FRASER RIVER WHITE STURGEON MONITORING PROGRAM

Comprehensive Report

(1995 to 1999)

RL&L

ENVIRONMENTAL SERVICES

rivers, lakes, & land

FRASER RIVER WHITE STURGEON MONITORING PROGRAM

COMPREHENSIVE REPORT (1995 to 1999)

Prepared for

BC Fisheries

by

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December 2000

Suggested Citation: RL&L Environmental Services Ltd. 2000. Fraser River White Sturgeon Monitoring Program - Comprehensive Report (1995 to 1999). Final Report Prepared for BC Fisheries. RL&L Report No. 815F: 92 p + app.

ACKNOWLEDGMENTS

The Fraser River White Sturgeon Monitoring Program (*FRWSMP*) was funded by the Habitat Conservation and Trust Fund (HCTF), Forest Renewal BC (FRBC), and Fisheries Renewal BC (FsRBC). The author wishes to recognize the efforts of the Fraser River Sturgeon Technical Committee (*FRSTC*) for their input and guidance. The following *FRSTC* members from BC Ministry of Environment, Lands and Parks (MELP) and BC Fisheries significantly contributed to the program:

Ted Down (Program Manager, BC Fisheries, Victoria, BC)
Sue Pollard (BC Fisheries, Victoria, BC)
Marvin Rosenau (MELP, Surrey, BC)
Ian McGregor (MELP, Kamloops, BC)
Maurice Lirette (MELP, Williams Lake, BC)
Don Cadden (MELP, Prince George, BC)
Ted Zimmerman (MELP, Prince George, BC)

The author would also like to acknowledge L. Frey (Vanderhoof Flying Services), D. Bouillon (Alcan), C. McIvor (Fraser River Sturgeon Charters), F. Helmer, L. Ames, D. Hartlen and G. Hunt (Fred’s Fishin Adventures), K. Kristian (Fishin Mission Guiding), D. Kerridge (Domino Professional Guiding Services), R. Spooner (R&R River Charters), D. Horvath (Outbound River Tours), M. Laynes (Cascade Fishing Charters), G. Parfitt (Rivers North), S. Arcand (Fraser River Outdoor Adventures Ltd.), D. Baerg (Fraser River Raft Expeditions), and land owners C. and S. Derksen, J. Keillor, L. Joiner, E. and S. Wedler, I. and K. Stacey, F. Williams, D. Hay, W. and P. Haenschke, K. Sigaty, and T. Sawchuk for their assistance.

Thanks also to the Yale Band, Sto:Lo Nation, Agassiz Indian Band, Carrier Sekani Tribal Council, Nad’leh Whut’en, Stellaquo Whut’en, and Lheidli T’enneh First Nation, Fraser River Sturgeon Conservation Society, Department of Fisheries and Oceans, Environment Canada, and the Wildlife, Habitat and Enforcement Division of MELP for their contributions to the program.

The following staff members of RL&L Environmental Services Ltd. (RL&L) participated in annual field investigations and reporting:

C. McLeod	*(Senior Biologist, Project Advisor, Edmonton)*
S. McKenzie	*(Senior Biologist, Project Manager, Edmonton)*
L. Hildebrand	*(Senior Biologist, Project Manager, Castlegar)*

C. Stefura	*(Project Biologist, Edmonton)*
S. Millar	*(Project Biologist, Edmonton)*
B. Chapman	*(Fisheries Technician, Castlegar)*
M. Hildebrand	*(Fisheries Technician, Castlegar)*
J. Campbell	*(Fisheries Biologist, Edmonton)*
R. Stack	*(Fisheries Technician, Edmonton)*
M. Braeuer	*(Fisheries Technician, Edmonton)*
D. Hendricks	*(Fisheries Biologist, Prince George)*
N. Elliot	*(Fisheries Biologist, Prince George)*
F. Audy	*(Fisheries Technician, Prince George)*
H. Van de Vosse	*(Fisheries Technician, Prince George)*

The author would also like to thank Aboriginal Assistants C. Heathcliff, M. French, E. Prince, and R. Gerome as well as past employees of RL&L who participated in the Fraser River White Sturgeon Monitoring Program.

Several staff of RL&L participated in the preparation of this report. Scott Millar and Corey Stefura provided considerable input to the analysis and tabulation of data. Rob Stack prepared the report maps and Dana Schmidt provided guidance in statistical analysis and interpretation. The efforts of Curtiss McLeod and Larry Hildebrand of RL&L, and the Fraser River Sturgeon Technical Committee in reviewing and editing the draft were greatly appreciated.

EXECUTIVE SUMMARY

The results of five years of research on white sturgeon in the Fraser River drainage are described according to the study objectives developed in 1995. Five putative populations of white sturgeon were identified in the Fraser River drainage, with four stocks residing in the Fraser River mainstem and a fifth stock documented in the Nechako River drainage.

The lower and middle Fraser River Stock Groups (SG) of white sturgeon (SG-1 to SG-3) exhibited a wide range of size-classes and maturity cohorts. The density of white sturgeon was determined to be highest in the Lower Mainland section of the Fraser River, with populations generally declining as the geographic range of the Stock Group became more northerly. The growth models showed a slower growth rate and later age-at-maturity for the more northerly stocks; however, evidence was provided that suggested white sturgeon in the lower and middle Fraser River may become reproductively mature at a later age than previously documented.

For all Stock Groups, localized movements were the most common, although larger-scale movements were observed for feeding, overwintering, and spawning. Evidence of white sturgeon movement from the middle to lower Fraser River through Hell's Gate was also gathered that suggested genetic mixing between these stocks.

Indirect evidence of spawning by white sturgeon was documented in the Lower Mainland and Lower Canyon sections of the Fraser River mainstem by the capture of early life history stages. Spawning was considered widespread and occurred during the declining hydrograph in spring, when water temperatures were between 11 and 18 °C; spawning was thought to occur in a wide range of habitats. White sturgeon spawning was not confirmed in the middle Fraser River although the capture data suggested white sturgeon may stage or possibly spawn near the Texas and Red Rock creeks, and the confluences of the Nahatlach and Cottonwood rivers.

Although investigations of white sturgeon in the upper Fraser River above Prince George are still in the preliminary stages, information has been collected that suggests the area is mainly used by juvenile and sub-adult cohorts; their densities are low, with individuals commonly found near the confluences of major tributaries. The growth rate of this Stock Group was slow yet similar to Nechako River sturgeon.

