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Status and management of white sturgeon in the Columbia River in British Columbia, Canada: an overview

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Summary

White sturgeon (*Acipenser transmontanus*) in the Columbia River in Canada have recently been listed as Endangered/Critically Imperiled, based on a shift in size and age-class composition from a population dominated by juveniles in the early 1980s to one presently dominated by adults. This shift has been attributed to a poor survival of early life stages. To determine the causes for this poor survival, investigations conducted annually since 1990 have focussed on identifying white sturgeon movement patterns, population dynamics, reproductive biology, and critical habitats. The reasons for the low recruitment remain poorly understood but river regulation and reservoir formation due to dam construction and pollution from municipal and industrial effluent inputs are suspected as contributing factors.

The history of dam development on the Columbia River and implications to white sturgeon are discussed from a historical perspective. A synopsis of post-1990 study results is provided and discussed in the framework of management strategies that include: 1) angling regulations, 2) flow enhancement strategies during spawning, 3) development of a population stabilization plan, 4) investigations into the feasibility of artificial stock supplementation, and 5) proposed future study programs to identify factors limiting recruitment.

Introduction

White sturgeon (*Acipenser transmontanus*) is the largest freshwater or anadromous fish species in North America. The largest authentic record from the Fraser River was a 630 kg fish captured in 1897 (Scott and Crossman 1973). The unauthenticated record from the Columbia River is a 5.5 m long, 860 kg fish captured in the late 18th century. The largest white sturgeon on record from the Columbia River Basin was caught in 1898 and weighed 682 kg (Simpson and Wallace 1982). Reproducing populations are present in the Columbia, Fraser, and Sacramento-San Joaquin river systems. Some members of these populations complete their life cycles in fresh water. For populations with access to the ocean, some individuals may spend a portion of their lives in brackish or marine environments.

In the past, white sturgeon supported commercial fisheries in all major river systems where they were found. Commercial harvest of white sturgeon became illegal throughout most of the species range in the late 1800s due to stock collapses of all commercially fished populations (Pacific States Marine Fisheries Commission 1992). Today, limited commercial harvest occurs only in the Columbia River estuary and in the lower Columbia River in the United States. Incidental harvest or mortality also occurs during commercial salmon fisheries in the lower Columbia and Fraser rivers. Sport fishing is currently the main form of exploitation for this species. Depending on population abundance, recreational fisheries are either consumptive (i.e., limited harvest) or non-consumptive (i.e., catch-and-release).

White sturgeon in the Columbia River in Canada consist of several known or suspected populations that are isolated (by dams) from each other and from historical critical habitats (Figure 1). Regulation of the riverine environment and reservoir creation has drastically altered the natural ecosystem in which sturgeon have adapted and evolved. These alterations, combined with reductions in water quality and exploitation in the form of harvest by recreational anglers, have impacted the species to the point where recruitment levels for all the remnant populations in the system are insufficient to maintain viable populations.

In 1993, based on assumptions of zero recruitment and using the natural mortality and exploitation (fishing mortality) rates determined for the white sturgeon population that resides in the lowermost unimpounded section of the Columbia River in Canada, we estimated this population would decline from 1300 fish to less than 100 individuals within approximately 15 years (R.L. & L. Environmental Services Ltd. 1994a). Using an exploitation rate of zero (as theoretically should occur if the fishery was closed) and assuming zero recruitment, the population would decline to 100 individuals in approximately 40 years. These estimates do not account for potential compensatory changes in growth and recruitment as the population changes or the influence of the very low recruitment that infrequently does occur. For remnant populations trapped in the various upstream reservoirs in the system, recruitment is likely non-existent. Declines in these populations can be expected to occur much sooner, with the definite possibility these populations will become extinct in the next thirty to forty years.

On the basis of these predictions, intensive studies on white sturgeon in the upper Columbia River in Canada have been conducted since 1993. These studies, funded by power producers (BC Hydro and Cominco Ltd.) and by the B.C. Ministry of Environment, Lands and Parks had the following objectives: 1) to describe the population characteristics, spawning biology, movements, and critical habitats of white sturgeon; 2) to describe the historical and current status of white sturgeon; 3) to review and summarise historical and current regulation and management strategies for white sturgeon; and 4) to develop additional management strategies related to population stabilization and to the enhancement of white sturgeon spawning habitats.

Genetic Diversity

White sturgeon in the Sacramento River Basin are genetically unique, but closely related to Columbia River and Fraser River populations (Brannon et al. 1987). Brown et al. (1992) implied a small number of females founded the present populations in both the Columbia and Fraser rivers. Columbia River sturgeon probably provided the founders for the Fraser River population based on zoogeographical evidence. During studies conducted in the lower Fraser River in 1998, we recovered a tag from a white sturgeon that had originally been tagged in the lower Columbia River. This provides support for the founder theory and suggests

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continued genetic interchange occurs between populations with access to the ocean.

White sturgeon in the Kootenay River constitute a distinct interbreeding population apart from other sturgeon in the Columbia River Basin (Setter and Brannon 1990). These authors determined that the genetic variation for the Kootenay River white sturgeon was much less than the lower Columbia River population in the United States, and concluded there was adequate evidence to distinguish the Kootenay River stock as a separate population. Genetic studies on remnant populations of white sturgeon throughout the Columbia River Basin are currently in progress.

