COSEWIC
Assessment and Status Report

on the

White Sturgeon
Acipenser transmontanus

Lower Fraser River population
Upper Fraser River population
Upper Columbia River population
Upper Kootenay River population

in Canada

Lower Fraser River population - THREATENED
Upper Fraser River population - ENDANGERED
Upper Columbia River population - ENDANGERED
Upper Kootenay River population - ENDANGERED
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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Ptolemy, J. and R. Vennesland. 2003. Update COSEWIC status report on the white sturgeon *Acipenser transmontanus* in Canada, *in* COSEWIC assessment and update status report on the white sturgeon, *Acipenser transmontanus,* in Canada. Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Ottawa. 1-51 pp.

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COSEWIC
Assessment Summary

Assessment Summary – November 2012

Common name
White Sturgeon - Lower Fraser River population

Scientific name
Acipenser transmontanus

Status
Threatened

Reason for designation
This large-bodied fish occurs in a small area and number of locations in the lower Fraser River Valley. It has declined greatly in abundance over the last 100 years and, although adult abundances now appear to be stable or increasing slightly, habitat degradation continues and fish are subject to mortality from by-catch in commercial salmon fisheries as well as mortality associated with a growing catch-and-release recreational fishery.

Occurrence
British Columbia

Status history
The species was considered a single unit and designated Special Concern in April 1990. Status re-examined and designated Endangered in November 2003. Split into four populations in November 2012. The Lower Fraser River population was designated Threatened in November 2012.

Assessment Summary – November 2012

Common name
White Sturgeon - Upper Fraser River population

Scientific name
Acipenser transmontanus

Status
Endangered

Reason for designation
This large-bodied fish occurs at a small number of locations in the upper Fraser River. The species has declined considerably over the last century (to about 1,300 adults) and will likely continue to decline owing to localized habitat degradation and recruitment failure.

Occurrence
British Columbia

Status history
The species was considered a single unit and designated Special Concern in April 1990. Status re-examined and designated Endangered in November 2003. Split into four populations in November 2012. The Upper Fraser River population was designated Endangered in November 2012.

Assessment Summary – November 2012

Common name
White Sturgeon - Upper Columbia River population

Scientific name
Acipenser transmontanus

Status
Endangered

Reason for designation
This large-bodied fish occurs at a small number of locations (5) in the upper Columbia River. The species has declined considerably over the last century, to fewer than 850 adults, owing to habitat fragmentation and degradation, and recruitment failure. Modelling predicts an 80% chance of extinction of the population within the next two generations.

Occurrence
British Columbia

Status history
The species was considered a single unit and designated Special Concern in April 1990. Status re-examined and designated Endangered in November 2003. Split into four populations in November 2012. The Upper Columbia River population was designated Endangered in November 2012.

Assessment Summary – November 2012

Common name
White Sturgeon - Upper Kootenay River population

Scientific name
Acipenser transmontanus

Status
Endangered

Reason for designation
This large-bodied fish occurs at only one or two locations in the upper Kootenay River. The species has declined considerably over the last century, to fewer than 1,000 adults, owing to habitat fragmentation and degradation, and recruitment failure. Modelling predicts an 80% chance of extinction of the population within the next two generations.

Occurrence
British Columbia

Status history
The species was considered a single unit and designated Special Concern in April 1990. Status re-examined and designated Endangered in November 2003. Split into four populations in November 2012. The Upper Kootenay River population was designated Endangered in November 2012.

COSEWIC
Executive Summary

White Sturgeon
Acipenser transmontanus

Lower Fraser River population
Upper Fraser River population
Upper Columbia River population
Upper Kootenay River population

Wildlife Species Description and Significance

Sturgeons are part of an ancient lineage of ray-finned fishes. Most of their internal skeleton (including the skull) is composed of cartilage; however, there are superficial bones on the surface of the head and several distinct rows of diamond-shaped bony projections (scutes) on the body. Sturgeons have conspicuous barbels on their snouts. Two species occur along the Pacific Coast of Canada: the Green Sturgeon, *Acipenser medirostris*, and the White Sturgeon, *Acipenser transmontanus*. They are distinguished by colour: the lower flanks are greenish in the Green Sturgeon and dark grey shading into white in the White Sturgeon. Usually there is a dark stripe along the ventral midline of the Green Sturgeon, whereas the ventral surface of the White Sturgeon is white. Although the White Sturgeon is primarily a freshwater species, some individuals enter the sea. In contrast, in Canada, the Green Sturgeon is primarily a marine fish but occasionally occurs in estuaries and the tidal areas of large rivers. The White Sturgeon is the largest freshwater fish in Canada, and is the focus of an important recreational fishery in the Lower Fraser River, British Columbia (BC).

Distribution

The White Sturgeon is found only in western North America. Here, they spawn in three major river systems: the Fraser, Columbia, and Sacramento-San Joaquin rivers. Although they are primarily freshwater fishes, some individuals make forays into the sea and are known to enter rivers, estuaries, and bays along the Pacific Coast from southeastern Alaska to Baja California; however, there is no evidence that they breed in any of these other coastal rivers.

Within Canada, White Sturgeon occur as four designatible units (DUs) in BC: the Lower Fraser DU, the Upper Fraser DU, the Upper Columbia DU, and the Upper Kootenay DU. White Sturgeon in the Lower Fraser DU are continuously distributed from the river's estuary to Hells Gate, about 200 km upstream. They also occur in Harrison and Pitt lakes.

The Upper Fraser DU encompasses the Fraser River from Hells Gate upstream to its confluence with the Morkill River: a river distance of almost 1,000 km. They also occur in large upper Fraser River tributaries like the Nechako and Stuart rivers.

In the 1950s White Sturgeon in the Upper Columbia DU ranged from the U.S. border upstream at least as far as Kinbasket Lake (a river distance of about 560 km) and historically they may have extended as far upstream as Columbia Lake. They still occur in the mainstem Columbia River as far up as Revelstoke Dam, and there may be a small remnant population in the area between Revelstoke and Mica dams.

At one time, in the Canadian portion of the Kootenay River system, White Sturgeon ranged from the confluence of the Kootenay and Columbia rivers upstream to the Idaho border (a river distance of about 440 km). Sturgeon in the lower Kootenay River (i.e., below Bonnington Falls) were directly connected to, and part of, the Upper Columbia DU. Bonnington Falls is a natural barrier that isolated the Upper Kootenay DU from the Upper Columbia DU. This Kootenay portion of the Columbia DU consists of a remnant population in Slocan Lake and perhaps a few individuals in the impounded portion of the river between Brilliant Dam and the lower Bonnington Dam. White Sturgeon still exist in the Upper Kootenay DU and there is still a remnant population in Duncan Lake, which is isolated from Kootenay Lake by the Duncan Dam although it is possible that individuals may pass through Duncan Dam occasionally.

Habitat

The habitats used by White Sturgeon vary with age and season; however, since the arrival of Europeans, sturgeon habitats have declined in both quality and quantity. Water diversions, dams, and flood-control structures in the Columbia, Kootenay and Nechako drainage systems have permanently changed the natural hydrograph, water temperatures, and bottom topography of these rivers. The mainstem Fraser River still runs free, but the amount of available sturgeon habitat (especially the flood plains and seasonally flooded riparian zones) has declined steadily. Dredging, gravel extraction, diking, and channel control have all changed the topography of the riverbed, particularly in the Lower Fraser River. Also, contaminants and pollution have degraded water quality in both the Columbia and Fraser Rivers.

Biology

Their long life span allows White Sturgeon to survive short-term natural disruptions in their environment but they are not particularly adaptable. They live a long time, but are slow to mature. Females produce a prodigious number of eggs but individual females do not necessarily spawn every year. Adults have few natural enemies but the larvae are fragile and appear to suffer high mortalities. Typically, White Sturgeon make seasonal migrations in pursuit of mobile prey (e.g., Eulachon, Pacific Salmon) and migrations to spawning and overwintering sites. In the Lower Fraser River, White Sturgeon of different size classes make different seasonal movements. Apparently, individual fish display some degree of fidelity to required habitats (e.g., spawning and overwintering sites). Thus, everything about the life history of White Sturgeon argues that they are not biologically adapted to deal with abrupt, permanent changes in their environment. Genetic analyses suggest that they survived glacial periods by retreating into unglaciated refuges and then expanded their distribution when the environment improved. Consequently, their biology does not fit them for the rapid pace of human changes in the aquatic environment.

Population Sizes and Trends

The Lower Fraser DU encompasses the most populous group of White Sturgeon in Canada. The total number was estimated in 2004 at 56,268 fish (> 40 cm in length) and 44,713 in 2011. This suggests that the total number of individuals in this region has continued to decline subsequent to major historical declines over the 1900s, although there may be occasional pulses of increased recruitment (e.g., in 2003 and 2004) and the total number of mature adults appears to show slight increases over the same time period. Nonetheless, over this same time period the smallest size classes sampled (40 to 99 cm) showed a downward trend, with the strongest declines observed in the 40-59 cm size range. The Upper Fraser DU consists of three groups of sturgeon: a middle Fraser group, the Nechako group, and the group in the Fraser River upstream of the Fraser's confluence with the Nechako River (the upper Fraser group). There are no barriers among these three groups and tagging data indicate movement between the Nechako and upper Fraser groups; however, some genetic data indicate that the groups are distinct from one another.

The middle Fraser sturgeon group appears to be stable at about 750 adults; however, there are not enough data to indicate a trend in abundance. Similarly the upper Fraser sturgeon group also appears to be stable at about 170 adults. In contrast, the adjacent Nechako group (estimated at about 600 fish in 2000) suffers from recruitment failure (i.e., there is little or no evidence of young fish) and the number of sturgeon in this group is in decline.

Hugh L. Keenleyside Dam (HLK) divides the sturgeon in the Upper Columbia DU into two segments. A small number of sturgeon (estimated at 52 adults in 2005) occur in the segment located between HLK and Revelstoke dams. Although there is some natural spawning in this segment, there is no evidence of naturally spawned juveniles.

The segment below HLK is estimated to consist of 1,157 adults. Over the last 30 years there is no evidence of natural recruitment within this segment; however, adults continue to spawn at three known sites. Additionally, there is movement between the segment below HLK and the much larger number of sturgeon in Roosevelt Reservoir, Washington. Adult sturgeon also spawn in Roosevelt Reservoir but, again, there is little evidence of subsequent juvenile recruitment. The annual adult mortality rate in the Canadian segment below HLK is estimated to be 0.027. Assuming this mortality rate, and no further recruitment, the adult population will reach fewer than 200 individuals in 25 years.

The number of sturgeon in the Upper Kootenay DU was estimated at about 7,000 in the mid-1970s and 500 in 2005. This 2005 estimate appears to be low and a reassessment of the population in 2009 estimated there were between 800 and 1,400 adults. Nonetheless, under present conditions the number of adult sturgeon will be < 50 by 2080.

The causes of the declines probably vary among the different groups of sturgeon; however, for the Upper Columbia DU, the Upper Kootenay DU, and the Nechako Sturgeon Group, the declines coincide with evidence of recruitment failure. Spawning regularly occurs in all three, their eggs are fertile and, they hatch successfully in the laboratory; however, naturally spawned young-of-the-year are rare or non-existent. Still, hatchery-reared young-of-the-year sturgeon derived from sturgeon in the Upper Kootenay and Upper Columbia DUs do survive in the wild. Relative to wild fish, these hatchery-reared young are released at a size that wild sturgeon typically achieve only in their second year. This suggests that, in the wild, recruitment failure in White Sturgeon is associated with high mortality rates early in their first year of life.

Threats and Limiting Factors

The primary threats to White Sturgeon result from habitat degradation resulting from dam construction and subsequent changes to flow regime that appear to be a primary driver of recruitment failure. Threats also include dams and habitat fragmentation especially among DUs within the Canadian portion of the Columbia River system. Other threats include dikes, dredging, gravel mining, commercial fisheries by-catch, incidental mortality from catch-and-release recreational fisheries, declines in important forage fishes, and introduced species, all of which are particularly relevant threats in the lower Fraser River.

Protection, Status, and Ranks

Section 35 of the federal *Fisheries Act* provides Fisheries and Oceans Canada with powers to protect and conserve fish and fish habitat (as defined in the *Fisheries Act*). Changes to the act proposed for 2013 will limit such protections to habitats essential to sustaining commercial, recreational, and Aboriginal fisheries. This proposed new act therefore protects White Sturgeon from harmful alteration, and disruption or destruction, of their habitat only if they are exploited in fisheries.

Provincially, Section 4 of the BC *Fish Protection Act* designates some rivers as "protected rivers". The Fraser and Stuart rivers are "protected rivers". Both these rivers contain White Sturgeon and under this Act they cannot be dammed bank-to-bank. The *Fish Protection Act* also contains riparian areas regulations.

Four of the six Canadian populations of White Sturgeon — the Upper Kootenay, the Nechako River, the Upper Columbia, and the Upper Fraser — are listed as Endangered under Schedule 1 of the *Species at Risk Act*. Two others, the Lower and Middle Fraser populations, were assessed together with the other four by COSEWIC in 2003 as Endangered, but the Middle and Lower Fraser River population were not given separate listings under SARA.

TECHNICAL SUMMARY - Lower Fraser River population

Acipenser transmontanus
White Sturgeon — Esturgeon blanc
Lower Fraser River population — Population du cours inférieur du Fraser
Range of occurrence in Canada (province/territory/ocean): BC
In Canada this DU is restricted to the Strait of Georgia and the lower Fraser River. It extends from the Fraser Delta to Hells Gate (about 204 river kilometres upstream).

Demographic Information

Generation time (average age of parents in the population) The minimum age at first maturity ranges from 11-26 years. The average age at first maturity is about 26 to 30 years (150-160 cm Fork Length). Maximum age could exceed 100 years.	~35 years
Is there an inferred continuing decline in number of mature individuals? *Estimates are sensitive to annual adult mortality rates; 0.04 was used to forecast trends (S. McAdam, BC Ministry of Environment, pers. comm. 2012). (From 2004-2011, a reduction of 20% was inferred from counts of all ages classes, but adults appear to be increasing).	Probably not
Estimated percent of continuing increase in total number of mature individuals within two generations.	0-5% increase
Observed percent reduction in total number of mature individuals over the last three generations. From 2004 to 2011 adult (> 160cm TL) numbers have increased (~4,550 in 2004 to about 8,460 in 2011) Estimated reduction from Whitlock (2007 PhD thesis) analysis of fishery data over 20th Century (approximately three generations). Other estimates (e.g., Walters *et al*. 2006) range upwards to ~55%.	~45%
Projected percent increase in total number of mature individuals over the next three generations. Assumes trend in decline of juveniles over the last 10 years is temporary or perhaps an artifact of changes in sampling methods.	up to 5-10%
Observed percent reduction in total number of mature individuals over any three generations including both the past and the future. Overall, the Lower Fraser DU appears to be stable currently; however, there has been large decline from historical levels and there is evidence of a reduction of 78% in the 40-59 cm size group (immature fish) from 2004-2011	~30-40%

Are the causes of the decline clearly reversible and understood and ceased? The causes of the apparent current decline in the smallest size group are not clearly understood but may involve habitat degradation and/or periodic differences in recruitment success, or could be an artifact of changes in sampling methods. Historical declines were largely owing to commercial fishery over-exploitation.	Yes for larger fish, but not understood for juveniles
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Extent of occurrence (EO) Mainstem Fraser River is most common habitat and is thought to be where all spawning occurs, but fish are reported both from Harrison and Pitt lakes (McPhail 2007)	3,798 km^2 (mainstem Fraser River only) 6,177 km^2 (including Pitt and Harrison lakes)
Index of area of occupancy (IAO) Based on areas of spawning habitat IAO is estimated to be < 500 km^2	804 km^2 (2X2 grid) (mainstem Fraser River only) 1,492 km^2 (including Pitt and Harrison lakes)
Is this DU severely fragmented? There are no natural barriers within the Lower Fraser DU. Hells Gate is a partial barrier at the upper end of the DU; however, tagging data indicates some limited movement, in both directions, of sturgeon over this barrier.	No
Number of current locations (total) in Lower Fraser DU. In the lower Fraser DU there are four confirmed spawning sites and two-three likely (but unconfirmed) ones and probably at least two major over-wintering sites and several minor ones.	4-6
Is there a continuing observed decline in extent of occurrence?	No
Is there a continuing observed decline in index of area of occupancy?	No
Is there a continuing observed decline in number of populations?	No
Is there a continuing observed decline in number of locations?	No
Is there a continuing observed decline in extent and/or quality of habitat?	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	**N Reproductive (>160 cm) Individuals**
Lower Fraser	~8,460 (2011)
Based on mark-recapture estimates of Nelson *et al.* (2011). Alternative estimates of Whitlock (PhD thesis, 2007) suggest abundances could be somewhat higher ~15,000)	

Quantitative Analysis

Assuming a 0.04 annual adult mortality rate and recruitment of juveniles, the Lower Fraser DU population has been estimated to grow to contain about 34,000 mature individuals in 2040.	

Threats (actual or imminent, to populations or habitats)

Gravel mining in side channels may be a problem. Loss of riparian habitat due to diking, flood control measures (e.g., dredging), and urban sprawl. Industrial and agricultural impacts on water quality, declines in forage base (e.g., Eulachon, salmon), catch-and-release recreational fishing, by-catch in salmon gillnet fisheries, retention in ceremonial fisheries, and domestic pollution are potential medium-long-term problems.

Rescue Effect (immigration from other DUs or outside populations)

Is immigration known or possible? Immigration is possible between the Fraser DUs (Hells Gate is a high flow area, but there are records of sturgeon both ascending and descending this barrier). Also, the lower Fraser River is known to receive occasional immigrants from the lower Columbia and Sacramento rivers, but whether or not they actually spawn in the Fraser River is unknown.	Probably
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada? Immigration from outside Canada would be through the sea into the lower Fraser. If the lower Fraser population crashed there probably would be sufficient habitat for immigrants.	Yes
Is rescue from outside populations likely? Over the medium to long term (decades)	Possible, but unlikely

Status History

COSEWIC: The species was considered a single unit and designated Special Concern in April 1990. Status re-examined and designated Endangered in November 2003. Split into four populations in November 2012. The Lower Fraser River population was designated Threatened in November 2012.

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** B1ab(iii)+2ab(iii)
Reasons for designation: This large-bodied fish occurs in a small area and number of locations in the lower Fraser River Valley. It has declined greatly in abundance over the last 100 years and, although adult abundances now appear to be stable or increasing slightly, habitat degradation continues and fish are subject to mortality from by-catch in commercial salmon fisheries as well as mortality associated with a growing catch-and-release recreational fishery.	

Applicability of Criteria

Criterion A: Not applicable. Does not meet criteria, but inferred decline rate over last three generations (45%), owing largely to a commercial fishery that is now closed, is close to threshold for Threatened (50%).
Criterion B: Meets Threatened for B1 and B2 as EO (3,978 – 6,177 km^2) and IAO (804 – 1,492 km^2) are less than thresholds. Meets sub-criteria a,b(iii) as there are only 4 known localities (spawning areas), and habitat continues to decline with gravel mining, channelization, and reduced forage base (Eulachon).
Criterion C: Not applicable. Does not meet criteria.
Criterion D: Not applicable. Does not meet criteria.
Criterion E: Not applicable. Appropriate data not available.

TECHNICAL SUMMARY - Upper Fraser River population

Acipenser transmontanus

White Sturgeon — Esturgeon blanc

Upper Fraser River population — Population du cours supérieur du fleuve Fraser

Range of occurrence in Canada (province/territory/ocean): BC

This DU encompasses about 1,000 km of the mainstem Fraser River between Hells Gate and the confluence of the Morkill and Fraser rivers. There are three geographic groups of sturgeon within the DU: the middle Fraser, upper Fraser, and Nechako River sturgeon groups.

Demographic Information

Generation time: average age of parents in the population	40 yrs
Is there an inferred continuing decline in number of mature individuals? Stable in the middle and upper Fraser groups, but a decline in the Nechako group owing to natural mortality of adults and lack of recruitment	Yes
Estimated percent of continuing decline in total number of mature individuals within two generations <u>Middle Fraser Sturgeon Group</u> Apparently stable, 0% decline <u>Upper Fraser Sturgeon Group</u> Apparently stable, 0% decline <u>Nechako Sturgeon Group</u> Assuming low to zero recruitment since about 1970 (18 years after Kenney Dam was completed) and an adult mortality rate of 0.04 and 336 adults in 2012	About 27% (between 0 (Middle and Upper Fraser River) and >90% (Nechako River) based on proportional contribution of Nechako River population, complete recruitment failure for the Nechako population and annual mortality of 0.04)
Observed percent reduction in total number of mature individuals over the last three generations <u>Middle Fraser Sturgeon Group</u> <u>0%, appears stable</u> <u>Upper Fraser Sturgeon Group</u> <u>0%, appears stable</u> <u>*Nechako Sturgeon Group</u> <u>-58%</u> *Estimates based on annual adult mortality rate of 0.04 Whitlock (2007), Irvine *et al.* (2007) and no natural recruitment since 1970.	About 27% (between 0 (Middle and Upper Fraser River) and 58% (Nechako River) based on proportional contribution of Nechako River population, complete recruitment failure for this population and annual mortality of 0.04)

Projected percent reduction in total number of mature individuals over the next three generations <u>Middle Fraser Sturgeon Group</u> <u>0%, appears stable</u> <u>Upper Fraser Sturgeon Group</u> <u>0%, appears stable</u> <u>*Nechako Sturgeon Group</u> <u>> 95%</u> *Estimates based on annual adult mortality rate of 0.04 Whitlock (2007), Irvine *et al.* (2007) and no natural recruitment.	About 28% (between 0 (Middle and Upper Fraser River) and >95% (Nechako River) based on proportional contribution of Nechako River population, complete recruitment failure for this population and annual mortality of 0.04)
Inferred percent reduction in total number of mature individuals over any three generations including both the past and the future. Assuming no recruitment of mature hatchery fish, and an annual mortality rate of 0.04, the total loss of the Nechako group could occur over the next three generations.	At least 28% (between 0 (Middle and Upper Fraser River) and >95% (Nechako River) based on proportional contribution of Nechako River population, complete recruitment failure for this population and annual mortality of 0.04)
Are the causes of the decline clearly reversible and understood and ceased? The decline in the Nechako group is caused by persistent recruitment failure attributed to spawning habitat degradation.	Partially understood, unclear if reversible
Are there extreme fluctuations in number of mature individuals? The middle and upper Fraser groups are stable. The Nechako group is in steady decline	No

Extent and Occupancy Information

Extent of occurrence (EO)	23,390 km^2
Index of area of occupancy (IAO) <u>Middle Fraser Sturgeon Group:</u> 3,920 km^2 <u>Upper Fraser Sturgeon Group:</u> 608 km^2 <u>Nechako Sturgeon Group:</u> 1,880 km^2	6,408 km^2 (2 x 2 km grid)
Is the total population severely fragmented? There are no natural or man-made barriers in the Fraser River between Hells Gate and the upstream distributional limit of sturgeon.	No

Number of current locations** (total) in Upper Fraser DU. There is one confirmed spawning site and 12 suspected ones, and at least 30 known over-wintering sites. <u>Middle Fraser Sturgeon Group</u> There are no confirmed spawning or over-wintering sites in the middle Fraser; however, nine sites where rivers or creeks enter the Fraser are year-round high use areas and are probably both spawning and over-wintering sites. <u>Upper Fraser Sturgeon Group</u> There are no confirmed spawning sites in the upper Fraser but three over-wintering sites may also function as spawning sites. <u>Nechako Sturgeon Group</u> One confirmed cluster of spawning sites near Vanderhoof, nine known mainstem over-wintering sites but sturgeon probably also overwinter in some of the large lakes (e.g., Stuart and Fraser lakes).	Unknown, but between 1 and 12
Is there a continuing decline in extent of occurrence?	No
Is there a continuing decline in index of area of occupancy?	No
Is there a continuing decline in number of populations?	No
Is there a continuing decline in number of locations?	No
Is there a continuing decline in quality of habitat? Habitat degradation continues at the known, Nechako River spawning site owing to ongoing hydroelectric-based water level fluctuations	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗	No
Are there extreme fluctuations in extent of occurrence?	No, stable
Are there extreme fluctuations in index of area of occupancy?	No.

**In the Upper Fraser DU White Sturgeon are distributed from Hells Gate to its confluence with the Morkill River (about 1,000 km). The locations given above are sites to which sturgeon consistently return for spawning and over-wintering (see Tables 4 and 5 for lists of these sites).