Nechako River sturgeon displayed a population structure that resembled other populations from other regulated systems. The size of the white sturgeon population in the Nechako River was low and comprised mainly of older fish, and the stock exhibited poor spawning success and recruitment. Extensive movements of Nechako River sturgeon for feeding, overwintering, and spawning purposes were generally more common than in other stocks,

with some individuals moving between the Nechako and Stuart rivers. Spawning by white sturgeon was not confirmed although results suggested areas such as Isle Pierre, Whitemud, and Hulatt rapids, and the Nautley (Fraser Lake outflow) and lower Stuart rivers provided suitable spawning habitat and may be used for spawning. The population exhibited late maturation and slow growth, which may be attributable in part to the shorter growing season or to the availability of food resources.

The Stock Groups of white sturgeon in the lower and middle Fraser River each exhibited what appeared to be a population structure that implied successful reproduction and adequate recruitment. However, results suggested the population of white sturgeon in the Nechako River may be at risk of extirpation. This population will likely require recovery efforts to mitigate impacts and to re-establish a stable, self-sustaining population where future loss of genetic variability is prevented.

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CHAPTER 1 RATIONALE

1.1 BACKGROUND

White sturgeon (*Acipenser transmontanus*) are widely distributed throughout the Fraser River watershed, with fish present in the lower, middle and upper Fraser River mainstem (RL&L 1996a, 1997a-c, 1998a-d, 1999a-d, 2000a-c; Scott and Crossman 1985). White sturgeon are also known to occur in tributaries to the Fraser River including the Nechako River drainage (RL&L 1996a; Dixon 1986; Scott and Crossman 1985), and the Harrison, lower Pitt, Thompson (Scott and Crossman 1985), McGregor (RL&L 1998d, 2000c; LTFN 2000; Dixon 1986) and Torpy (RL&L 1999d, 2000d; LTFN 2000) rivers. This fish species has also been reported in Seton, Fraser, Stuart, and Anderson lakes (RL&L 1996a, 1997a-c; Northcote 1974; Scott and Crossman 1985).

Fraser River white sturgeon populations have been historically impacted by commercial exploitation (Echols 1995; Binkowski and Doroshov 1985; Semakula and Larkin 1968) and loss of habitat (Rochard et al. 1990; Deacon et al. 1979), and by an increasing sport fishery (Dixon 1986). In response to these impacts and limited information on the status of Fraser River white sturgeon, BC Ministry of Environment, Lands and Parks (MELP) implemented a catch and release fishery for white sturgeon in 1994 and initiated plans for a large-scale monitoring program of Fraser River sturgeon.

RL&L Environmental Services Ltd. (RL&L) was commissioned by MELP in 1995 to develop and implement a white sturgeon monitoring program in the Fraser River watershed. The program spanned a period of five years (1995 to 1999), with funding largely provided by the Habitat Conservation Trust Fund (HCTF) and Forest Renewal BC (FRBC). As a component of the Fraser River White Sturgeon Monitoring Program (*FRWSMP*), the Fraser River Sturgeon Technical Committee (*FRSTC*), comprised of representatives from BC Fisheries (BCF)[1], MELP, and RL&L, was formed to review annual reports and assist in research planning.

The intent of this report is to summarize the results of the past five years of the Fraser River White Sturgeon Monitoring Program as defined by a combination of data from the genetic, movement, life history, and abundance studies.

[1] Prior to February 1998, all provincial fishery management was part of the mandate of MELP. In 1998, this role was split between two ministries with the creation of the Ministry of Fisheries. BC Fisheries is currently a program area within the Ministry of Agriculture, Food and Fisheries.

1.2 OBJECTIVES

The Terms of Reference for the *FRWSMP* (April 1995), identified a requirement for scientifically credible surveys to determine the following:

1. The abundance, distribution and characteristics of white sturgeon by size, age and sex,
2. the bio-physical attributes of sturgeon habitat,
3. the presence, absence and characteristics of spawning activity in various areas, and
4. the seasonal movement patterns of sturgeon between river sections including spring migrations to feeding and spawning areas, summer residency, and fall migration to overwintering areas.

Based on annual meetings with the *FRSTC*, specific work programs were developed and implemented on a regional level for MELP Regions 2 (Lower Mainland), 3 (Thompson-Nicola), 5 (Cariboo-Chilcotin), and 7 (Omineca-Peace). Each regional work program was designed to obtain information on white sturgeon populations in the Fraser River watershed that would enable scientific management of sturgeon stocks based on an understanding of stock-specific population dynamics and potential limiting factors.

In 1997, BC Fisheries initiated genetic studies as part of the *FRWSMP* to delineate discrete groups or putative populations of white sturgeon in the Fraser River watershed (Nelson et al. 1999; Pollard 2000), hereafter referred to as Stock Groups (SG). A summary of the tentative Stock Groups of white sturgeon identified in the Fraser River drainage is provided in Table 1.1 (refer to Chapter 4 discussion of the Stock Group definitions). As illustrated in Figure 1.1, the regional MELP boundaries were similar to the tentative Stock Group boundaries.

Table 1.1 Summary of Tentative Stock Groups of White Sturgeon in the Fraser River Drainage

Stock Group[1]	Waterbody			MELP Region
	System	Kilometre	Section	
SG-1	Fraser	78 – 153	Lower	2
SG-2	Fraser	154 – 211	Lower	2
SG-3	Fraser	212 – 790	Middle	3 and 5
SG-4	Fraser	791 –1042	Upper	7
SG-5	Nechako/Stuart	0 – 290	All	7

[1] SG-1=Stock Group 1; refer to Chapter 4 for discussion of Stock Groups.

1.3 PROGRAM COMPONENTS

The main elements of the *FRWSMP* were to: determine presence and absence; collect baseline information on the dynamics of the populations related to growth, size and age-class composition, and maturity; and, document the distribution, habitat use, and seasonal movement patterns of the various life history stages. In those areas of the Fraser River watershed where the *FRSTC* considered information on white sturgeon recruitment to be a high priority (i.e., Nechako River drainage and lower Fraser River mainstem), additional effort was expended to assess reproductive potential, spawning, and early life history. For a more detailed outline of annual work program objectives, refer to the *FRWSMP* data reports prepared annually since 1995 and listed in Appendix A.