Historical Distribution and Location of Critical Habitats

Historically, white sturgeon were widely distributed throughout the upper Columbia River Basin and probably ranged throughout the mainstem Columbia and Kootenay rivers in Canada and also in large tributaries and lakes with connections to these systems. Populations in the upper Columbia River would have had access to the Pacific Ocean although resident populations may have been present in some parts of the drainage. Since the last glaciation age approximately 10 000 years ago, a natural barrier to upstream fish movement was formed at Bonnington Falls in the lower Kootenay River between the outlet of Kootenay Lake and the Columbia River (Northcote 1972). This barrier isolated white sturgeon in Kootenay Lake and the Kootenay River (termed the Kootenay population) from the Columbia River population.

Historical locations of white sturgeon spawning, rearing, feeding, and overwintering areas in the upper Columbia River have been inferred from anecdotal evidence or from limited knowledge of pre-dam habitat characteristics. The Columbia River headwaters are glacial fed and prior to regulation, the river was very turbid during the spring freshet that coincides with the sturgeon spawning period. White sturgeon are broadcast spawners and the eggs and post-hatch larvae are relatively large and black in colour. Post-hatch white sturgeon larvae undergo a passive downstream migration to rearing habitats. Turbid water conditions during the egg incubation and early pelagic larval stage would provide protection from visual predators for these life stages and also for the early benthic feeding stage of sturgeon fry. This suggests historical spawning habitats may have been situated in systems that had a high suspended sediment load such as the upper Columbia River or the lower Pend d'Oreille River.

The historical locations of rearing, feeding, and overwintering habitats were likely distributed throughout the Columbia River and lower reaches of larger tributaries. Prior to dam construction in the United States, upper Columbia white sturgeon likely relied heavily on runs of spawning salmon as an important seasonal food source. Large runs of salmon historically moved into the Slocan River and the Salmo River (a tributary to the Pend d'Oreille River) suggesting these areas may have provided important feeding habitats. The Arrow Lakes and deeper portions of the mainstem Columbia River also would have provided suitable habitats for rearing, feeding, and overwintering.

Chronology of River Regulation and Effects on Sturgeon

The first of five dams on the lower Kootenay River was built over Lower Bonnington Falls in 1897 (Figure 1). The other dams were constructed between 1907 and 1944. Anecdotal accounts of white sturgeon observed in the vicinity of the dams during construction and subsequent sightings suggests there may be individuals trapped between these dams.

In 1938, the construction of Bonneville Dam on the mainstem Columbia River separated white sturgeon populations in the lower river from populations in middle and upper sections. The construction of Grand Coulee Dam in 1941 further fragmented mainstem stocks. Since the construction of Grand Coulee Dam, 12 more dams have been constructed on the mainstem Columbia River; nine in the United States and three in Canada. In addition to the 14 dams currently present on the mainstem, there also are 94 dams on Columbia River tributaries.

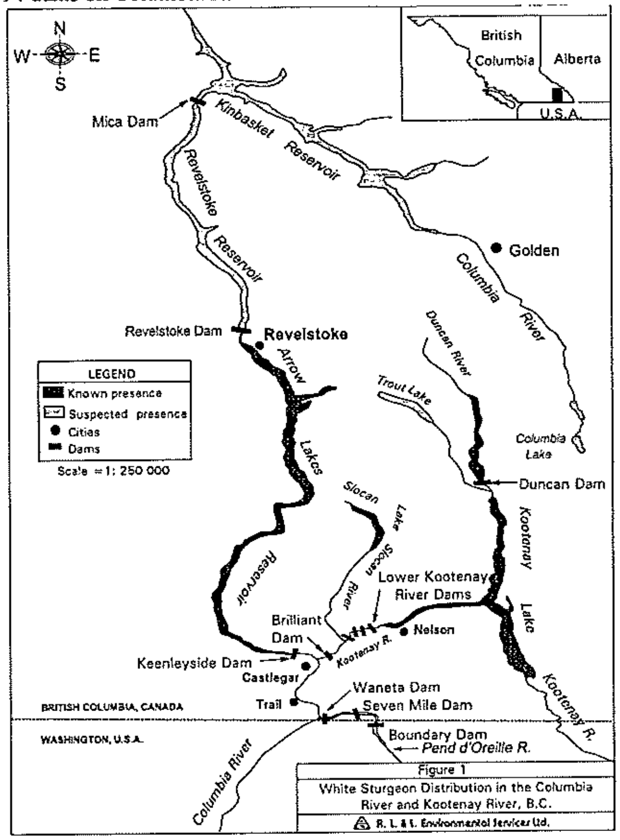

Fig 1. White sturgeon distribution in the Columbia River and Kootenai River, B.C

On the upper Columbia River in Canada, three mainstem dams (i.e., Keenleyside, Mica, and Revelstoke) have been constructed (Figure 1) since the ratification of the Columbia River Treaty with the United States in 1968. These dams ensured that adequate storage was available to provide the flood control and hydro generation potential required by the Treaty. Keenleyside Dam is the furthest downstream of the three dams and is located at the south end of Arrow Lakes Reservoir. The river from Keenleyside Dam downstream to Lake Roosevelt (Figure 2) is one of the few remaining unimpounded sections of the Columbia River and supports a small population of white sturgeon. This population is effectively trapped in the approximate 100 km length of river and 200 km length of reservoir situated between Keenleyside Dam and Grand Coulee Dam. The construction of Keenleyside Dam also isolated those populations in the former Arrow Lakes from downstream populations. In addition, the filling of Arrow Lakes Reservoir flooded a diverse and productive river-lake ecosystem and replaced it with an oligotrophic reservoir that has low habitat diversity.