Number of Mature Individuals (in each population)

Population	**N Mature (>160 cm) Individuals**
Middle Fraser Sturgeon Group [1999]	749 (2012)
Upper Fraser Sturgeon Group [2008]	185 (2012)
Nechako Sturgeon Group [1999]	336 (2012)
Total	**1,294**
The year of the last data-based estimates are in square brackets and were provided by G. Wilson and S. McAdam (BC Ministry of Environment 2012). Values in regular brackets (right column) are inferred population estimates assuming stable population sizes for the Upper and Middle Fraser groups, and no recruitment and a 0.04 mortality rate from the last data-based estimates for the Nechako	

River group.	

Quantitative Analysis

Wood *et al.* 2007 provide a quantitative analysis of the three groups of sturgeon in the Upper Fraser DU. They assumed a 0.09 annual adult mortality rate, and no recruitment of adult hatchery-reared fish, the probability of extinction in the Nechako group is predicted within 70-80 years.	NA

Threats (actual or imminent, to populations or habitats)

Middle Fraser Sturgeon Group: The habitats used by this population are in good shape but there is some concern about the long-term effects of pollution from pulp mills near Prince George

Upper Fraser Sturgeon Group: The habitats used by this population are as close to pristine as any on the river.

Nechako Sturgeon Group: The main problem in this river is recruitment failure, probably because of siltation and changed hydrology of the spawning sites near Vanderhoof. This problem is being partially addressed by hatchery supplementation and attempts to cleanse known spawning sites. A proposed oil pipeline crosses the Stuart River (an important tributary to the Nechako River) at a site known to be sturgeon habitat.

Rescue Effect (immigration from other DUs or outside populations)

Is immigration known or possible? While movements of White Sturgeon from US populations into the lower Fraser River are possible, subsequent movements between upper and lower Fraser DUs (requiring passage through Hells Gate proper or the fishway) have been documented only once and are considered very rare. Lack of recruitment observed in Nechako River area suggests no significant successful immigration into at least portions of the upper Fraser DU	Yes
Would immigrants be adapted to survive in Canada?	Probably
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely? Possible, but unlikely, from the Lower Fraser population DU.	Unknown, unlikely in short term

Status History

COSEWIC: The species was considered a single unit and designated Special Concern in April 1990. Status re-examined and designated Endangered in November 2003. Split into four populations in November 2012. The Upper Fraser River population was designated Endangered in November 2012.

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** C1
Reasons for designation: This large-bodied fish occurs at a small number of locations in the upper Fraser River. The species has declined considerably over the last century (to about 1,300 adults) and will likely continue to decline owing to localized habitat degradation and recruitment failure.	

Applicability of Criteria

Criterion A: Almost meets Threatened A2bc as decline rate is ~27% over the last three generations owing to continued degradation of habitat.
Criterion B: Not applicable. Does not meet criteria.
Criterion C: Meets Endangered for C criterion as estimated total population of mature adults (1,294) is below threshold (2,500) and C1 as population of mature adults is inferred to decline at about 27% over the next two generations owing to persistent recruitment failure in a major spawning population.
Criterion D: Not applicable. Does not meet criteria.
Criterion E: Not applicable. No data available for this population.

TECHNICAL SUMMARY - Upper Columbia River population

Acipenser transmontanus
White Sturgeon — Esturgeon blanc
Upper Columbia River population — Population du cours supérieur du fleuve Columbia

Range of occurrence in Canada (province/territory/ocean): BC
In Canada, this DU is restricted to the mainstem Columbia River between the U.S. border and Revelstoke Dam in British Columbia. Here it encompasses about 425 km of the upper Columbia River. Suggestions of a remnant population between Revelstoke and Mica dams are unconfirmed.

Demographic Information

Generation time average age of parents in the DU	40 yrs
Is there an inferred continuing decline in number of mature individuals?	Yes
Estimated percent of continuing decline in total number of mature individuals within two generations* *Assuming no natural recruitment and assuming a natural mortality rate of 0.03 per year	~90%
Observed percent reduction in total number of mature individuals over the last three generations Considering differences in the initiation of recruitment failure for different areas (1969, 1977; Irvine *et al.* 2007), hindcasted estimate of the historical total abundance (assuming M=0.03) of mature fish is 1,500 vs. 830 in 2012 representing a 45% decline (S. McAdam, pers. comm., 2012, BC MoE).	~45%
Projected percent reduction in total number of mature individuals over the next three generations. Assuming little to no recruitment and an adult mortality rate of 0.03.	~95%
Inferred percent reduction in total number of mature individuals over any three generations over a time period including both the past and the future.	>50%
Are the causes of the decline clearly reversible and understood and ceased? The proximate cause of the declines in both segments is recruitment failure probably caused by habitat degradation associated with dam construction and perhaps industrial pollution. If these problems can be corrected the declines probably will cease.	Somewhat understood, not ceased
Are there extreme fluctuations in number of mature individuals? Steady declines are occurring	No

Extent and Occupancy Information

Extent of occurrence (EO) These estimates are the sum of both population segments.	12,190 km^2
Index of area of occupancy (IAO) These estimates are the sum of both population segments.	1,760 km^2

Is the total DU severely fragmented? There are five dams (four of them impassible, at least in the upstream direction) within the Upper Columbia DU. There is a small remnant population in Slocan Lake and there may be another small remnant between HLK and Revelstoke dams. The steady declines suggest that the total population in Canada is unsustainable	Yes
Number of current locations*** (total) in Canada. <u>Segment above HLK</u> There is one confirmed spawning site and rumours of others associated with the Arrow Lakes Reservoir. There are at least four overwintering sites: Big Eddy, Beaton Flats, Northeast Arm, and Illecillewaet Arm. <u>Segment below HLK</u> There are four confirmed spawning sites: Waneta Eddy, Kinnard, and just below the Arrow Lakes Generating Station. There are at least six over-wintering sites: below the HLK dam, Kootenay Eddy, Brilliant Dam tailrace, Fort Shepherd Eddy, and Waneta Eddy. Although White Sturgeon are continuously distributed between HLK dam and the U.S. border and there are four areas below HLK where sturgeon are regularly observed.	5 based on hydroelectric fluctuation, recruitment failure.
Is there a continuing decline in extent of occurrence? The remnant populations between the HLK Dam and Revelstoke Dam will eventually be lost.	Possibly
Is there a continuing decline in index of area of occupancy? The remnant populations between the HLK Dam and Revelstoke Dam will eventually be lost.	Possibly
Is there a continuing decline in number of populations? The remnant populations between the HLK Dam and Revelstoke Dam will eventually be lost.	Possibly
Is there a continuing decline in number of locations? The remnant populations between the HLK Dam and Revelstoke Dam will eventually be lost.	Possibily
Is there a continuing decline in extent and/or quality of habitat? Ongoing hydroelectric-based water level fluctuations	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

**The Upper Columbia DU is divided into two segments by the Hugh L. Keenleyside Dam (HLK), and the sturgeon, at least those below the dam, represent three genetic populations (Nelson and McAdam 2012).

*** The locations given above are sites that sturgeon consistently return to for spawning and over-wintering (see Tables 4 and 5 for lists of these sites).

Number of Mature Individuals (in each population)

Population	N Mature Individuals
HLK population segment [2004]	789 (2012)
Population segment above HLK [2004]	41 (2012)
Total Upper Columbia DU	830
The years of the last data-based estimate are in square brackets and have been extrapolated to 2012 based on zero recruitment and 0.04 annual mortality rate	

Quantitative Analysis

Wood *et al.* 2007 provided a quantitative analysis of the Upper Columbia DU. Assuming no recruitment of adult hatchery-reared fish, the population declines to <50 mature fish within 38 years and extinction within 70-80 years.	Extinction likely within 70-80 years

Threats (actual or imminent, to populations or habitats)

Recruitment failure, fragmentation and habitat degradation due to existing dams, heavy metal pollution from a smelter, chemical pollution from a pulp mill, and domestic pollution.

Rescue Effect (immigration from other DUs or outside populations)

Is immigration known or possible? Sturgeon from Roosevelt Reservoir in the USA can (and do) move into the Upper Columbia segment below HLK, but they are also undergoing severe recruitment failure. Sturgeon also may be able to move downstream, and possibly upstream, through a small boat lock from the Arrow Reservoirs into the segment below HLK. In the segment above HLK the dams (Revelstoke and Mica Creek) are impassible in the upstream direction.	Yes
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada? Given the persistent declines, there probably is sufficient habitat to support new adult immigrants, but whether they can spawn successfully appears unlikely.	Yes
Is rescue from outside populations likely? US population in Roosevelt Reservoir are experiencing severe recruitment failures; possible for the Upper Columbia DU below HLK Dam, but not above HLK.	No

Status History

COSEWIC: The species was considered a single unit and designated Special Concern in April 1990. Status re-examined and designated Endangered in November 2003. Split into four populations in November 2012. The Upper Columbia River population was designated Endangered in November 2012.

Status and Reasons for Designation

Status:	**Alpha-numeric code:**
Endangered	A3bc+4bc; C1+2a(ii); E

Reason for Designation:

This large-bodied fish occurs at a small number of locations (5) in the upper Columbia River. The species has declined considerably over the last century, to fewer than 850 adults, owing to habitat fragmentation and degradation, and recruitment failure. Modelling predicts an 80% chance of extinction of the population within the next two generations.

Applicability of Criteria

Criterion A: Meets Endangered for A3bc, A4bc owing to projected decline of at least 90% over the next three generations and of at least 50% over three generations including the past and future based on tagging indices of abundance and unceasing habitat degradation. Meets Threatened A2bc as decline rates in past three generations are estimated at 45%.
Criterion B: Meets Threatened for B1 and B2 as EO and IAO are below thresholds; meets sub-criteria a (severely fragmented and number of locations (5) is below threshold (10) and b(iii,v) as both quality of habitat and number of mature adults are projected to continue to decline.
Criterion C: Meets Endangered for C as total population of mature adults in Canada estimated to be fewer than 1,000 and C1 as population is inferred to decline by about 90% over the next two generations. Meets Endangered for C2a(ii) as population below HLK dam contains 95% of all mature individuals in Canada.
Criterion D: Not applicable. Does not meet criteria.
Criterion E: Meets E criterion for Endangered as population projections suggest a minimum probability of extinction over the next 2-3 generations of 80% (Wood *et al.* 2007).

TECHNICAL SUMMARY - Upper Kootenay River population

Acipenser transmontanus

White Sturgeon — Esturgeon blanc

Upper Kootenay River population — Population du cours supérieur de la rivière Kootenay

Range of occurrence in Canada (province/territory/ocean): BC

In Canada this DU is restricted to Kootenay Lake and the Kootenay River between upstream of Bonnington Falls and the Idaho border with British Columbia. Here it encompasses about 288 km of the Kootenay River (including Kootenay Lake).

Demographic Information

Generation time average age of parents in the population	40 yrs
Is there an inferred continuing decline in number of mature individuals?	Yes
Estimated percent of continuing decline in total number of mature individuals within two generations *Estimates based on annual adult mortality rate of 0.04 Beamesderfer *et al.* (2009), and no natural recruitment.	~90% over two generations
Observed percent reduction in total number of mature individuals over the last three generations. > 90% reduction between 1978 and 2001 (Irvine *et al.* 2007)	>50%
Projected percent reduction in total number of mature individuals over the next three generations. *Estimates based on annual adult mortality rate of 0.04 Beamesderfer *et al.* (2009), and no natural recruitment.	>90% over three generations
Inferred reduction in total number of mature individuals over any three generations over a time period including both the past and the future. *Estimates based on annual adult mortality rate of 0.04 Beamesderfer *et al.* (2009), and no natural recruitment.	>50%
Are the causes of the decline clearly reversible and understood and ceased? The proximate cause of the declines is recruitment failure probably associated with siltation of spawning grounds caused by dam operation. They have not ceased. If these problems can be corrected the declines probably will cease.	Partially, unknown if reversible
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Extent of occurrence (EO)	6,780 km^2
Index of area of occupancy (IAO) Upper Kootenay DU	1,920 km^2
Is the total population severely fragmented? The Kootenay DU was isolated from the Columbia DU by Bonnington Falls and is now isolated by Corra Linn Dam. There are two remnant populations in Duncan Reservoir and Slocan Lake which are isolated from sturgeon in the rest of the DU by the Duncan Dam and multiple Kootenay River dams, respectively.	No

Number of current locations (total) in Canada. The one confirmed spawning site is located in the US. Two over-wintering sites, Kootenay Lake and the delta of the Kootenay River, are in Canada	1-2
Is there a continuing decline in extent of occurrence? The Duncan and Slocan lakes remnant populations will eventually be lost	Possibly
Is there a continuing decline in index of area of occupancy? The Duncan and Slocan lakes remnant populations will eventually be lost	Possibly
Is there a continuing decline in number of populations? The Duncan and Slocan lakes remnant populations will eventually be lost	Possibly
Is there a continuing decline in number of locations? The Duncan and Slocan lakes remnant populations will eventually be lost	Possibly
Is there a continuing decline in extent and/or quality of habitat? Ongoing hydroelectric-related water regulation	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No.

**The locations given above are sites that sturgeon consistently return to for spawning and over-wintering (see Tables 4 and 5 for lists of these sites). Although White Sturgeon are continuously distributed within the Upper Kootenay DU, the delta where the Kootenay River enters Kootenay Lake is consistently the highest use area.

Number of Mature Individuals (in each population)

Population	**N Mature Individuals**
Upper Kootenay DU [2004]	~960 (2012)
The year of the last data-based estimate is in square brackets and was used to infer the population size in 2012 assuming zero recruitment and an annual mortality rate of 0.04.	

Quantitative Analysis

Assuming a 0.04 annual adult mortality rate the probability of extinction of Kootenay populations is at least 80% within 2 generations (Beamesderfer *et al.* 2009). Wood *et al.* (2007) provide a quantitative analysis of the Kootenay DU. Assuming no recruitment of adult hatchery-reared fish, the population declines to <20 mature fish within 50 years and extinction occurs within 70-80 years.	Extinction likely within 100 years.

Threats (actual or imminent, to populations or habitats)

Recruitment failure, river regulation by impoundments; siltation due to an existing dam; low genetic diversity, uncertain benefits of hatchery propagation (use of wild fish as broodstock)

Rescue Effect (immigration from other DUs or outside populations)

Is immigration known or possible? Isolated by natural (Bonnington Falls) and multiple dams	No
Would immigrants be adapted to survive in Canada?	NA
Is there sufficient habitat for immigrants in Canada?	NA
Is rescue from outside populations likely? There is no possibility of natural immigration into the Upper Kootenay DU. While fish may move into Canada from US portions of the Kootenay River, these are likely part of the same biological population.	No

Status History

COSEWIC: The species was considered a single unit and designated Special Concern in April 1990. Status re-examined and designated Endangered in November 2003. Split into four populations in November 2012. The Upper Kootenay River population was designated Endangered in November 2012.

Status and Reasons for Designation

Status: Endangered	**Alpha-numeric code:** A3bc+4bc; C1+2a(ii); E
Reasons for designation: This large-bodied fish occurs at only one or two locations in the upper Kootenay River. The species has declined considerably over the last century, to fewer than 1,000 adults, owing to habitat fragmentation and degradation, and recruitment failure. Modelling predicts an 80% chance of extinction of the population within the next two generations.	

Applicability of Criteria

Criterion A:
Meets Endangered for A3bc and A4bc owing to projected decline of at least 90% over the next three generations and of least 50% over three generations including the past and future based on tagging indices of abundance and unceasing habitat degradation. Meets Threatened A2bc as decline rates over the past three generations are estimated at > 50%.

Criterion B:
Meets Threatened for B1 and B2 as EO and IAO are below thresholds; meets sub-criterion a (severely fragmented and number of locations (2) less than threshold (10) and b(iii,v) as both quality of habitat and number of mature adults are projected to continue to decline.

Criterion C:
Meets Endangered for criterion C as estimated total population of mature (960) is below threshold and Endangered for C1 as population is inferred to decline by about 90% over the next two generations. Meets Endangered for C2a(ii) as single population has > 95% of all mature adults.

Criterion D:
Meets Threatened D2 (only one known spawning location).

Criterion E:
Meets E criterion for Endangered as population projections suggest a minimum probability of extinction over the next 2-3 generations of 80% (Wood *et al.* 2007).

PREFACE

The White Sturgeon (*Acipenser transmontanus*) is the largest freshwater fish in North America. In Canada, it breeds in two drainage systems: the Fraser and Columbia rivers. This species was last reviewed in 2003; six Nationally Significant Populations (NSPs) were described in that report and COSEWIC assigned them a single species-wide status of Endangered (COSEWIC 2003). The SARA listing decision, however, recognized the NSPs, and four of the six NSPs were added individually to *SARA* Schedule 1, all as Endangered: the Kootenay population, the Nechako population, the Upper Columbia population, and the Upper Fraser population. For socio-economic reasons, the other two groups — the Lower and Middle Fraser NSPs — were not added to Schedule 1 and were not protected under *SARA* (Canada Gazette, vol. 140, No. 18, September 6, 2006; Species at Risk Public Registry 2010). These reasons for non-listing under SARA focused on the importance of recreational and Aboriginal fisheries in the Lower and Middle Fraser River. In addition, the catch-and-release recreational fisheries provide important information to monitor and manage the populations. Consequently, it was reasoned that listing these populations could result in reduced stewardship for conserving and rebuilding White Sturgeon populations. The BC Conservation Data Base lists all six Canadian White Sturgeon groups as imperiled, and the Upper Kootenay, Nechako, and Upper Columbia groups as critically imperiled. Since 2003, COSEWIC has replaced the "Nationally Significant Population" concept with the Designatable Unit (DU) concept. In this report four DUs replace the earlier six NSPs. These four DUs have the same geographic boundaries as four of the six previous NSPs; however, the former Middle Fraser, Nechako, and Upper Fraser groups are combined into a single DU — the Upper Fraser DU.

Considerable work has been conducted on the genetics of White Sturgeon and on population monitoring and research on aspects of recruitment since the last COSEWIC report. More is now known about the biology of White Sturgeon than in 2003, but there are still significant knowledge gaps. The most obvious gaps are ignorance about the habitat needs and ecology of young-of-the-year sturgeon, and understanding of how the gradual erosion of the food base that supports White Sturgeon influences their sustainability.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2012)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

COSEWIC Status Report

on the

White Sturgeon
Acipenser transmontanus

Lower Fraser River population
Upper Fraser River population
Upper Columbia River population
Upper Kootenay River population

in Canada

2012

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Kingdom: Animalia
Phylum: Chordata
Class: Actinopterygii
Order: Acipenseriformes
Family: Acipenseridae
Scientific name: *Acipenser transmontanus*
Common names:
English: White Sturgeon
French: esturgeon blanc
Aboriginal: Dakelh/Southern Carrier (lhkwencho), Nadleh Whut'en/Lheidl (lhkw'encho),Wet'suwet'en (hagwilnegh), Yekooche (lhecho), Carrier (La Cho), Secwepemc (xÃº7i(pronounced Hoo ee), Halkomelem/Halq'emeylem or Kwikwetlem Nation (skwo`:wech), Halkomelem/Hul'q'umi'num or Musquem Nation (qwtaythun), Northern S imcets(xu7't), Kxunta (wiya‡) and Michif (Sîpîy).

<u>Common name</u>

In the past, several common names were used for the White Sturgeon (e.g., Pacific Sturgeon, Columbia Sturgeon, and Sacramento Sturgeon). Now the official English common name is White Sturgeon (Nelson *et al.* 2004). Although there is no official French common name, most Canadian documents use "esturgeon blanc" as the French common name.

<u>Scientific name</u>

The White Sturgeon was described as *Acipenser transmontanus* in 1836 by Sir John Richardson. The type locality is the Columbia River near Vancouver, Washington. In the same year a sturgeon, *Acipenser aleutensis*, was described from the vicinity of the Aleutian Islands. This is the only record of a sturgeon in that region and the locality is thought to be an error because the morphological description and scute counts given for *A. aleutensis* are not those of *Acipenser transmontanus* (see Mecklenburg *et al.* 2002). Nonetheless, a number of authors (e.g., Jordan and Evermann 1896; Scott and Crossman 1973) list this enigmatic species as a synonym of *A. transmontanus*. *Acipenser transmontanus* has been the accepted scientific name for the White Sturgeon for 175 years.

Morphological Description

Two sturgeon species occur along the Pacific Coast of Canada: the Green Sturgeon, *Acipenser medirostris*, and the White Sturgeon, *Acipenser transmontanus*. In Canadian waters the Green Sturgeon is primarily a marine species and, although it occasionally enters the estuaries of large rivers (e.g., the Fraser, Skeena, Nass and Taku rivers), it probably does not breed in Canada. The White Sturgeon is primarily a freshwater species and it does breed in Canada; however, some individuals in the lower Fraser River make sporadic forays into salt water. Thus, occasionally, both species are encountered in the tidewaters of the lower Fraser River and in salt water in the Strait of Georgia, the Strait of Juan de Fuca, and west coast of Vancouver Island.

Colour distinguishes the two species: the lower (ventral) flanks are greenish in the Green Sturgeon and dark grey shading into white in the White Sturgeon, and there is usually a stripe of dark pigment along the ventral midline in the Green Sturgeon that is absent in the White Sturgeon. Also, the barbels on the snout of the Green Sturgeon are closer to the mouth than they are to the tip of the snout. While the barbels on the snout of the White Sturgeon — at least in the lower Fraser population — are closer to the tip of the snout than they are to the mouth (McPhail 2007)**.**

Sturgeon are derivatives of an ancient lineage of ray-finned fishes, and most of their internal skeleton (including the skull) is composed of cartilage, and their tail is heterocercal (the upper (dorsal) lobe of this fin is noticeably longer than the ventral lobe). Although most of the skeleton is cartilaginous, there are superficial bones on the surface of the head, and several scutes (distinct rows of diamond-shaped bony projections) on the body: 11 to 14 scutes along the dorsal mid-line; 38 to 48 along the lateral mid-line; and 9 to 12 between the pectoral and pelvic fins on each side of the body (see Figure 1). Also, there are two parallel rows of 4 to 8 small scutes located on the ventral surface between the pelvic and caudal fins.

Figure 1. A lower Fraser White Sturgeon, *Acipenser transmontanus*. Illustration by Diana McPhail.

Population Spatial Structure and Variability

White Sturgeon breed in three river systems: the Sacramento-San Joaquin, Columbia, and Fraser river basins (Figures 2, 3). Given the geographic distances between these rivers, and differences in their physical and biological environments, some restrictions on movements among rivers, and some local adaptation within each of these river systems, might be expected. The White Sturgeon in the three spawning rivers show some spatial genetic structuring (see the **Genetics** section). Genetic diversity (as estimated from D-loop haplotype frequencies and microsatellite DNA allele diversity) in all three of these river systems is highest in their lower reaches. These reaches have direct access to the sea, and either gene flow (via the sea) and/or high effective population sizes may explain the elevated diversity in the lower reaches of these river systems (e.g., Anders and Powell 2002).

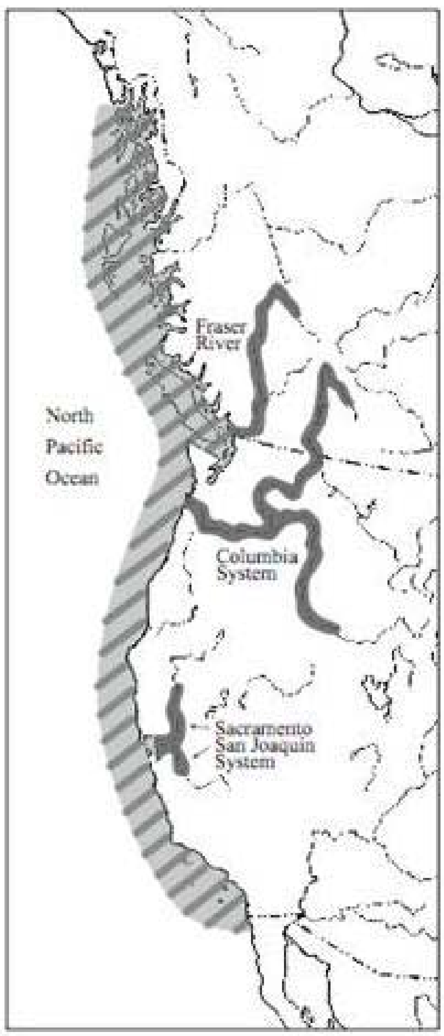

Figure 2. Global distribution of *Acipenser transmontanus*: Freshwater (solid grey) marine (hatched grey). See Figures 3 and 4 for distribution of White Sturgeon in the Nechako River (Fraser River system) and the Kootenay River (Columbia River system), respectively.