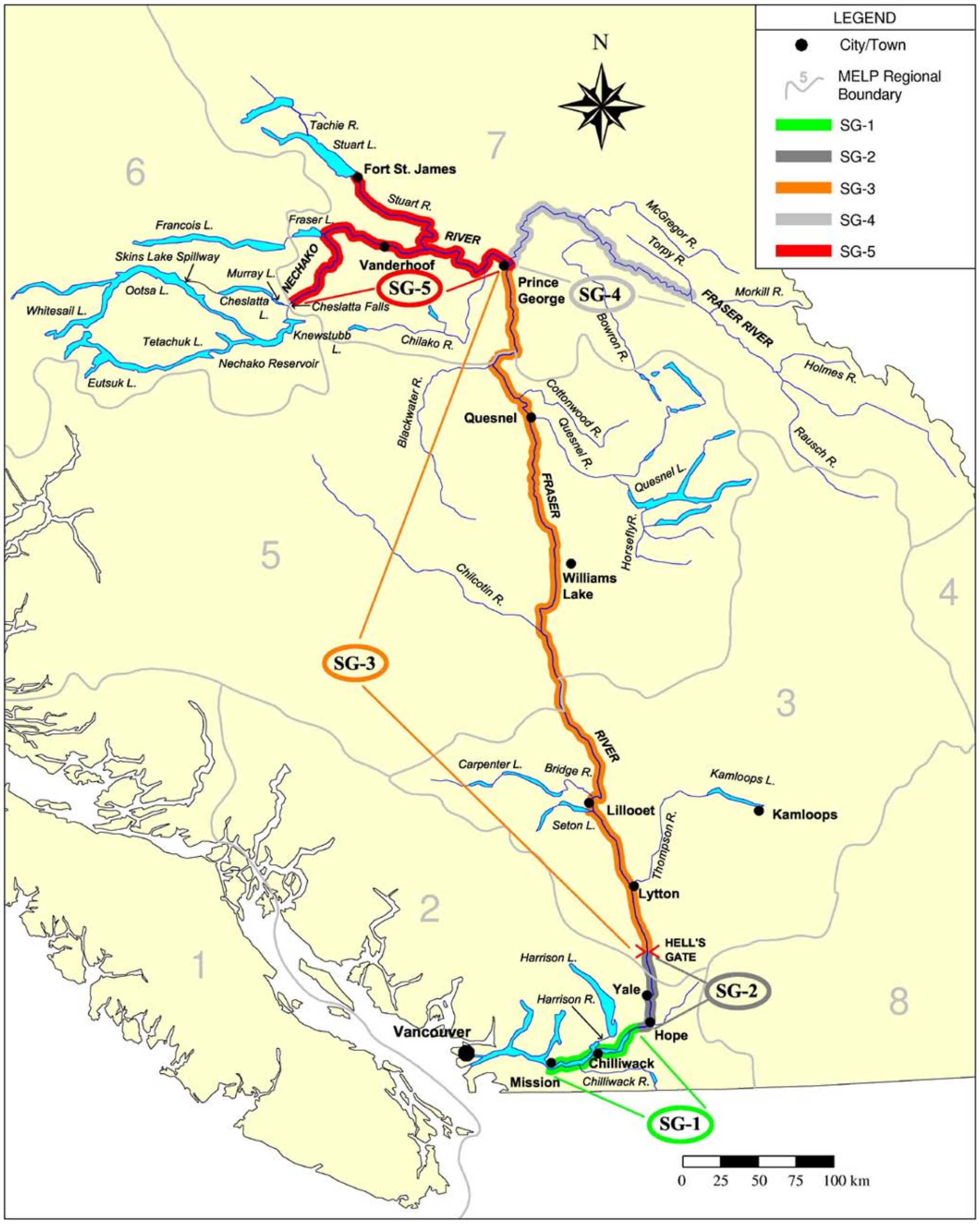

Figure 1.1 White Sturgeon Stock Groups and Regional MELP Boundaries in the Fraser River Drainage

CHAPTER 2 DATA COLLECTION

2.1 STUDY AREA

The study area for the *FRWSMP* encompassed a large portion of the Fraser River drainage and included over 1000 km of the Fraser River mainstem from below Mission, BC (river kilometre; rKm 68) to upstream of the confluence of the Morkill River (rKm 1083; Figure 2.1).

Tributary systems that were sampled included the lower reaches of the Harrison, Bowron, McGregor, Torpy, and Blackwater rivers, the Quesnel River, as well as Seton Lake, the east arm of Kamloops Lake, and the west arm of Quesnel Lake (Figure 2.1). Extensive sampling was conducted in the Nechako River drainage, including the 280 km of the Nechako and 110 km of the Stuart river systems. Sampling also occurred in the Tachie and Nautley rivers, the outlet of Stuart Lake, and the south arm (outlet to the Nautley River) of Fraser Lake.

2.2 STUDY PERIODS

The *FRWSMP* was conducted seasonally over a five-year period. The timing and seasonal coverage of field programs varied for each Stock Group depending on study objectives and the agency conducting the work. A summary of the sampling periods, waterbody, and agency is provided in Table 2.1.

2.3 SAMPLING PROGRAMS

A summary of the sampling programs conducted as part of the *FRWSMP* is shown in Table 2.2. The sampling programs were separated into categories to provide a general guide as to the types of studies conducted annually on each Stock Group. These categories included spawning, early life history, rearing, population dynamics, movements and abundance, telemetry, and habitat. Spawning refers to those programs where intensive effort was expended to locate potential white sturgeon spawning areas and to identify spawning activity. Effort applied to the collection of white sturgeon eggs and larvae was categorized as early life history sampling, whereas effort directed toward the capture of juvenile sturgeon was grouped under rearing.

The population dynamics section is divided into three components; size and growth, sex and maturity, and movement and abundance. The size and growth, and sex and maturity components are essentially the life history data collections while the movement and abundance component relates to the mark-recapture studies. Telemetry refers to the white sturgeon radio-tagging programs and the habitat category applies to the programs specifically designed to assess the characteristics of critical habitats (e.g., spawning, rearing, overwintering).

