at release) will occur from FY2007 through FY2009.

Table 1. Projected Fiscal Year 2002 – 2009 budgets

	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009
Planning and design								
Construction/implementation								
Operations and maintenance	325,000	325,000	275,000	250,000	200,000	0	0	0
Monitoring and evaluation	0	0	0	0	0	300,000	0	300,000

Table 2. Past program investments, milestones, and plans.

Year	**Budget**	**Milestones**
1998	$25,000	Propagation research plan developed and approved.
1999	$150,000	Improvements to hatchery facility completed. Broodstock collected, spawning unsuccessful
2000	$200,000	Broodstock collected; spawning unsuccessful.
2001	$325,000	Broodstock collected; spawning successful.

1.5) Location(s) of hatchery and associated facilities.

The temporary satellite holding and spawning facility is located along the Columbia River at the McNary Dam, directly below the juvenile fish sorting facility operated by the Army Corps of Engineers. This is a temporary facility, consisting of six ten-foot circular tanks, a broodstock-holding tank, and two egg bath tanks. It is operated using surplus water from the juvenile fish sorting facility with the cooperation of the Corp of Engineers.

The Abernathy Fish Technology Center (AFTC), site of the juvenile rearing facility, is located on Abernathy Creek, 4.8 Kilometers upstream of its confluence with the Columbia River at River Kilometer 91.7, west of Longview, Washington. It is a U.S. Fish and Wildlife Service facility that's mission is to provide leadership in scientifically based management of national fishery resources through development of new concepts and techniques to solve specific resource problems in aquatic restoration and recovery activities.

1.6) Type of program(s).

This is an Integrated Recovery Program as defined by criteria prescribed by this template. (*An integrated recovery program is primarily designed to aid in the recovery, conservation or reintroduction of a particular natural population, and fish produced are intended to spawn in the wild or be genetically integrated with the targeted natural population).* In reality, this program is only the first step in an Integrated Recovery Program. The focus is on evaluating various release strategies; therefore, numbers of fish released will be relatively low. Findings from this evaluation will be useful to managers if supplementation efforts are undertaken in the future.

1.6) Purpose (Goal) of program(s).

The goals of the overall program are to (1) implement and evaluate selected measures to protect and enhance white sturgeon populations and to mitigate for effects of the hydropower system on production of white sturgeon in Columbia River impoundments downstream from McNary Dam, and (2) determine the need and identify potential measures for protecting and enhancing white sturgeon populations and mitigating for the effects of the hydropower system on production of white sturgeon in the Columbia and Snake rivers upstream from McNary Dam. The artificial propagation task is part of the strategy to meet goal (2).

The purpose of the propagation component of the program is to develop techniques and protocols in preparation for supplementing white sturgeon populations in areas of the Columbia and Snake rivers where recruitment has been lost due to development and operation of the hydropower system. The purpose therefore falls under the category of research – *the study of critical uncertainties regarding the application and effectiveness of artificial propagation for augmentation, mitigation,* *conservation, and restoration purposes, and identification of how to effectively use artificial propagation to address those purposes*.

1.8) Justification for the program.

The white sturgeon experimental hatchery release program is being developed to answer two research questions: 1) what is the best method for the propagation of juvenile white sturgeon, and 2) how can supplementation of juvenile white sturgeon be best used to mitigate for lost productivity due to the hydropower system.

Remnant populations of white sturgeon in the Columbia River reservoirs above McNary dam lack recruitment. Under the current hydropower system these populations are unlikely to regain more than sporadic and minimal recruitment and are considered unsustainable. Due to development of the hydropower system and the lack of suitable passage for white sturgeon at dam facilities, upstream movement of more productive downstream populations is very limited. The naturally produced population in the upper Columbia River now consists almost entirely of mature, older individuals and is gradually declining as fish age and die without replacement.

The sparse biological information that exists on these upper Columbia River populations revealed that survival and condition factor of adult white sturgeon are similar to that of white sturgeon in other reservoirs below McNary Dam. Lack of spawning habitat and recruitment to young-of-year appear to be the limiting factors preventing a potentially healthy and sustainable white sturgeon population, and thus limiting the possibility of having a valuable sport or commercial harvest fishery in the upper Columbia River.

Columbia River reservoirs below McNary dam support both a valued sport fishery and a commercial fishery. The Dalles and John Day reservoirs have been supplemented using trawl and haul techniques where fish downstream from Bonneville Dam have been collected and transported upstream to supplement populations that have previously been over harvested or have suffered several years of low recruitment. This effort has proven that white sturgeon can be successfully transplanted into a reservoir that is lacking recruitment, but has substantial habitat to sustain adult white sturgeon. These techniques, though useful for supplementing lower Columbia River reservoirs, are not feasible for upper Columbia River reservoirs do to production limitations on the population below Bonneville, and the significant cost incurred to catch wild fish and transport them long distances.

Should this project lead to a long term management scheme of mitigation using supplementation some benefits could be 1) a model for other managers of Columbia and Snake river white sturgeon to imitate 2) a closer opportunity for sport and/or commercial fisherman in Eastern Washington to fish on white sturgeon and 3) it may relieve mounting fishing pressures on lower Columbia River white sturgeon populations.

1.9) List of program "Performance Standards."

The purpose of the propagation component of the program is to develop techniques and protocols in preparation for supplementing white sturgeon populations in areas of the

Columbia and Snake rivers where recruitment has been lost due to development and operation of the hydropower system. The performance standards corresponding to this purpose as defined in NPPC (1999) are to:

1. Conduct research to improve the performance and cost effectiveness of artificial propagation efforts and to minimize risks.
2. Avoid mortality risks to wild broodstock at capture and spawning.
3. Avoid disease introduction or increase in disease incidence in the wild population.

1.10) List of program "Performance Indicators", designated by "benefits" and "risks."

Performance indicators are specific operational measures of fish or hatchery attributes that address each performance standard. They determine the degree to which program standards have been achieved, indicate the specific parameters to be monitored and evaluated, and are used to detect and evaluate the success of the hatchery program and any risks to or impairment of recovery of affected, listed fish populations. Performance indicators must be are measurable, realistic, feasible, understandable, affordable, and time specific. Table 3 lists the specific performance indicators corresponding to each performance standard and indicators are discussed in more detail below.

Table 3. Performance standards and indicators for Columbia sturgeon hatchery program.

Performance Standard	*Type*	*Performance Indicator*
1. Improve performance & reduce costs	**Benefit**	Evaluate effectiveness of various release strategies: Marking methods to allow release as age 0+, 1+, and 2+; Hold fish to allow three annual releases of each age group; Mark-recapture effort to compare post-release survival among and within age groups.
2. Avoid broodstock mortality	**Risk**	Additional mortality does not speed population decline Mortality rate of broodstock in hatchery & after release
3. Avoid disease transfer	**Risk**	Minimal incidence of disease in the facility Appropriate spawning & rearing practices & densities Rigorous disease testing protocols

1.10. "Performance Indicators" addressing benefits.

Benefits of the sturgeon hatchery program include; 1) the determination of the best methods to propagate juvenile white sturgeon using wild white sturgeon as broodstock 2) the evaluation to determine the best release strategies with the potential benefit of developing a mitigation plan for the upper Columbia River reservoirs via hatchery released white sturgeon. The release of three consecutive age classes will allow evaluation of release strategies and cost benefit analysis of future supplementation efforts. We have designed a method to determine performance standards of the releases.