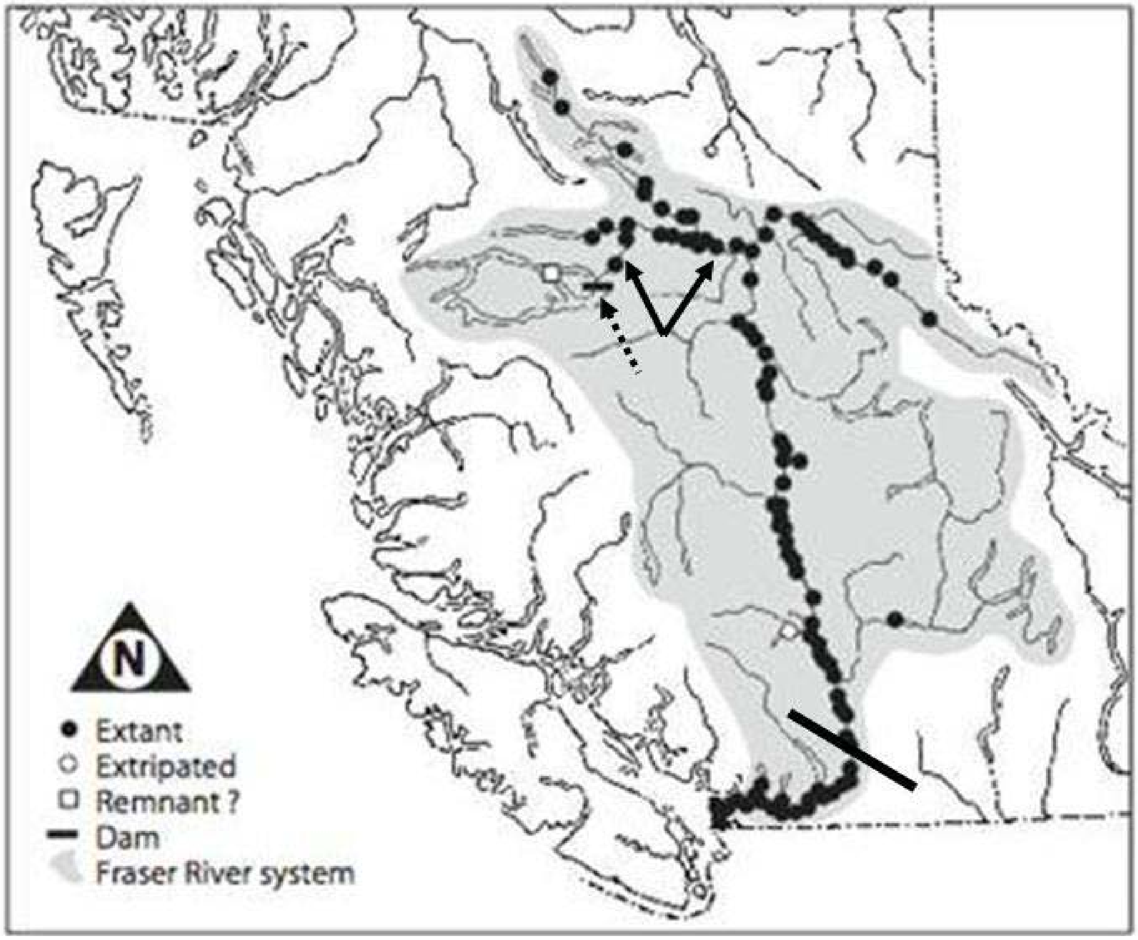

Figure 3. Geographic distribution of White Sturgeon within the Fraser River drainage basin. The thick black bar represents the division between DU1 (Lower Fraser, west and south of the line) and DU2 (upper Fraser). The thick arrows mark the position of the Nechako River system. The broken arrow marks the position of Kenney Dam on the Nechako River. Each dot represents a record of occurrence.

Morphology

Researchers studying White Sturgeon in the Fraser River have commented on differences in snout and fin shapes between the upper (above Hells Gate) and lower (below Hells Gate) Fraser River sturgeon. R.L.&L. (2000) quantified this observation by statistically analyzing the morphology of 1,875 Fraser River sturgeon (914 from below, and 961 from above, Hells Gate) and showed that fish sampled above Hells Gate had significantly longer snouts (by about 11% at 200 cm fork length). These data were used in a discriminant function analysis that successfully identified 76% and 84% of below and above Hells Gate White Sturgeon, respectively (R.L.&L. 2000). The same is true of fin shapes: the fins of upper Fraser sturgeon are more falcate (sickle shaped) than those of lower Fraser sturgeon. There are no comparable analyses for White Sturgeon in the Columbia and Sacramento-San Joaquin river systems, although photographs of sturgeon in the upper Columbia and Kootenay drainage systems in the U.S. suggest their snout morphology closely resembles that of the Fraser River sturgeon found above Hells Gate (Crass and Cray 1980; Brannon *et al.* 1986). It is not clear whether these differences represent local adaptations or are a phenotypic response to differences in the environments (e.g., water velocities and temperatures) between inland and coastal populations.

Genetics

Up to this point, the term population has been used loosely for the geographically delineated groups of White Sturgeon. In a genetic context, however, the word population has a specific meaning which in this report follows Hartl (1981): a population is a group of individuals of the same species that live within a restricted geographic area such that any member of the population is more likely to mate with another member of this same population rather than with members of some other population.

One consequence that follows from this genetic definition is the restriction of gene flow among populations which, ultimately, results in genetic divergence between populations. Depending on a population’s size, the amount of gene flow between populations, and the amount of time that populations have been separated, the degree of divergence will vary. Nonetheless, the detection and geographic boundaries of genetic populations are the basis of rational conservation and management strategies. All six of the so-called “populations” designated in previous White Sturgeon status assessments are not necessarily genetic populations. Some of the six may be populations in the genetic sense, but others clearly contain more than one genetic population (Nelson and McAdam 2012).

Brown *et al.* (1992a) conducted the first mitochondrial DNA (mtDNA) sturgeon study. They applied the then new technique of mtDNA restriction site analysis to sturgeon collected from the Fraser and Columbia rivers’ systems. Samples were collected from four areas in the Columbia River (one near the mouth = “lower Columbia”, and three from localities at least 230 km upstream (= “upper Columbia”) and separated from the lower Columbia by Bonneville Dam) and from three areas in the Fraser River (near the river’s mouth, about 70 km upstream, and at 320 km upstream (i.e., above the Hells Gate canyon area of the Fraser River)). The authors documented significant mtDNA haplotype differences between upper and lower Columbia River areas, and between the Columbia and Fraser rivers (see also Brown *et al.* 1992b). One haplotype, however, was the most common in all areas (i.e., the “At2” haplotype ranged in frequency from 0.49 to 0.92 across sites), there were no significant differences between the lower and middle Fraser River samples, and sample sizes were too small (N = 9) to test for differences between the latter areas and the upper Fraser River area. The two haplotypes found at the upper Fraser River site, however, were common in the middle and lower Fraser (Brown *et al.* 1992a).

The data of Brown *et al.* (1992a), and subsequent sequencing work of Brown *et al.* (1993), are consistent with the postglacial founding of Fraser River populations by fish from the Columbia River (the lower Columbia was a known glacial refugium in the Pleistocene, McPhail and Lindsey 1986). Also, Columbia River populations have undergone severe postglacial bottlenecks, perhaps accentuated by the extensive fragmentation of the Columbia River by hydroelectric dams since the early 1900s. More recently, mtDNA sequencing, and microsatellite DNA analyses, were employed (Smith *et al.* 2002; Schreiers 2012) on larger samples from the Fraser and Columbia rivers. Microsatellite DNA analyses in sturgeon are complicated by the octoploid nature of much of the genome, and that only recently have White Sturgeon species-specific loci been developed (Smith *et al.* 2002; Shreier 2012).

Smith *et al.* (2002) sampled fish from nine areas of the mainstem Fraser River, from the mouth to greater than 900 km upstream, as well as from the mainstem Nechako River — a tributary of the upper Fraser River located about 850 km upstream from the mouth of the Fraser River. In addition, five areas were sampled in the Columbia River including four in Canada (upper Columbia River near Castlegar, Arrow Lakes, Kootenay River below Bonnington Falls (a natural barrier to upstream migration by fishes), and Kootenay Lake upstream of Bonnington Falls). Frequencies of the nine mtDNA haplotypes resolved amongst all areas (Table 1) demonstrated strong and significant differences, especially between the Canadian portions of the Columbia River and the Fraser River and between the Kootenay Lake sample and sturgeon from the Kootenay River and upper Columbia River (Smith *et al.* 2002). In the Fraser system, four groups were recognized: lower Fraser (downstream of Hells Gate); middle Fraser; upper Fraser (upstream of Prince George, BC), and the Nechako River sturgeon. These groups were recognized on the basis of significant mtDNA haplotype frequency differences (Smith *et al.* 2002). In the Fraser mainstem there are no natural physical barriers to gene exchange in the sections of the river system occupied by White Sturgeon (Hells Gate is a relatively new — < 100 years — man-made partial barrier). Consequently, the spatial mtDNA structuring of the four Fraser groups may depend somewhat on where the inter-group boundaries are drawn. Analysis of four microsatellite DNA loci failed to resolve consistent allele frequency differences amongst the four Fraser River groups (e.g., differences among sites within each group often exceeded differences amongst the groups, Table 2). For instance, out of 45 pairwise comparisons of F_{ST} within the Fraser River, 11 were significant, but three of these were found among sites within the lower Fraser River, seven were found between lower Fraser River sites and sites within the middle Fraser, upper Fraser, and the Nechako River, and only one significant difference was found between sites within the middle Fraser, upper Fraser, and Nechako River (Table 2). Consequently, ten of the 11 significant differences were found either among the lower Fraser River sites, or between these sites and sites located above Hells Gate on the Fraser River (i.e., middle and upper Fraser River and Nechako River). In addition, of eight pairwise comparisons between the Nechako River and all other sites, only two were significant; one between a site in the lower Fraser River and the other with the most downstream site within the middle Fraser River (Table 2). Consistent with the mtDNA data, however, was the striking difference between the Kootenay Lake sample (located above Bonnington Falls,

Figure 4) and all other samples (Table 2). The limited number of microsatellite loci (four) undoubtedly limited the power to rigorously test for differences in allele frequencies especially if there is some gene flow between groups.

Table 1. Mitochondrial DNA dloop restriction site haplotype frequencies among White Sturgeon sampled from the Fraser and Columbia Rivers' systems (Smith *et al.* 2002). DU indicates which of the four designatable units the sample area is within. H1-H9 are haplotypes resolved by restriction of a segment of the mitochondrial DNA dloop with three restriction enzymes. LFR = Lower Fraser River, MFR = middle Fraser River, UFR = Upper Fraser River, km = river kilometres upstream of mouth of Fraser River. The Nechako River is a tributary of the Fraser River located between MFR km 555-790 and UFR km 791-920. The only pairwise differences that are not statistically significant (i.e., P < 0.0104 corrected for multiple simultaneous tests after Narum 2006) are: LFR km 78 – 123 vs. LFR km 169 – 85, LFR km 169 – 85 vs. all others in the FR and Nechako River, LFR km 220 – 265 vs. all others in the FR, MFR km 266 – 335 vs. MFR lm 336 – 480, and Nechako River, MFR lm 336 – 480 vs. MFR km 481 – 554, UFR km 791 – 920 vs. Nechako River, and between Upper Columbia and Arrow Lakes. The sample MFR km 555 – 790 was not considered in statistical analyses owing to small sample size (5).

Sample area	DU	H1	H2	H3	H4	H5	H6	H7	H8	H9
LFR km 78 - 123	1	0	4	11	11	2	1	0	0	0
LFR km 169 - 85	1	0	3	13	5	1	0	7	0	0
LFR km 220 - 265	1	0	0	14	0	3	0	9	0	0
MFR km 266 - 335	2	0	4	9	0	4	0	13	0	0
MFR lm 336 - 480	2	0	2	9	0	4	0	15	0	0
MFR km 481 - 554	2	0	3	9	0	0	0	15	0	0
MFR km 555 - 790	2	0	1	3	0	1	0	0	0	0
UFR km 791 - 920	2	0	9	21	0	0	0	0	0	0
Nechako R.	2	0	11	12	0	0	0	6	0	0
Upper Columbia	3	4	10	9	1	3	1	0	1	1
Arrow Lakes	3	0	6	9	1	0	0	0	1	1
Kootenay River*	3	3	42	5	4	0	0	0	0	1
Kootenay Lake	4	0	3	13	5	1	0	7	0	0

*Below Brilliant Dam (i.e., connected to upper Columbia River)

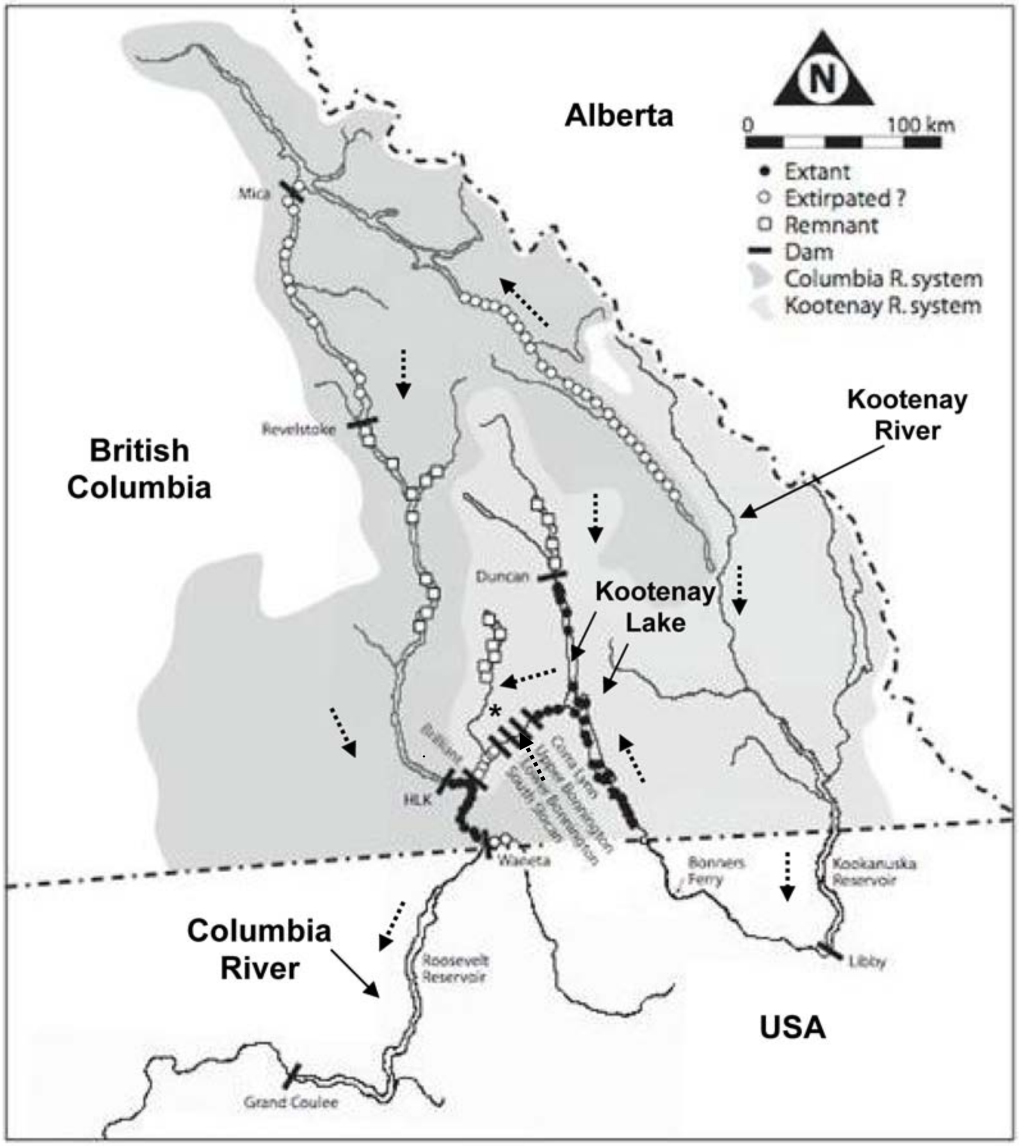

Figure 4. Distribution of White Sturgeon in the Canadian portion of the Columbia River system from historical records of occurrences. The division between DU3 (Upper Columbia) and DU4 (Upper Kootenay) at Lower Bonnington Dam is shown by an asterisk (*). Dashed arrowheads depict direction of water flow, and thick bars indicate positions of major storage and hydroelectric dams. Each dot represents a record of occurrence.

Schreiers (2012) revisited many of the samples examined earlier using a new panel of 13 microsatellite loci and detected “strong” differences between the upper and lower Fraser River as well as some structure within the upper Fraser River (particularly between the middle Fraser River and all others above Hells Gate) as would be expected given the greater number of loci employed (Table 3, Figure 5). Schreiers’ (2012) analysis suggest some modest genetic distinctions between the middle Fraser River and the Nechako River and she suggested that the upper Fraser River population comprised a “mixing” zone of fish from the Nechako River and middle Fraser River, providing indirect evidence of some movements and gene flow amongst all three areas. A recent tagging study also demonstrated movement of an adult White Sturgeon between the middle Fraser River (near Williams Lake, BC) and the Nechako River and eventual spawning in the latter locality (M. Ramsey, BC MoE, pers. comm. 2012). The value of Phi-PT (a measure of genetic differentiation analogous to F_{ST}, but used for dominant data; see Table 3) was 0.082 between the upper and lower Fraser River and was always greater than 0.156 between samples from the Kootenay River and other regions of the Columbia River basin and the Fraser River (all $P < 0.001$). These new data support previous conclusions of major differences between the upper and lower Fraser River, the Canadian portion of the Columbia River and the upper Kootenay River.

Behaviour

Studying the behaviour of a large mobile animal that lives in murky water is not easy, and it is not surprising that little is known about spatial structure and variation in the behaviour of White Sturgeon. There is one brief account of their spawning behaviour (Liebe *et al.* 2004), and most observations on the behaviour of larvae and newly metamorphosed young-of-the-year are based on laboratory studies (Kynard *et al.* 2010; McAdam 2011). Still, we know enough about their biology to establish that they return to the same spawning and overwintering sites year after year. They also perform annual seasonal foraging migrations (Nelson *et al.* 2011) and, perhaps, regular diel movements (Parsley *et al.* 2008). Potentially, all of these behaviours could vary between, and within, the major river systems.

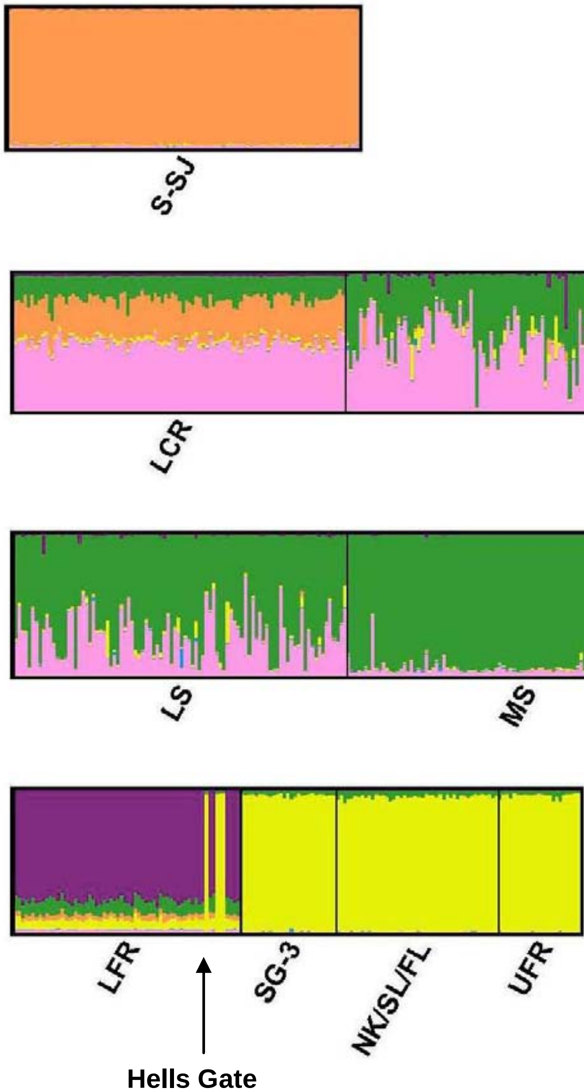

Figure 5. Results from Structure analysis depicting individual genetic assignments for White Sturgeon sampled from across its geographic range and based on variation at 13 microsatellite DNA loci (see Pritchard *et al*. (2000) for description of the Structure algorithm). Each vertical bar represents one individual fish's genome, each colour represents a genetic population identified by Structure, and the proportion of each colour in each bar represents the proportional assignment of each genetic group (colour) to individual fish. S-SJ = Sacramento-San Joaquin River (California, USA), LCR = lower Columbia River (Washington and Oregon, USA), ColR = upper Columbia River (Washington, USA and Canadian portion of Columbia River), LS = lower Snake River (Washington, USA), MS = middle Snake River (Idaho, USA), KT = Kootenay River (British Columbia, Canada; Idaho, Montana, USA), LFR = lower Fraser River (British Columbia, Canada), SG-3 (middle Fraser River, British Columbia, Canada), NK/SL/FL = Nechako River (British Columbia, Canada), UFR = upper Fraser River above the confluence with the Nechako River). Hells Gate is a historical velocity barrier that marks the division between the upper and lower Fraser River. Adapted from Schreiers (2012). Sample sizes exceeded 50 for all localities.

Physiology

Again, not much is known about the spatial structure and variation in the physiology of White Sturgeon; however, there are observations that hint at local physiological adaptations. For example, in the Sacramento-San Joaquin drainage system, juvenile White Sturgeon concentrate in the estuary (Schafter and Kohlhorst 1999), whereas in the Fraser River estuary young White Sturgeon appear to be less common than they are in California. This may be an artifact of sampling; however, the tolerance of young Fraser River sturgeon to saltwater is known to be size-dependent: the smallest individuals within a cohort are less tolerant of salinity than the larger individuals in the same cohort (Amiri *et al.* 2009). Thus, there may be differences in the osmoregulation capabilities of the Fraser and Sacramento-San Joaquin sturgeon stocks. Additionally, it is possible that there are physiological differences in salinity tolerance even within the lower Fraser River. It is known that some sturgeon make forays into the sea and that these individuals spend different amounts of time in salt water (Veinott *et al.* 1999). Recent research on juveniles in the lower Fraser suggests that there may be three different physiological types of White Sturgeon in the lower Fraser River: river residents, estuarine residents, and sturgeon that go to sea (Steve McAdam, pers. comm. 2011).

Temperature is another environmental factor that may select for local physiological genotypes. Water temperature affects most aspects of the White Sturgeon's metabolism and life cycle. In captivity, Webb *et al.* (1999) found that gravid females failed to ovulate at constant temperatures of 15ºC and 18ºC, whereas females held at fluctuating normal seasonal temperatures (10-15ºC) ovulated and produced viable eggs. In the wild, spawning appears to be triggered by a combination of temperature and changes in flow (Golder 2006) and, in the Kootenay River, a temperature decrease of about 0.8ºC was enough to disrupt sturgeon spawning (Paragamian and Wakkinen 2002). In Canadian White Sturgeon the minimum temperature associated with the start of spawning is about 8ºC and spawning ceases at about 21ºC (Tiley 2006, Golder 2006). This lower temperature is about 6ºC below the published optimal temperature for survival of larvae (14-16ºC; Wang *et al.* 1985). Nonetheless, Tiley (2006) found that 75% of the eggs successfully hatched at about 10ºC and the resulting larvae were normal, although small (11-13 mm TL). In the Kootenay River, Paragamian and Wakkinen (2002) found a similar low (7.4ºC) temperature for the initiation of spawning and a spawning peak at 9.5-10ºC. Thus, northern groups of White Sturgeon appear to have a lower range of optimal temperatures than White Sturgeon in California.