Figure 2.1 Study Area and Areas Sampled for White Sturgeon in the Fraser River Drainage

2.4 PHYSICAL CONDITIONS

2.4.1 Flow and Temperature

Flow and temperature data for the *FRWSMP* were obtained from several sources. Mean daily discharge data for each study area were acquired from Water Survey of Canada, Data Management and Applications Department of Environment Canada. Discharge data were obtained for the Nechako River at Cheslatta Falls and Isle Pierre, the Nautley River near Fort Fraser, and the Stuart River at Fort St. James (Figure 2.1). Water Survey of Canada also provided discharge data for the Fraser River at Shelley, Marguerite, above Texas Creek and Hope, and for the Quesnel River at Quesnel. Alcan provided discharge records for the Skins Lake Spillway.

Table 2.1 Sampling Periods for the Fraser River White Sturgeon Monitoring Program by Stock Group, Agency, Waterbody, and Sample Method, 1995 to 1999

Stock Group[1]	Agency[2]	Waterbody	Sample Method[3]	Study Year				
				1995	1996	1997	1998	1999
SG-1	RL&L	Fraser River	AB/SSL/ECM/DN/RT	Jun & Oct	Jul & Nov	Jul & Nov	Sep & Nov	
		Harrison River	AB	Oct				
	Limnotek	Fraser River	ECM/DN/RT				Jun & Aug	Jun & Aug
SG-2	RL&L	Fraser River	AB/SSL/ECM/DN/RT	May & Oct	Jul & Nov	Jul & Nov	Sep & Nov	Apr & Sep
	Limnotek	Fraser River	ECM/DN/RT				Jun & Aug	Jul & Aug
SG-3	RL&L	Fraser River	AB/SSL/RT	Aug & Oct	Sep	Apr & Nov	Aug & Sep	Apr & Sep
		Kamloops Lake	SSL	Aug				
		Quesnel Lake	SSL	Oct				
		Quesnel River	SSL	Aug				
		Seton Lake	AB/SSL/GN/TN			Apr & Sep		
	MELP	Fraser River	AB/RT				Apr & Nov	May & Oct
	RL&L	Fraser River	AB/SSL/GN/ES/RT			Sep & Oct	Sep	
		McGregor River	SSL			Sep		
SG-4	Rivers North	Blackwater River	AB				May	
		Bowron River	AB				May & Jul	
		Fraser River	AB				May & Sep	
		McGregor River	AB				Sep	
		Torpy River	AB				Jul	
	LTFN	Fraser River	AB/SSL/GN/GT					Aug & Oct
		Bowron River	SSL/GN					Aug
		McGregor River	SSL					Aug
SG-5	RL&L	Fraser Lake	SSL	Jun	Jun	Jun		
		Nautley River	SSL	Jun		May		
		Nechako River	AB/SSL/GN/ES	Jun & Sep	Jun & Sep	May & Sep	May & Sep	Jun & Sep
			ECM/DN/RT				Jun	Jun
		Stuart River	AB/SSL/GN/ES/RT		Jun & Jul	Sep	Sep	Jul
		Tachie River	SSL		Sep			
	Rivers North	Nechako River	AB				May	
	Triton	Nechako River	GN					Jun & Aug

1 SG-1=Stock Group 1. Refer to Chapter 4 for discussion of Stock Groups.

2 LTFN=Lheidli T'enneh First Nation; Triton=Triton Environmental Consultants Ltd.; Limnotek=Limnotek Research and Development Inc.; RL&L=RL&L Environmental Services Ltd.; MELP=BC Ministry of Environment, Lands and Parks.

3 AB=Angling with bait; SSL=Sturgeon set line; GN=Gill net; TN=Tangle net; ES=Boat electroshocking; ECM=Egg collection mat; DN=Drift net; GT=Gee minnow trap; RT=Radio telemetry. Some sample methods may not have been employed during some sessions.

Table 2.2 Sampling programs for the Fraser River White Sturgeon Monitoring Program by Stock Group and Year

Stock Group[1]	Year	Sampling Programs[2]							
		Spawning	Early Life History	Rearing	Population Dynamics			Telemetry	Habitat
					Size and Growth	Sex and Maturity	Movement and Abundance		
SG-1	1995	✔			✔	✔	✔	✔	
	1996	✔			✔	✔	✔	✔	
	1997	✔	✔		✔	✔	✔	✔	
	1998	✔	✔		✔	✔	✔	✔	✔
	1999	✔	✔					✔	✔
SG-2	1995				✔	✔	✔	✔	
	1996				✔	✔	✔	✔	
	1997				✔	✔	✔	✔	
	1998	✔	✔		✔	✔	✔	✔	✔
	1999	✔	✔		✔	✔	✔	✔	✔
SG-3	1995				✔	✔	✔		
	1996				✔	✔	✔	✔	
	1997				✔	✔	✔	✔	
	1998				✔	✔	✔	✔	
	1999				✔	✔	✔	✔	
SG-4	1995								
	1996								
	1997				✔	✔	✔	✔	
	1998				✔		✔		
	1999				✔		✔		
SG-5	1995	✔			✔	✔	✔	✔	
	1996	✔			✔	✔	✔	✔	✔
	1997	✔			✔	✔	✔	✔	✔
	1998	✔	✔	✔	✔	✔	✔	✔	✔
	1999	✔	✔	✔	✔	✔	✔	✔	✔

1 SG-1=Stock Group 1. Refer to Chapter 4 for discussion of Stock Groups.

2 Sample programs conducted by all agencies as part of the *FRWSMP* are shown.

Department of Fisheries and Oceans (DFO) provided water temperature data for stations set up in the Fraser and Nechako River drainages to monitor water temperatures during the salmon spawning periods. RL&L implemented a water temperature monitoring program in the Fraser and Nechako drainages to supplement data collected by DFO. Within the Fraser River mainstem, mean daily water temperature was recorded at Shelley, Quesnel, and Lillooet. Thermographs were also deployed in the Nechako River including upstream of the Nautley River confluence, at Finmoore, downstream of the Stuart River confluence, and at Isle Pierre. Water temperature data were also collected for the Stuart River upstream of the Nechako River confluence.

Thermographs were not necessarily operated continuously because of factors such as unit malfunction and vandalism, and annual study design.

2.5 BIOLOGICAL DATA COLLECTION

The following sections provide a general overview of the sample methods and monitoring techniques employed during the *FRWSMP*. A more detailed description of methods used and the rationale for their use can be found in the annual data reports. Reports detailing the sample methods employed by other agencies as part of the *FRWSMP* are cited in the appropriate sections below.