A comprehensive monitoring and evaluation of hatchery fish in the wild following release will address these performance standards. Numbers and mortality of juveniles are tracked throughout the rearing process. Two years of field sampling will be implemented to recapture and evaluate hatchery-reared fish and any wild-produced fish. Data on numbers, lengths, weights, and marks will be used to estimate survival and growth rates. Comparison of wild numbers, if any, with known hatchery release numbers will also provide empirical estimates of natural recruitment rate. Growth and condition factors will also provide an index of density dependent effects that could affect productivity of the wild population. Excess eggs and hatchery-reared fish also provide a source of experimental fish for contaminant assessments, animal health research, in situ hatching experiments, and other research that might provide insight into factors limiting the wild population.

1.11. "Performance Indicators" addressing risks.

Risks of the sturgeon hatchery program include accelerating the decline of the wild population if (1) significant mortality of adults resulted from handling or (2) increased mortality or reduced productivity of wild fish resulted from hatchery practices that introduced new diseases or increased the incidence of endemic diseases. The small numbers of fish used for this research program virtually preclude the possibility of accelerating the decline of wild fish due to handling mortality. Broodstock capture and spawning methods have been developed and refined to minimize stress and improve artificial spawning success, and an intensive health-monitoring program has been implemented. Adjustments have been made throughout the development of this program and will continue to be made based on monitoring and evaluation results consistent with the adaptive management principles recommended by the Artificial Production Review Committee of the ISRP.

1.11) Expected size of program.

Because the purpose of the program is limited to research, the size of the program is small.

1.11.1) **Proposed annual broodstock need (maximum number of fish):**

The captive-breeding program will use 1-6 females and 1-24 males captured from the Columbia River in the spring. The number of broodstock available is variable and limited by our ability to collect potential broodstock, but will not exceed 6 females and twenty-four males in any collection year. The potential to hold captive broodstock over a year will be considered in cases where a potential spawning female might mature over the course of a year in captivity. All broodstock will be held at the temporary spawning and holding facility at McNary Dam unless held over a year, in which case the fish will be transferred to the Abernathy Fish

Technology Center. Final maturation and subsequent spawning of all fish is conducted at the McNary spawning and holding facility. Fish are spawned in pairs or in cross mating designed to produce as many families as possible.

Proposed annual fish release levels (maximum number) by life stage and location:

Fish will be PIT-tagged and marked to identify year class and age at release. Numbers of fish to be released are based on the number required to ensure recapture of sufficient numbers to estimate survival of the various release groups.

Life Stage	Release Location	Annual Release Level
Fingerling (Age 0+)	Rock Island Reservoir	12,000 (FY2002-04)
Yearling (Age 1+)	Rock Island Reservoir	6,000 (FY2003-05)
Age 2+	Rock Island Reservoir	4,500 (FY2004-06)

1.12) Current program performance, including estimated survival rates, adult production levels, and escapement levels. Indicate the source of these data.

As this is a research effort to determine survival rates, downstream entrainment rates, and dam passage mortality of released hatchery white sturgeon, much of this information will not be available until the actual project has been executed. The number of white sturgeon of each age class (see table above), that need to be released to estimate the program performance, are based on trawl and haul mark and recapture estimates for population assessments performed in the lower Columbia River in John Day and The Dalles reservoirs by ODFW, WDFW, and CRITFC (North, 1999, 2000).

1.13) Date program started (years in operation), or is expected to start.

The program was originally scheduled to begin in 1998; however, unforeseen delays in program approval precluded implementation in 1998. Preparation of hatchery facilities began in 1999, and broodstock were first collected in 1999 and 2000. Spawning attempts during these two years was not successful. Broodstock were collected again in 2001 and spawned successfully.

1.14) Expected duration of program.

Broodstock will be collected and spawned annually from 2001-03. Hatchery-reared fish will be released from 2002-06. Monitoring and evaluation of the various release groups (comparison of survival rates among groups) will occur in 2007 and 2009.

1.15) Watersheds targeted by program.

Columbia River mainstem (Rock Island Reservoir).

1.16) Indicate alternative actions considered for attaining program goals, and reasons why those actions are not being proposed.

Alternative actions include: 1) no action; and 2) reliance on transplanting juvenile sturgeon to restore populations.

1) No action would probably preclude restoration of sturgeon populations in areas of the Columbia and Snake rivers where recruitment has been lost due to development and operation of the hydropower system. Production-level artificial propagation will not be implemented until critical uncertainties are resolved. This program addresses critical uncertainties so that eventual performance by production-level programs will be enhanced.

2) More reliance on transplanting juvenile sturgeon may result from the absence of production-level artificial propagation programs. Potential difficulties of this scenario include (1) limited areas with robust sturgeon populations from which to transplant, (2) a finite number of fish within even the most robust populations, and (3) potential genetic differences between populations if the receiving area is far from the donating area.

SECTION 2. RELATIONSHIP OF PROGRAM TO OTHER MANAGEMENT OBJECTIVES

2.1) Describe alignment of the hatchery program with other hatchery plans and policies Explain any proposed deviations from the plan or policies.

This research hatchery program is and will continue to be operated consistent with all extent plans and agreements including those identified in Section 2.2.

Many hatchery reviews and policies were developed for application to anadromous salmon and steelhead programs which were historically geared toward a harvest objective. Specific activities and recommendations in those reviews and policies may not directly apply to a white sturgeon research hatchery program but the general scientific framework and policies contained in reviews such as the NPPC Artificial Production Review are applicable.

The NPPC recommended 10 policies to guide use of artificial production based on a scientific foundation for ecologically sound fish and wildlife management developed as a part of the Multi-Species Framework process, and on a scientific assessment by the Scientific Review Team of how artificial production might fit within that ecological framework. Not all policies are applicable to a research program; however, the following is a summary of how the current program addresses the applicable policies:

Policy #1 requires artificial production to be used consistent with an ecologically based scientific foundation for fish and wildlife recovery. The current white sturgeon program is designed to provide this scientific foundation for possible future production-level programs.

Policy #2 requires that artificial production be implemented within an experimental, adaptive management design that includes an aggressive program to evaluate benefits and address scientific uncertainties. The current white sturgeon program is an experiment designed to address scientific uncertainties.

Policy #6 requires an explicit identification of whether the artificial propagation product is intended for the purpose of augmentation, mitigation, restoration, preservation, research, or some combination of those purposes for each population of fish addressed. The research goal of the current program is clearly and explicitly defined in the NPPC Fish and Wildlife Program, and this HGMP.

Policy #7 requires that decisions on the use of the artificial production tool be made in the context of deciding on fish and wildlife goals, objectives and strategies at the subbasin and province levels. The current white sturgeon hatchery program is included as an important component in white sturgeon program summary for the Mainstem/Systemwide Provincial Review.

2.2) List all existing cooperative agreements, memoranda of understanding, memoranda of agreement, or other management plans or court orders under which program operates.

<u>Northwest Power Planning Council Fish and Wildlife Program (1994)</u>: This project specifically addresses the following measures in the program adopted in 1995:

- 10.4A.2: "In consultation with the appropriate state agencies and tribes, fund research to determine the impact of development and operation of the hydropower system on sturgeon in the Columbia River Basin. These studies may include…4) potential for artificial propagation…"
- 10.4A.7: "In consultation with the appropriate tribes and state agencies, fund an evaluation of the development and maintenance of operations and facilities to enhance white sturgeon production by supplementation for depressed populations in the impounded portions of the Columbia and Snake rivers."