Mica Dam, constructed in 1973, further fragmented the river ecosystem above Arrow Lakes Reservoir (Figure 1). The reservoir created by the dam flooded over 250 km of the Columbia River mainstem that likely provided spawning and feeding habitats for sturgeon. The reservoir also serves as a sediment and nutrient trap, reducing productivity and increasing water clarity downstream of Mica Dam. Anecdotal reports of white sturgeon in the reservoir suggest the presence of a small, remnant population. Recent studies to verify their presence have proved unsuccessful.

Revelstoke Dam, constructed in 1984, effectively eliminated the 130 km section of free-flowing river between Mica Dam and the Arrow Lakes Reservoir. The reservoir formed by Revelstoke Dam flooded a canyon section of the Columbia River that may have served as a spawning area for white sturgeon. The presence of sturgeon in this reservoir also is suggested by anecdotal reports.

Isolated, remnant populations of white sturgeon have been confirmed in Arrow Lakes Reservoir and in Slocan Lake (Figure 1). All of the white sturgeon captured and aged from these waterbodies pre-dated dam construction in the Canadian portion of the Columbia River (R.L. & L. Environmental Services Ltd. 1996b, 1996c). The absence of younger fish suggests a complete lack of recruitment to these populations, although more sampling is required to confirm this assumption.

Population characteristics

The following discussions pertain primarily to the white sturgeon population that resides within the 56 km section of the upper Columbia River from Keenleyside Dam to the Canada-United States border (Figure 2). The data presented are a summation of study results obtained since 1990 (Hildebrand and English 1991; R.L. & L. Environmental Services Ltd. 1993, 1994a, 1994b, 1995, 1996a). White sturgeon in other areas of the Columbia River in Canada have not been studied to the same extent as the population below Keenleyside Dam. Investigations on the presence and status on other populations in the upper Columbia River drainage commenced in 1995 (R.L. & L. Environmental Services Ltd. 1996b, 1996c).

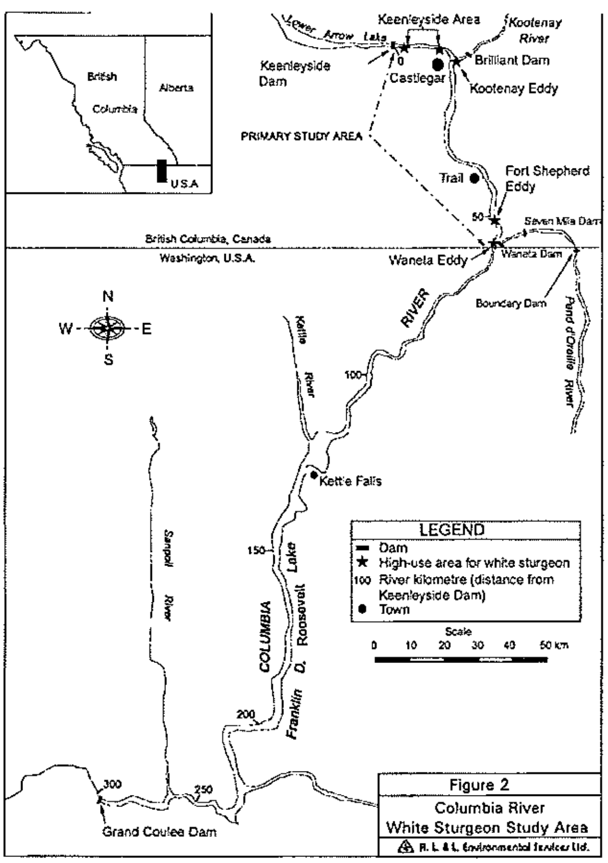

Fig. 2. Columbia River White sturgeon study area

Distribution and Movements

White sturgeon exhibit a restricted, localized distribution, with highest concentrations located in four high use areas: the seven kilometre long section below Keenleyside Dam and the Columbia-Kootenay confluence (Kootenay Eddy) in the upper section; Fort Shepherd Eddy and Waneta Eddy in the lower section (Figure 2). This distribution reflects the availability of deep (>15 m) water areas with lower velocity relative to average mainstem flows. White sturgeon concentrate in these areas throughout the year. Three of the four primary holding/feeding areas are associated with major inflow sources (i.e., tributary confluences or dam tailwaters). Considering the small fraction of the total riverine habitat these areas represent, their importance to white sturgeon is increased.

White sturgeon movements have been investigated since 1990 by conventional mark-recapture techniques and by radio and sonic telemetry. Analysis of conventional tag recaptures (n=386) from 1990-1995 indicated approximately 98% of recaptured fish had moved less than 10 km. Radio and sonic telemetry results supported these movement patterns. Defined seasonal migrations of white sturgeon have not been identified. Localised movements occur mostly between adjacent high-use areas in both the upper and lower sections. Movements out of high-use areas to nearby shallower habitats occur at a greater frequency during the spring-summer period. These movements are attributed to feeding activities since this period coincides with the highest seasonal use of shallow-water habitats by potential prey species.

Limited movements also occur downstream into the United States portions of the river but none have been recorded further downstream than Kettle Falls, Washington. These movement patterns are similar to those described for white sturgeon in Lake Roosevelt, where some fish did not move much over the study period, while others moved frequently but mainly between preferred areas (Brannon and Setter 1992).