Designatable Units

Following the 2003 COSEWIC assessment of White Sturgeon, six NSPs (Nationally Significant Populations) were recognized in Canada during the SARA listing process: the lower Fraser "population", the middle Fraser "population", the Nechako "population", the upper Fraser "population", the upper Columbia "population", and the upper Kootenay "population". These six "populations" became the geographic framework for research, management, and conservation of White Sturgeon in Canada. In 2004 COSEWIC switched from the concept of NSP to that of designatable units (DUs). Consequently, the current reassessment of the status of White Sturgeon in Canada follows the current COSEWIC guidelines for recognizing designatable units that are different from those used to identify NSPs (COSEWIC 2012a). For White Sturgeon, various types of data were examined in light of the "discrete" and "significance" criteria used for DU recognition by COSEWIC (COSEWIC 2012a).

The most basic aspect of discreteness for White Sturgeon is the physical separation between the Fraser and Columbia rivers' systems whose mouths are separated by about 500 km of ocean. This separation is, however, incomplete as it is likely that sturgeon occasionally move through the sea between the lower portions of these two rivers at least when they are young (Veinott *et al*. 1999). This physical separation has probably formed repeatedly during the Pleistocene and been re-established since the end of the most recent Wisconsinan glacial advance (about 10,000 years ago, Johnsen and Brennand 2004). The discreteness between the Fraser and upper Columbia rivers White Sturgeon is also supported by strong and statistically significant differences in mtDNA haplotype frequencies, and in allele frequencies at four-13 microsatellite DNA loci (Tables 1-3, Figure 5). In addition, while genetic data suggest exchange of White Sturgeon between the Fraser and Columbia rivers over historical times, Veinott *et al.* (1999) inferred marine migrations from strontium levels of White Sturgeon and concluded that these declined as sturgeon aged and that after about 40 years of age White Sturgeon are permanent residents of freshwater.

Within the Fraser River, there is good evidence of discreteness between sturgeon in the Lower Fraser River and those in the Upper Fraser River (consisting of the upper and middle Fraser River, and the Nechako River) from mtDNA haplotype and microsatellite DNA allele frequencies (Tables 1-3). Within the Canadian portion of the Columbia River, sturgeon in the Upper Kootenay River are physically isolated from other Columbia basin fish by Bonnington Falls, which were created early during the most recent deglaciation (Northcote 1973). The discreteness of the Upper Kootenay River and Upper Columbia sturgeon from each other is also supported by striking differences in the frequencies of mtDNA haplotypes and microsatellite DNA allele frequencies (Tables 1-3). Based on geographic distribution and genetic data there are, therefore, four DUs proposed in terms of discreteness: Lower Fraser, Upper Fraser, Upper Kootenay, and Upper Columbia. There is also mtDNA evidence that the Nechako River is a discrete genetic population from that in the other portions of the Fraser River (see **Population Spatial Structure and Variability** section and Table 1), but not consistently in terms of microsatellite DNA frequencies (Table 2,3). Schreiers (2012) examined microsatellite DNA allele frequencies in the upper and lower Fraser River (including the Nechako River system) and showed a striking division of the samples in upper and lower Fraser River genetic groups (e.g., Figure 5). While some structure was also apparent between the upper Fraser River samples (as defined herein) and the Nechako River, when the Fraser River system was considered alone or in range-wide analysis, Schreiers (2012) concluded that the most likely number of subpopulations within the Fraser River was two (upper and lower Fraser River). In fact, the level of genetic divergence between the upper and lower Fraser River samples was two-four times that observed between the lower Fraser and the lower Columbia and Sacramento-San Joaquin rivers, and 10 alleles were found to be unique to the lower Fraser River (i.e., not recovered in the upper Fraser River, Schreiers 2012).

Table 2. Estimates of genetic differentiation (F_{ST}) derived from variation across four microsatellite DNA loci among samples of White Sturgeon (*Acipenser transmontanus*). Adapted from Smith *et al.* (2002) DU1: LF = Lower Fraser River, DU2: MFR = middle Fraser River, UFR = Upper Fraser River, km = river kilometres upstream of mouth of Fraser River, NR = Nechako River (a tributary of the Fraser River located between MFR km 555-790 and UFR km 791-920), DU3: AL = Arrow Lakes, UCR = Upper Columbia River, KR = Kootenay River below Brilliant Dam; DU4: KL = Kootenay Lake. Boldfaced values are significantly greater than 0 (at P ≤ 0.05). Sample sizes exceeded 40 for all areas within the Fraser River (range 43 - 156), and ranged from 20 (AL) to 50 for all other areas of the Columbia and Kootenay river basins.

	LFR km 78- 123	LFR km 169-185	LFR km 200-265	MFR km 266-335	MFR km 336-480	MFR km 481-554	MFR km 555-790	UFR km 791-920	NR	KL	KR	UCR	AL	LCR
LFR km 16-75	0.03057	**0.03831**	**0.10239**	0.01122	0.01576	**0.03213**	0.00141	0.00217	0.0157	**0.28446**	**0.05662**	**0.07458**	0.01045	**0.04498**
LFR km 78-123		0.00163	**0.02283**	**0.0295**	0.00595	0.00532	0.02003	0.01284	0.0099	**0.19615**	0.01937	0.01003	0.00854	0.00388
LFR km 169-185			0.00327	**0.02345**	0.00452	0.00774	0.02651	0.00671	0.0014	**0.20342**	0.00431	0.00236	0.01628	0.00942
LFR km 200-265				**0.06184**	**0.0269**	0.01087	0.00479	**0.05225**	**0.0405**	**0.17212**	0.00994	0.00672	0.01002	0.00445
MFR km 266-335					0.01088	0.01242	0.00771	0.01415	**0.0267**	**0.1894**	0.0132	**0.03699**	0.0054	**0.03191**
MFR km 336-480						0.00519	0.02132	-0.00508	-0.005	**0.23011**	0.01212	**0.01528**	0.01371	0.00096
MFR km 481-554							0.02113	0.00554	0.004	**0.19505**	0.00051	0.00189	0.01257	0.00267
MFR km 555-790								-0.01078	-0.013	**0.20031**	0.01729	0.01513	0.02635	0.01832
UFR km 791-920									-0.007	**0.2703**	**0.03099**	**0.0368**	0.00672	0.01276
NR										**0.27509**	**0.03245**	**0.03056**	0.00898	0.00599
KL											**0.13342**	**0.1475**	**0.22094**	**0.20039**
KR												-0.0014	0.00143	0.00984
LCR													0.00124	0.00102
AL														0.01127

Table 3. Estimates of genetic differentiation (Phi-PT, lower diagonal) and their statistical significances (upper diagonal) derived from variation across 13 microsatellite DNA loci among samples of White Sturgeon (*Acipenser transmontanus*) from ten localities along the Pacific coast. S-SJ = Sacramento-San Joaquin, LC = Lower Columbia, MC = Middle Columbia, TR = Transboundary Reach (Columbia River between Canada and U.S.), KT = Kootenay, LS = Lower Snake, MS = Middle Snake, LF = Lower Fraser, and UF = Upper Fraser. All values are significant greater than 0 in as shown in the upper diagonal. Sample sizes for each sample exceeded 50 in all cases. Adapted from Schreiers (2012).

Population	S-SJ	LC	MC	TR	KT	LS	MS	LF	UF
S-SJ		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
LC	0.043		0.0005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
MC	0.084	0.023		0.0001	0.0001	0.0050	0.0001	0.0001	0.0001
TR	0.093	0.029	0.026		0.0001	0.0004	0.0001	0.0001	0.0001
KT	0.222	0.171	0.169	0.156		0.0001	0.0001	0.0001	0.0001
LS	0.094	0.025	0.016	0.010	0.186		0.0001	0.0001	0.0001
MS	0.171	0.083	0.050	0.050	0.240	0.020		0.0001	0.0001
LF	0.040	0.022	0.055	0.057	0.193	0.056	0.118		0.0001
UF	0.122	0.065	0.082	0.079	0.209	0.075	0.136	0.082	

The separation between units within the Fraser River and within the Columbia River is also supported by the observation that the upper and lower portions both of the Fraser and Columbia rivers are widely recognized to represent very different biogeoclimatic zones (Coastal Western Hemlock and Interior Douglas Fir) with a very sharp (e.g., less than a few kilometres) division between them in the Fraser River (Austin 2008). Finally, discreteness between the Lower and Upper Fraser DUs is also supported by the distinct morphological differences (snout shape and length, fin shape) between fish from these areas (R.L.&L. 2000 see also **Spatial Population Structure and Variability** above).

In terms of evolutionary significance of these aspects of discreteness, the evidence of a morphological distinction between upper and lower Fraser River sturgeon (see **Spatial Population Structure and Variability**) may plausibly be interpreted as adaptations, perhaps to different flow characteristics in the relatively narrower and faster flowing upper river compared to the broad valley bottom of the lower Fraser River (although phenotypic plasticity may also play a role). Certainly, considerable evidence exists for distinct evolutionary origins and adaptations in upper and lower Fraser River populations of other fishes (e.g., Taylor and McPhail 1985; Taylor *et al.* 1999; Smith *et al.* 2001). Schreiers (2012) also suggested that one potential explanation for high differentiation between the upper and lower Fraser River was that the lower Fraser River includes colonists from a second source other than the Columbia River suggesting that the evolutionary legacy of one group (Upper Fraser DU) is, in part, distinct from the other (Lower Fraser DU). In addition, there is evidence of behavioural differences between sturgeon from the upper and lower Fraser River; only fish from the lower Fraser River have been inferred (from fin ray analyses of strontium levels) to make occasional migrations to the sea (Veinott *et al.* 1999; S. McAdam, BC Ministry of Environment, pers. comm. 2012).

Although there is some evidence for the genetic discreteness of the Nechako River population(s) (Smith *et al.* 2002; Schreiers 2012) within the upper Fraser DU, the evolutionary significance of small differences in mtDNA haplotype frequencies is likely minor (i.e., they do not represent preglacial isolation and probably stem from some post-founding restriction in gene flow perhaps exacerbated by small population size — mtDNA is four times as susceptible to shifts through genetic drift compared to nuclear loci, Moore 1995). In particular, the upper Fraser River samples and those from the Nechako River share the same two mtDNA haplotypes at high frequency (0.30 and 0.38 for haplotype 2, respectively, and 0.70 and 0.41 for haplotype 3, respectively – Table 1). Further, the Nechako River population does not occupy a discrete ecological or evolutionary setting and its loss would not induce a gap in the range of the species in the upper Fraser River that could not, at least potentially, be filled by natural dispersal from the middle or upper Fraser River (or at least it would likely be much more probable than dispersal from the lower Fraser River). In summary, while there may well be subunits within the lower and upper Fraser River DUs that are to a large degree demographically independent (Nechako River, middle Fraser River, subunits with the lower Fraser River), the major genetic, morphological, biogeographic, and evolutionary divisions between the lower and upper Fraser support their recognition as two DUs.

In the case of the Upper Columbia and Upper Kootenay DUs, evolutionary significance rests on the fact that the loss of any one of them would produce a significant gap in the Canadian range of this species. Loss of the Upper Kootenay and/or Upper Columbia DUs would result in a major contraction of Canadian distribution of the species and in one of the only two major river systems in which it occurs in Canada. Such losses in the Upper Columbia or Upper Kootenay DUs cannot be re-established naturally owing to the presence of a natural upstream migration barrier that isolates the Upper Kootenay DU or a plethora of human migration barriers that isolates the Upper Columbia DU (i.e., loss of either DU would result in a permanent loss of about 17-18% of the total Canadian extent of occurrence and both would result in a permanent loss of about 36% of the total Canadian index of area of occupancy). In addition, two aspects of the molecular genetic data suggest that the Upper Columbia and Upper Kootenay DUs represent a distinct aspect of the evolutionary legacy of Canadian White Sturgeon. First, mtDNA data show that these two DUs harbour unique haplotypes (three) not found in the Fraser River system (Table 1). Second, microsatellite DNA data (e.g., Figure 5) indicate that the differences between these two DUs, and between both of them and those of the Fraser River, are relatively pronounced and not simply a function of minor, but statistically significant, differences in allele frequencies (e.g., each of the four proposed DUs is characterized by major distinctions in allele assemblages which are not shared amongst them). While it is unclear how to interpret such patterns in a strict phylogeographic sense, they do suggest that unique aspects of the genetic legacy of White Sturgeon reside within the Upper Columbia and Upper Kootenay DUs.

SPECIAL SIGNIFICANCE

Sturgeon are often referred to as “living fossils” and the order Acipenseriformes has been around for a long time — at least 200 million years (Grande and Bemis 1996, Hilton and Grande 2006). Their antiquity alone is reason enough to make them fishes of special significance; however “living fossils” is a misnomer. The living sturgeons are the descendents of ancient fossil sturgeon, but they are not ancient in themselves. The earliest fossil evidence of White Sturgeon comes from a Pliocene site on the Columbia River (Smith *et al.* 2000) dated at about 4.5 million years ago. Additionally, this species' restricted Canadian distribution (only in British Columbia) makes it an important part of our national biological heritage. The White Sturgeon has long been of significance to Aboriginal peoples of the west coast both in terms of being the subject of stories and legends as well as providing food and clothing (COSEWIC 2012b).

Genetically, modern sturgeon are unusual among vertebrates. Apparently, the living sturgeons evolved through a complex series of hybridization events and gene duplications (Fontana *et al.* 2008). Assuming a theoretical ancestor with a diploid chromosome number of 60, the living sturgeon form three distinct groups: a supposedly primitive group possesses about 120 chromosomes; a second group of species have diploid chromosome numbers of about 240, and a third group have chromosome numbers of about 360. The White Sturgeon appears to fit in the middle group with a diploid chromosome number of 248; however, some researchers (e.g., Ludwig *et al.* 2001) count about 500 chromosomes in this species. Thus, depending on their diploid chromosome count, White Sturgeon are either a hexaploid or an octoploid species, and this makes sturgeon unique among the living vertebrates (Fontana et al 2008).

In addition to their antiquity, and their bizarre propensity for genome duplication, they are unusually large for freshwater fishes. The White Sturgeon is the largest freshwater fish in North America — one individual caught in the Fraser River is reputed to have weighed over 800 kg and was a bit over 6 m in length (Glavin 1994). Also, they are long-lived, and occasional individuals of over 100 years in age are still caught in the Fraser and Columbia rivers. Towards the end of the 19^{th} and the first decades of the 20^{th} centuries there was a commercial fishery for White Sturgeon in the lower Fraser River. This fishery collapsed in the 1920s; however, a small commercial and First Nations fishery continued into the 1990s. A catch-and-release recreational fishery came into existence in 1994. The White Sturgeon's large size attracts anglers from all over the world and there is a rapidly growing guiding industry that in 2008 was estimated to be worth $7,000,000 annually (Glova *et al.* 2009).

DISTRIBUTION

Global Range

The White Sturgeon is endemic to western North America (Figure 2). At present, it only spawns in three major drainage systems: the Fraser, the Columbia, and the Sacramento-San Joaquin rivers. Although the White Sturgeon is primarily a freshwater species, some individuals make forays into the sea (Veinott *et al*. 1999; Welch *et al.* 2006), and they are known to enter other rivers, estuaries, and bays along the Pacific Coast from southeastern Alaska to Baja California. It is possible that in the past they spawned in some of these other rivers; however, there is no recent evidence of spawning except in the Fraser, the Columbia, and the Sacramento-San Joaquin rivers.

The confirmed marine records of White Sturgeon span almost 27 degrees of latitude (about 2600 km) — from southeastern Alaska in the north (Point Saint Mary in Lynne Canal) to Baja California, Bahia de Todos Santos, Ensenada (Rosales-Casian and R. Ruz-Cruz 2005) in the south (Figure 2). This wide marine distribution indicates that some White Sturgeon make long-distance marine journeys and, occasionally, tagged Columbia River sturgeon are caught in the lower Fraser River (Nelson *et al.* 2004). In addition, a sturgeon tagged in the Columbia River was recovered in the Sacramento River (DeVore *et al.* 1999) and, recently, Welch *et al*. (2006) reported a White Sturgeon (presumably of Sacramento origin) but tagged as an adult in the Klamath River and later detected in the Fraser River (a journey of over 1,000 km). Whether these marine wanderers breed in their "new" rivers is unknown; however, it is clear that long-distance movements do occur among the three known spawning rivers.

Canadian Range

In Canada, White Sturgeon breed in the Fraser and Columbia rivers. A recent confirmed record of a White Sturgeon in Kamloops Lake (and several previous unconfirmed sightings elsewhere in the Thompson River system) suggests adults from the middle Fraser Sturgeon Group may occasionally enter the Thompson River. Within the drainage systems where they breed, most records of White Sturgeon are from river mainstems. Nonetheless, they also occur in large tributaries, large lakes and, in the lower Fraser system, in flood-plain lakes, sloughs, and the river's estuary (Figure 3). Some White Sturgeon enter salt water and, occasionally, these sturgeon turn up in coastal rivers on Vancouver Island (e.g., the Somass and Cowichan rivers) and Howe Sound (the Mamquam River); however, there is no evidence that they breed in these rivers. North of the Fraser River, records of White Sturgeon are uncommon; however, there are unverified reports of White Sturgeon in the estuaries of the Skeena, Nass, and Taku rivers. Some of these reports probably refer to Green Sturgeon (Lane 1991) but confirmed records of White Sturgeon from southeastern Alaska (Mecklenburg *et al*. 2002) suggest that some of these northern BC sturgeon reports may include White Sturgeon.

The extent of occurrence (EO) of White Sturgeon in Canada is 46,158 km^2. This estimate was based on the freshwater distribution of White Sturgeon and does not include marine occurrences that span approximately 27 degrees of latitude along the Pacific Coast of North America. The index of area of occupancy (IAO) has been estimated as between 10,892 km^2 (2 x 2 km grid) and 5,123 km^2 (1 x 1 km grid, all estimates provided by J. Wu, Environment Canada, 2012).

White Sturgeon form aggregations both during spawning and overwintering. Locations were defined in terms of known spawning areas and if these were unknown, locations were defined in terms of known overwintering areas because sturgeon may aggregate during overwintering and be vulnerable to disturbances (Tables 4 and 5).

Lower Fraser DU

In the mainstem lower Fraser River, White Sturgeon occur from the Fraser estuary upstream to a potential barrier (Hells Gate) located about 200 km upstream from the sea. This DU has an EO of 3,798 km^2 and an index of area of occupancy (IAO) of 804 km^2 (2 km x 2 km grid) including areas of the mainstem Fraser River only. The corresponding estimates that include both Pitt and Harrison lakes where White Sturgeon have been reported (McPhail 2007) are 6,177 km^2 and 1,492 km^2 , respectively, The four-six known lower Fraser spawning areas represent separate locations because, in this DU, these spawning sites are vulnerable to localized habitat disturbances (e.g., gravel mining).

Upper Fraser DU

The Upper Fraser DU extends from Hells Gate upstream to the confluence of the Morkill and Fraser rivers (Yarmish and Toth 2002): a river distance of about 1,000 km (R.L.&L. 2000). In this DU sturgeon regularly occur in large tributaries like the Nechako and Stuart rivers, and in the lower reaches of smaller tributaries like the Bowron, McGregor and Torpy rivers. In addition, they occur, but do not breed, in lakes associated with large tributaries (e.g., Fraser, Takla, Trembleur, Stuart, and Williams lakes, Figure 3). There is an old record from Ootsa Lake. Originally, Ootsa Lake was part of the Nechako River system but in the 1950s construction of Kenney Dam created a barrier to movements between the new reservoir and the rest of the Nechako system. Still, there are persistent, but unconfirmed, rumours of sturgeon in Knewstubb Reservoir above Kenney Dam and it is possible that a small isolated remnant (i.e., a group that is no longer self-sustaining) is trapped in the reservoir. This DU has an EO is 23,390 km^2 and the IAO is between 1,620 km^2 (1 km x 1 km) and 6,408 (2 km x 2 km) km^2.

There are a total of 12 suspected spawning sites plus one confirmed spawning site in the Upper Fraser DU (Table 3). The confirmed site is a cluster of adjacent spawning sites in a braided portion of the Nechako River near Vanderhoof. Here they are treated as a single site.

Upper Columbia DU

The original distribution of White Sturgeon in the mainstem of the Canadian portion of the Columbia system extended upstream from the border with Washington State for about 560 km (Figure 4). The confirmed upstream records are from Kinbasket Lake (now the Kinbasket Reservoir), but locals remember them as far upstream as Spillimacheen (Prince 2001). A few remnant sturgeon may still exist in the mainstem Columbia River between Revelstoke and Mica Dam but apparently they are no longer present above Mica Dam (attempts to re-introduce them above Mica Dam are under consideration).

Historically, White Sturgeon also occurred in major Columbia River tributaries within BC (e.g., the Pend d'Oreille River as far upstream as its confluence with the Salmo River, and the Kootenay River upstream from its confluence with the Columbia River to the original site of Bonnington Falls). There are unconfirmed reports of White Sturgeon in the Kettle River below Cascade Falls. In the Pend d'Oreille system, the sturgeon above Waneta and Seven Mile reservoirs are now extirpated (Golder 2009b). Similarly, except for 2.8 km of the Kootenay River below Brilliant Dam and a small population in Slocan Lake (R.L.&L. 1998) and the impoundment behind Brilliant Dam, the lower Kootenay sturgeon essentially are a remnant and isolated component of the Upper Columbia DU. The EO of the Columbia DU is estimated as 12,190 km^2 and the IAO between 440 (1 x 1 km) and 1,760 (2 x 2 km) km^2.

Impassable (at least in the upstream direction) dams separate the known spawning sites in this DU (one site below Revelstoke Dam, and four sites between Hugh L. Keenleyside Dam and the U.S. border, Table 4). As the dams operate independently in terms of their effects on sturgeon (water level fluctuations, scouring) these five spawning areas constitute five separate locations.

Table 4. White Sturgeon spawning sites.

River	Spawning site*	River kilometre	Channel type**
Lower Fraser DU			
Lower Fraser	Chilliwack	110	SC, cobbles, gravel, sand
	Minto	109	SC, cobbles, gravel
	Jesperson	119	SC, cobbles gravel
	Herrling	125-128	SC, cobbles, gravel
	Peters	139	SC, cobbles, gravel
	Coquihalla	169	MS, cobbles, boulders
Upper Fraser DU			
Middle Fraser*	Nahatlach	233	ECF
	Stein	272	"
	Texas	321	"
	Bridge	343	"
	French Bar	426	"
	Chilcotin	482	"
	Williams	535	"
	Cottonwood	698	"
	Blackwater	728	"

River	Spawning site*	River kilometre	Channel type**
Upper Fraser*	McGregor R.	895	ECF
	Bowron R.	910	“
	Longworth	948-950	“
Nechako	Vanderhoof	1 site kms 136-139	SC, cobbles, coarse gravel heavily silted
Upper Columbia DU			
Segment below HLK	Waneta Eddy	0.5-1.0 km above U.S. border.	ECF, boulders, cobbles
	Ft Shepherd Rapids	3 km	MS, Cobbles
	Kinnard Rapids	40.5 km	MS, Cobbles
	Kootenay Rapids	1 km above confluence with Kootenay R.	MS, Cobbles
	Below Arrow Generating Stn.	56.4 km	MS, Cobbles
Segment above HLK	6 km below Revelstoke Dam	229 km*	Cobbles, boulders, Rip Rap
Upper Kootenay DU	Bonners Ferry, Idaho	River km 239-245	MS, sand over underlying cobbles

*None of the Middle and Upper Fraser spawning sites are verified. They are, however, high-use sites in the spring.
**SC= side channel; MS=mainstem, ECF= eddy at the confluence with the Fraser or Columbia rivers.

Upper Kootenay DU

Upstream of Corra Linn Dam there is still a breeding population associated with Kootenay Lake and the Kootenay River (Figure 4). The only known breeding site in this DU is located upstream of the U.S. border near Bonners Ferry, Idaho. Also, there is a remnant population in Duncan Lake which drains via the Duncan River into the north end of Kootenay Lake (R.L.&L. 1998). Duncan Dam separates this reservoir from other sturgeon within this DU; however, it is possible that some Duncan sturgeon pass through the dam. The western boundary of the Kootenay DU is at the downstream end of Bonnington Falls (Figure 4). This DU’s EO is estimated at 6,780 km^2 and the IAO is between 480 (1 x 1 km) and 1,920 (2 x 2 km) km^2. There is one known spawning area, and hence one location, for sturgeon in the Upper Kootenay DU, but this is located in the US. Consequently, the number of locations in Canada is estimated as areas of known concentrations of sturgeon for overwintering (two).