<u>Columbia Basin Fish and Wildlife Authority Multi-Year Implementation Plan (1997)</u>: The goal of this plan is to promote the long-term viability of native fish in native habitats where possible. The following strategy was included in the MYIP

for white sturgeon in the mainstem Columbia River: If abundance of naturally-spawning white sturgeon cannot be restored to pre-impoundment levels in mainstem reservoirs, supplement populations with artificially-produced fish where risks to naturally spawning populations are minimal.

White Sturgeon Program Summary for the Mainstem/Systemwide Province prepared for the Northwest Power Planning Council (2002): The summary describes the status of white sturgeon populations in the Columbia and Snake rivers (including limiting factors) and provides a detailed listing of actions necessary for mitigation and restoration. This HGMP is consistent with the Subbasin Summary in all respects.

2.3) Relationship to harvest objectives.

2.3.1) Describe fisheries benefiting from the program, and indicate harvest levels and rates for program-origin fish for the last 12 years (1988-99), if available.

One objective of the overall white sturgeon program in the Columbia and Snake rivers is to restore abundance and productivity of white sturgeon to allow sustainable annual harvest or use equivalent to 5 kg per hectare per year (CBFWA 1997). Development and operation of the hydropower system has severely limited natural production of white sturgeon in many impounded reaches. Because growth and survival of juvenile white sturgeon is often not a limiting factor, abundance in some areas may be significantly enhanced by supplementation. The focus of the current program is on evaluating various release strategies; therefore, findings will be useful to managers if supplementation efforts are undertaken in the future.

2.4) Relationship to habitat protection and purposes of artificial production.

The purpose of the current white sturgeon propagation program is to address scientific uncertainties before production-level propagation programs are implemented. These potential programs would be an interim measure for preventing extirpation from a number of impounded reaches while habitat restoration measures are identified and implemented. Spawning and rearing success of white sturgeon may eventually be enhanced through changes in the configuration and operation of the hydropower system.

2.5) Ecological interactions.

The Columbia River ecosystem includes a diverse assemblage of native and exotic fish species. White sturgeon generally occupy a benthic habitat niche and do not interact with most of these species in any significant fashion. Where interactions may occur, they are subtle and beyond our ability to project, measure, or distinguish from interactions with other features of the system. Some species are likely food sources; however, interactions with most sensitive species are minimal or non-existent.

The greatest potential for program impacts is between hatchery and wild sturgeon. Wild sturgeon might negatively impact the program by introducing endemic diseases into the hatchery environment. Disease transfer, genetic effects, or competition effects of a poorly conceived program might negatively impact wild sturgeon. Wild sturgeon positively impact the program by contributing source broodstock. Wild sturgeon will benefit positively from the program addition of fish to the population to prevent extinction until successful habitat recovery measures are implemented.

SECTION 3. WATER SOURCE

3.1) Provide a quantitative and narrative description of the water source (spring, well, surface), water quality profile, and natural limitations to production attributable to the water source.

A) The temporary spawning and holding facility at McNary Dam uses Columbia River water as it only source. The primary water source draws water from the juvenile separating facility operated by the Army Corps of Engineers. This water is drawn from the forebay upstream from McNary Dam. The secondary source is drawn from the McNary Dam tailrace water via an electric pump submerged in the river directly down the riverbank from the juvenile separating facility.

B) Well water is used at AFTC for the incubation of eggs, hatching, and rearing of juvenile sturgeon. Well water provides a pathogen-free water source and adequate temperature (12.5^{o}C) to attain needed growth. Analysis of the well water is given in Table 4. Water usage will be single pass for incubation, hatching, and early rearing. At four months post hatch through three years, juveniles will be reared in a re-use system. All effluent water enters a pollution abatement pond prior to entering Abernathy Creek.

Table 4. Well water analysis (raw water) at Abernathy Fish Technology Center, USFWS. Longview, WA. 1995

Constituent	mg/l
Alkalinity	58
Chloride	10.6
Total Hardness	60
Calcium Hardness	33
Magnesium Hardness	27
Iron	0.21
Ortho Phosphate	0.3

Total Phosphate	0.4
Nitrate	0.12
Nitrite	.001
Total Dissolved Solids	163

3.2) Indicate any appropriate risk aversion measures that will be applied to minimize the likelihood for the take of listed species as a result of hatchery water withdrawal, screening, or effluent discharge.

A) The McNary spawning and holding facility does not impact listed species as a result of hatchery water withdrawal, screening or effluent discharge. Water via the primary source is managed by Army Corps of Engineers and is withdrawn as part of the standard operating procedure at McNary Dam juvenile fish separation facility. The secondary water source is via a small electric fountain pump submerged just off the riverbank. The intake for this pump is buried deep within the facilities riprap bank structure and capped with a fine mesh screen. River discharge from the tanks contains no effluents and the circulated tank water is discharged through a 2 ″ PVC pipe following standard procedures of Army Corps of Engineers' juvenile fish separation facility operations.

B) The use of well water at AFTC prevents any impact on listed species as a result of water withdrawal from a surface source. AFTC currently holds a National Pollutant Discharge Elimination System permit (number WA000050-7), to help insure minimal impacts due to effluent discharge.

SECTION 4. FACILITIES

4.1) Broodstock collection, holding, and spawning facilities.

The broodstock holding and spawning facility is a low capital temporary research station designed to perform broodstock-spawning trials. It is operated by the Columbia River Inter-tribal Fish Commission under the auspices of the Army Corps of Engineers.

All broodstock collected in the experimental propagation research project are captured from Wanapum or McNary reservoirs by set lining in a cooperative effort with Washington Department of Fish and Wildlife.

Male and female adult white sturgeon exhibiting pre-spawning characteristics are collected during the spring and placed in tanks until eggs and sperm are fully developed. The holding facility itself consists of six circular fiberglass tanks bedded over gravel and sand. Each tank is ten foot in diameter by four feet deep and is covered with a plywood top. A rectangular twelve-foot by three foot deep by three foot wide tank acts as the female spawning tank and two small egg bath sinks make up the rest of the facility. All tanks and sinks are plumbed from 2-inch pipe stemming off the main water line of the juvenile by pass facility and a back up electrical pump that has a direct line from the river to the tanks.

4.2) Fish transportation equipment (description of pen, tank truck, or container used).

Following sex determination and stage of maturity, sexually mature white sturgeon are transferred from the boat to a specialized truck and fiberglass tanker trailer. Fish are transported from the boat to the transport tank via custom-built stretchers. Water for the tanker trailer is collected at the McNary facility and bottled oxygen is used to maintain the water at saturated oxygen levels. The truck is parked at the Hat Rock boat ramp, a thirty-minute drive from the broodstock holding facility.

The tank is constructed of a variety of materials, and was custom built based upon an existing prototype used by the United States Fish and Wildlife Service Northeast Research Station at Lamar, Pennsylvania (personal communication, Jerry Mohler). It began with a frame of 4 cm square of stainless steel tubing, to which 2 cm thick marine grade plywood was attached to provide a foundation of 5 cm thick rigid foam insulation, overlain by layers of fiberglass material and resin. Approximately 208 liters of resin were used to finish the walls and shell of the tank. Finished outside dimensions is 4.3 m long, by 2.2 m wide, by 1.1 m deep. This shell is divided longitudinally by a vertical dividing wall that spans the length of the tank; creating two separate but identical holding compartments, that are 3.7 meters in length, by 1.1 meters in width, and 1.1 meters in depth, for a total compartment volume of approximately 3050 liters or 800 gallons. The compartments are linked by 15-cm ports that are at each end of this dividing wall on the bottom. This was done to facilitate water flow between compartments and can be blocked off if necessary.