Population Dynamics

Since 1992, annual estimates of the white sturgeon population in the upper Columbia River have consistently remained between approximately 1100 and 1400 fish. The 1995 population estimate was 1120 (range=980 to 1300) white sturgeon (R.L. & L. Environmental Services Ltd. 1996a). This estimate mainly reflects the number of white sturgeon that reside in the four major areas of sturgeon concentration previously described. The abundance of white sturgeon in the remainder of the river is low, likely due to the absence of suitable deep-water habitats. The population status in the United States portion of the Columbia River above Grand Coulee Dam is currently unknown. White sturgeon in Lake Roosevelt may represent a localised population that does not frequently intermix with stocks in the Canadian portion of the Columbia River.

Recaptured percentages of marked fish in the upper Columbia River have increased each year, from 5% in 1990 to 53% in 1995. Annual sample efforts over this period have varied between 30,000 and 47,000 set-line hook-hours from 1991 to 1994 and 13,000 to 14,000 hook-hours in 1990 and 1995, respectively. The high recapture rate provides further evidence of low population abundance, limited recruitment, and low rates of immigration or emigration.

White sturgeon captured in the upper Columbia River have ranged from 0.8 to 3.15 m total length (TL). Fish were grouped into undersize, mid-size, and oversize classifications that represented fish <1.0 m in total length (TL), between 1.0 and 1.5 m TL, and >1.5 m TL, respectively (R.L. & L. Environmental Services Ltd. 1994). These classes roughly correspond to juvenile (<age-20), sub-adult (age-20 to age-30), and adult (>age-30) maturity stages. In all study years, catches were dominated by mid-size and oversize cohorts.

The length-frequency distribution of white sturgeon in the upper Columbia River has shifted in the last decade from a population comprised predominantly of undersize (juvenile) fish in the early 1980s to one presently dominated oversize (adult) fish (Figure 3). Approximately 65% of white sturgeon caught in the 1980s were in the undersize category compared to 3% for combined catches from 1990 to 1995. These data indicate the abundance of juvenile white sturgeon in the study area has declined since the early 1980s. The reported size distribution of white sturgeon in Lake Roosevelt (Brannon and Setter 1992) was similar to the population in the Columbia River in Canada, which implied that juveniles are not abundant in either area. Sampling efforts have been limited in Lake Roosevelt and the possibility of undiscovered concentrations of juveniles in the reservoir cannot be completely discounted.

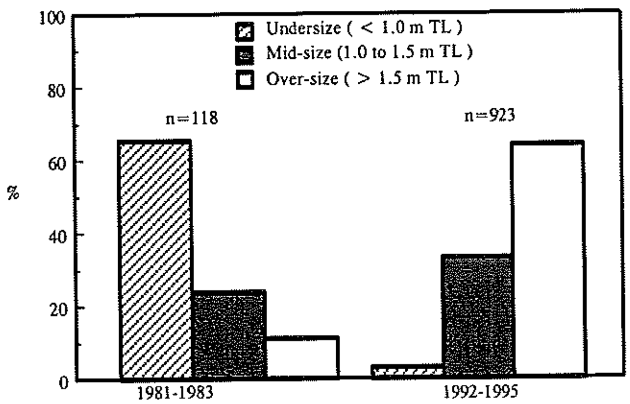

Fig. 3. Length-frequency distribution of white sturgeon in the Columbia river during the early 1980s and from 1992 to 1995. Data from R.L. & L. Environmental Services Ltd. (1996d)

Spawning

Although potentially suitable white sturgeon spawning habitat is available at several locations within the upper Columbia River between Keenleyside Dam and the Canada-United States border, spawning has only been recorded below Waneta Dam at the Pend d'Oreille-Columbia confluence area (Figure 2). Spawning in the Waneta area was initially documented in 1993 (i.e., the first year spawning studies were initiated) and five temporally distinct white sturgeon spawning events were identified. In 1994, three to four separate spawning events were recorded while in both 1995 and 1996, eight to ten spawning events were identified. Sample effort (using artificial substrates to capture spawned eggs) was similar in all of these years. The number of distinct spawning events recorded in all years was lower than the estimated 14 to 20 females that potentially could spawn annually. This estimate was based on the population size in the area, a sex ratio of 1.7 males:1 female, sex maturity data that indicated 4% of females could potentially spawn in any given year, and the unverified assumption that all females capable of spawning in a given year would do so if suitable conditions were available. Although data are limited, differences in the number of recorded spawning events compared to the number of potential female spawners were greatest in low water years. This may suggest that in years when spawning conditions are less suitable, a greater proportion of the females potentially capable of spawning, may not spawn.

The numbers of white sturgeon eggs collected in 1995 and 1996 were considerably greater than in either of the previous years (Figure 4). The main flow-related difference between these years was the timing and volume of peak discharges from the Pend d'Oreille River. Discharges were higher and declined less abruptly and more steadily in 1995 and 1996 than in either of the two previous years. The significance of these changes to white sturgeon spawning periodicity, frequency, and success are not fully understood, but do suggest a positive relationship with discharge. Based on available data, conditions for white sturgeon spawning and potential recruitment were more suitable in 1995 and 1996 than in 1993 or 1994.

In all years since 1993, white sturgeon spawning has commenced in early to mid-June and continued to late July. The first recorded spawning event has consistently occurred when mean daily water temperatures reached 14°C. Subsequent recorded spawning events occurred at gradually increasing temperatures, up to a maximum of 21°C. Another consistent observation has been that all recorded spawning events have occurred on the descending limb of the spring hydrograph. Spawning is associated with high velocity areas (>1.0 m/s surface velocity), with eggs deposited over clean cobble and boulder substrates at depths between 3.0 and 5.0 m.