Sampling Effort

Lower Fraser DU

In 1990 White Sturgeon were assigned Vulnerable status by COSEWIC. This sparked public interest in White Sturgeon conservation but monitoring of the lower Fraser White Sturgeon had began earlier (1985). The Fraser River Sturgeon Conservation Society (FRSCS) was founded in 1997 and in 1999 the society, in conjunction with the BC government, launched the Lower Fraser River White Sturgeon

Monitoring and Assessment Program. This program established standardized data collection protocols and in 2004 the FRSCS released the first comprehensive report on the status of lower Fraser White Sturgeon. Since then a status report has been published annually. By 2011, 50,154 White Sturgeon had been tagged in the lower Fraser River, and 83,353 sturgeon had been checked for tags. Of the tagged fish, 37,179 were recaptures (Nelson *et al.* 2012). These annual reports provide a time series of population estimates (Figure 6), age structure, and a wealth of data on the biology of White Sturgeon in the Lower Fraser DU. The estimated total population in 2011 was 44,713 fish 40-279 cm FL (Fork Length).

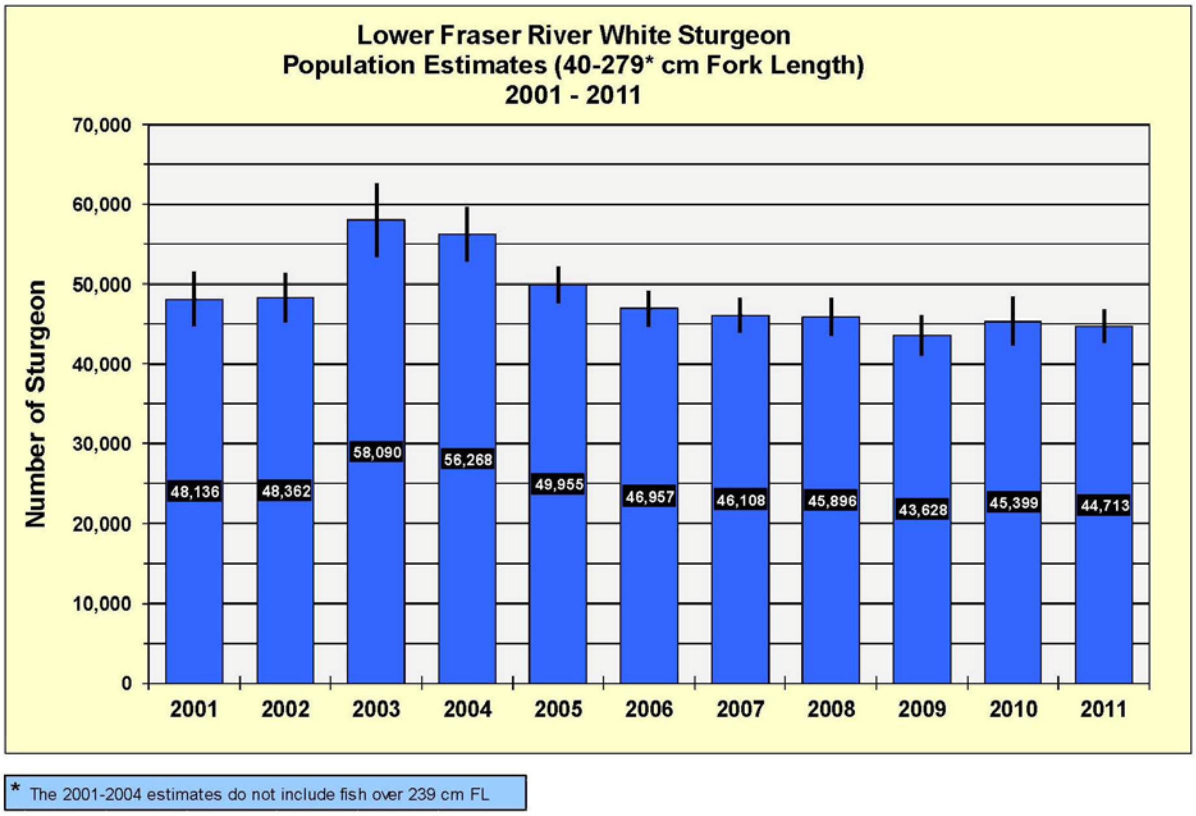

Figure 6. Mean annual estimates of immature and mature White Sturgeon numbers in the Lower Fraser DU, 2001 to 2011 (after Nelson *et al.* 2012). Vertical black bars are 95% confidence intervals.

Whitlock (2007) used the FRSCS data and a Bayesian mark and recapture model that incorporated spatial structure to estimate abundance and annual adult mortality rates. This analysis indicates annual adult mortality rates are lower (about 0.04) than previous estimates (e.g., 0.08 Walters *et al.* 2005) used for this DU. This analysis may result in eventual estimates of population sizes that are substantially higher than those depicted in Figure 6. This same analysis found evidence of differences in seasonal movement patterns among size classes.

Upper Fraser DU

Four of the designatable units (DUs) used in this report coincide geographically with the older “Nationally Significant Populations” (NSPs) used in the 2003 COSEWIC assessment of White Sturgeon, but not all of the former NSPs qualify as DUs. In this report three of the former NSPs — the middle Fraser, Nechako, and upper Fraser NSPs — are combined into a single Upper Fraser DU. To avoid confusion between the Upper Fraser DU and the three “populations” that make up this DU, these “populations” are referred to as “Sturgeon Groups”.

Middle Fraser Sturgeon Group

Monitoring of the middle (Hells Gate to Prince George) Fraser River sturgeon began in 1995 and continued to 1999 (R.L.&L. 2000). The status of this geographic group of sturgeon during the period 1995-1999 was evaluated based on abundance estimates and age structure. Abundance was estimated from mark and recapture data. The number of sturgeon > 50 cm FL was estimated at 3,800 individuals. Most of these fish were in the 6-20 year age group. After age 20, the age distribution tapered off to about 50 years with a few individuals reaching 100 years (Figure 7). This wide age structure skewed toward younger individuals indicates a healthy population stock that shows no sign of recruitment failure. Consequently, this group has not been monitored as vigorously as the other Fraser groups.

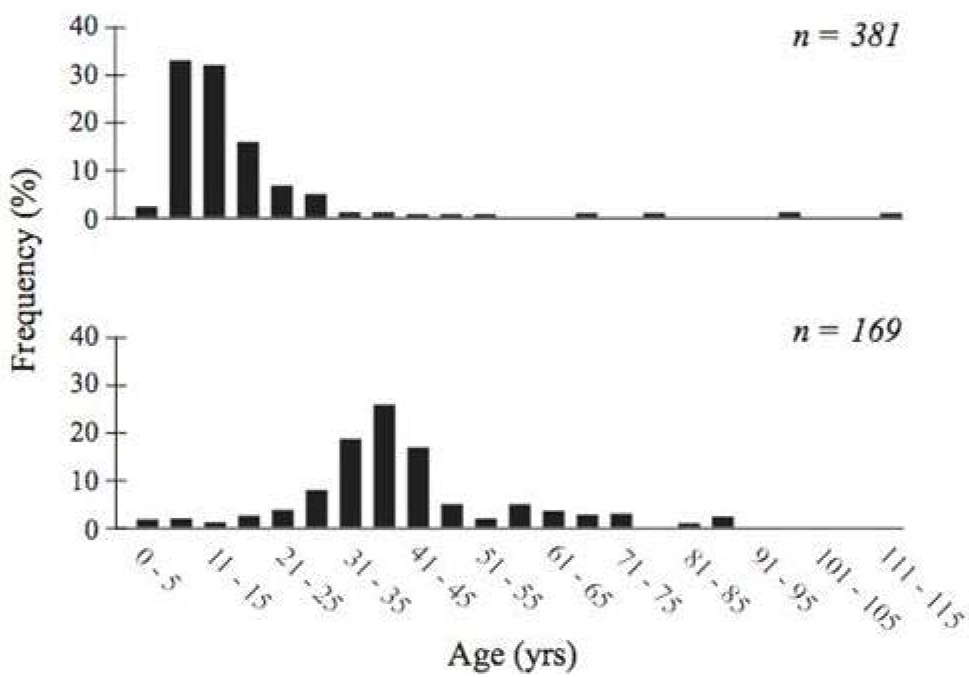

Figure 7. Age-class distribution in the Middle Fraser Sturgeon Group (upper) and the Nechako Sturgeon Group (lower). Note the relative lack of the smallest age classes in the Nechako Sturgeon Group (after R.L.&L. 2000).

Upper Fraser Sturgeon Group

Monitoring of the upper Fraser River (i.e., upstream of the confluence of the Fraser and Nechako Rivers) began in 1997 (R.L.&L. 2000) and has continued into the present (Lheidli T'enneh 2009). Abundance in the period 1999-2001 was estimated at 815 fish > 50 cm FL (Yarmish and Toth 2002). This estimate was based on analysis of mark and recapture data using a modified Schnabel model. Using the same technique, the estimate for the period 2007-2008 was 685 fish (Lheidli T'enneh 2009). This apparent reduction in population size probably reflects the relatively small sample size (46 fish) underlying the 2007-2008 estimates. The age structure of the 2008 sample — an age range of 4-50 years with a strong peak at 15-17 years — indicates this population is stable and that recruitment is still occurring.

Nechako Sturgeon Group

Monitoring of the Nechako River began in the early 1980s (Dixon 1986), intensified in the period 1995-1999, and in 2000 the Nechako Recovery Initiative (a co-operative effort involving provincial and federal agencies, First Nations, industry, and other stakeholders) was formed (NWSRI 2004). One objective of the first phase of this plan (2003-2007) was to assess the abundance and status of White Sturgeon in the less studied areas of the Nechako River system.

Mark-recapture data accumulated from 1995-1999 gave a population estimate of 571 fish (R.L.&L. 2000); however, the age-frequency data showed a strong peak at ages 31-45 that tapers off in both directions (Figure 7). Roughly, there was the same small number of fish in the youngest (age 5) and oldest (age 85) age groups. The shape of this age distribution suggests serious, and persistent, recruitment failure in the Nechako population. McAdam *et al.* (2005) analyzed the probable cause of this recruitment failure. They suggested that a documented series of landslides flowed into the river below Cheslatta Falls, and that these slides moved 1,000,000 m^3 of dirt, silt and gravel into the river. The landslides were probably caused by excessive flows diverted into the Cheslatta River during construction and operation of the Kenney Dam (S. McAdam, BC MoE, pers. comm. 2012). This silt slowly washed downstream onto the only known major sturgeon-spawning site in the Nechako River. Apparently, the timing of the arrival of this silt on the spawning site coincided with the beginning of recruitment failure in this population (McAdam *et al.* 2005).

<u>Upper Columbia DU</u>

In 1968 Hugh L. Keenleyside Dam (HLK) divided the Canadian portion of the Columbia mainstem into two segments: a segment above HLK, and a segment below HLK. Abundance in the downstream segment was estimated from mark and recapture data (R.L.&L. 1994) and, over 15 years, 1,504 fish were marked and 492 were recaptured. With time, the estimates became increasingly sophisticated (Irvine *et al.* 2007) and in 1993 the estimate was 1,120 adults (R.L.&L. 1994). In 2006 the number of adults was estimated at 948 (Golder 2005); however, recruitment virtually ceased in the

1970s. In 1981-1986 sturgeon sizes ranged from 60-200 cm FL with a strong mode at 80-100 cm. Ten years later (1997-1998) the size range was 100-220 cm with a mode at 140-160 cm (Upper Columbia White Sturgeon Recovery Initiative, 2002). This suggests an aging population with no recruitment. Irvine *et al.* (2007) estimated the annual natural mortality rate to be about 3%. At this mortality rate, and a worst-case estimate of the 2007 sturgeon numbers, there will be less than 50 pre-dam adults left in 25 years.

Upper Kootenay DU

Monitoring of Kootenay River sturgeon began shortly after the completion of Libby Dam in 1974 and increased in intensity in the early 1990s. Abundance was estimated from multiple mark recapture data using an open Jolly–Seber model (Paragamian *et al.* 2005). In the late 1970s the population was estimated at 7,000. The age structure of the population in the period 1977-1983 was bimodal and ranged from 6-69 years with clear peaks at 8-9 years and 20-25 years. This suggests that recruitment was sporadic and that the last major year-class was sometime in the mid-1970s. By 1996 the population was estimated at 1,470, by 2000 the estimate was 760, by 2002 it was 630, and by 2005 it was 500 and expected to reach less than 400 individuals by 2007. More recently, a revised status assessment (Beamesderfer *et al.* 2009) incorporated spatial structure into the models and changed the estimated population size from 400 to about 1,000 (800-1,400); however, it does not change the long-term outlook for this population. Natural recruitment is not occurring and the population continues to decline at about 4% per year.

Hatchery releases of juveniles started in this DU in 1992. The age structure of the population in 1997-2001 was strikingly variable with one clear mode at 3-10 years (mostly hatchery-reared juveniles but perhaps occasional wild individuals), and another group at 17-85 years.

HABITAT

Habitat Requirements

Much of the data on the habitat requirements of White Sturgeon comes from studies of sturgeon in the Columbia River, and the Columbia is no longer a free-flowing river. Its hydrograph is regulated and there are 32 major dams in the portion of the drainage system originally occupied by White Sturgeon. Consequently, it is not clear whether the habitat-use data derived from this highly modified river represents the natural habitat preferences of White Sturgeon, or if this data simply reflects the best of the habitat that is left. An exception is the data from the lower Columbia River (i.e., the river below Bonneville Dam). Although dikes, dredging, and other human activities have changed this section of the Columbia River, the available habitats are similar to those in the lower Fraser River.

The following habitat descriptions are arranged by life-history stages (e.g., adults, juveniles, young-of-the-year, and larvae). Where there is sufficient information, descriptions of different seasonal habitats are embedded within the different life-history stages.

Adult Habitats

Descriptions of the habitats used by adult White Sturgeon throughout the species' geographic range suggest that they are associated with large rivers, large natural lakes, and large reservoirs (Hildebrand *et al*. 2010; Moyle 2002; COSEWIC 2003; and Wydoski and Whitney 2003). Although age (and size) at maturity varies among rivers (and between the sexes), in terms of habitat use, sturgeon > 100 cm FL are considered adults. Typically, in rivers, adults are described as occupying deep backwaters adjacent to eddies (R.L.&L. 2000; Hatfield 2005); however, their habitat use is not static and, in some populations, they make regular seasonal movements associated with foraging opportunities, spawning sites, and over-wintering sites. Also, in the Upper Kootenay DU there is a habitat dichotomy within this sturgeon group: except for spawning, some individuals spend most of their time in Kootenay Lake, whereas other individuals appear to be river residents (Beamesderfer *et al.* 2009). Also, in the segment of the Upper Columbia DU below HLK there are high-use areas that provide different foraging opportunities (van Poorten and McAdam 2010). Sturgeon show fidelity to these areas and there is evidence that some of these ecological differences reflect different genetic populations (Nelson and McAdam 2012).

For convenience, seasonal habitats are described separately. Also, except for the winter period, adults make active diel movements (Parsley *et al.* 2008). Little is known about these fine-scale diel movements but they may be an important aspect of White Sturgeon biology.

Spawning Habitats

In BC, White Sturgeon spawn during June and July but adults do not necessarily spawn every year. Because of their protracted spawning season, and the small number of spawners, their spawning migrations often are not obvious.

Descriptions of White Sturgeon spawning sites differ strikingly in regulated and unregulated rivers, and most published descriptions pertain to spawning in regulated rivers (e.g., the Columbia and Sacramento-San Joaquin rivers). In these rivers, White Sturgeon usually spawn downstream of the tailraces of dams (Parsley and Beckman 1994; Parsley and Kappenman 2000; R.L.&L. 1994; Golder 2006; Tiley 2006). These sites are often deep (4-10 m) with fast (up to 2.5 $m \cdot s^{-1}$ mean water column velocities), turbulent flows, and coarse (cobbles and boulder) substrates (McCabe and Tracy 1994; R.L.&L. 1994; Golder Associates 2006; Tiley 2006).

Descriptions of undisturbed natural spawning sites are rare. Perrin *et al*. (2003) describe spawning sites in the gravel deposition region of the Lower Fraser River between Hope and Chilliwack. Six spawning sites were identified in this region: five in side channels and one main channel site in a confined reach of the river. The lower Fraser sites differed from those in regulated rivers in that turbidity is higher, water velocities are lower (they averaged 1.8 $m \cdot s^{-1}$), water depths are shallower (3.0-4.5 m), and flow is less turbulent. A major difference is the use of side channels by Fraser River sturgeon. Side channels are important spawning sites in the lower Fraser but they are often absent in regulated rivers. The substrate in the Fraser side channels was mainly cobbles, gravel, and sand, with the highest percentage of sand at the farthest downstream site. The single mainstem site in the lower Fraser was the farthest upstream, and the substrate here was predominately cobbles and boulders.

Data on spawning sites in the middle and upper portions of the Fraser system are sparse, although tagging data (R.L.&L. 2000) hint that spawning may take place at sites where tributaries enter the river's mainstem (Table 4). The confirmed spawning site in the Nechako River is located in a small area of braided channels near Vanderhoof (Liebe *et al.* 2004; Sykes 2010). This Vanderhoof site is now embedded with silt from the downstream transport of fine substrates. This probably was a result of changes in hydraulic erosion upstream associated with the construction of the Kenney Dam (S. McAdam, BC MoE, pers. comm. 2012). Like the Kootenay River site mentioned below, the Nechako River site is still used by spawning sturgeon; however, there is little evidence of successful recruitment (Sykes 2010).

One site on the regulated Kootenay River is of special interest in regard to the characteristics of White Sturgeon spawning sites. Flow in the Kootenay River was regulated when Montana's Libby Dam became operational in 1975 and since the early 1980s, or perhaps earlier (Duke *et al.* 1999), recruitment failure has been a problem for the Kootenay population. Flow augmentation (an attempt to match water temperature and flow to the natural hydrograph) was started in 1995. In that year, 136 eggs were recovered in an 18 km reach of the river on the U.S. side of the border near Bonners Ferry, Idaho. This site is a little downstream of a transition in gradient where average water velocity changes to less than 0.3 $m \cdot s^{-1}$ from 0.6 $m \cdot s^{-1}$, and the substrate changes from cobble and gravel to sand (Rust and Wakkinen 2009). Eggs, and occasional larvae, are still collected at this site; however, survival is low and there is no evidence of natural recruitment from the site. Recently, coring data revealed that about a metre under this sandy reach there is a cobble and gravel substrate (Paragamian *et al.* 2009). It is possible that these sturgeon are spawning at a traditional (pre-dam) site, and this suggests that White Sturgeon remain faithful to specific spawning sites even after the hydraulic and substrate conditions are no longer suitable (Paragamian *et al.* 2009). Recent work (Rust 2011) suggests it may be possible to translocate these adults in spawning condition to a more suitable adjacent upstream site.

Foraging Habitats

Adult White Sturgeon live a long time, grow to a large size, and the females are extremely fecund. This life-history strategy requires major energy inputs but, paradoxically, *in situ* productivity is not high in most rivers where these fish breed. These rivers, however, support major runs of anadromous fishes that bring large amounts of marine-derived energy into these drainage systems. Consequently, the foraging habitats used by adult sturgeon in these systems change with the migratory progress of their major food sources.

Thus, in the lower Fraser River in the spring, sturgeon move downstream from overwintering sites to exploit Eulachon (*Thaleichthys pacificus*). Now, Eulachon only spawn in the river below Mission so, when the Eulachon are present, adult sturgeon forage in the lower reaches of the river. In the late summer and fall, when the salmon start running, the adult sturgeon move upstream. These spring downstream and fall upstream movements are well documented (see Nelson *et al.* 2010). As far as is known, the lower Fraser sturgeon do not follow the salmon runs through Hells Gate; however, they do follow Chum Salmon (*Oncorhynchus keta*) into Pitt and Harrison lakes and forage at sites within these lakes.

One insight provided by Whitlock and McAllister (2009) is the presence of significant differences in the length classes and seasons of the estimated movement rates in lower Fraser White Sturgeon. These suggest that there are differences in seasonal movement patterns among the different life history stages. This heterogeneity in seasonal movement patterns makes it difficult to generalize about White Sturgeon habitat preferences.

For sturgeon populations above Hells Gate the major salmon runs are Sockeye Salmon (*O. nerka*) and Chinook Salmon (O*. tshawytscha*) and, again, sturgeon follow these species into large tributaries and big lakes. Anadromous Pacific Lampreys (*Entosphenus tridentatus*) also ascend the Fraser River as far upstream as the lower Nechako River, and at one time they may have been an important food source for sturgeon. Many of the large lakes in the Nechako system also support another important sturgeon food source: Kokanee (*O. nerka*, non-anadromous Sockeye Salmon).

In the upper Columbia system, before Grand Coulee Dam was completed, Chinook Salmon migrated as far upstream as Windemere Lake (Nisbet 1994). Sturgeon probably followed this run at least as far upstream as Kinbasket Lake and perhaps as far as Spillimacheen (Prince 2001). Originally, Chinook Salmon runs also occurred in the Pend d'Oreille and Kootenay rivers and there is reliable evidence that sturgeon followed these runs into smaller tributaries (i.e., the Salmo and Slocan rivers).

Historically, there were no salmon runs in the Kootenay River above Bonnington Falls, but there are native Kokanee. In the Kootenay DU sturgeon are concentrated in the most productive portion of the lake: the area adjacent to the delta and wetlands where the Kootenay River flows into the lake. In the fall, however, some sturgeon move to the Duncan Lake Delta to forage on spawning Kokanee (R.L.&L. 1998; Neufeld and Rust 2010) and, perhaps, the Pygmy Whitefish (*Prosopium coulterii*) that congregate in this area in the late fall.

In summary, adult White Sturgeon exploit highly mobile prey which are a critical resource.

Overwintering Habitats

When water temperature drops below 7ºC (usually in early winter) White Sturgeon become inactive and they congregate in specific overwintering areas (Table 5). In the lower Fraser River, these areas are characterized by deep water > 8 m, silt or silt and sand substrates, and slow water (relative to the main channel) (Glova *et al.* 2009, Neufeld *et al.* 2010). Fish tagged in these overwintering areas usually return to the same site year after year (Glova *et al.* 2009). This suggests a high degree of fidelity to specific overwintering sites.

Table 5. White Sturgeon overwintering sites.

River	Overwintering site	River kilometres*	Location & type
Lower Fraser DU			
	Port Mann Bridge	34 km	Abutment pool
	Douglas Island	47 km	Mouth of Pitt R.
	Pitt R.	8.5 km	Upstream of mouth with Fraser R.
	Pitt R. Ernie's Hole	11 km	Upstream of mouth
	Sturgeon Slough, Pitt R.	13 km	Upstream of mouth
	Golden Ears Bridge	65 km	Abutment pool
	Stave mouth	75 km	Eddy pool
	Matsqui	82 km	Side channel
	Hatzic Eddy	91 km	Eddy pool
Upper Fraser DU			
Middle Fraser	Nahatlach	233 km	Deep eddy at confluence
	Stein	272 km	“
	Texas	321 km	“
	Bridge	343 km	“
	French Bar	426 km	“
	Chilcotin	482 km	“
	Williams	535 km	“
	Cottonwood	698 km	“
	Blackwater	728 km	“
Upper Fraser	McGregor	895 km	Eddy at confluence
	Bowron	910 km	“
	Longworth	948-950	Deep eddy
Nechako	Hutchinson Ck.	67 km	Eddy at confluence
	Sinkut R.	115-117 km	MS & confluence eddies

River	Overwintering site	River kilometres*	Location & type
Upper Columbia DU	Waneta Eddy	0.5 to 1.0 km above U.S. border.	Deep eddy at confluence
Segment below HLK	Ft. Shepherd Eddy	5 km	Deep eddy
	Kootenay Eddy	44 km	"
	Brilliant Pool	2.8 km	Tailrace
	Area below HLK	54-55 km	"
Segment above HLK	Big Eddy	283 km above U.S. border	Deep eddy
	Beaton Flats**	168 km	Deep area off the mouth of Beaton Arm.
Upper Kootenay DU	Creston Delta, Kootenay Lake	170 km	Deep pool

*River kms are measured from the downstream boundary of the DUs.
**There may be other overwintering areas at river mouths in Arrow Lakes.