The top edge of this dividing wall provides the attachment location for the doors that are used to secure each holding compartment, one for each side. Each door is secured by three (3) freezer latch handles that can be locked. Two “D” shaped handles on the top of each lid are used to raise and lower the doors using a metal bar that is slid through the handle and back to center divider. Each door weighs in excess of 45 kilograms each, so the added leverage of the bar is a safety factor.

Each tank compartment contains a built in vertical aeration unit that moves approximately 284 liters of water per minute. These units combined with bottled oxygen and fine pore aeration stones (30cmx5cmx5cm) are capable of maintaining the dissolved oxygen at saturation over long travel distances. The thick insulated tank walls maintain water temperatures with 1-2^{o}C of the initial water temperature, even when air temperatures exceed the water temperatures by 20^{o}C or more.

The water temperature and dissolved oxygen levels are monitored via 4 trap style lids on the top of the doors. These openings are approximately 6” square and can also be used to add water continuously for a flow through conditions, as overflow drains are located within 15 cm of the underside of the top doors. This allows us to hold fish on flow through water for extended periods of time if necessary. Drainage of each individual tank is facilitated via a 25-cm diameter drain port located at the bottom, back end of each tank. Each drain hole is secured by a large brass friction cap. Draining of the tank is completed within approximately 2 minutes after the release of these caps. The tank is mounted on a 9.1meter long gooseneck style triple axle flatbed trailer. The trailer was custom built for the transport tank. The entire tank trailer combination weighs approximately 8,200 kilograms when loaded with fish and water.

4.3) Incubation facilities.

Incubation occurs in modified MacDonald jars (7-liter capacity, round bottom cylinders, 45.7 cm tall, and 15.2 cm in diameter), which drain into rectangular fiberglass fry collection troughs (480 cm long x 40.6 cm wide x 38.1 cm deep). The incubation jars are made of acrylic plastic that allows for direct observation of the eggs and flow pattern. Water enters the jars through water distribution pipes, each equipped with a control valve. The PVC pipe is sleeved in a clear acrylic pipe extending from the jar-top to about 2.5 cm from the bottom of the jar. This design provides adequate control of water velocity and egg agitation (Conte et al. 1988). The water flows out of the jar, over a lip, and directly to the fry collection trough. During incubation, initial flow is started at 2.7 lpm and at 81 hours post fertilization flow is increased to 6.8 lpm. Water depth in the trough is maintained at 20.3 cm and the trough is screened at a length of 172.7 cm. To prevent light exposure during incubation and hatch, jars and troughs are covered with black plastic.

The hatchery uses up to 12 jars and up to 6 troughs to separate all families and half-sib families. The capacity of each jar is 5,000 to 12,000 eggs. Eggs are incubated with well water at approximately 12.5^{o}C. Eggs begin hatching in approximately 10 days post-fertilization and the hatch is complete at approximately 14 days post-fertilization. As eggs hatch, the emerged fry tend to move vertically and the water flow carries them to the top of the jar and over the lip, directly into the fry collection trough. Eggshells are siphoned daily from the fry collection troughs. The incubation and hatching methodology is adapted from Conte et al. (1988).

4.4) Rearing facilities.

Early rearing occurs inside a building at AFTC that has photoperiod-controlled lighting. Initially larvae are reared in 24 circular fiberglass tanks, 73.6-cm diameter x 60.9-cm depth. Water depth is maintained at 42.5 cm. Each tank is equipped with a PVC spraybar plumbed with a valve to control flow, with well water supplied at a flow of 7.5 lpm. An outer standpipe with 50% open surface area is covered by flexible small mesh fiberglass window screen. This outer standpipe separates the clean out standpipe from the larval rearing area. Feed initiation occurs approximately 2-3 weeks post-hatch, after the yolk sac is absorbed. Larvae are fed by hand until active feeding is confirmed by the presence of fecal material. Subsequent feeding is by automatic aquarium feeders set for approximately one feeding every two hours. Fry are transferred to 16 fiberglass circular tanks, 119.4-cm diameter x 76.2-cm depth, 3-4 weeks after initiation of feeding. Water depth is maintained at 66.0 cm with flows of 18.9 lpm, and feeding occurs by belt feeders, which feed for a 20-hours during a 24-hour period.

At approximately 4 months post-fertilization juveniles are transferred to outdoor rearing. This temporary facility consists of 16 fiberglass tanks, 3.05-m diameter x 1.22-m depth, installed on a pre-existing concrete slab. Tanks are supported on a sand platform, 9.15 m x 36.6 m, with a sand depth of 0.86 m. The sand is held in place with timber and steel- supported walls that are bolted to the concrete slab. Each tank is supplied with two water sources, well water and creek water, utilizing PVC pipe with inline valves. This provides a backup water supply in the unlikely event both well pumps fail. Water level is maintained at 72.4 cm with a well water flow of 22.7 lpm. Shade cloth is used to cover the tanks and provides 70% shade but also prevents the entry of bird predators and debris from nearby trees.

In addition to the 3.05-m diameter tanks, rearing occurs in the AFTC water re-use system, comprised of 6 concrete raceways, 2.44 m x 22.87 m. The entire system utilizes 302.4 lpm of well water to make up for water lost to cleaning activities, leakage, and evaporation. Water flow per raceway can be maintained from 1200 lpm to 1700 lpm depending on the electric motor and pump used (a 40 or 50 horsepower motor is available). To minimize bird predation netting is used to cover raceways. A 70% shade cloth is used to provide cover for the juvenile sturgeon.

4.5) Acclimation/release facilities.

No specialized acclimation or release facilities are required for sturgeon.

4.6) Describe operational difficulties or disasters that led to significant fish mortality.

4.6.1) Indicate available back-up systems, and risk aversion measures that minimize the likelihood for the take of listed species that may result from equipment failure, water loss, flooding, disease transmission, or other events that could lead to injury or mortality.

The AFTC has an automated alarm system that notifies off-station personnel of emergencies. It calls from a list of personnel until the alarm is acknowledged. This system monitors a multitude of systems including power, water pressure, and water levels. The AFTC has diesel generators to supply power when normal electrical service is lost. All systems have backup motors and pumps. As a third level backup for water supply, all rearing facilities are plumbed to utilize creek water.

4.6.2) Indicate needed back-up systems and risk aversion measures that minimize the likelihood for the take of listed species that may result

from equipment failure, water loss, flooding, disease transmission, or other events that could lead to injury or mortality.

In utilizing well water for rearing, minimal impact should occur with listed species utilizing Abernathy Creek.

SECTION 5. BROODSTOCK ORIGIN AND IDENTITY

5.1) Source.

All broodstock used in this program are wild Columbia River fish that are captured, spawned, and released following spawning.

5.2) Supporting information.

5.2.1) History.

No broodstock other than wild Columbia River white sturgeon have ever been used in the program.

5.2.2) Annual size.

A small number of broodstock can supply the amount of gametes necessary for this research experiment. We collect a maximum of 24 males and 6 females. All broodstock collected in this project are returned to the Columbia River reservoir from which they were collected.