The Pend d'Oreille River warms more rapidly and also exhibits a more natural flow pattern in the spring than either the Columbia or Kootenay rivers. In the Pend d'Oreille River, water temperatures consistently exhibited a more gradual, sustained increase prior to and during the spawning period than was recorded in other potentially suitable spawning areas. In addition, parameters of water depth, water velocity, and substrate in the Waneta area were all in the optimal suitability range determined for white sturgeon spawning in the Columbia River in the United States (Parsley and Beckman 1994). The confined channel morphology of the lower Pend d'Oreille River results in high water velocities over a wide range of discharges. Another factor that may increase spawning suitability of the Waneta area is the turbulent nature of the outflow. Researchers in the United States have postulated that turbulence may be an important factor contributing to spawning success (J. DeVore, Washington Department of Fish and Wildlife, pers. comm.).

The Pend d'Oreille River can attain temperatures of up to 21.0°C during the white sturgeon spawning period (Figure 5). This is substantially above the 14.0 to 16.0°C temperature range reported as optimal for successful white sturgeon egg incubation by Wang et al. (1985). Cultured white sturgeon eggs incubated at temperatures above 18.0°C exhibit increased mortalities and abnormal development rates (Anders and Beckman 1993; Conte et al. 1988). In three of the four years examined since 1993, a portion of white sturgeon eggs spawned in the Waneta area were incubated at above optimal developmental temperatures.

The significance of water clarity to white sturgeon spawning site selection has not been intensively examined in the literature. Prior to regulation, the Columbia River was a turbid system in the spring and retained a glacial colouration well into the summer. At present, the Pend d'Oreille River is more turbid in the spring than the mainstem Columbia River. This may be a factor in the selection of this area by white sturgeon for spawning. The lack of evidence to indicate white sturgeon spawning in other potentially suitable habitats in the study area suggests that either physical conditions are unsuitable to promote vitellogenesis or cue ovulation or that, historically, sturgeon did not use these areas for spawning. The adaptability of sturgeon, in terms of their ability to use new habitats, is poorly understood. The occurrence of spawning in tailrace areas of dams in the United States, however, suggests they will use new spawning habitats, in instances where historical habitats have been flooded or are inaccessible.

In some years, load shaping operations at Waneta Dam occur during the white sturgeon spawning period. These operations take the form of high discharge levels (720 m^3/s) during a portion of the day and minimum discharges (34 m^3/s) during the remainder of the day and at night. The occurrence of spawning during load shaping suggests that this magnitude of daily or weekly fluctuations in flow does not preclude spawning. There is some concern, however, that fluctuating discharge during the spawning period may influence both the intensity of spawning and survival of spawned eggs. Based on the data collected, spawning intensity is greatest when discharges are high and steady, as was the case in 1995 and 1996 (Figure 4). Survival of eggs to hatch would likely be greater during periods of sustained high discharges due to the maintenance of high velocities and turbidity levels that would help reduce predation.

Feeding, Overwintering, and Staging

The four high-use areas used by white sturgeon in the Columbia River below Keenleyside Dam are depositional type habitats. These areas also support high densities of other fish species that likely provide a food source. In high-use areas located below dams, entrained fish would represent an important food source for white sturgeon. An analysis of white sturgeon feeding habits in the study area has not been conducted due to their protected status. Information collected elsewhere in the Columbia River indicates white sturgeon are opportunistic feeders and use whatever invertebrates and fish (both living and dead) are seasonally or locally available (Pacific States Marine Fisheries Commission 1992).

White sturgeon also use deeper portions within each of the four high-use areas for overwintering. The winter is a critical period for fish survival, as food resources are generally limited. The elimination of salmon runs into the Columbia River in Canada may have implications to sturgeon spawning frequency and fecundity. In our area, sturgeon tend to select calm water habitats in the winter period, likely to reduce energy expenditures. This energy conservation mechanism may be of great importance to pre-spawning female white sturgeon.

These fish often move to the vicinity of the Waneta spawning area in the summer or fall prior to the actual spawning event (R.L. & L. Environmental Services Ltd. 1996a). They then remain in the area over winter, selecting low velocity areas (i.e., nose velocities <50 cm/s) for staging. Use of the Waneta and Fort Shepherd eddies for staging by pre-spawning females that subsequently spawn in the Waneta area, has been confirmed by radio telemetry.

Studies on Russian sturgeon have shown that highly fluctuating discharges during the winter period adversely affected the conditions under which sturgeon overwinter and caused changes in behaviour and gonad maturation (Khoroshko 1972). These deviations in normal development were attributed to abnormal overwintering conditions below dams that required sturgeon to maintain an increased level of activity during the winter period in response to frequent and appreciable water level fluctuations. Winter flows in the upper Columbia River below Keenleyside Dam have increased substantially from pre-regulated conditions. The effects of this increase, in terms of potential increased energy expenditures by white sturgeon in the winter, are unknown but may have implications to fish growth and spawning success.

Rearing

Juvenile white sturgeon in the upper Columbia River are considered to be individuals between 1.8 cm (post-hatch larval stage) and 100.0 cm TL. The smallest white sturgeon recorded in the area was 0.8 m FL and was seven years old. Juvenile white sturgeon used the same habitats as adults and sub-adults. In the lower Fraser River, slough and large backwater habitats adjacent to the mainstem provided important rearing habitats for juvenile white sturgeon (Lane and Rosenau 1995); these types of habitats are unavailable in the Columbia River between Keenleyside Dam and Grand Coulee Dam.