2.5.1 Capture Techniques

Several capture techniques were employed to collect juvenile to adult white sturgeon from a variety of habitats. These methods included setline, angling, tangle and gill nets, and boat electroshocking. Sampling techniques, including egg collection mats and drift nets, were also used to capture white sturgeon eggs and larvae. A summary of the methods used to capture white sturgeon in each Stock Group is provided in Table 2.1.

Set Lines

Setlines were used to sample white sturgeon from each Stock Group. The technique was generally similar in all areas with only slight modifications made to the line configuration, depending on river conditions. Setlines successfully captured a wide range of fish sizes and sampled a variety of habitats in the Fraser River drainage. Elliott and Beamesderfer (1990) noted that setlines provided greater catches while being less size selective than other gear during sampling in the Columbia River. Three setline configurations were used during the *FRWSMP*; short lines (20 m in length), medium lines (40 m in length), and long lines (120 m in length). The long line configuration was similar to that used by the Oregon Department of Fish and Wildlife to capture white sturgeon in the lower Columbia River (Nigro et al. 1988; RL&L 1996a). The hook assembly consisted of a 0.64 cm swivel snap and a 0.7 m dropper line tied between the swivel and the hook. Ten sharpened hooks (barbs removed) of three hook sizes (12/0, 14/0, and 16/0) were baited and placed in random order on each line. Salmon flesh was the most common bait used during the *FRWSMP* although other bait types (e.g., eulachon, salmon roe, lamprey) were used opportunistically.

The amount of potentially suitable white sturgeon habitat that could be effectively sampled by long lines was typically limited; therefore, this setline configuration was used sparingly. Medium lines and short lines were used more frequently. The configuration of these lines was similar to the long lines with the exception that fewer hooks (8 and 4 hooks, respectively) were placed on the lines.

Angling

Angling for white sturgeon was performed with heavy-duty tackle that consisted of 27 to 45 kg test nylon braided or monofilament line spooled onto a casting reel. A single shank stainless steel hook (5/0 to 9/0) was baited and the line was weighted so that the bait rested on the bottom. Angling was conducted either from boat or from shore, depending on habitat characteristics. In many areas, angling was conducted with the assistance of experienced white sturgeon charter guides.

Tangle and Gill nets

Gill nets ranging in size from 63.5 to 127.0 mm (2.5” to 5.0”) stretched measure mesh were used to target juvenile white sturgeon. A limited amount of tangle net sampling was also conducted using nets that ranged in mesh size from 203.2 to 304.8 mm (8.0” to 12.0”). The typical net configuration consisted of either a single panel (area of 37.2 m^2) or multiple panels (i.e., 2 to 3), with each panel being of different mesh size. Efforts were made to sample over extended periods although nets were checked frequently and set times rarely exceeded 4 hours between checks.

Boat Electrofishing

Boat electrofishing was performed using either a 4.9 m Roughneck hull equipped with a Smith-Root Type VI portable electrofishing unit or a 5.5 m Smith-Root SR-18 electofishing boat. Both systems were equipped with twin anode booms. Sampling was conducted along river margins and in shallow-water or braided river sections, primarily in an attempt to collect juvenile fish.

2.5.2 Movements and Abundance

Fish Marking

Fish were conventionally tagged with an external T-anchor tag or Dart tag (manufactured by Floy Tag Manufacturing Inc.) and Passive Integrated Transponder (PIT) tags (manufactured by Biomark Inc.). A small portion of the leading ray on the left pectoral fin was removed for ageing purposes and to provide a secondary external identification mark. The movements of conventionally tagged fish were summarized using mark-recapture information.

Radio Tagging

Select fish were equipped with an external radio tag to monitor their movement and behavior. Several radio tag designs and specifications were used during the *FRWSMP*. Detailed specifications of the radio tags can be found in RL&L (1996a, 1997a-c, 1998a-d, 1999d). The high frequency tags were manufactured by Lotek Engineering

Inc. These radio tags were either 16×60mm (32g in air; 12 month rated lifespan; programmable) or 30×140mm (165 g in air; 24 month rated lifespan) and operated within a frequency range of 148.000 to 152.000 MHz; each tag was individually coded. The low frequency radio tags were manufactured either by Custom Telemetry Inc. or by Advanced Telemetry Systems Inc. The tags had either a 13 or 36 month rated life span and operated on a specific individual frequency within a range of 41.000 to 42.000 MHz and emitted 55 to 56 pulses per minute. Each tag was approximately 30×140 mm and weighed either 115 g (13 month) or 167 g (36 month) in air and was tapered at the point of attachment of the antenna. All the radio tags had steel cables anchored to the capsule that were approximately 0.15 cm in diameter.

The radio tags were externally attached to anterior dorsal scutes of select specimens following the methods described by Haynes et al. (1978) and RL&L (1996a, 1997c). The radio tag cables were passed through the holes drilled in the scutes and fastened against a neoprene pad and backing plate on the opposite side. Tracking of radio tagged individuals was accomplished using a variety of techniques that included fixed wing aircraft, helicopter, riverboat, shore, and fixed remote ground stations (Lotek data loggers).

Population Estimates

Stock Group-specific population estimates were derived from mark-recapture data using the Modified Schnabel Estimation Technique [Schumacher and Eschmeyer method as outlined in Krebs (1988)]. Confidence Intervals (*CI*) were calculated at the 95% level or determined using a Poisson distribution table if the number of recaptures was low.

This method assumes a closed population. There have been only two instances during the *FRWSMP* where recapture information suggests this assumption was violated. The first instance was in Stock Groups 1 and 2 where two fish moved between the Lower Canyon (SG-2) and Lower Mainland (SG-1) sections of the Fraser River. The second instance was the recapture of a fish in the Stock Group 2 area that was originally tagged in Stock Group 3; these individuals were omitted from the estimates. In another study, Veinott et al. (1999) collected data that suggested white sturgeon in the lower Fraser River rarely migrate to sea although some juveniles spend extended periods in the Fraser River estuary. After age 40, most Fraser River white sturgeon were considered permanent residents of the river.