In other parts of the Fraser system, the movements of radio-tagged sturgeon increase in the fall and then become inactive from October to March (R.L.&L. 2000). Most of these inactive sturgeon were located in deep eddies with relatively calm water near the eddy centres (e.g., the “Grand Canyon” area in the upper Fraser River, Lheidli T’enneh 2009).

In the lower Columbia River, White Sturgeon moved upstream out of a study area in the winter and returned downstream in the spring (Parsley *et al.* 2008). Presumably the upstream movements were to overwintering sites. In the spring these fish reoccupied the areas where they were initially tagged. Again, this suggests some fidelity to specific areas. In the upper Columbia (HLK to the US border) there are four areas that sturgeon use year round. These are the area below HLK, the Kootenay Eddy at the confluence of the Kootenay and Columbia rivers, the Fort Shepherd Eddy, and the Waneta Eddy. Sturgeon appear to over-winter (i.e., they are inactive) in all four areas. These areas are characterized by deep water (> 15 m), large eddy pools with strong counter currents along the eddy margins but relatively calm (< 0.3 $m \cdot s^{-1}$) water and sand or fine gravel or silt substrates in the centre of the eddy (R.L.&L. 1994).

In the Kootenay River, Neufeld and Rust (2010) identified the Creston Delta as an overwintering site (i.e., areas with low sturgeon mobility in the late fall and winter). As a generalization, adult sturgeon overwintering sites appear to be associated with deep (> 10 m) eddies and backwaters with slow currents (often with reverse flows), and fine substrates.

Juvenile Habitats

Depending on food availability, water temperature, and length of the growing-season, juvenile White Sturgeon range in size from 20 to 150 cm, but at fork lengths above 50 cm their habitat use appears to be similar to that of adults. Most descriptions of juvenile habitats are based on hatchery-released one- or two-year-old sturgeon (Ireland *et al.* 2002; Young and Scarnecchia 2005; EDI 2006; and Golder 2009a, 2010). Hatchery-reared sturgeon grow faster than wild sturgeon and, typically, they are released in the fall of their first year or the spring of their second year. They are usually 20-35 cm in fork length when released. In contrast, wild juvenile sturgeon, at least in the lower Fraser River, usually are less than 14 cm at the end of their first growing period (Glova *et al.* 2010). Consequently, if size influences juvenile survival, the high survival rates of hatchery-released juveniles may not occur in juveniles that are hatched in the wild.

During the summer months in the lower Fraser River, Lane and Rosenau (1995) found juvenile sturgeon in both main river channels and peripheral areas (sloughs, side channels, and backwaters). More juveniles were caught in areas with depths > 5 m than in areas with depths < 5 m. They also found that flow was an important component of juvenile White Sturgeon habitat. At high-use sites the water was turbid and velocities were low (0.04 to 0.35 $m \cdot s^{-1}$). The substrates were sand, silt and clay. Temperature also seemed to be important. Juveniles moved into the sloughs in the spring and out in the fall. Emigration from the sloughs occurred when surface temperatures dropped to 13-15ºC. Another summer study in the same region found concentrations of juveniles (mostly 20-50 cm FL) at similar lower Fraser River sites. Again, these areas were usually > 5 m deep with fine silt and clay substrates and multidirectional currents with velocities < 0.05 $m \cdot s^{-1}$ (Bennett *et al.* 2005). The survival rate of these juveniles was estimated at 0.189.

In the fall (September to November), Glova *et al*. (2008) found juvenile sturgeon (one or more years old) distributed from the river's estuary upstream to the Sumas area: a total distance of about 94 river-km. Juveniles were not uniformly distributed over this distance. There were hotspots where concentrations of juveniles were consistently higher than in surrounding areas. These hotspots shared similar characteristics. They were usually < 5 m deep, the water velocities were relatively low, and the substrates were silt or a mix of silt and sand. The juveniles also appeared to favour side channels, side pools, backwaters, and nearshore mainstem channels.

Hatchery-reared juveniles (mean fork lengths of 20-32 cm) released at several sites in the upper Columbia River (above HLK) appeared to respond to water velocities: those released in relatively fast-water areas moved downstream (at 21 km per day) and settled in slower (< 0.5 $m \cdot s^{-1}$) deeper (> 10m) waters with fine substrates (Golder 2010). In contrast, fish released in slower water areas did not move downstream as rapidly.

In the Columbia system below HLK, hatchery-reared juveniles released in fast water areas moved to slower (< 0.5 $m \cdot s^{-1}$) deeper (> 15 m) water with a substrate of small gravel and fines (Golder 2009a). Again, juveniles released at slow water sites tended to stay near the release site. The average (for 5 different years) six-month juvenile survival rate was estimated at 0.28.

In the Kootenay River, Neufeld and Rust (2009) followed a sonic-tagged hatchery release of one-year old juveniles (26-34 cm). Those released in high gradient areas moved downstream immediately, whereas those released in a low gradient area stayed near the release site for 25 days before moving downstream. Preferred holding areas had slow currents (< 0.04 $m \cdot s^{-1}$), and relatively deep mainstem channels with sand and silt substrates.

In summary, juvenile sturgeon appear to favour relatively slow water (usually < 0.5 $m \cdot s^{-1}$) with fine substrates. Water depth does not seem to be critical, and in the Kootenay River a negative relationship between the first year survivals of hatchery released fish and the density of juveniles suggest that survival of the smallest juveniles may be density dependent (Justice *et al*. 2009).

Young-of-the-Year Habitats

The ecology of young-of-the-year (Y-O-Y) White Sturgeon is still a mystery. Persistent recruitment failure is a characteristic shared by most seriously endangered White Sturgeon populations; however, the ultimate causes of recruitment failures are unclear. What is clear is that there is a major bottleneck in recruitment that occurs somewhere between egg release and the size (usually > 20 cm) where juveniles are easily sampled. Although information derived from laboratory studies about habitat-use by hatchlings is available, aspects of their first year of life in nature are essentially unknown.

In the laboratory, newly hatched larvae react negatively to light and they shelter in the substrate during the day. Preference tests involving pea-gravel, gravel, and bare substrates suggest early embryos prefer pea-gravel (average size 12 mm) and gravel (average size 22 mm) over bare substrates (Bennett *et al.* 2007). After about two weeks the embryos became tolerant of light and began to forage off the bottom during the day (Kynard *et al.* 2010). Increases in water velocity appear to trigger dispersal in older hatchlings and, in the laboratory young sturgeon prefer dark habitats during the winter (Kynard *et al.* 2007).

McAdam (2011) examined the effects of substrate size, water velocity, and days after hatching on interstitial hiding and drifting in White Sturgeon larvae. Over porous substrates and low water velocities (4 $cm \cdot s^{-1}$) interstitial hiding began 2.0-13.3 seconds after larvae (0-6 days after hatching) were released into a flow tank. In contrast, larvae drifted in response to non-porous substrates (sand < 0.2 cm and embedded cobbles). He suggested that, in the wild, yolk sac larvae probably hide in the substrate close to spawning sites.

Observations of larvae in the wild are rare. Parsley *et al*. (1993) collected yolk-sac larvae in the lower Columbia River at depths of 4-29 m and mean water column velocities ranging from 0.7-2.7 $m \cdot s^{-1}$. The substrate was sand. At about 25 mm the larvae metamorphose into small sturgeon (Gadomski and Parsley 2005b). After metamorphosis the habitats used by wild young sturgeon are poorly known. Using a trawl net in the lower Columbia River, Parsley *et al.* (1993) caught Y-O-Y White Sturgeon 2.0-3.2 cm TL (Total Length) in low velocity, deep (9-38 m) waters over sand substrates. In the lower Fraser River, a Y-O-Y sturgeon (35 mm FL) was caught near the mouth of the Sumas River by seining at night over fine sand-gravel substrates. Introductions into the wild of large numbers of newly metamorphosed hatchery-reared sturgeon eventually may provide clues about this critical first year of life.

Habitat Trends

After the arrival of Europeans, White Sturgeon habitats steadily declined in both extent and quality; however, this downward trend has slowed in recent years and there have been no major declines in sturgeon habitats since the last status assessment (COSEWIC 2003). Apparently, the frenzy of dam building, diking, and industrial expansion that characterized the post-war period is easing off. No new dams have been built in the Columbia River system since the 1970s, and there have been no serious proposal for dams on the Fraser River since the 1950s. In addition, federal and provincial legislation now provide some protection for water quality and the required habitats of species at risk such as White Sturgeon.

Although the trend in habitat degradation has slowed, it has not stopped and it is unlikely to stop. This is because the force that drives habitat loss in the Fraser and Columbia drainage basins is human population growth. The number of humans in the Pacific Northwest and in British Columbia is estimated to grow exponentially from now to 2100 (Lackey *et al.* 2006), and more people means increasing industrial development and pollution as well as higher demands on land, natural resources, and energy. Inevitably, this human population trend will lead to the incremental loss of sturgeon habitat.

BIOLOGY

Life Cycle

Spawning period

White Sturgeon usually spawn in the late spring or summer. Apparently, rising water temperatures at, or shortly after, peak river discharge trigger spawning. In the Sacramento River, spawning begins in late February when water temperatures range from 8-19°C and peak spawning occurs at about 14°C (Moyle 2003). In the lower Columbia River spawning occurs from April through July at water temperatures ranging from 9-15°C. Peak spawning also occurred at about 14°C (Wydoski and Whitney 2003). In the mainstem Columbia River above Grand Coulee Dam, but below Hugh L. Keenleyside Dam (HLK), the spawning period extends from June 7 to July 25 at water temperatures ranging from 14.5-21.5°C. Farther upstream (above HLK) in the mainstem Columbia River, spawning was observed at a site about 6 km below Revelstoke Dam (Tiley 2006; Golder 2008). Spawning started on July 31 (water temperature 8.3°C) and ended on August 21 (water temperature 11.1°C). In the upper Kootenay River spawning occurs at 8-12°C (Paragamian and Wakkinen 2002). In the lower Fraser River, spawning occurs from mid-June to late July at water temperatures ranging from 15.6-19.4°C (Perrin *et al*. 2003). Spawning was observed in the Nechako River in mid-May at water temperatures between 13-15°C (Liebe *et al.* 2004).

Spawning behaviour

Little is known about the actual spawning behaviour of White Sturgeon, although several authors (Parsley *et al*. 1993; Perrin *et al.* 2003) have commented on surface activities (e.g., breaching and rolling) by large sturgeon during the spawning season and in the vicinity of known spawning sites. This behaviour may represent some form of pre-spawning displays. Multiple spawning events (2-12) at the same site are common; however, each spawning usually involves different females (Golder 2006; Tiley 2008). This suggests that gravid females spawn all their eggs at once and, although more than one male may be involved in some spawnings, microsatellite analyses of progeny obtained from a large number (157) of mixed individuals indicate that most families are derived from a unique pair (Rodzen *et al*. 2004).

Apparently the eggs and sperm are released in the water column, and the fertilized eggs are broadcast over a wide area. The eggs are adherent and denser than water so they quickly sink to the bottom and stick to the substrate. The only recorded description of White Sturgeon spawning behaviour comes from the Nechako River. What follows is paraphrased from Liebe *et al.* (2004). In mid-May an aggregation of large sturgeon was noted just downstream of the Vanderhoof Bridge, and spawning was observed from a helicopter on May 18, 2004. At this time, some of the sturgeon grouped into pairs and some were in groups of three or four. Most of the pairs included a small fish (a male?) adjacent to a larger fish (a female?). The groups of sturgeon usually contained one large fish (a female?) and two or three smaller fish (males?). The males appeared to jostle for position alongside the female. A small male was observed making crossing-overs across the caudal peduncle of a large female (i.e., repetitive shifts from one side of the female to the other side). When gamete release was observed, the male tilted its ventral surface towards the female (presumably placing his vent close to that of the female) and then rapidly undulated his body and released milt (Liebe *et al.* 2004).

Fecundity

The fecundity of sturgeon is legendary and, like many fishes, the number of eggs produced by sturgeon increases as an ascending curvilinear function of body size. Actual egg counts per female are, however, rare. Wydowski and Whitney (2003) gave some estimates of egg numbers in lower Columbia River females; a 1.0 m female contained 61,500 eggs while a 2.8 m female contained 4,500,000 eggs.

Incubation and larval period

The diameter of fertilized eggs ranges from 3.0 to 3.5 mm and under controlled temperature conditions (15ºC) they hatch in 6.5 days (Wang *et al.* 1985). The following account of larval behaviour is from Kynard *et al.* (2010). Temperature was controlled during egg incubation (14ºC), and during larval rearing the temperature was held at 16ºC. Newly hatched larvae avoid light and seek shelter in the substrate. At this stage they are a uniform grey colour. As they age the larvae gradually become photopositive and develop a distinctive black tail. By day 13 they begin to forage during the day and at night swim up into the current and drift downstream. Under laboratory conditions, Kootenay River larval sturgeon showed a strong downstream dispersal response for about 21 days. In nature, the length of this dispersal period is unknown and probably varies with temperature and locality. At about 60 days (post hatching), the larvae develop into small sturgeon; however, they do not develop their scutes until they reach about 25 mm TL (Gadomski and Parsley 2005a).

Growth

As adults, White Sturgeon grow relatively slowly but they are long-lived. Consequently, they have the potential to reach a large size, and the largest White Sturgeon recorded from the Fraser River was a bit over 6 m long and weighed about 800 kg (Glavin 1994). Nowadays, such giants are rare. Occasionally, however, sturgeon of between 3-4 m FL are still caught in the lower Fraser River (Nelson *et al.* 2004).

Age-growth curves exist for the six Canadian groups of sturgeon (R.L.&L. 2000; Paragamian and Beamesderfer 2003). In the Fraser DUs, the highest growth rates occur in the lower river and lowest growth rates are found in the upper Fraser and Nechako rivers (Figure 8). These graphs are sensitive to the method used to age the fish: typically, sturgeon are aged by counting the annuli on cross-sections of the enlarged leading ray of the pectoral fin. Paragamian and Beamesderfer (2003) compared age-growth curves obtained from pectoral ray cross-sections with growth increments gained from mark and recapture data. Their results indicate that the fin ray method underestimates age in small fish and overestimates age in large fish (Paragamian and Beamesderfer 2003). Still, the available growth curves are a useful way of illustrating differences in growth rate, and clearly show that growth rate in the Lower Fraser DU differs from that in the Upper Fraser DU as well as those from the two DUs in the Canadian portion of the Columbia system (Figure 8).

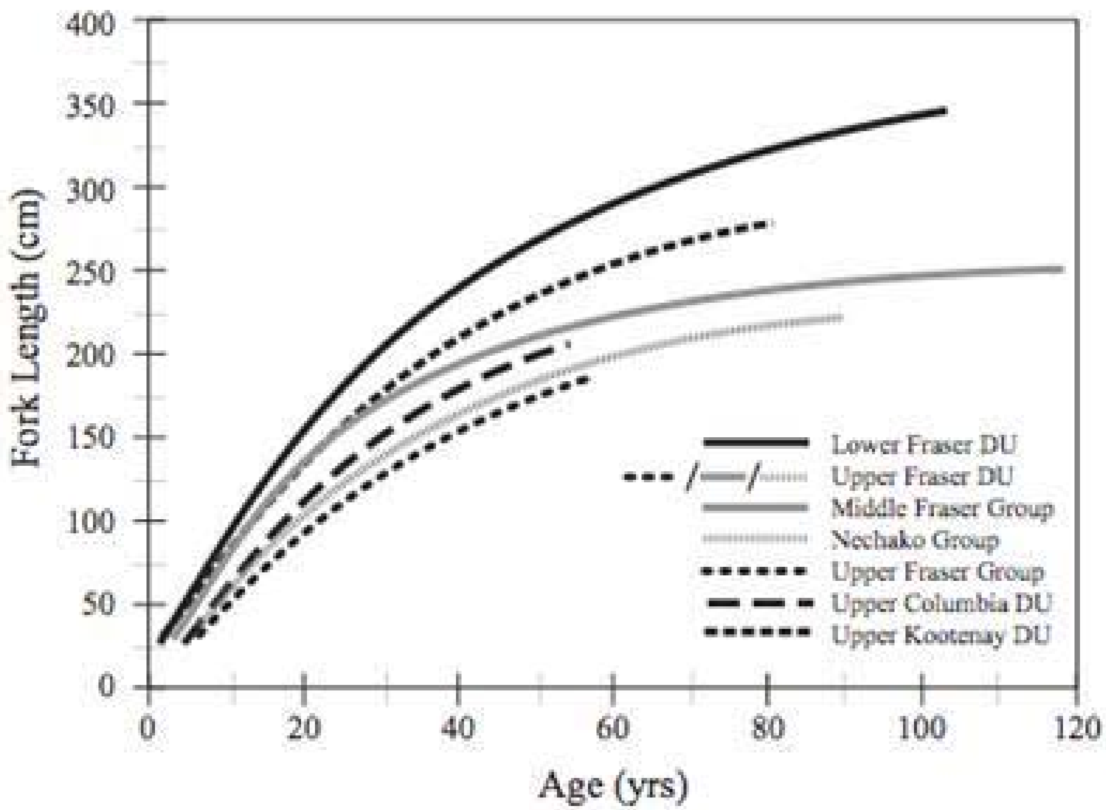

Figure 8. Growth curves for different groups of White Sturgeon in Canada.

Maturation

White Sturgeon are slow to mature and their ages at first maturity vary within and among populations. In the Lower Fraser DU, the youngest mature males were estimated at 11 years, and the youngest mature females at 26 years (Semakula and Larkin 1968). Less age-at-maturity information is available on sturgeon in the Upper Fraser DU, but the existing data suggest that males probably mature in their late teens or early 20s, and females in their late 20s (R.L.&L. 2000). A similar pattern occurs in the Columbia system: males in the lower Columbia River (below Bonneville Dam) first mature in 9-16 years and females at 13-16 years (Wydoski and Whitney 2003). In populations where recruitment failure is a problem (i.e., in the Nechako Sturgeon Group and in the two segments of the Upper Columbia DU), ages are available only for mature fish. Thus, in the Nechako River the youngest recorded male was age 25 and the youngest female was age 35. In the Upper Columbia DU, the youngest male was age 16 and youngest female was age 27 (R.L.&L. 1994). In the Upper Kootenay DU the youngest male was 16 and the youngest female was 22.

Lifespan

White Sturgeon are long-lived and most populations contain a small number of remarkably old fish. In recent years, the age of the oldest sturgeon in the Lower Fraser DU was estimated at 118 years (M. Rosenau, BCIT, pers. comm. 2011). Although sturgeon of such advanced age are now rare, there are still a few individuals in the 80- to 90-year-old category in most populations. The oldest age recorded from the Middle Fraser Sturgeon Group is also 118 years (R.L.&L. 2000); for the Upper Fraser Sturgeon Group it is 53 years (Lheidli T'enneh 2009), and 99 years for the Nechako Sturgeon Group. In the Upper Columbia DU, downstream of HLK, most sturgeon are over 30 years old and some exceed 80 years of age. In the Upper Kootenay DU the oldest individual was aged at 85 years.

Generation time

Given the different size-at-age relationships amongst sturgeon from the different DUs (Figure 8) and assuming a minimum size at first reproduction of 160 cm fork length (S. McAdam, pers. comm. 2012), an approximate generation time of 35 years for the Lower Fraser DU and 40 years for all other DUs has been estimated. The latter estimate has been adopted by the White Sturgeon Recovery team. Note that applying method 2 of the IUCN guidelines produces estimates of between 40-50 years assuming an annual mortality rate of 0.04 and unchanging fecundity with age and no senescence. Both of the latter factors likely change with age in the White Sturgeon; consequently, the estimate of 40 years was retained. An estimate of 35 years was used for the Lower Fraser DU given apparently sustained recruitment, faster growth, and a generally younger age structure than in the other DUs.

Reproduction

Age- and length-frequency distributions for the Canadian populations indicate regular recruitment occurs in the mainstem Fraser River (R.L.&L. 2000; Nelson *et al.* 2004; Lheidli T'enneh 2009); however, there is some evidence of a declining trend in recruitment in the Lower Fraser DU (Figure 9). Here, the 40-59 cm size group has declined by 79% since 2004 (Nelson *et al*. 2012). Although this downward trend is worrisome, it is only obvious in the smallest size group that is regularly sampled, and estimates for this size group may be more sensitive to annual differences in movement patterns or subtle changes in sampling procedures than sturgeon in older age groups.

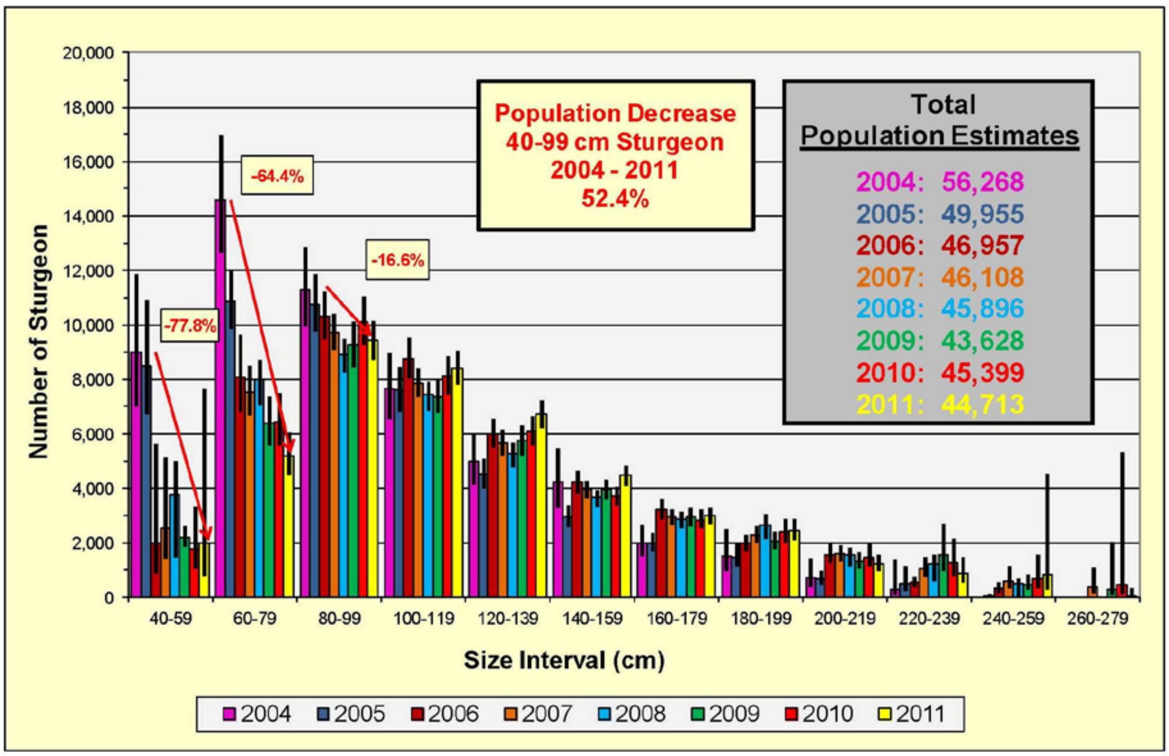

Figure 9. Estimated total numbers of White Sturgeon and those in different age classes in the Lower Fraser DU, 2004 to 2011 (after Nelson *et al.* 2012). Mature fish are typically those > 160 cm in total length.

Data for sturgeon in regulated systems (i.e., Nechako, Columbia, and Kootenay rivers) indicate persistent recruitment failure. The Nechako River Sturgeon Group is aging, and only a few fish are younger than 30 years (Figure 7). Recruitment reconstruction (Korman and Walters 2001) indicates recruitment declined slowly as the Knewstubb Reservoir filled, and then dropped precipitously in 1964 and failed in the late 1960s (McAdam *et al.* 2005). In the Nechako, it appears that habitat changes (e.g., siltation of spawning sites) are a major contributor to recruitment failure. Although some fish still spawn within the system, natural recruits are rare (Liebe *et al.* 2004; Sykes 2010).

In the Upper Columbia DU, regular spawning events continue to occur in the HLK reach (Golder 2006) and at a site about 6 km downstream of Revelstoke Dam (Tiley 2006); however, natural recruitment is rare or non-existent. Similarly, in the Kootenay DU, some spawning occurs but natural recruitment also is rare (Rust and Wakkinen 2009).