Laboratory studies have shown that larval white sturgeon enter a swim-up phase after hatching (Brannon et al. 1985). Time spent in the water column was inversely related to water velocity. This behaviour represents a dispersal mechanism to transport larval sturgeon to suitable rearing habitats. Larval white sturgeon are most vulnerable to predation at this swim-up stage. Factors that increase the time larvae spend in the drift (i.e., slower current velocity due to reduced discharge from upstream dams) or increase their visibility to predators (i.e., increased water clarity due to upstream impoundments) undoubtedly would reduce survival.

Another factor that may affect larval survival is high levels of total dissolved gas pressure (TGP). During periods of spill release from Keenleyside Dam, downstream TGP levels in the mainstem Columbia River can occasionally exceed 140% saturation and often exceed 125% (Hildebrand and English 1991). Spill releases from dams on the Pend d'Oreille River also can result in TGP levels >125% below Waneta Dam. Brannon et al. (1984) reported that water quality parameters for gas supersaturation might be more critical for white sturgeon than for salmonids.

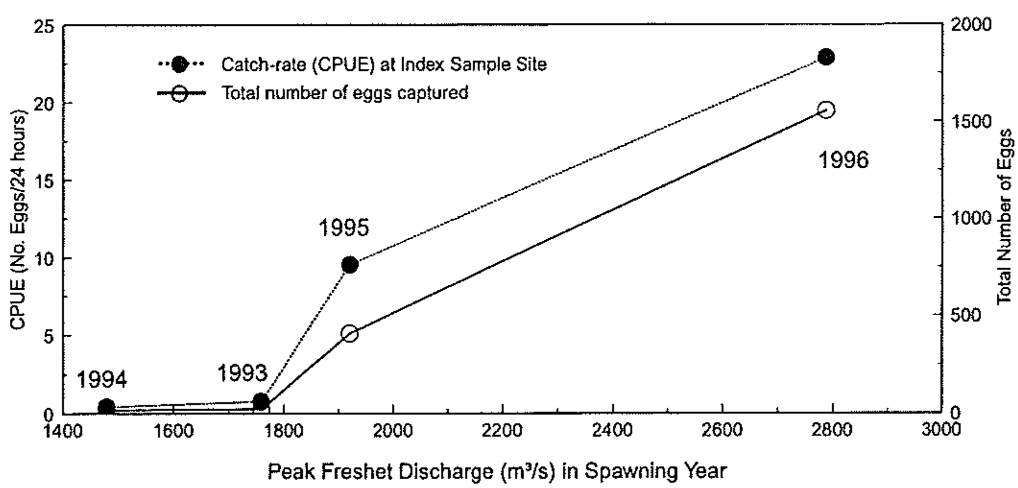

Fig. 4. White sturgeon egg collection (total numbers and catches-rates at an index site) in relation to Peak Freshet discharges in the Pend d'Oreille River. 1993 to 1996. Data from R.L. & L. Environmental Servuces Ltd. (1996d)

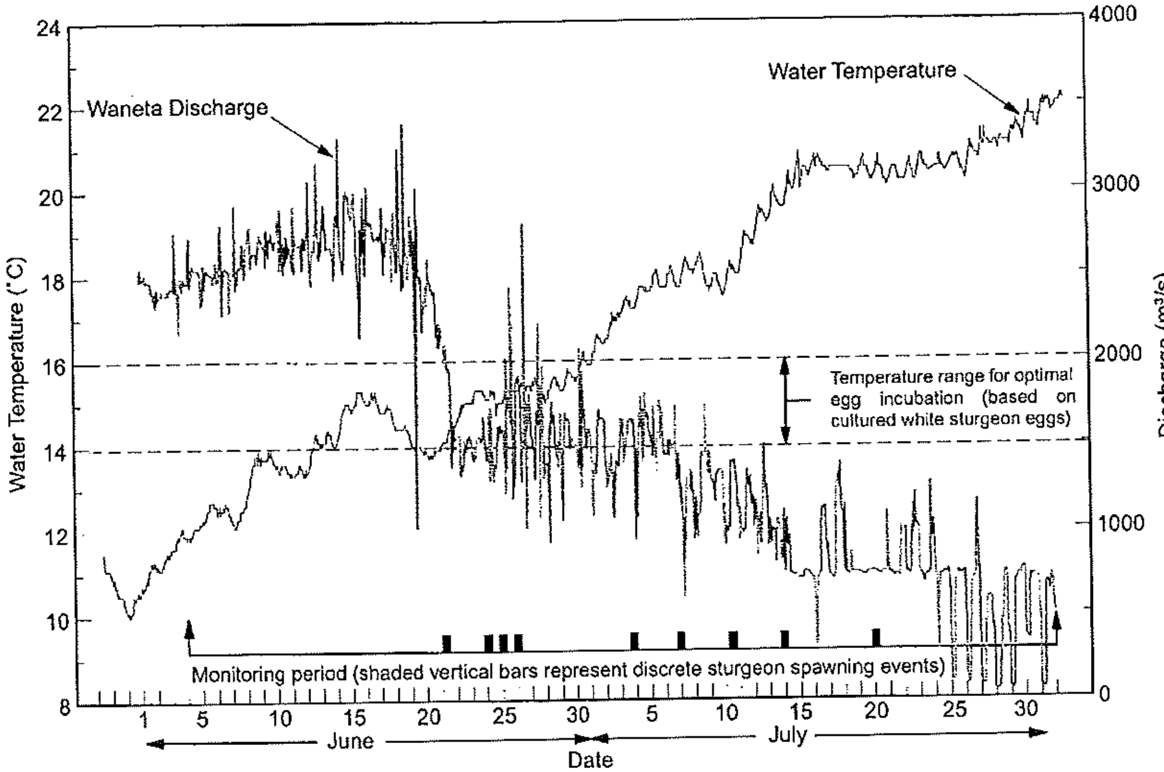

Fig. 5. White sturgeon spawning periodicity in relation to hourly water temperatures and hourly discharges in the Waneta spawning area during June and July 1996. From R.L. & L. Environmental Services Ltd. (1996d)

The maximum recommended nitrogen gas pressure for cultured (and presumably wild) white sturgeon is 110% (Conte et al. 1988).