For Stock Groups 1 and 2, data from all capture sessions for the four years of sampling was grouped by year to meet the assumption of random mixing of individuals among sample periods. Movement information determined from recapture data suggested substantially more mixing occurs within these stocks between years rather than within years (RL&L 1999a). For Stock Groups 3 and 5, mark-recapture data were grouped by session based on the seasonal nature of sampling and the opportunity for random mixing of tagged fish between sample events. A population estimate was not generated for Stock Group 4 due to the low number of recaptures.

2.5.3 Life History

This section provides an overview summary of the life history information gathered from white sturgeon in the Fraser River drainage during the *FRWSMP*. White sturgeon life history information (e.g., length, weight, age) collected by other researchers (LTFN 2000; Triton 2000) was incorporated into the data set for analysis and discussion. A description of the methods and techniques used by these researchers to collect life history information is provided in their reports (Appendix A).

Measurements

Standard methods were used for the collection of life history data as described in RL&L (1996a, 1997c, 2000d). White sturgeon were measured for fork length (FL) and total length (TL) to the nearest 0.5 cm. Girth was measured behind the pectoral fins to the nearest 0.5 cm and weight was determined using a 135 kg capacity spring scale accurate to ±2.3 kg. Pre-opercular (tip of snout to posterior margin of operculum) and post-orbital (tip of snout to posterior margin of orbit) length was also measured in select Stock Groups to gather morphometric data on snout length.

Growth Characteristics

A section of the leading right pectoral fin ray was removed for ageing purposes to provide information on the growth characteristics. A description of the technique used to obtain fin ray sections is provided in RL&L (1997c). Fin rays were dried and then sectioned into several thin (0.3 to 0.6 mm) transverse sections using a jewelers saw. The sections were permanently mounted on a glass microscope slides using synthetic mounting medium and examined using a dissecting microscope and transmitted light. The age of the fish was determined by counting translucent zones (i.e., annuli) in the basal cross sections using the methods described by Cuerrier (1951), Beamesderfer et al. (1989), Brennan and Caillet (1991), and Rien et al. (1993). RL&L was responsible for assigning the age to all fish, including those sampled by other researchers (LTFN 2000; Triton 2000). Fin ray sections from the white sturgeon mortalities reported in the Lower Mainland section of the Fraser River, below Hope, BC in 1993 and 1994, were submitted to RL&L for ageing and grouped with the white sturgeon from SG-1. The age of each fish was derived from the examination of a minimum of four fin ray sections, aged twice by two readers independent of each other.

Sex and Maturity

Sex and maturity of white sturgeon was determined by surgical examination. Surgical procedures were similar to those described by Beamesderfer et al. (1989). The description of maturity stages generally followed the qualitative histological classifications used by Conte et al. (1988). Subjective assessments were used when maturity stage was intermediate relative to the classification system. In some instances, the stage of maturity could not be determined. A description of the surgical procedure is provided in RL&L (1996a, 1997a, 1999d).

2.5.4 Genetic Sampling

A sample of soft tissue was collected for genetic DNA analysis from a sub-sample of white sturgeon captured during the *FRWSMP*. A small section (1 cm^2) of tissue from the distal end of the pectoral fin was removed and preserved in 99% denatured ethyl alcohol. Samples were submitted to S. Pollard (BCF, Conservation Section, Victoria, BC) for analysis and inclusion in a white sturgeon genetic database.

Mitochondrial DNA (mtDNA) and microsatellite loci found in nuclear DNA were considered for genetic comparisons (Nelson et al. 1999; Pollard 2000). As mtDNA is inherited maternally, it provides a history of maternal lineages and female-mitigated gene flow; however, it offers no information regarding paternal input. Microsatellite loci are inherited biparentally (i.e., allele from each parent) and can provide information on heterozygosity, mating structure and gene flow associated with both parents (Nelson et al. 1999; Pollard 2000). By combining both of these markers, a more powerful tool was available to determine population structure. A description of the methods used to evaluate the genetic population structure of Fraser River white sturgeon is provided in Nelson et al. (1999) and Pollard (2000). The rationale for the selection of putative groups of white sturgeon for genetic comparisons is discussed further in Chapter 4.

2.5.5 Habitat Selection

General descriptions of habitat were recorded at most sampling locations and included water temperature, visibility, water depth, general flow patterns, and site description. (RL&L 1996a, 1997c). The amount and type of habitat information collected depended on the Stock Group and stock-specific objectives. For some Stock Groups, the habitat assessments were expanded to include collection of additional data such as depth, velocity, substrate, flow characteristics, cover (physical cover and turbidity), and channel characteristics (bathymetric cross-section profiles, underwater videography). Generally, additional effort went to defining habitat conditions within areas used more extensively by white sturgeon (RL&L 1996a, 1997c, 1998d) or those used for critical life history stages (Perrin et al. 2000; RL&L 1997c, 1998d).

2.5.6 Statistical Analysis

Potential morphological differences in relative snout length and condition factor among Stock Groups were evaluated statistically using the General Linear Model (GLM) function in SYSTAT™ version 8.0. The model was used to estimate and test a multivariate general linear model for Analysis of Covariance (ANCOVA) following the methods described by Sokal and Rohlf (1981). Variables included in the model that tested for difference in regression slopes and intercepts were FL, SL, using Stock Group as the covariate. The initial model was expressed as:

$$SL=b0 + (b1*FL) + (b2*Stock\ Group) + (b3*Stock\ Group*FL) + error$$

For the test of parallelism of slopes, the null hypothesis (H_0) was common slopes (*b1*) among Stock Groups versus the alternative hypothesis that slopes were different. Similarly, the homogeneity of the Y-intercepts (*b0*) was tested among Stock Groups using the null hypothesis that the regression lines of the Stock Groups shared a common intercept or the alternative hypothesis that the intercepts were different. Snout length to fork length regressions were compared among Stock Groups by standardizing the data to select only fish greater than 1m in total length because this subset of data was consistent among stocks. The *Tukey HSD Multiple Comparison Procedure* or *T-Method*, as described in Sokal and Rohlf (1981), was used to test pairwise differences among the stocks with respect to SL and FL coefficients.