Physiology and Adaptability

<u>Physiology</u>

Dissolved gasses

Total Gas Pressure (TGP), Gas Bubble Trauma (GBT), and Dissolved Gas Super-saturation (DGS) are potential problems for the early life history phases of White Sturgeon in impounded rivers (Counihan *et al.* 1998). Spills from dams can result in TGP levels >125% (Hildebrand *et al*. 1999): the recommended maximum gas pressure is 110%. For White Sturgeon, larvae appear to be the most sensitive stage for both gas bubble trauma and dissolved gas super-saturation (Counihan *et al*. 1998) and, in the Columbia River, spills of water at dams have caused super-saturation of atmospheric gases. In Canada, only water spills at Waneta Dam could potentially cause high levels of TGP (Golder Associates 2009b).

Pollutants

Significant sources of pollution occur in the Canadian portion of the Columbia River: municipal sewage treatment facilities, the Lead-Zinc smelter at Trail and the pulp mill at Castlegar, as well as a number of abandoned and inactive mining properties. Krause and Webb (2006) provide a summary of the levels of potentially toxic metals and polychlorinated biphenyls (PCBs), chlorinated pesticides, dioxins (PCDDs), furans (PCDFs), and polybrominated diphenyl ethers (PBDEs) in upper Columbia White Sturgeon. Of the 30 metals analyzed, 11 were below the minimum detectible level, 10 were at detectable but low levels, and nine were at a sufficient level to be of concern. Although not a metal, selenium was viewed as having the potential to bioaccumulate.

Most organochlorides, chlorinated pesticides and PCBs were at concentrations too low to have detectable physiological effects; however, the PCBs had some potential to affect egg and larval survival. Also, other lipophilic contaminants can accumulate throughout life and, given how long sturgeon live, they may be a problem for old adults (Feist *et al.* 2005).

Generally, contaminant levels in the Fraser River system are similar to, or lower than, those measured in other large North American rivers and, relative to the Columbia River, the Fraser River is not heavily polluted. Nonetheless, there are concerns about pollution in the Fraser mainstem between Prince George and Quesnel, and in the tidal area of the lower Fraser River. There are five major pulp-mills on the mainstem Fraser River. They all produce potentially toxic effluent and, although the dilute effluent is not highly toxic to young Pacific Salmon, these fish are only exposed to the effluent for a short time (usually less than a year). Sturgeon, however, can be exposed to the effluent for years and the physiological effects of long-term exposure are unknown (MacDonald *et al.* 1997).

In the lower Fraser River the main concerns are agricultural and urban runoff, pesticides, wood preservatives, toxic metals, and anthropogenic compounds in sewage (Johannessen and Ross 2002). These contaminants are at significantly higher levels downstream of Mission than at a reference site upstream at Agassiz.

Sediment

Silt is implicated in two of the three Canadian White Sturgeon areas where persistent recruitment failure is a problem (McAdam *et al*. 2005, Paragamian *et al*. 2001). In a laboratory study, Koch *et al*. (2006) demonstrated that egg survival was negatively correlated with the duration of sediment cover, and that sediment cover also delayed hatching and resulted in smaller larvae. Their results suggest that sediment cover may be an important cause of early mortality in situations where spawning sites are covered in fine sediments.

Adaptability

Unlike salmonids, we know little about the specific adaptations of White Sturgeon to local conditions, and some of what we know suggests that they are slow to adapt to environmental changes. For example, they persist in using spawning sites where anthropogenic activities have rendered the sites inappropriate for reproduction (Liebe *et al.* 2004; Paragamian *et al.* 2009). Still, it appears that they can be induced to use adjacent sites with the appropriate conditions for successful reproduction if humans introduce them to the new site at the right time (Rust 2011). This suggests that they are not incapable of adapting, but only that the speed of evolutionary adaptation is sensitive to generation time (among other things), and White Sturgeon have a relatively long generation times (20-40 years). Also, because adults live for a long time, generations can overlap for 50 or more years and intergenerational mating can slow the speed of evolutionary adaptation.

Dispersal and Migration

Dispersal

Dispersal implies movement away from a source and in rivers dispersal is often unidirectional (i.e., dispersal does not necessarily imply a return journey). The most obvious dispersal movement in White Sturgeon is the downstream dispersal of larvae from spawning sites. Coutant (2004) hypothesized that downstream dispersal of eggs and larvae into seasonally flooded riparian habitats is essential for successful recruitment into White Sturgeon populations. Recently, van der Leeuw *et al.* (2006) validated a critical assumption of this riparian habitat hypothesis — they demonstrated that in the lower Columbia system both eggs and larvae drift downstream into seasonally flooded riparian habitats.

In many fishes, dispersal can result in range expansion and the founding of new populations; however, this does not seem to happen regularly with White Sturgeon. White Sturgeon enter virtually every river and bay between the Columbia River and San Francisco Bay as well as every river and bay between the Columbia and Fraser rivers, yet none of these marine forays appear to have established new populations. Nonetheless, it must happen occasionally, since 20,000 years ago the Fraser River system was under ice.

If marine wanderers originating from the three different rivers spawn in a river other than their natal river, this could introduce new alleles into the recipient river. This assumption is supported by the documented movements of adults among the three known spawning rivers, and the observation (Anders and Powell 2002) that sturgeon inhabiting the lower reaches of these three rivers are, genetically, more diverse than sturgeon from upstream areas.

Migration

Migration implies a directional, and usually seasonal, movement between habitats. Also, it normally includes a return migration. In most sturgeon populations there is a spawning migration and, in the Canadian populations, a migration to overwintering sites. The consistency over years in the timing of these movements, and the observation that individual sturgeon show fidelity to both spawning (Paragamian *et al.* 2009) and overwintering (Parsley *et al.* 2008) sites suggest these movements are true migrations.

In the Lower Fraser DU, there is evidence for different seasonal movements by different size classes of White Sturgeon (Whitlock 2007). Adults move downstream in the spring and then move upstream in the summer. These directional movements are seasonally consistent and well documented (Nelson *et al.* 2011) foraging migrations. In contrast, the forays that White Sturgeon make into marine environments do not appear to be temporally consistent or directed at a specific site or resource. Although these marine forays do not appear to be migrations in the strict sense, not enough is known about their movements to exclude the possibility of marine migrations.

<u>Interspecific Interactions</u>

Prey

Adult sturgeon can grow to several metres in length. To achieve this large size they require abundant prey, and although they lack teeth, adults can ingest large, agile prey (e.g., adult Pacific Salmon). They have big, protrusible mouths that allow them to suck even large prey into their mouths in milliseconds. Also, although their eyes are not well developed, they can detect prey in deep or murky water using chemoreceptors on their barbels and passive electroreceptors on their snouts.

The diets of White Sturgeon change as they grow. When the larvae first start feeding (about 8-14 days after hatch), they forage on the substrate and, in the lower Columbia River, amphipods are their primary prey; however, they also eat ostracods, ceratopogonoids, and oligochaetes (Muir *et al.* 2000). As they grow they add larger prey to their diet and, after metamorphosis, *Neomysis*, chironomids, copepods, and bivalves are added to the diet but amphipods remain an important energy source. As subadults, White Sturgeon start to eat fish: lampreys, Eulachon, Threespine Sticklebacks (*Gasterosteus aculeatus*), and sculpins (Cottidae). As adults their diet consists mainly of fish: when salmon are available they eat salmon, when Eulachon are available they eat Eulachon. They also consume lampreys, Longfin Smelts (*Spirinchus thaleichthys*), salmon eggs and salmon carcasses.

In regions where salmon are no longer available (e.g., above Grand Coulee Dam) the absence of this large input of marine-based energy may have resulted in more localized variation in food availability (van Poorten and McAdam 2010). These authors found local differences in growth rates in two subpopulations within the HLK reach of the Columbia mainstem. They argue that these differences are related to food availability: one subpopulation is in an area that has seasonal aggregations of Kokanee and Mountain Whitefish (*Prosopium williamsoni*), whereas the other subpopulation lacks such aggregations of prey. Similarly, in the Kootenay Lake/River system above Bonnington Falls, White Sturgeon gather in autumn at creek mouths where Kokanee and Mountain Whitefish are spawning. Indeed, White Sturgeon probably exploit any fish species that aggregate at sites that are accessible to sturgeon.

Predators

Except for man, inland populations of adult White Sturgeon have no significant predators and, after reaching a total length of about 40 cm, they are virtually immune from predation. In the lower Columbia River, however, Pinnipeds (seals and sea lions) prey on sturgeon. In 2008 pinnipeds killed at least 607 sturgeon in the lower Columbia River (Stansell *et al.* 2010): 200 of these sturgeon were 61-90 cm long and 21 were > 152 cm. Steller Sea Lions (*Eumetopias jubatus*) were the primary predators on the largest sturgeon. Harbour Seals (*Phoca vitulina*) follow salmon runs as far upstream as Harrison Lake; however, these seals are probably too small to prey on adult sturgeon.

Miller and Beckman (1996) found sturgeon eggs in the stomachs of Northern Pikeminnows (*Ptychocheilus oregonensis*), Largescale Suckers (*Catostomus macrocheilus*), and Prickly Sculpins (*Cottus asper*). In laboratory studies, Gadomski and Parsley (2005a) found that Prickly Sculpin would eat White Sturgeon larvae (14-24 mm TL) but that fewer larvae were eaten under low light condition and the presence of cover. In another laboratory study the same authors (Gadomski and Parsley 2005b) found Channel Catfish (*Ictalurus punctatus*) and Northern Pikeminnows 46-47 cm long would eat 12-13 cm White Sturgeon, whereas Walleye (*Sander vitreus*) of similar length ate almost no sturgeon but juvenile Walleye ate sturgeon up to 6 cm in length. Prickly Sculpin (average size 12.6 cm) consumed sturgeon up to 5 cm in length. Gadomski and Parsley concluded that predation by other fishes is likely a cause of mortality in age-0 White Sturgeon and predation may contribute to the year-class failures that often occur in sturgeon populations.

POPULATION SIZES AND TRENDS

Estimates of the number, and the trends, in the numbers of White Sturgeon are critical components in assessing the status of the different groups of these fish. An earlier Status Report (COSEWIC 2003) concluded that for all groups of White Sturgeon for which appropriate data were available for assessment, declines were evident. The causes of these declines vary among the groups; however, for three of groups of sturgeon — the Upper Columbia and Upper Kootenay DUs, and the Nechako River Sturgeon Group in the Upper Fraser DU — the declines coincide with evidence of recruitment failure (McAdam *et al*. 2005; Irvine *et al*. 2007; Paragamian *et al.* 2009). Adults in all three of these groups continue to spawn, the eggs are fertile, and in the laboratory they hatch successfully (Liebe *et al*. 2004; Golder 2006; Rust and Wakkinen 2009). Still, naturally spawned larvae are rare or non-existent in these groups, whereas introduced hatchery-reared young-of-the-year derived from these same geographic areas, survive in the wild (Golder 2006). This suggests that, although evidence of recruitment failure often is associated with declines, the ultimate cause(s) of the declines are still unclear.

Sampling Effort, Methods, and Abundance

Lower Fraser DU

For over a decade, the FRSCS has published annual estimates of the number of White Sturgeon in the lower Fraser River (Nelson *et al.* 2012). Although some authors (e.g., Walters *et al*. 2005; Whitlock 2007) argue that these estimates are low, a major strength of the FRSCS data is that the data collection protocol is standardized. Consequently, although the estimates may be low, any decadal trends in numbers probably are real (Figure 6). The 2001 estimate for White Sturgeon in the 40-280 cm fork length range was 48,136 fish. This number peaked in 2003 at 58,090 fish and then gradually declined. Since the 2006 estimate of 46,957 the decline has levelled out and the 2011 estimate was 44,713 fish (Figure 6).

Upper Fraser DU

Middle Fraser Sturgeon Group

Middle Fraser sturgeon were monitored between 1994 and 2000 (R.L.&L. 2000). Based on mark and recapture data, the modified Schnabel technique was used to estimate the number of fish. For fish > 50 cm FL the estimate was about 3,700 individuals. No recent abundance estimates are available for this group of sturgeon. Consequently, it is not possible to determine whether the number of sturgeon in this area has declined or remained stable. Nonetheless, the available length frequency and age distribution data suggest that, at least up to 2000, there was regular recruitment in this group (Figures 7 and 8).

Upper Fraser Sturgeon group

Monitoring of sturgeon above the confluence of the Nechako and Fraser rivers began in 1997 (R.L.&L. 2000) and has continued at least until 2008 (Lheidli T'enneh 2009). Based on mark and recapture information, a modified Schnabel technique was used to estimate the number of sturgeon in this region. The 1999 to 2001 data estimated a population size of 815 fish > 50 cm (Yarmish and Toth 2002). The 2007 to 2008 data gives an estimate of 685 fish over 50 cm in fork length (Lheidli T'enneh 2009). The similarity of the two estimates, plus the sturgeon's age structure (4 to 53 years), suggests regular recruitment and a relatively stable, but small (171) group of adults in 2008.

Nechako Sturgeon Group

Since the 1950s, Kenney Dam has regulated water flows in the Nechako River. Sporadic monitoring of Nechako sturgeon started in 1982 (Dixon 1986) and became more intensive in 1995 (R.L.&L. 2000). Recreational catch statistics and mark-recapture data were used to estimate sturgeon abundance. Using the modified Schnabel technique, the total number of sturgeon in the Nechako system was estimated to be 571 fish (R.L.&L. 2000), with the number of adults (100 cm or more) estimated to be 305 individuals (Korman and Walters 2001). The length frequency and age structure data for this region (Figures 7 and 8) suggests recruitment failure; 94% of the fish sampled were > 100 cm in length, and 95% of samples were age-30 or older. The Nechako River is not a closed system (i.e., there are no physical barriers separating this river from the rest of the Upper Fraser DU). Consequently, immigration and emigration between this river and the rest of the Upper Fraser DU is possible and has been documented at least twice (M. Ramsey, BC MoE, pers. comm. 2012).

In 2004 and 2005 the Carrier Sekani Tribal Council in conjunction with EDI (Environmental Dynamics Inc.) conducted a survey of juvenile (< 100 cm) White Sturgeon abundance and distribution on the Nechako River. A total of 13 “new” juveniles were sampled; all of them over 60 cm in fork length. This suggests that there may be some recruitment occurring in the Nechako River system albeit at a low and sporadic level. As a pilot program, from 2006 to 2009, about 14,000 hatchery-reared juveniles were released into the Nechako River.

Upper Columbia DU

Both the Upper Columbia and Upper Kootenay DUs are subject to some hatchery supplementation (which is entirely a U.S. initiative in the Kootenay River), but known hatchery-produced sturgeon have not been used in any of the assessments below. Monitoring of the Upper Columbia DU began in 1990 and continues to the present. Recreational catch statistics and mark-recapture data were used to estimate sturgeon abundance. The HLK Dam divides the White Sturgeon in Upper Columbia DU into two segments: those above, and those below, the dam. The sturgeon in Roosevelt Reservoir (Washington State) complicate abundance estimates for the segment between HLK and the U.S. border. There is a sturgeon-spawning site near Northport, Washington, and some sturgeon tagged in Roosevelt Reservoir move into Canada at the Waneta spawning site, but it is unknown if they actually spawn, Similarly, some sturgeon tagged in Canada also move to Washington at the Northport site (Howell and McLennan 2007). Consequently, the distinction between Roosevelt Reservoir sturgeon and sturgeon in the segment below HLK in the Upper Columbia DU is somewhat unclear although there is evidence of spatial fidelity between fish from the two areas (Nelson and MacAdam 2012).

Most sturgeon in the segment above HLK Dam, but below Revelstoke Dam, are located in the upper Arrow Reservoir (Figure 4). In the past, sturgeon occurred in the Columbia mainstem between the Revelstoke and Mica dams. Although there are no recent reports of sturgeon from this area, a remnant group may still exist.

Segment below HLK

This segment supports the largest number of sturgeon in the Upper Columbia DU. Mark-recapture data gathered in 1993 estimated 1,120 fish (R.L.&L. 1994) in this segment, while in 2003 the estimate was 1,157 fish (Golder 2005). All of these fish were adults: age 30 or older. These sturgeon regularly spawn at two sites: one near Waneta and another in the tailrace of the Arrow Lakes generating station at HLK Dam. A third, less well-known spawning site, is a run near Kinnard. The eggs spawned at the Waneta site are viable (Golder 2006), yet there is no evidence in the last 30 years of natural recruitment. The most accepted current estimate of population size employing an annual mortality rate of 0.04 is 830 fish (Irvine 2007; S. McAdam and G. Wilson, BC MoE, pers. comm. 2012).

Segment above HLK

The abundance estimate for this segment is 52 fish (Golder 2005). All of the fish are adults 38 years of age or older. There is a known spawning site about 6 km below Revelstoke Dam and, perhaps, other spawning sites where large rivers enter the Arrow Reservoirs. The fish continue to spawn and produce larvae, at least at the known spawning site. The eggs and larvae are viable under hatchery conditions (Tiley 2006); however, there is no evidence of natural recruitment in this segment.

Upper Kootenay DU

Monitoring of the Upper Kootenay DU began in the 1970s. At this time the number of sturgeon was estimated at about 7,000 fish and by 2000 the estimate had dropped to 760 fish (Paragamian *et al.* 2005). In 2002 the estimate was 630 fish, and the annual mortality rate was estimated to be about 0.09.

Ages in the Upper Kootenay DU ranged from 6 to 69 years in the period 1977-1983. By 1997-2001 the ages ranged from 3 to 89 years, but the age distribution showed broad peaks at 3-10 and 17-60 years (Paragamian *et al.* 2005). Hatchery supplementation started in 1992, and most of the fish in the smallest age group probably were immature hatchery-reared sturgeon. In 2009 the annual mortality rate was revised to 0.04 (Beamesderfer *et al.* 2009) and the estimated number of adults was 800-1,400 (average of 960) which includes both Canadian and American fish as they act as a single population (S. McAdam, pers. comm., 2012).

Fluctuations and Trends

Lower Fraser DU

There are no fishery-independent data for all four DUs to assess fluctuations in abundance over three or more generations. The best historical data come from the analysis of commercial catch data presented by Semakula and Larkin (1968) which dated back to 1880. In addition, Echols (1995) reviewed the growth, development, and decline of the lower Fraser River sturgeon fishery. These analyses showed a decline from a peak catch in 1897 of around 520 metric tons to values that rarely exceeded 15 metric tons over the next 90 years (the fishery was closed in 1994 only after a series of unexplained mortalities of adult sturgeon appeared in the lower Fraser River – see Rosenau and Angelo 2007). These observations were used to conclude that a substantial decline, likely in excess of 50%, in White Sturgeon abundance had occurred in the lower Fraser River between 1900 and 1994, which was also observed over the same time period in the lower Sacramento River and lower Columbia River fisheries (COSEWIC 2003; Rosenau and Angelo 2007). Walters *et al*. (2006) used stock reduction analyses to estimate that the un-fished, mature population size of mature sturgeon in the lower Fraser was approximately 50,000 fish and has likely declined by at least 50% since the late 1800s. Further, Walters *et al*. (2005) suggested that in terms of egg production (which they argued could be a better measure of reproductive status as it considers age-fecundity relationships), the current Lower Fraser River mature population, although growing, is producing eggs at perhaps only about 10% of the level of the unexploited population.

More recently, Nelson *et al.* (2012) reported a 77% increase in the numbers of adult sturgeon in the Lower Fraser DU (from ~4,550 to 8,090 adults, fish > 160 cm fork length) between 2004 and 2011 although wide confidence intervals on yearly estimates were present and the overall trend was not significant (r = 0.12, P = 0.73). Between 2001 and 2011, however, a significant decline of about 80% (r = -0.86, P < 0.001) was observed in the estimated abundance of immature fish in the 40-99 cm size range (Nelson *et al.* 2012, Figure 9). It is possible that the apparent decline of this size class reflects a switch in sampling gear that focused more on sampling larger size classes (G. Wilson, BC MoE, pers. comm. 2012). Alternatively, the apparent declines could be a result of a natural cycle in reproductive success or some change in the movement patterns of these fish; however, it could also be an early signal of declining recruitment. The only reliable way of distinguishing short-term volatility from a genuine long-term trend is more years of standardized data collection. Over all size classes, there has been a slight decrease of about 20% over the 2004-2011 time period (there is some debate over the veracity of estimates from 2001-2003; Figure 9, r = -0.82, P = 0.013); with fish less than 100 cm declining by 52.4% and mature fish (> 160 cm) remaining stable or showing increases.

Whitlock (2007) employed Bayesian analysis to mark-recapture data and concluded that over a range of parameter values the posterior probability of at least 50% decrease in mature individuals from 1880-2004 was 0.46 (i.e., more than half the probability density was associated with declines of < 50%). While uncertainty remains associated with all these estimates, the decline in mature adults over the last three generations is likely at least 30% and possibly greater than 50%.

Upper Fraser DU

The Nechako Sturgeon Group within the Upper Fraser DU is in serious decline. The proximate cause of this decline is persistent recruitment failure, which began within the last 40 years, but the ultimate causes of the recruitment failures are unknown. The declines in the Nechako River occur in a regulated river, whereas the Lower Fraser DU, and the middle Fraser and upper Fraser Sturgeon Groups embedded within the Upper Fraser DU appear to be stable. These stable groups all reside in an unregulated river, and this suggests some connection between dams and the declines of sturgeon. Recent experimental and hindcasted recruitment reconstructions have provided considerable support for the causal connection between river regulation and declines in sturgeon recruitment (McAdam 2012). Changes in substrate composition associated with dam construction and ensuing river regulation appear to be an important causal mechanism driving recruitment failure. Assuming continuing complete recruitment failure in the Nechako River population and stability of populations in the other components of the DU and the current population sizes of all components, the upper Fraser River DU is projected to decline by a minimum of 27% over the next two-three generations.

Upper Columbia and Upper Kootenay DUs

White Sturgeon within both of these DUs are also in serious decline and are characterized by recruitment failure in these rivers regulated by several hydroelectric dams (e.g., Irvine *et al.* 2007). Wood *et al.* (2007) used a 0.09 annual mortality rate (incorporating natural and angling mortality) of Upper Columbia DU sturgeon to project a minimum decline of 47% over the next 10 years. A revised estimate of the average annual adult mortality rate of 0.027 (range 0.009 to 0.082, Irvine *et al.* 2007) predicted a population of 1,150 fish. A worst-case scenario employing the lower 95% confidence level for abundance (414 fish) and a mortality rate of 0.082 predicts < 50 fish after 25 years and a 43% decline of adults over the next 10 years (Irvine *et al.* 2007).

Paragamian *et al*. (2005) reported over a 90% decline of adult White Sturgeon within the Upper Kootenay DU between 1978 and 2001. Currently, some declining populations of sturgeon are supplemented with hatchery-reared fish which are projected to dominate the adult production within the next 10 years (e.g., Paragamian *et al.* 2005). Given the small number of adults in the declining populations, their relatively long age to first maturity, and their annual natural mortality rate (about 2.7 – 9.0%), it is not clear if the downward trends can be reversed by hatchery programs. Assuming hatchery-reared sturgeon have survival rates at least equal to wild fish, eventual extinction of White Sturgeon can only be prevented if the hatchery program is maintained indefinitely unless the ultimate causes of recruitment failures are reversed (i.e., in large part changes in substrate conditions associated with river regulation, McAdam 2012). Alternatively, it is unlikely that naturally spawned young derived from hatchery sturgeon will have any better first year survival than the original wild fish, the continued operation of the hatchery program is uncertain, and there is considerable lag in time of several decades before hatchery-produced fish will become reproductive. Assuming that recruitment failure continues in these regulated rivers and a minimum natural mortality rate of 0.04, both the Upper Columbia and Upper Kootenay DUs are projected to decline by > 90% over the next two-three generations.

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Rescue Effect

In Canada, the potential for natural re-colonization of White Sturgeon differs between the Fraser and Columbia rivers systems. The range of White Sturgeon in the Fraser River includes some unoccupied habitat and a partial migration barrier (Hells Gate): they occur from the Fraser Estuary upstream to the confluence of the Fraser and Morkill rivers (Figure 3). In contrast, in the Columbia River system, Grand Coulee Dam isolates the Upper Columbia and Kootenay DUs from the rest of the drainage system. The possibilities for natural rescue in the six Canadian groups of White Sturgeon are examined below. Most of the following comments on the potential for rescue are based on evidence (usually tagging data) of movements between DUs. Note, however, this does not mean that individuals that move among DUs necessarily remain, or spawn, in their new DU so the actual likelihood of rescue is highly uncertain.