Shrimpton et al. (1993) investigated the susceptibility of white sturgeon to gas bubble trauma (GBT), a physically induced syndrome that involves the growth of gas bubbles internal or external to the animal. Based on a review of the literature, they identified the planktonic stage of white sturgeon following hatch as the most sensitive period to high TGP levels. During this stage, the larvae swim up into the water column and may be present near the surface where hydrostatic pressure will not compensate for excess TGP.

Management strategies

The confirmation that white sturgeon have spawned and hatched successfully in the Waneta area annually from 1993 to 1996, suggested that the apparent low abundance of young juveniles in the upper Columbia population was related to poor survival of the early life-stages. The natural hydrologic and thermal regimes of the mainstem Columbia River, the Kootenay River, and the Pend d'Oreille River have all been altered by flow regulation. These alterations have likely reduced white sturgeon reproductive success in the upper Columbia River between Keenleyside and Grand Coulee dams. Similar instances of reduced reproductive success have been reported for all white sturgeon populations isolated by dams in the United States portion of the Columbia River (Reiman and Beamesderfer 1990).

In the upper Columbia River, very few juvenile white sturgeon less than age 15 have been recorded. As a consequence, the population is ageing and current levels of recruitment may be insufficient to maintain the population without some type of assistance or remedial action. In the past, management options to protect existing stocks of white sturgeon in the Columbia River have mainly consisted of angling/harvest regulations and research activities. Additional management strategies currently under development include adaptive management options related to flow manipulation during the spawning period, the development of a population stabilization strategy, and preliminary investigations into stock supplementation options.

Regulations and Species Listings

The following is a history of angling regulations for white sturgeon in the Columbia River in British Columbia:

Tab.1

History of angling regulations

Period	Regulation
1960s to March 1978	yearly quota of one, by permit (no size restriction)
April 1978 to March 1992	yearly quota of one, by permit (none <1.0 m TL)
April 1992 to March 1993	yearly quota of one, by permit (none <1.0 m or >1.5 m TL)
April 1993 to March 1996	catch-and-release only
April 1996 to present	catch-and-release fishery closed; angling ban

In Washington State, regulations before 1995 allowed for the daily harvest of one white sturgeon within a slot limit of 1.22 m TL (48 in.) to 1.68 m (66 in.). Maximum possession limit was 10 fish per angler. In May 1995, the fishery was changed to catch-and-release.

The federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC) first listed white sturgeon as Vulnerable in April 1990. Subsequently, the provincial B.C. Conservation Data Centre designated white sturgeon in British Columbia as BLUE listed (S3 Ranking) in November 1991 (Cannings 1993).

This designation implies a species that is rare or uncommon or that may be susceptible to large-scale disturbances. In December 1994, this ranking was upgraded to RED listing (threatened or endangered). At that time, white sturgeon in British Columbia were separated into four main populations, the Fraser, Nechako, Kootenay, and Columbia populations. The Fraser population was classed as S2 (imperilled). The Nechako, Kootenay, and Columbia stocks were classed as S1 (endangered/critically imperilled). The Kootenay white sturgeon in the United States was listed as Endangered under the U.S. Endangered Species Act on 6 September 1994.

Research Activities

Additional research activities planned in future years include co-operative studies with United States agencies to provide further information on the status of white sturgeon in Lake Roosevelt and to examine the genetic status of populations in the upper Columbia River. Currently, the restriction of sampling to the Canadian portion of the drainage does not provide an accurate indication of early life-stage survival and recruitment. This information is needed to determine the effectiveness of management actions and detect differences in year-class abundance that may be attributable to physical or biological factors. Additional planned studies include further investigations on spawning chronology and intensity in the Waneta spawning area and on the status of the remnant population in Arrow Lakes Reservoir.

Flow Manipulation Options

In 1996, Cominco Ltd., the owners of Waneta Dam, committed funds for a five-year program to study white sturgeon spawning in the Waneta area as a condition of approvals for a project to upgrade generation facilities at Waneta Dam. These studies will monitor the effects of a proposed flow augmentation program designed to enhance white sturgeon spawning success during low water years. The program provides for minimum flow releases from Waneta Dam (i.e., during the June to July spawning period) of 285 m^3/s during the day and 142 m^3/s during the night. In the past, discharges from Waneta Dam during years of low water availability in June and July, have fluctuated between 708 m^3/s and 34 m^3/s on a daily basis.

The two primary assumptions of the flow augmentation program are: 1) that the 285 m^3/s daytime minimum flow release will provide a mean column velocity of 0.8 m/s or greater, necessary to attain the minimum velocity stimulus for white sturgeon spawning and 2) that the night-time minimum flow of 142 m^3/s will achieve target mean column velocities of 0.4 m/s or greater and that these flows will be sufficient to prevent or discourage predation on deposited eggs. The program will also provide a more stable daily flow pattern by eliminating the occurrence of near-zero (i.e., 34 m^3/s) flow events.