5.2.3) Past and proposed level of natural fish in broodstock.

All (100%) of broodstock are wild fish.

5.2.4) Genetic or ecological differences.

Hatchery and natural stocks are identical except that the broodstock in any single year represent a subset of the available population

5.2.5) Reasons for choosing Broodstock traits

No specific broodstock traits or characteristics are selected.

5.2.6) ESA-Listing status

No listing for Columbia River White Sturgeon.

5.2) Indicate risk aversion measures that will be applied to minimize the likelihood for adverse genetic or ecological effects that may occur as a result of using the broodstock source.

The risk of among population genetic diversity loss will be reduced by selecting the indigenous white sturgeon population for use as broodstock in the supplementation program.

SECTION 6. BROODSTOCK COLLECTION

6.1) Life-history stage to be collected (eggs, juveniles, adults).

All broodstock are collected as mature adults several months prior to spawning.

6.2) Collection or sampling design.

All broodstock used in the Columbia River experimental propagation program are captured from the wild population by set lining. Male and female broodstock are captured from February through May in areas containing pre-spawning aggregations confirmed by three years of ongoing broodstock sampling. Annual collection of late vitellogenic females from these areas, and subsequent spawning of these fish in the hatchery suggested that fish spawning throughout the entire spawning season congregated simultaneously in the same areas. Thus, our broodstock-sampling regime incorporated spawners from the duration of the spawning run.

To identify potential broodstock in the field, all captured fish are biopsied to determine sex and gonad maturation stage (Conte et al. 1988). Captured fish are placed ventral side up on the bottom of the boat and sand bags are used to hold the fish in place, a continuous flow of water is supplied to the gills via a on board water pump and hose inserted into the fishes mouth. Sex and reproductive development is determined by visual observation of gonadal tissues through a 2-3 cm midline incision on the ventral surface of the fish. Reproductive development of males and females is categorized according to criteria reported by Conte et al. (1988). Every broodstock size fish collected is measured to the nearest mm by fork length and total length, checked for recapture, and if not a recapture, marked with an individually scute mark and a pit tag. Once sex and reproductive status is determined, fish are either brought to the hatchery for subsequent spawning or released back into the river. Fish smaller than broodstock size are measured, checked for tags or scute marks and immediately released.

6.3) Identity.

Only one target population is present. Wild broodstock that have been captured before or have contributed to previous hatchery broods are distinguished with individually-numbered PIT tags and data regarding all captured fish is provided to field crews on an annual basis in a field notebook organized alphabetically and numerically by PIT tag number. Hatchery origin fish are identified by a PIT tag and a scute removal mark and are also included in the field notebook database.

6.4) Proposed number to be collected:

6.4.1) Program goal (assuming 1:1 sex ratio for adults):

A plan has been implemented to guide management in the systematic collection and spawning of wild adults. The objective of the research is to produce three consecutive years classes of brood and release a portion of each year class over three years, thus the program will have five years of consecutive releases from three years of broodstock collection. Each year class will have staggered releases of three age classes, twelve thousand 0+, six thousand 1+, and forty-five hundred 2+ aged fish. This will generally require at least 1 female and 1 male per year. We will attempt to collect and spawn several adults with multiple crosses if possible. Actual numbers for any given year depends upon the annual number of females available in the spawning population and the success in capturing ripe females. The implementation plan incorporates the expectation that annual numbers may vary.

6.4.2) Broodstock collection levels for the last 12 years, or for most recent years available:

White sturgeon broodstock collection since inception of project:

	Males	Females
1999	6	2
2000	14	2
2001	23	4

6.5) Disposition of hatchery-origin fish collected in surplus of broodstock needs.

Unlike most salmon and steelhead hatcheries where hatchery broodstock enter the collection system, sturgeon must be caught one by one in the wild. Broodstock collection activities for sturgeon cease when adequate numbers of mature fish are in hand. In many years, collection activities may continue through the duration of the wild sturgeon-spawning season

6.6) Fish transportation and holding methods.

All broodstock used in the Columbia River propagation research program are captured from the wild population by set lining between February and June. White sturgeon broodstock are often large, weighing between 45 and 75 kg, and special handling is required to avoid injury to the fish. Each captured fish is handled to ensure minimal stress when placing them aboard the boat and transporting them to trailer and the holding tanks. Fish are transported from the boat to the specialized transport trailer and to the holding tanks using a stretcher. The sturgeon's axial skeleton is cartilaginous, and the stretcher distributes the weight evenly and provides support, preventing injury to the internal organs when the fish is moved (Conte et al. 1988). The stretcher is constructed of smooth nonabrasive fiber-reinforced nylon sheeting attached to two 2.4-meter poles. It has a hood at one end to cover the fish's head, acting as a respiration chamber when water is added.

Following sex determination and gonad development by biopsy in the field, potential male and female broodstock are directly transferred from the boat to a covered fiberglass tank mounted on a trailer for immediate transfer to the holding facility at the McNary Dam juvenile fish facility. Oxygen is provided by a bottled oxygen system to provide aeration for the short trip. Water for the tank is obtained from the McNary facility (Columbia River) prior to transport. The truck is parked near the sampling area and transfer from the collection area to the holding and spawning facility generally takes approximately ½ hour.

After transport to the holding facility, females and males are held separately, in circular fiberglass tanks (3.05 m diameter x 1.2 2m deep) with no more than 6 males to a tank and 2 females to a tank. Broodstock are held in ambient Columbia River water pumped into the tanks and are fed live juvenile suckers and/or hatchery salmonids that are collected at various sources specifically for this purpose. An external standpipe maintains water level at approximately 1.14 m inside the tank. Water exchange is provided at approximately 10 to 15 volumes per day and O_2 is maintained at approximately 5.0 mg/L or greater. The center drain is level with the tank bottom to reduce obstruction and provide for efficient waste removal. Broodstock are generally held in the hatchery for 2 weeks to 4 months for final gonad maturation. Broodstock are returned to the river approximately one month after the spawning event.

6.7) Describe fish health maintenance and sanitation procedures applied.

Biopsies to assess sex and gonad maturation are completed with sterile surgical methods. Methodology is detailed in Conte el al. (1988). In preparation for surgery, the abdominal area anterior to the genital pore is treated with a 4 percent antibacterial solution of nitrofurazone, administered with a wash bottle. Using a scalpel with a size 10 blade, a 2-3 cm incision is made through the ventral midline, a distance of three to five ventral scutes anterior to the genital pore. The presence or absence of ripe oocytes or testes is then confirmed and the incision is closed and sutured using a cruciate or continuous suture pattern with sterile sutures. The surgical area is then washed with a 4 percent solution of nitrofurazone.

6.8) Disposition of carcasses.

Not applicable for sturgeon. Broodstock are released alive after spawning.

6.9) Indicate risk aversion measures that will be applied to minimize the likelihood for adverse genetic or ecological effects to listed species resulting from the broodstock collection program.

Adverse genetic or ecological measures by use of wild broodstock are eliminated by the use of a small fraction of the population and the live release of all fish after spawning. Fish capture methods by angling or set lining minimize any size selectivity associated with other capture gears such as gillnets. The fish captured thus represent a random sample from the adult population of potential spawners. Disease amplification risks in capture and handling are eliminated by use of sterile techniques in field biopsies and the isolation of broodstock at the holding facility.