The relationship of snout and fork length to the geographic distribution of white sturgeon in the Fraser River drainage also was examined by use of discriminant function analysis (SYSTAT version 8.0). Based on the initial analysis by linear regression of snout length as a function of fork length for each of the Stock Groups, a discriminant function was generated using the combined Stock Groups upstream (i.e., SG-3, SG-4, SG-5) and downstream of Hell's Gate (i.e., SG-1 and SG-2), with snout length and fork length as the discriminant functions. Using the canonical scores from the discriminant analysis, white sturgeon from each Stock Group were assigned to an "upstream" or "downstream" group, which was subsequently compared with their actual location of capture. Frequency distribution of the canonical scores for all white sturgeon from each Stock Group were also plotted and compared.

The approach used to test for differences among the length and weight coefficients of the stocks was the same as that described above. The model parameters were weight, fork length, and Stock Group; model diagnostics were assisted by excluding fish less than 1 m in total length. The initial model used for the analysis was:

$$Log\ W=b0 + (b1*log\ FL) + (b2*Stock\ Group) + (b3*Stock\ Group*log\ FL) + error$$

The five Stock Groups and sex differences within Stock Groups were evaluated for differences in age-growth parameters by non-linear regression using the von Bertalanffy growth model assuming the intercept (length at time 0) equaled zero as follows:

$$L_t = L_\infty \left(1 - e^{-k(t-0)}\right)$$

Where : L_t= Fork Length at age t
t=age in years
k= growth constant
L_∞ =asymptotic maximum length

The model parameters L_∞ and k were estimated using non-linear least squares minimization with a Gaus-Newton algorithm in SYSTAT version 8.0. Analysis was conducted using the average length values for each age class observed recorded for each stock resulting in equal weighting for each age class observed for the Stock Group analysis. Individual fish were used for evaluation of the sex differences within Stock Groups.

An overall comparison of all groups, all possible combinations of pairs of groups, and sex differences within groups were tested for significant differences using a Maximum Likelihood Ratio Test of the individual groups versus models of the combined groups following the procedures of Geaghan and Moser (1995). The likelihood ratio was defined as:

$$\lambda = \frac{L(\Omega_0)}{L(\Omega)}$$

Where: $H_0 : \theta = \Omega_0$ versus H_1: $\theta = \Omega$

For the analysis, the null hypothesis (H_0) was the combined model with 2 or more groups versus the alternative hypothesis that the individual groups resulted in the best prediction of fork length at age. The analysis assumed the variation about the estimated fork length was normally distributed, resulting in the non-linear fit being the maximum likelihood solution and the variance equal to the unrestricted maximum likelihood estimator of the parameter “fork length”.

The ratio of the variance estimates, under the null (combined groups) and alternate hypothesis (individual groups), is λ , and –2 ln (λ), and should follow a chi square statistic, where the degrees of freedom (*df*) are the *df* differences under the null and alternate hypothesis, and which for these tests, *df* will equal 1. Therefore:

$$\lambda = \frac{L(\Omega_0)}{L(\Omega)} = \left(\frac{\sigma^2}{\sigma_0^2}\right)^{\frac{n}{2}}$$

$$-2\ln(\lambda) = -2\ln\left(\left(\frac{\sigma^2}{\sigma_0^2}\right)^{\frac{n}{2}}\right) = -n * \ln\left(\frac{\sigma^2}{\sigma_0^2}\right)$$

The chi square probabilities for all group pair combinations and a full model versus the combined model are reported.

CHAPTER 3 CHARACTERISTICS OF THE FRASER RIVER

3.1 PHYSICAL CHARACTERISTICS

The Fraser River system has been described by several authors (Bocking 1997; Northcote 1974; Northcote and Larkin 1989; RL&L 1997a-c, 1998a-c, 1999b, 2000a). The Fraser River exhibits variable river conditions and surrounding topography throughout its length of 1375 kilometres. The Fraser River is a non-regulated river, originating in the Rocky Mountains near Jasper, and flows northwesterly toward Prince George (Figure 2.1). The river then flows south until Hope, then turns westward and empties into the Strait of Georgia near Vancouver. The following section provides a general overview of geophysical conditions and sturgeon habitat features in the Fraser River based on major zones as illustrated in Figure 3.1.

The upper Fraser River, between Tête Jaune Cache and Prince George (Zone 1) is typified by a broad, relatively shallow channel where cobble/gravel bars and islands are prevalent. The river channel narrows and water velocities increase, however, in several localized sections of the river (Rearguard Falls and the Grand Canyon area). The upper portion of the middle Fraser River (Prince George to Soda Creek; Zone 2) is defined by habitat features similar to those found upstream of Prince George; however, the river channel eventually becomes a series of tight meanders within a relatively broad valley bottom. Water velocities and depths are generally moderate and in only a few areas (i.e., where the river channel narrows and becomes confined by narrow bedrock cliff valley walls), are turbulent and up-welling flows present (e.g., Hawks Creek area, French Bar Canyon). Depositional areas, often associated with the capture of white sturgeon, are moderately abundant and found near broad bends in the river channel (RL&L 1998c).

The Fraser River becomes tightly confined by the valley walls and exhibits fast and turbulent flows as it enters the bedrock canyon section above Lillooet (Zone 3). Exposed substrate and large boulders are evident although eddy and depositional areas are relatively uncommon as this section is almost devoid of large meanders and bank outcroppings. As the Fraser River exits Bridge River Rapids and flows south toward the confluence of the Thompson River (Zone 4), the valley width broadens and large channel meanders and depositional areas become more prevalent. Water velocities are generally lower and areas of turbulence and upwelling are more sparse compared with upstream sections. Large backwater and eddy areas are abundant nearshore and usually found in association with depositional type habitats (RL&L 1999b).

The Fraser River, between the Thompson River confluence and Boston Bar (Zone 5), exhibits higher river discharge and water velocities, and more abundant turbulent and rapids areas, which partly reflects the added flow from the Thompson River. Channel width is often restricted by high, sheer bedrock valley walls, with sections of the river exhibiting rapid and turbulent flow conditions. Nearshore depositional areas are moderately abundant throughout this section and are typically more common in areas where the channel is broader and water velocities are lower (RL&L 1999b).