<u>Lower Fraser DU</u>

The Lower Fraser DU is open to rescue by sturgeon from the Upper Fraser DU (upstream of Hells Gate). A sturgeon tagged in the middle Fraser River near Williams Lake was recovered in the lower Fraser River near Mission (Nelson *et al*. 2007). Thus, downstream movement through Hells Gate does occur. How often this happens is unknown but, as long as there are sturgeon above Hells Gate, recolonization of the lower river from upstream is possible.

Some adult White Sturgeon are known to make forays into the ocean (Veinott *et al.* 1999), consequently the Lower Fraser DU also is open to rescue by way of the sea. Most of the marine forays made by White Sturgeon are local and of relatively short duration; however, about 10% of the Fraser White Sturgeon that go to sea stay out for a longer period of time (Veinott *et al.* 1999), and some may travel great distances. For example, there are records of White Sturgeon tagged in both the lower Columbia River and Sacramento-San Joaquin rivers and recovered, or located, in the lower Fraser River (Nelson *et al.* 2004; Welch *et al.* 2006).

Upper Fraser DU

Middle Fraser Sturgeon Group

There is some confusion concerning the upper boundary of middle Fraser sturgeon. Originally, the boundary was set at the confluence of the Nechako and Fraser rivers (R.L.&L. 2000). This is the boundary used by Smith *et al.* (2002) in their genetic study of the Fraser River sturgeon, and it is also the boundary used in the Fraser River White Sturgeon Conservation Plan (Hatfield 2005), but the Lheidli T'enneh First Nation (2008, 2009) place the boundary about 80 km farther downstream at the confluence of the Fraser and Blackwater rivers. Because there are no substantial physical barriers between Hells Gate and the confluence of the Fraser and Nechako rivers, the exact upper boundary of the middle Fraser population is uncertain. R.L.&L. (2000) also noted that sturgeon are relatively rare in the 80 km reach between the Blackwater and Nechako rivers. This suggests there may be an ecologically significant boundary between middle Fraser sturgeon and the sturgeon farther upstream, although there are documented cases of sturgeon moving between the Middle Fraser and Nechako rivers (M. Ramsey, BC MoE, pers. comm. 2012).

Regardless of the position of the upper boundary, the Middle Fraser Sturgeon Group is potentially open to rescue from upstream given the absence of a complete physical barrier. In addition, the Middle Fraser Group is open to potential rescue from below Hells Gate. At one time Hells Gate was assumed to be an impassible barrier to the upstream movement of sturgeon (R.L.&L. 2000). Recently, however, a sturgeon tagged near Mission in the lower Fraser River was recaptured near Lillooet (Nelson *et al.* 2007). So far, this is the only documented case of sturgeon moving upstream through Hells Gate. Nonetheless, it does show that movement from the lower Fraser upstream into areas above Hells Gate is possible.

Nechako Sturgeon Group

There are no physical barriers between the upper Fraser and Nechako sturgeon; consequently, movements between the two regions are possible. How often this happens is unknown, but there are records (Lheidli T'enneh First Nation 2008) of movements in both directions between these groups of sturgeon. Again, the observation that sturgeon move between the Nechako and upper Fraser rivers does not necessarily mean that they stay, or breed, in their new river, but there is at least one instance of a Fraser River fish moving into the Nechako River and spawning there (M. Ramsey, BC MoE, pers. comm. 2012).

Upper Fraser Sturgeon Group

The absence of physical barriers separating the upper Fraser from both the middle Fraser and Nechako rivers suggests that the upper Fraser could be recolonized from either of these adjacent groups of sturgeon. Tagging data (Lheidli T'enneh First Nation 2008) indicates some movement between the Nechako and upper Fraser rivers. Again, it is not known how frequently these exchanges occur, but such movements and the genetic data of Schreiers (2012, see **Spatial Population Structure and Variability** - *Genetics*) suggest that rescue is possible albeit unlikely especially given current recruitment failure in the Nechako River.

Upper Columbia DU

Although Grand Coulee Dam is impassable, the reservoir above the dam (Roosevelt Reservoir) still contains sturgeon and tagging data show that some fish from Roosevelt Reservoir spawn on the Canadian side of the border. Thus, although the mainstem Columbia between the US border and HLK is potentially open to rescue from Roosevelt Reservoir, fish in the latter are also suffering from severe recruitment failure (G. Wilson, BC MoE, pers. comm. 2012). The sturgeon isolated in Slocan Lake and, perhaps, the impounded area between Brilliant and lower Bonnington Dam, are not open to rescue.

The upper and lower Arrow Reservoirs lie between HLK and Revelstoke dams. They contain a remnant of what once was part of the original Upper Columbia DU (Nelson and McAdam 2012). There is a small boat navigation lock at HLK Dam, but no evidence that sturgeon use this lock, at least in the upstream direction. Thus, the possibility of the rescue of this remnant from downstream is low.

White Sturgeon still spawn at a site about 6 km downstream of Revelstoke Dam (Tiley 2006) and are rumoured to spawn elsewhere in the Arrow Lakes; however, there is no evidence of natural post-dam recruitment. It is also possible that a remnant of original upper Columbia mainstem sturgeon is isolated between Revelstoke and Mica dams. If such a remnant population still exists, there is no indication of natural recruitment in this region and only a remote likelihood of recolonization from downstream.

Upper Kootenay DU

A natural barrier, Bonnington Falls, and five dams (one at the site of the original falls), separates the Upper Kootenay DU from the Upper Columbia DU (Figure 4). Thus, the probability of natural rescue from other Columbia populations is zero. Additionally, the isolated remnant group of sturgeon in Duncan Lake is probably part of the Kootenay sturgeon group. Natural rescue for this remnant is low, although at times movement through Duncan Dam may be possible. Although fish may move downstream into Kootenay Lake and the Kootenay River above Corra Linn Dam from the U.S. portions of the Kootenay River (known as Kootenai in the US), these U.S. fish are likely part of the same biological population.

Although hatchery-produced fish are not relevant to natural rescue, they may stem population declines. All hatchery programs within the Upper Columbia, Upper Kootenay, and for the Nechako group within the Upper Fraser DU used broodstock sampled within their respective DUs (S. McAdam, pers. comm. 2012). The program on the Nechako is no longer operating and that in the Upper Kootenay is a US-driven initiative that typically collects broodstock or feeding fry in U.S. reaches upper Kootenay River and releases fish (at ages ranging from fry to yearlings) in U.S. portions of those rivers while the program in the Upper Columbia DU is run by BC Hydro (S. McAdam, pers. comm. 2012). Some simulations by Paragamian *et al*. (2005) suggest that at estimated adult mortality rates of 9% per year, more than 90% of the fish in the U.S. portions of the Kootenay River are expected to be of hatchery origin by about 2030.

THREATS AND LIMITING FACTORS

Threats

The primary indicator of contemporary decline in the White Sturgeon is recruitment failure. Although the root causes of recruitment failure may differ among the sturgeon groups, some form of habitat degradation probably underlies most of the declines.

Dams and river regulation

The effects of dam construction and ensuing river regulation and their combined effects on spawning and rearing habitat are undoubtedly the most serious contemporary threat to White Sturgeon, especially in the Upper Fraser (Nechako River Group), Upper Columbia, and Upper Kootenay DUs. Recent modelling and experimental work by McAdam (2012) has provided strong evidence of the causal mechanisms behind recruitment failure in regulated rivers. The White Sturgeon is a fluvial species and, although it regularly occurs in large lakes, it requires flowing water to complete its life cycle. With the exception of the Nechako River, dams are not a major problem in the Fraser River system; however, they pose serious problems in the Columbia River system (including the Canadian portion of the river). Within Canada, there are three dams on the mainstem Columbia River, two on the Pend d'Oreille River, and six on the

Kootenay River. Ten of these 11 dams are thought to be impassable, at least in the upstream direction. The one dam (HLK) that theoretically is passable has a small boat lock, but so far there is no indication that sturgeon use the lock to pass upstream. It is known that occasionally large sturgeon pass downstream through this dam. In total, five dead adults, with injuries consistent with passing through the dam, were observed immediately downstream of the dam over a seven year time period (1999-2006) since reporting began in 1999 (Wood *et al.* 2007).

These dams fragment what were once continuous groups of sturgeon, and probably prevent upstream movements between the existing fragments. In some cases, dams convert free-flowing riverine habitats into large reservoirs. In a series of modelling studies Jager *et al*. (2001) and Jager (2005, 2006a,b) examined the cumulative effects of a series of dams on White Sturgeon. The results are not encouraging: increased fragmentation produced an exponential decline in the likelihood of persistence as well as the erosion of genetic diversity within and among the fragments. This appears to be happening in the Canadian portion of the Columbia system. Small, isolated fragments (e.g., those in the Kootenay and Pend d'Oreille systems) are now either extinct or functionally extinct (no longer self-sustaining) and the already low genetic diversity in the extant Upper Kootenay DU (owing to its historical isolation by Bonnington Falls) may be exacerbated by construction of multiple dams in the system (Paragamian *et al.* 2005).

Dikes

European settlement on the floodplains of the lower Fraser River, initiated large-scale land clearing, networks of dikes and drainage ditches, and the conversion of the riparian and floodway regions into agricultural land (Rosenau and Angelo 2005). The largest single modification of the lower Fraser floodplain was the draining of Sumas Lake. Sumas Lake was an important rearing habitat for sturgeon and salmon. The lake was about 40 km^2 in area and expanded to about 120 km^2 during high water. The Chilliwack River, that fed the lake, had its lower portions diverted into a canal (the Vedder Canal) and the lake was drained through a series of dikes, canals, and pumping stations.

There now are more than 300 km of dikes in the lower Fraser Valley, and a less extensive system of temporary dikes in the Prince George region. In the Creston Valley (Upper Kootenay DU), dikes protect about 10,000 ha of what once were wetlands. One effect of dikes on White Sturgeon is that they reduce the number of flow-through side channels and prevent the seasonal flooding of riparian zones. These habitats are thought to be important for spawning and for the survival of eggs and larvae of White Sturgeon (Perrin *et al.* 2003; Coutant 2004).

Dredging

Most dredging on the lower Fraser River is associated with either navigation or flood control; however, except in limited areas dredging is unlikely to reduce flooding risk (Lower Fraser River Hydraulic Model 2006). Dredging in the tidal region of the lower Fraser River is used to deepen channels for shipping. It is unclear what effect this has on White Sturgeon; however, deepening the navigation channels increases the salinity of the bottom water in these channels. Thus, on ebb tides young-of-the-year sturgeon that are too small to survive salinity changes (Amiri *et al*. 2009) may be entrained into these channels. Nonetheless, a recent study in the lower Columbia River (Parsley *et al.* 2011) showed no effects of dredging and the disposal of dredge waste on the natural behaviour of juvenile White Sturgeon.

Fisheries

In the lower Fraser River, there are seasonal drift-net fisheries for Pacific Salmon (*Oncorhynchus* spp.) that incidentally catch sturgeon, as well as a seasonal Test Fishery used to estimate the strength of different salmon stocks. Normally, the drift net by-catch is released, but occasionally a sturgeon dies in a net and there is a clear evidence of some post-release mortality and sub-lethal effects of unknown consequence (Robichaud *et al.* 2006). First Nation fishers voluntarily release sturgeon from their nets; however, if one from a non-SARA listed population (e.g., Lower Fraser DU) dies in a net they have the right to keep the fish. The combined mortality from the drift net and test fisheries for salmon accounts for about 8% of the total estimated sturgeon mortality (Robichaud *et al.* 2006). Also there are catch-and-release recreational fisheries for White Sturgeon in the lower and middle Fraser River (i.e., from the bridge at Mission, BC, upstream to near Williams Lake River, BC). The angling, and post-release mortality, in the Lower Fraser DU is estimated to be 2.7% (Robichaud *et al.* 2006). Given that angling surveys estimate that between 30,000 and 40,000 White Sturgeon are handled in the lower Fraser River annually (D. Jesson, pers. comm. 2012), this amounts to an estimated 800-1,000 angling-induced mortalities per annum. Sub-lethal physiological effects, which have not been studied, could also contribute to impaired productivity of the lower Fraser River DU. In addition, the recreational fishery in the lower and middle Fraser River is very popular and will likely grow and put greater pressure on fish in these areas. In the rest of the Fraser River system, sturgeon fishing is banned, but by-catch mortality occurs in areas where net fisheries for salmon operate, including the Nechako River

Sturgeon fishing is banned in the Canadian portion of the Columbia River system; however, the sport fishery for Rainbow Trout (*Oncorhynchus mykiss*) and Walleye occasionally catch sturgeon. Wood *et al.* (2007) estimated the annual sturgeon mortality associated with the sport fishery by-catch at 0.07%.

An undocumented, but possible, threat in the lower Fraser River is the presence of "Ghost Nets"; commercial fishing nets that are lost and continue to catch fish. For instance, in the lower Columbia River, 154 grapple tows, recovered 33 lost nets that contained 126 White Sturgeon. Newly lost nets caught significantly more White Sturgeon than older nets, and nets at large for less than 1 year were responsible for 63% of the total ghost net catch. Nets at large for 1-4 years accounted for 24% of the catch, and nets at large for > 4 years captured 13%. In the lower Columbia, approximately 10 nets are lost each year, and the estimated life span of lost nets is about 7 years. Thus, in the lower Columbia, ghost nets may kill more than 545 White Sturgeon annually (Kappenman and Parker 2007). Comparable data, however, are not available for the lower Fraser River.

Declines in forage fishes

Historically, in both the lower Fraser and lower Columbia rivers, White Sturgeon made seasonal migrations associated with runs of anadromous fishes, e.g., Pacific Salmon, Eulachon, and lampreys (*Entosphenus* and *Lampetra* spp.). In the Fraser River, these runs have steadily declined over the last few decades, although occasional unexpected strong runs still occur (e.g., Sockeye Salmon in 2010 and Eulachon in 2003). For Eulachon there is evidence of periodic collapses dating back to the mid-1800s (Moody 2008) and the Eulachon of the Fraser River DU is currently assessed as Endangered (COSEWIC 2011). Given the life span of White Sturgeon, they can probably survive episodic collapses of major food sources; however, if these forage species continue to decline their loss probably will have a negative effect on the White Sturgeon in these rivers.

Gravel mining

In a review of the human impacts on aquatic habitats between Hope and Mission, Rosenau and Angelo (2007) examined the contentious issue of gravel mining in the Fraser River. Of special concern are gravel-mining operations in side channels. In the lower Fraser River most of the known White Sturgeon spawning-sites are in the side channels (Perrin *et al.* 2003) found in the gravel deposition region between Hope and Chilliwack.

Commercial gravel mining in this part of the habitat of the Lower Fraser DU White Sturgeon started in the 1950s and continues into the present. In their natural state side channels have stable gravel and cobble substrates but to access gravel, the armouring layer of cobbles must be removed before the gravel can be scooped out. The end result is a much deeper channel with steep sides and no armouring layer. It is unclear how quickly, if at all, annual high water periods replace the gravel in mined areas. In the past, some berms were constructed across the upstream entrance of channels. These berms were not removed; consequently some side channels became sloughs and are no longer suitable sturgeon spawning sites.

Introduced species

Although, in inland waters, adult White Sturgeon have few predators, larval and yearling sturgeon are subject to predation. They have coexisted with native predators for thousands of years and survived; however, in recent years a number of non-native predators have established themselves in White Sturgeon habitats (e.g., Smallmouth and Largemouth bass, *Micropterus dolomieu* and *M. salmoides*) in the lower Fraser River, and Walleye in the Columbia River. Juvenile Walleye are known to eat yearling sturgeon (Gadomski and Parsley 2005b). These introduced predators hunt in different ways and in different habitats than the predators that have coevolved with White Sturgeon. Whether these introduced predators have a significant negative effect on young sturgeon is still unclear.

Poaching

For obvious reasons, poaching is a secretive activity. Consequently it is difficult to estimate the level of this threat. Nonetheless, in 2010 there were 48 known occurrences or violations that involved sturgeon. Of these, nine incidents involved reports of sturgeon poaching (Herb Redekopp, DFO, pers. comm. 2011). It is possible that White Sturgeon products from local aquaculture enterprises will affect the incidence of poaching. As legitimate farmed sturgeon products become more common, poaching may decrease. Conversely, poaching may increase because passing off wild sturgeon as farmed sturgeon may become easier.

Water quality

Trends in water quality and the apparently high susceptibility of White Sturgeon larvae to various toxins were summarized by FRWSWG (2005). Analysis of water quality trends have been published by Ministry of Environment, Lands and Parks, and Environment Canada (1996a, 1996b, 1997, 2000), and although improving trends in many parameters have been documented recently including adsorbable organo-halides (AOX), chloride and lead, many parameter indicators (colour, fecal coliforms, non-filterable residues, ammonia, vanadium, molybdenum, turbidity, barium, nickel, chloride, sodium, phosphorus, copper and AOX) spatial trends of concern have been documented (FRWSWG 2005). Despite the broad variety of pollutants present in the lower Fraser River, analysis of carcasses from the 1993/94 adult mortalities indicated relatively low levels of pollutants (McAdam 1995). This may be due to an adult diet that consists largely of salmon and eulachon (prey species that are predominantly marine), which may suggest that adult white sturgeon in the lower Fraser may be less prone to local pollutant effects that could be accumulated through their food supply. Because, however, juvenile White Sturgeon depend on locally derived food supplies such as benthic invertebrates and young fish, they may be more susceptible to pollutants. The possibility of a bitumen pipeline crossing the Stuart River (Nechako River group within the Upper Fraser DU) near an area of documented use by White Sturgeon also poses a potential threat from construction and possible leakage.

Limiting Factors

White Sturgeon are mobile creatures and use different habitats at different seasons and at different phases in their life cycle. Thus, the loss or degradation of any habitat used by sturgeon has the potential to limit White Sturgeon abundance. Still, some habitats are more important to the survival and abundance of the species than other habitats. Spawning sites are an example. To successfully spawn White Sturgeon need a relatively narrow range of water temperatures, water velocities, and substrates. Also, they appear to show fidelity to specific spawning sites and continue to use degraded sites even though the eggs rarely survive to hatching (Liebe *et al.* 2004; Paragamian *et al.* 2009).

Appropriate rearing sites for the early life-history stages represent another important habitat. Coutant (2004) proposed what is now known as the "Riparian Habitat Hypothesis". Basically, he posited that seasonally submerged riparian habitat is needed for successful early development. Under this hypothesis complex side channels and seasonally flooded riparian vegetation or rocky substrates are necessary for egg incubation and larval survival. van der Leeuw *et al.* (2006) found White Sturgeon embryos, free embryos, and larvae in shallow seasonally flooded riparian habitats in the lower Columbia River and this validates a critical assumption of Coutant's hypothesis. McAdam *et al*. (2005), however, tested this idea for the Nechako River and found that it was unsupported. In the lower Fraser River, Perrin *et al.* (2003) documented White Sturgeon successfully spawning (i.e., producing viable, fertile eggs and larvae) in side channels. Little is known about the habitat use and ecology of most-metamorphic sturgeon in their first year of life which is a major information gap.

In the lower Fraser River in the summer, juveniles (> 20 cm) use sloughs and side-channels more so than adults (Lane and Rosenau 1995; Glova *et al*. 2010). The availability of such habitats has decreased steadily since the arrival of Europeans but it is unclear how this has influenced sturgeon numbers. In the winter juveniles use the same overwintering sites as adults. How important overwintering sites are in areas like the lower Fraser River is unknown; however, the observation that individuals return to the same sites year after year (Neufeld *et al.* 2010) suggests that overwintering sites are important habitats. For inland sturgeon (e.g., the upper Fraser Sturgeon Group) suitable overwintering sites may be important habitat.

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

Four of the six recognized Canadian White Sturgeon groups (defined as "Nationally Significant Populations", NSP, under earlier COSEWIC guidelines) — the Upper Kootenay, Nechako, Upper Columbia, and Upper Fraser groups — are listed under the *Species at Risk Act* (SARA) as Schedule 1 Endangered species (Species at Risk Public Registry 2010). The lower Fraser and middle Fraser NSPs were assessed as Endangered by COSEWIC in 2003; however, for socio-economic reasons (i.e., their importance to recreational and Aboriginal fisheries) they were not listed under SARA. The habitat protection provisions of the *Fisheries Act* have recently been changed to provide protection only for fishes that are of recreational, commercial, or Aboriginal fishery significance. It is, therefore, possible that different White Sturgeon populations will be subject to different levels of protection (or none at all) under the new proposed *Fisheries Act* which is expected to be finalized in 2013. In the Fraser River and the Canadian portion of the Columbia River system, the provincial *Water Act* and *Land Act* and municipal legislation can also protect habitats of sturgeon in BC. In BC, the recreational sturgeon fishery in the entire province became a catch-and release fishery in 1994 and has been closed completely in some areas (Kootenay River (1990) and the Nechako River (1994)). In addition, the sturgeon fishery in the Columbia system above HLK was closed and, in 1997, the Canadian portion of the Columbia River between HLK and the U.S. border also was closed. In the U.S., fishing for sturgeon in the intermountain Montana segment of the Kootenay River was closed in 1979. In Idaho the sturgeon fishery became catch-and-release in 1984, and in September 1994, under the authority of the U.S. *Endangered Species Act*, the Kootenai River population was listed as Endangered.

Non-Legal Status and Ranks

Globally, the White Sturgeon has a NatureServe rank of G4 (apparently globally secure but of local concern); however, the six Canadian groups are ranked separately. Three of these groups (Kootenay, upper Fraser, and Nechako) are ranked as G4T1Q (critically imperiled). The middle and lower Fraser populations are ranked as G4T2Q (imperiled).The upper Columbia population is ranked G4T3T4Q (imperiled). The BC Conservation Data Base has red-listed all six of the Canadian White Sturgeon groups.

Habitat Protection and Ownership

The federal *Fisheries Act* provides Fisheries and Oceans Canada with powers to protect and conserve fish and fish habitat (as defined in the *Fisheries Act*) essential to sustaining commercial, recreational, and Aboriginal fisheries. As it now stands, the federal *Fisheries Act* (Section 35) provides White Sturgeon with protection from harmful alteration, and disruption or destruction, of their habitat, but proposed changes (due to take effect January 2013) could provide different levels of protection to different sturgeon populations. Those populations that are not the focus of commercial, recreational, or Aboriginal fisheries, which characterizes sturgeon in the upper Fraser River and in the Upper Columbia and Upper Kootenay DUs, will receive no protection under the *Fisheries Act*. All the Canadian rivers used by White Sturgeon are property of the Crown. As transboundary rivers, the Columbia and Kootenay rivers are special cases and subject to environmental obligations imposed by the International Joint Commission (IJC) and the Columbia River Treaty.

Provincially, Section 4 of the BC *Fish Protection Act* designates some rivers as “protected rivers”. The Fraser and Stuart rivers are “protected rivers”. Both these rivers contain White Sturgeon. One protection provided by the BC *Fish Protection Act* is that protected rivers cannot be dammed bank-to-bank. The *Fish Protection Act* also contains riparian areas regulations. Riparian areas border streams, lakes, and wetlands. They link rivers and streams to land, and the trees, shrubs and grasses (including seasonally flooded riparian areas) directly influence and provide fish habitat. There is some evidence that seasonally flooded riparian areas may be important for successful White Sturgeon reproduction (van der Leeuw *et al.* 2006).

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J. D. McPhail received a BA (English and Biology) from the University of British Columbia in 1957, an M.Sc. (Zoology) from UBC in 1959, and a PhD (Zoology) from McGill University in 1963. He started his career as a University Professor at the University of Washington in 1963 and moved to UBC in 1966. His early research interest was in Arctic freshwater fishes, and in 1970 he coauthored (with Dr. C. C. Lindsey) a book on the "Freshwater Fishes of northwestern Canada and Alaska." Throughout his career his major research interest has been the ecology, evolution, and biogeography of freshwater fishes, especially sticklebacks, but also other fishes of the inland waters of northwestern North America. He has published over 100 papers and reports on fishes, and acted as an advisor to the BC provincial government on the native fishes of BC and to BC Hydro on species at risk. In 2007 he published a book on BC Fresh Water Fishes.

COLLECTIONS EXAMINED

None.