Standard hatchery equipment and facility sanitation and fish health maintenance guidelines and procedures are followed.

SECTION 7. MATING

Sturgeon culture techniques differ from those used for salmonids because of inherent differences in gonad development, spawning frequency, and sperm and egg structure, physiology, and biochemistry. A complete description of broodstock evaluation, gamete processing, and incubation of eggs is outlined in the Hatchery Manual for White Sturgeon by Conte et al. (1988). This includes information concerning: 1) assay to determine spawnable females and final oocyte maturation; 2) spawning induction of females including schedule for hormone injection, injection procedures, and observation of response; 3) milt and egg extraction overview including checking sperm viability, sperm dilution, egg fertilization, and egg de-adhesion; and 4) incubation of eggs and early life stages.

7.1) Selection method.

The project uses 2-6 females and 10-24 males each broodyear, captured in McNary Reservoir, Columbia River. To maximize genetic diversity in juveniles, females are spawned with all males that achieve full maturation in synchrony. These half-sibling families are reared separately until limited rearing space requires reduction in number to the goal of 22,000 juveniles per brood year, at which time the size of families is equalized.

7.2) Fertilization.

Eggs from all potential female broodstock held in the hatchery are evaluated to estimate timing of final maturation. Germinal vesicle breakdown (GVDB, Conte et al. 1988) and Polarization Index (PI) values (VanEenennaam et al. 1996) are calculated at least twice for at least 20 eggs from each female brood fish prior to spawning. Selection criteria for female broodstock include $\geq$ 80% GVDB and PI values of $\leq$ 0.10. All selected female broodstock receive two doses of synthetic ovulatory (releasing) hormone LHRHa at 20ug/kg body weight: 1) an initial dose (10% of total calculated dose), and 2) a resolving dose (90% of total calculated dose). Males receive a single LHRHa injection of 10ug/kg body weight. A minimum water-activated sperm motility period of 2 min, verified under a dissecting microscope, as well as a high ratio of activated to nonactivated sperm, are required to designate viable sperm samples (Conte et al. 1988).

Eggs are removed solely by hand stripping (Siple and Anders 1993) to minimize the stress experienced by the broodstock. Eggs are collected within 48 hours post-ovulation after the LHRHa resolving dose, characterized by several hundred eggs visible on the bottom of the spawning tank. Sperm is collected within 20 hours post-injection. Milt is extracted as cited in Conte et al. (1988) and stored in ziplock bags filled with oxygen gas. Ziplock bags are stored over ice, with no direct ice contact, in a closed cooler. Oxygen is replaced every 24 hours and milt agitated three times during the day. Eggs are fertilized, volumetrically quantified, deadhesed with Fuller's Earth, and incubated in modified MacDonald hatching jars (Conte et al. 1988).

7.3) Cryopreserved gametes.

N/A

7.4) Indicate risk aversion measures that will be applied to minimize the likelihood for adverse genetic or ecological effects to listed natural fish resulting from the mating scheme.

Currently white sturgeon are not listed in the area of planned juvenile release or in the area of their potential downstream movement of Rock Island Reservoir, Columbia River. The genetic diversity of released juveniles is maximized and family sizes are equalized as much as possible. All adult broodstock are PIT tagged at the time of capture, insuring no adult is genetically over represented.

SECTION 8. INCUBATION AND REARING

8.1) Incubation:

8.1.1) Number of eggs taken/received and survival rate at stages of egg development.

In June 2001 one of two females was successfully spawned. Resulting eggs were fertilized with sperm from two males, creating 2 half-sib families. Approximately 104,000 eggs were harvested, and approximately 46,000 survived to hatched larvae, resulting in an egg to larvae survival rate of 44.2%

8.1.2) Loading densities applied during incubation.

Fertilized eggs are approximately 3-4 mm in diameter. Each MacDonald jar generally receives 5,000 to 25,000 fertilized eggs and flow is adjusted to maintain a 30-40% exchange per minute

8.1.3) Incubation conditions.

Water flow through the hatching jars provides a gentle rolling of the eggs, which allows oxygen to reach all eggs in each jar. Eggs typically hatch within 10 to 14 days at 12.5°C. Upon hatching, fry swim up and exit the MacDonald jars with the effluent water and are deposited directly into rectangular fiberglass fry collection troughs (480 cm long x 40.6 cm wide x 38.1 cm deep).

8.1.4) Ponding.

Upon completion of hatching, larvae are transferred to fiberglass circular tanks for grow-out. At 4 months post-fertilization juveniles are transferred to concrete raceways to be reared for 1-3 years. See Section 4.4 for further details regarding rearing facilities.

8.1.5) Fish health maintenance and monitoring.

Fungus is controlled during incubation by temporarily reducing the water flow and siphoning out dead eggs. Eggshells are also siphoned from the fry collection tank several times daily during hatch. The USFWS monitors the health of juveniles through periodic health checks during grow-out and prior to planned releases.

8.1.6) Indicate risk aversion measures that will be applied to minimize the likelihood for adverse genetic and ecological effects to fish during incubation.

Eggs are incubated using well water, which minimizes potential loss due to pathogens and temperature fluctuation. Egg densities in MacDonald hatching jars are kept low to minimize mortality risk from fungus and clumping. Additionally, eggs are incubated separately according to family so that parental contribution at stocking age can be identified and genetics can be monitored.

8.2) Rearing:

8.2.1) Provide survival rate data (*average program performance*) by hatchery life stage (fry to fingerling; fingerling to release) for the most recent twelve years (1988-99), or for years dependable data are available.

To date only early survival rate data are available for 2001 broodyear. From hatched larvae to fry, survival rate was 63%

8.2.2) Density and loading criteria (goals and actual levels).

Larval, fingerling, and juvenile densities are maintained below 225 g of fish per cubic foot of water as a precaution against density-dependent, stress-induced disease outbreaks.

8.2.3) Fish rearing conditions

Well water used in rearing remains fairly constant in temperature, 12.5^{o}C. See Section 3.1 for water analyses

8.2.3) Indicate biweekly or monthly fish growth information (*average program performance*), including length, weight, and condition factor data collected during rearing, if available.

Routine fish growth information is not collected

8.2.4) Indicate food *type* used, daily application schedule, feeding rate range (e.g. % B.W./day and lbs/gpm inflow), and estimates of total food conversion efficiency during rearing (*average program performance*).

When larvae are ready to initiate exogenous feeding (2-3 weeks of age), they are started on commercial grade trout starter feed (soft moist). As they grow, they are fed commercial grade trout food (soft-moist) throughout their time in the hatchery and food size is adjusted for fish size. Feeding rates are decreased during the fall/winter months.

8.2.5) Fish *health* monitoring, disease treatment, and sanitation procedures.
The USFWS periodically performs health checks during grow-out and prior to juvenile release.

8.2.6) *Indicate* the use of "natural" rearing methods as applied in the program.
Sturgeon are deep water, benthic feeders. Utilizing shade cloth with the outdoor rearing is meant to create a low light, more natural, rearing environment.

8.2.7) Indicate risk aversion measures that will be applied to minimize the likelihood for adverse genetic and ecological effects to fish under propagation.

Fish are currently being reared for release at multiple ages (1-3). To minimize the risk of domestication effects that may be imparted through rearing to age 1-3, no culling or grading of fish will occur accept in a random design.

SECTION 9. RELEASE

Describe fish release levels, and release practices applied through the hatchery program.