Discharge and associated parameters of velocity and turbulence likely play key roles in stimulating white sturgeon spawning. Based on this assumption, load shaping operations that produce extended periods of zero or near-zero flows would not be considered beneficial to white sturgeon spawning success. In addition, discharges from power plants should be shaped in a manner that simulates, to the nearest degree possible, a natural flow pattern.

White sturgeon spawning in the Waneta area often occurs at water temperatures greater than 18°C and these spawning events may not contribute to recruitment. In low flow years when load shaping occurs at Waneta Dam, provision of minimum augmentation flows that provide a constant suitable velocity stimulus, may serve to encourage earlier spawning.

The studies and methodologies identified above will be designed to provide quantitative data to determine the effects of flow augmentation. What cannot be predicted with any accuracy is the number of sampling years that will be necessary to develop a sufficient database from which definitive assessments can be obtained. At present, available data on sturgeon spawning in the Waneta area consists of information from four years of study; two years at high flows, one year at intermediate flows, and one year at low flows. Factors such as the duration of the spawning period (early June to late July), the period and temperature at initial spawning (early June at 14 C), and the number of observed spawning events (three to ten) have been relatively consistent during the four years examined. This consistency should facilitate the identification of changes that may result from the provision of flow augmentation during low water years.

Stabilization Strategies

White sturgeon have been identified by the B.C. Ministry of Environment, Lands and Parks as the number one regional management priority. As a first step towards management of this species, a draft White Sturgeon Population Stabilization Plan has been prepared and is currently under review.

Based on available information, two potential options for the stabilization of Columbia River white sturgeon are immediately apparent and will likely form key components of the final plan. These are:

- modifications to the annual hydrograph in the Columbia and Pend d'Oreille rivers; and
- supplementation of the population through a hatchery rearing program.

Recovery efforts for white sturgeon and other sturgeon species in North America have tended to focus on these two options as having the greatest likelihood for successful conservation and recovery of endangered populations.

Flow Regime Alterations

Dam construction has altered the natural temperature, flow regime, water chemistry, nutrient transport, and water clarity characteristics of the Columbia River. In addition, the dams have fragmented the river into long impoundments connected by short flowing sections. These alterations have had significant negative impacts on all resident riverine fish populations, including white sturgeon.

The stabilization and maintenance of the Columbia white sturgeon populations may require alterations to current operational regimes of Columbia River dams above and including Grand Coulee Dam. A complete return to the natural hydrograph of the system would likely be prohibitive in terms of economic and social costs and, as such, would not likely be considered a viable option. The feasibility of a partial return to natural conditions (i.e., to the extent possible) will be investigated.

In the Kootenay River system, the operations of Libby Dam have been altered in an attempt to provide suitable flows for natural white sturgeon spawning and successful recruitment. This flow manipulation program is still in the experimental stages and specific flow requirements necessary to provide conditions that result in annual recruitment remain largely unknown.

Natural spawning of upper Columbia white sturgeon occurs in the influence of Pend d'Oreille River flows, a system that exhibits a relatively natural hydrologic cycle. The effects of highly regulated Columbia River flows on white sturgeon spawning and recruitment are largely unknown. Available information, however, suggests that problems with recruitment coincide with the construction of Keenleyside and Mica dams. Since spawning has continued to occur after construction of these dams, their impacts may be more related to early life-stage survival of white sturgeon.

Stock Supplementation

The factors limiting recruitment of upper Columbia River white sturgeon may not be determined despite additional studies. Even if known, the remediation of the causes may not be socially or economically feasible (e.g., return of the river to a natural state). For either of these scenarios, the only management option available to prevent the ultimate extinction of this species, would be a stock supplementation program. Potential problems associated with a broodstock collection and artificial culture program include concerns about genetic diversity, difficulties in obtaining wild broodstock, and the potential effects of removing a portion of the natural spawning stock from a population with limited reproductive potential.

The genetic diversity of the supplemental population is a concern in situations where only a limited number of males or females can be captured for use as broodstock. This will likely be the case in the upper Columbia River where theoretically, only 14 to 20 females may potentially spawn annually; available information suggests the actual number of females that spawn annually are less than the estimated spawning cohort. The capture of six to eight females for egg-takes could, in some years, effectively eliminate the natural spawning cohort. Although it could be argued that the collections are warranted based on the failure of natural spawning to result in recruitment, this would effectively eliminate or substantially reduce the extent of natural recruitment that occasionally does occur. The effects of egg removal on a female's subsequent spawning periodicity and success also have not been adequately assessed. In addition, stress related to capture, handling, captivity, and artificial stimulation of ovulation can result in mortalities to collected broodstock.

In an attempt to alleviate some of these problems, the collection of naturally spawned and fertilized eggs and their subsequent culture is being investigated as an alternative to traditional hatchery supplementation methods. In 1996, white sturgeon eggs collected on artificial substrates were placed in perforated stainless steel canisters filled with appropriately sized substrate and incubated *in situ* in the spawning area. Survival of eggs to hatch ranged from 43 to 93% in four trials (3 canisters of 30 eggs each per trial). These preliminary results suggest that sturgeon eggs can tolerate handling; however, whether different egg developmental stages exhibit different tolerances has not been determined. This technique has potential applications for artificial supplementation of sturgeon populations with low reproductive potential by reducing potential problems associated with broodstock collection and genetic manipulation.

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Acipenser transmontanus

86 cm.

Originates from North American West Coast stock