All releases of hatchery-reared white sturgeon will be experimental, to assess survival of various release groups. Fish will be released each year from 2002 through 2006.

Proposed fish release levels.

Age Class	Maximum Number	Size	Release Date	Location
Fingerling (Age 0+)	12,000	25-35 cm TL	Late June or Early July	Upper mile of Rock Island Pool
Yearling (Age 1+)	6,000	Est. 30-45 cm TL	Same as Age 0+	Same as Age 0+
Age 2+	4,500	Est. 40-60 cm TL	Same as Age 0+	Same as Age 0+

Note: The goal of the program is to rear and release a total of nine groups from 3 separate brood years; 3 groups of Age 0+, 3 groups of Age 1+, and 3 groups of Age 2+. The releases would begin in 2002 and extend through 2006, provided that we are able to collect and successfully spawning adults in 2002 and 2003.

9.2) Specific location(s) of proposed release(s).

Stream, river, or watercourse: Rock Island Reservoir
Release points: Within the upper mile of the reservoir.
Major watershed: Columbia River
Basin or Region: Columbia River Basin/Mainstem/Systemwide Province

9.3) Actual numbers and sizes of fish released by age class through the program.

The actual release numbers are estimates until release. Maximum estimates are detailed in the table at the beginning of Section 9.

9.4) Actual dates of release and description of release protocols.

As written in 9.3, the actual release dates are not yet known and will not be set until several weeks prior to release. The actual release dates will be based upon the river temperatures, spring runoff peak timing, fish size and staff scheduling.

Release protocols will depend upon the size of the fish and water conditions. The emphasis will be on maintaining a minimal level of stress and handling during the release. It is planned to do shore based releases from the transport tank and/or fish liberation trucks for Age 0+ fish, due to their relatively small size and higher numbers. As fish increase in size, water based releases using boats, oxygenated totes, and livewells will likely be employed. Given the relative uniqueness of this work, some elements of the release strategy will be worked out and refined several times over the life of the project.

9.5) Fish transportation procedures, if applicable.

All age classes will transported using our sturgeon transport tanker/trailer or possibly using a state fish liberation truck. The fish liberation truck used for stocking catchable sized trout might be ideal for moving and offloading Age 0+ fish, while the transport tanker might be more effective on the large sized Age 1+ and 2+ fish.

9.6) Acclimation procedures.

Fish will not be acclimated in a pen or other on river holding facility. Water temperatures will be similar (+/- 3^{o} degrees C) between the hatchery water temperature and the river water temperature.

9.7) Marks applied, and proportions of the total hatchery population marked, to identify hatchery component.

One hundred percent of the fish released will be marked by having a scute removed and a PIT tag injected into the body cavity.

9.8) Disposition plans for fish identified at the time of release as surplus to programmed or approved levels.

All surplus fish will be disposed of according to USFWS policy.

9.9) Fish health certification procedures applied pre-release.

A subsample (i.e. 40-60 fish) will be lethally sampled for standard viral diseases known to be prevalent in white sturgeon. Such testing will likely be done by the Fish Health Laboratory located at the Spring Creek Hatchery in Washington

9.10) Emergency release procedures in response to flooding or water system failure.

Fish will not be released due to flooding or a water system failure as the reason for rearing the fish is to test supplementation in the Columbia River in Rock Island Reservoir, hundreds of kilometers upstream from the hatchery.

9.11) Indicate risk aversion measures that will be applied to minimize the likelihood for adverse genetic and ecological effects to listed species resulting from fish releases.

The only listed stock of white sturgeon is located in the Kootenai River hundreds of kilometers upstream of the release site and above several impassable dams. The sturgeon proposed for release in this HGMP will not impact the listed Kootenai River white sturgeon due to the distance and barriers previously described. Listed salmon stocks will not be threatened either since sturgeon and salmon are temporally and spatially separated.

SECTION 10. PROGRAM EFFECTS ON ALL ESA-LISTED, PROPOSED, AND CANDIDATE SPECIES (FISH AND WILDLIFE)

10.1) List all ESA permits or authorizations in hand for the hatchery program.

N/A

10.2) Provide descriptions, status, and projected take actions and levels for ESA-listed natural populations in the target area.

10.2.1) Description of ESA-listed, proposed, and candidate species affected by the program.

No ESA-listed, proposed, or candidate species are affected by the program.

- Identify the ESA-listed population(s) that will be directly affected by the program.

N/A

- Identify the ESA-listed population(s) that may be incidentally affected by the program.

N/A

10.2.2) Status of ESA-listed species affected by the program.

- Describe the status of the listed natural population(s) relative to "critical" and "viable" population thresholds.

N/A

- Provide the most recent 12-year (e.g. 1988 - present) progeny-to-parent ratios, survival data by life-stage, or other measures of productivity for the listed population. Indicate the source of these data.

N/A

- Provide the most recent 12-year (e.g. 1988 - 1999) annual spawning abundance estimates, or any other abundance information. Indicate the source of these data.

N/A

- Provide the most recent 12 year (e.g. 1988 - 1999) estimates of annual proportions of direct hatchery-origin and listed natural-origin fish on natural spawning grounds, if known.

N/A

10.2.3) Describe hatchery activities, including associated monitoring and evaluation and research programs, that may lead to the take of listed species in the target area, and provide estimated annual levels of take *(see "Attachment 1" for definition of "take")*. **Provide the rationale for deriving the estimate.**

N/A

- Describe hatchery activities that may lead to the take of listed species in the target area, including how, where, and when the takes may occur, the risk potential for their occurrence, and the likely effects of the take.

N/A

- Provide information regarding past takes associated with the hatchery program, (if known) including numbers taken, and observed injury or mortality levels for listed fish.

N/A

- **Provide projected annual take levels for listed species by life stage (juvenile and adult) quantified (to the extent feasible) by the type of take resulting from the hatchery program (e.g. capture, handling, tagging, injury, or lethal take).**

N/A

- **Indicate contingency plans for addressing situations where take levels within a given year have exceeded, or are projected to exceed, take levels described in this plan for the program.**

N/A

SECTION 11. MONITORING AND EVALUATION OF PERFORMANCE INDICATORS

11.1) Monitoring and evaluation of "Performance Indicators" presented in Section 1.10.

11.1.1) Describe the proposed plans and methods necessary to respond to the appropriate "Performance Indicators" that have been identified for the program.

For the first performance standard "improve performance and reduce costs" we will be marking to indicate the release group as unique, release three consecutive years of fish from the same brood and finally will be conducting extensive sampling to confirm the presence of released fish and how they have done (i.e. survival, growth, movements) during their time at large.

For the second performance indicator, "avoid broodstock mortality" we have continued to refine our handling and holding techniques for these large fish in our hatchery facility. By continuing to perform this work our knowledge of how to handle and optimally hold these fish expands. All fish we handled are marked with a PIT tag and also have a scute removed to indicate the presence of a PIT tag. This way we can monitor fish over time and evaluate the condition of fish recaptured in subsequent years.

The third and final performance standard "avoid disease transfers" focuses on the issue of viral diseases. Much has been discussed about this issue, but it is still a serious problem for any one raising sturgeon. It is clear that the pathogen is transferred vertically from the parent(s) to the offspring, but the specifics on culturing the juveniles to avoid an epizootic are very general and not specific enough to be repeatable. The general guidelines of "hands off" culture, low densities, and minimal stress are the keys, but only generalities at best.

11.1.2) Indicate whether funding, staffing, and other support logistics are available or committed to allow implementation of the monitoring and evaluation program.

Funding and staff for monitoring and evaluation are an integral component of annual contracts with the Bonneville Power Administration.

11.2) Indicate risk aversion measures that will be applied to minimize the likelihood for adverse genetic and ecological effects to listed species resulting from monitoring and evaluation activities.

Risks of monitoring activities are minimal. The proportion of wild fish handled is small and non-lethal sampling methods are employed.

SECTION 12. RESEARCH

12.1) Objective or purpose.

The objective is to release age specific groups of juvenile white sturgeon to test the merits of using hatchery produced (from wild broodstock) to enhance or restored declining populations of wild white sturgeon who are likely to become extirpated within 10-20 years.

12.2) Cooperating and funding agencies.

Funding agency; BPA, other cooperators include Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife and Oregon State University.

12.3) Principal investigator or project supervisor and staff.

Blaine L. Parker; Columbia River Inter-Tribal Fish Commission, Project Supervisor

Kevin Kappenman; Columbia River Inter-Tribal Fish Commission, Project Staff

John Holmes; United States Fish and Wildlife Service, Project Staff

12.4) Status of population, particularly the group affected by project, if different than the population(s) described in Section 2.

Status of population described in previous sections.

12.5) Techniques: include capture methods, drugs, samples collected, tags applied.

Research techniques are all described in previous sections.

12.6) Dates or time period in which research activity occurs.

The project is a year round project, with broodstock collection in early spring, holding and spawning in late spring and early summer, incubation and early rearing from early summer through the fall, with continued rearing, marking and tagging occurring in later winter through spring, and selected releases in late spring and early summer. Selected aspects of this schedule would occur through 2006 with the final release scheduled for that summer.

12.7) Care and maintenance of live fish or eggs, holding duration, transport methods.

Care and maintenance of live fish or eggs, holding duration, and transport methods are described in earlier sections.

12.8) Expected type and effects of take and potential for injury or mortality.

No mortality expected for wild white sturgeon or juvenile white sturgeon released into Rock Island Reservoir and subsequently recaptured.

12.9) Level of take of listed species: number or range of individuals handled, injured, or killed by sex, age, or size, if not already indicated in Section 2 and the attached "take table" (Table 1).

N/A

12.10) Alternative methods to achieve project objectives.

None have been determined at this time, aside from purchasing commercially produced juvenile sturgeon from licensed aquaculturists and using these fish as test subjects. There exists no other mechanism to test the validity of releasing hatchery reared stock as an enhancement tool without actually doing the releases and monitoring there progress over time.

12.11) List species similar or related to the threatened species; provide number and causes of mortality related to this research project.

N/A

12.12) Indicate risk aversion measures that will be applied to minimize the likelihood for adverse ecological effects, injury, or mortality to listed species as a result of the proposed research activities.

Releases of juvenile sturgeon in late spring and early summer pose no danger to listed sturgeon (Kootenai River White Sturgeon) or listed anadromous salmonids. Monitoring efforts using setlines and gillnets to evaluate project status will be done in winter to minimize accidental catches of listed anadromous salmonids that might be using the reservoir(s) as a passage (adults) or rearing (juveniles) habitat. Deepwater sets should minimize gillnet impacts and setlines do not catch salmonids, so overall our impacts will be very low, if at all

SECTION 13. ATTACHMENTS AND CITATIONS

Chapman, F.A. 1989. Sexual maturation and reproductive parameters of wild and domestic stocks of white sturgeon, *Acipenser transmontanus.* Doctoral dissertation. University of California, Davis.

Columbia Basin Fish and Wildlife Authority. 1997. Multi-year Implementation Plan.

Conte, F.S., S.I. Doroshov, P.B. Lutes, and M.E. Strange. 1988. Hatchery manual for the white sturgeon (Acipenser transmontanus) with application to other North American Acipenseridae. Publications Division, Agriculture and Natural Resources, University of California, Oakland. Publication 3322.

Kappenman, K.M., Parker, B.L. 2000. Report D. Pages 113-136 *in* D.L. Ward, editor. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and status and habitat requirements of white sturgeon populations in the Columbia and Snake rivers upstream from McNary Dam. Annual Report to the Bonneville Power Administration, Portland, Oregon

LaPatra, S.E., J.M. Groff, G.R. Jones, B. Munn, T. L. Patterson, R.A. Holt, A.K. Hauck, and R.P. Hedrick. 1994. Occurrence of white sturgeon iridovirus infections among cultured white sturgeon in the Pacific Northwest. Aquaculture Vol. 126:201-210.

LaPatra, S.E., J.M. Groff, T.L. Patterson, W.D. Shewmaker, M. Casten, J. Siple, and A.K. Hauck. 1996. Preliminary Evidence of Sturgeon Density and Other Stressors on Manifestation of White Sturgeon Iridovirus Disease. Journal of Applied Aquaculture. Vol. 6, No. 3 pp. 51-58.

LaPatra, S.E., S.C. Ireland, J.M. Groff, K.M. Clemens, and J.T. Siple. 1999. Adaptive disease management strategies for the endangered population of Kootenai River white sturgeon. Fisheries 24(5): 6-13.

North, J.A,T.A.Rien and R.A. Farr. 1998. Report A. Pages 1-28 *in* D.L. Ward, editor. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and status and habitat requirements of white sturgeon populations in the Columbia and Snake rivers upstream from McNary Dam. Annual Report to the Bonneville Power Administration, Portland, Oregon.

North, J.A., L.C. Burner, and R.A. Farr 1999. Report A. Pages 1-36 *in* D.L. Ward, editor. Effects of mitigative measures on productivity of white sturgeon populations in the Columbia River downstream from McNary Dam, and status and habitat requirements of white sturgeon populations in the Columbia and Snake rivers upstream from McNary Dam. Annual Report to the Bonneville Power Administration, Portland, Oregon

Northwest Power Planning Council. 1994 as amended in 1995. Fish and Wildlife Program (FWP). Portland, Oregon.

Northwest Power Planning Council. 1999. Definition of terms referenced in the HGMP template.

Siple, J.T. and P.J. Anders. 1993. Annual Kootenai Hatchery Report. In: Kootenai River White Sturgeon Studies. Annual Report B. BPA Project No. 88-64.

Van Eenennaam, J.P., S.I. Doroshov, and G.P. Moberg. 1996. Spawning and reproductive performance of domestic white sturgeon (Acipenser transmontanus). Pages 117-122 in S. Doroshov, F. Binkowski, T. Thuemeler, and D. MacKinlay, eds. Culture and Management of Sturgeon and Paddlefish Symposium Proceedings. Physiology Section, American Fisheries Society, Bethesda, MD.

SECTION 14. CERTIFICATION LANGUAGE AND SIGNATURE OF RESPONSIBLE PARTY

"I hereby certify that the foregoing information is complete, true and correct to the best of my knowledge and belief. I understand that the information provided in this HGMP is submitted for the purpose of receiving limits from take prohibitions specified under the Endangered Species Act of 1973 (16 U.S.C.1531-1543) and regulations promulgated thereafter for the proposed hatchery program, and that any false statement may subject me to the criminal penalties of 18 U.S.C. 1001, or penalties provided under the Endangered Species Act of 1973."

Name, Title, and Signature of Applicant:

Certified by:

Blaine Parker
White Sturgeon Project Leader
CRITFC

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