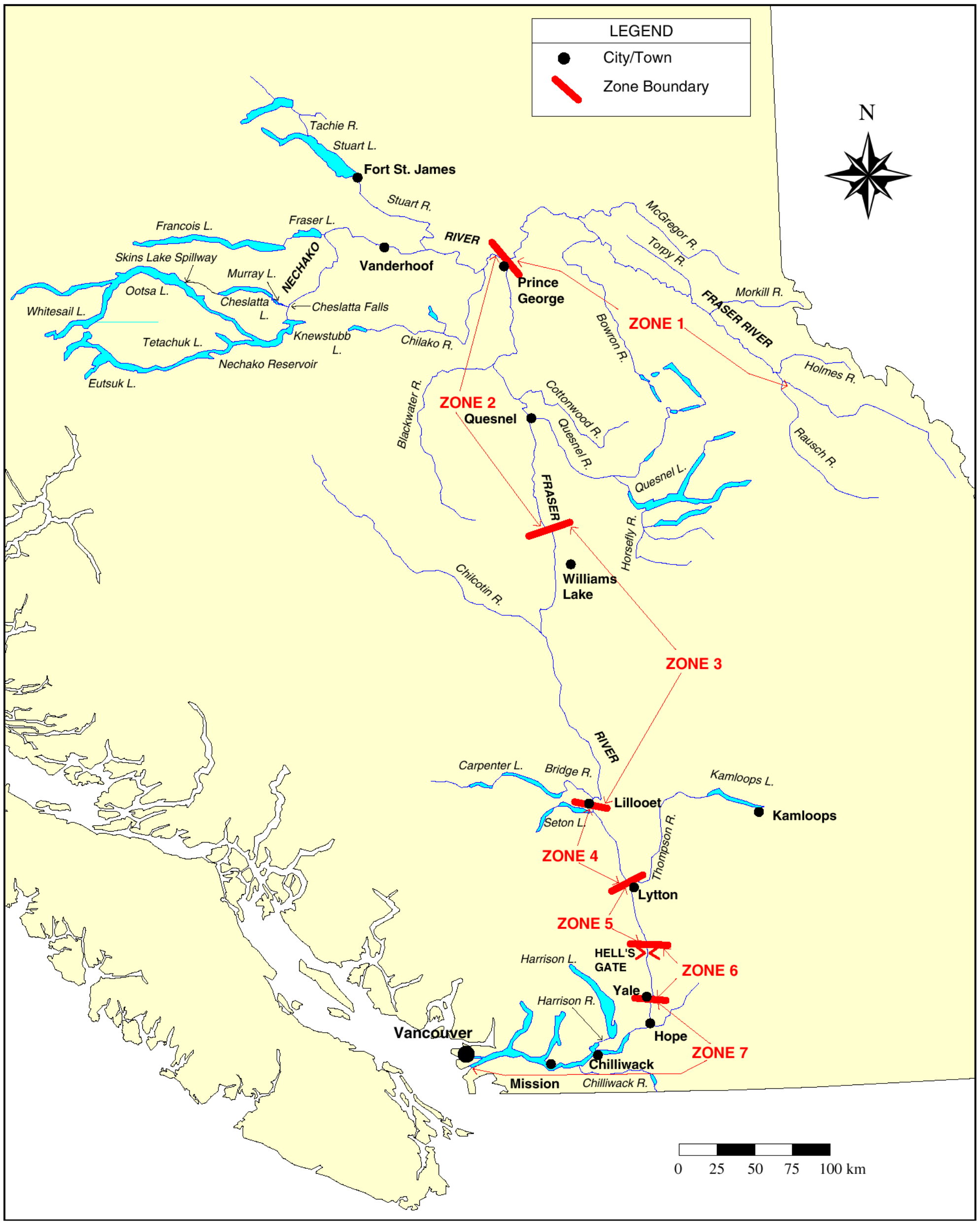

Figure 3.1 Location of Major Geophysical Zones in the Fraser River

The Lower Canyon section of the Fraser River downstream of Boston Bar (Zone 6) is confined between steep, narrow bedrock cliffs with numerous areas defined by extremely high flow conditions. Rapids are common, with depositional areas distributed sporadically downstream to Yale (RL&L 1999b). The Fraser River below

Yale (Zone 7) exhibits a low gradient and braided channel form as large side-channels, marshes, and backwater sloughs become more prevalent (RL&L 1999a). The substratum in the area is more depositional than in the Lower Canyon section, with higher concentrations of fine sediment and small gravel.

RL&L (1997a) described the lower Stuart River, a tributary to the Nechako River in the upper Fraser watershed, as being extensively braided and shallow. Localized riffle-rapid sequences are evident in areas with coarse substrate (i.e., cobble, boulder) and submerged bedrock ledges. The middle Stuart River is relatively straight and exhibits a more uniform "U" shaped river channel. The gradient of the river is lower and the floodplain wider than in the lower river. Water velocities are rated as moderate and mainly laminar in mid-channel areas, with a low number of backwater habitats and small eddy pools. The Stuart River constricts in the upper reaches as it enters a canyon. In this section of the Stuart River, the banks are armoured by parent bedrock material and the substratum is substantially coarser (i.e., boulder, bedrock). Most of the river channel in the upper Stuart River, however, is described as being similar to the middle Stuart River.

The general habitat features of the Nechako River and its tributaries have been described by several authors (Slaney et al. 1986; RL&L 1996, 1997c, 1999d). The Nechako River in the upper portions, immediately below Cheslatta Falls, is high gradient with coarse substrate (i.e., bedrock and boulder). The rest of the river is characterized by low to moderate channel gradients, thalweg depths less than 10 m, and low water velocities. Slough-like conditions are most prevalent downstream of Vanderhoof to below the Stuart River confluence, where substrate is dominated by fines (i.e., sand and clay). Areas with turbulent, up-welling flows exist upstream of Vanderhoof toward the confluence of the Nautley River, and at Hulatt, Isle Pierre, and Whitemud rapids.

3.2 RIVER FLOW AND DISCHARGE REGIME

Discharge records for the Fraser and Stuart rivers were typical of non-regulated systems (RL&L 1996, 1997a-c, 1998a-d, 1999a-d, 2000a-c; Figure 3.2). Generally, discharge remained relatively stable over the winter and early spring period with peak flows developing during spring and early summer (i.e., late May and early June). Flows tended to diminish gradually throughout the summer and fall periods. Within the middle and Lower Fraser River (Figure 3.2), two periods of high flow were typically noted; in mid- to late April, and in mid-May to early June through to early August. Seasonal discharge values for the Fraser River and its tributaries that were obtained as part of the *FRSWMP* can be found in the annual data reports (Appendix A).

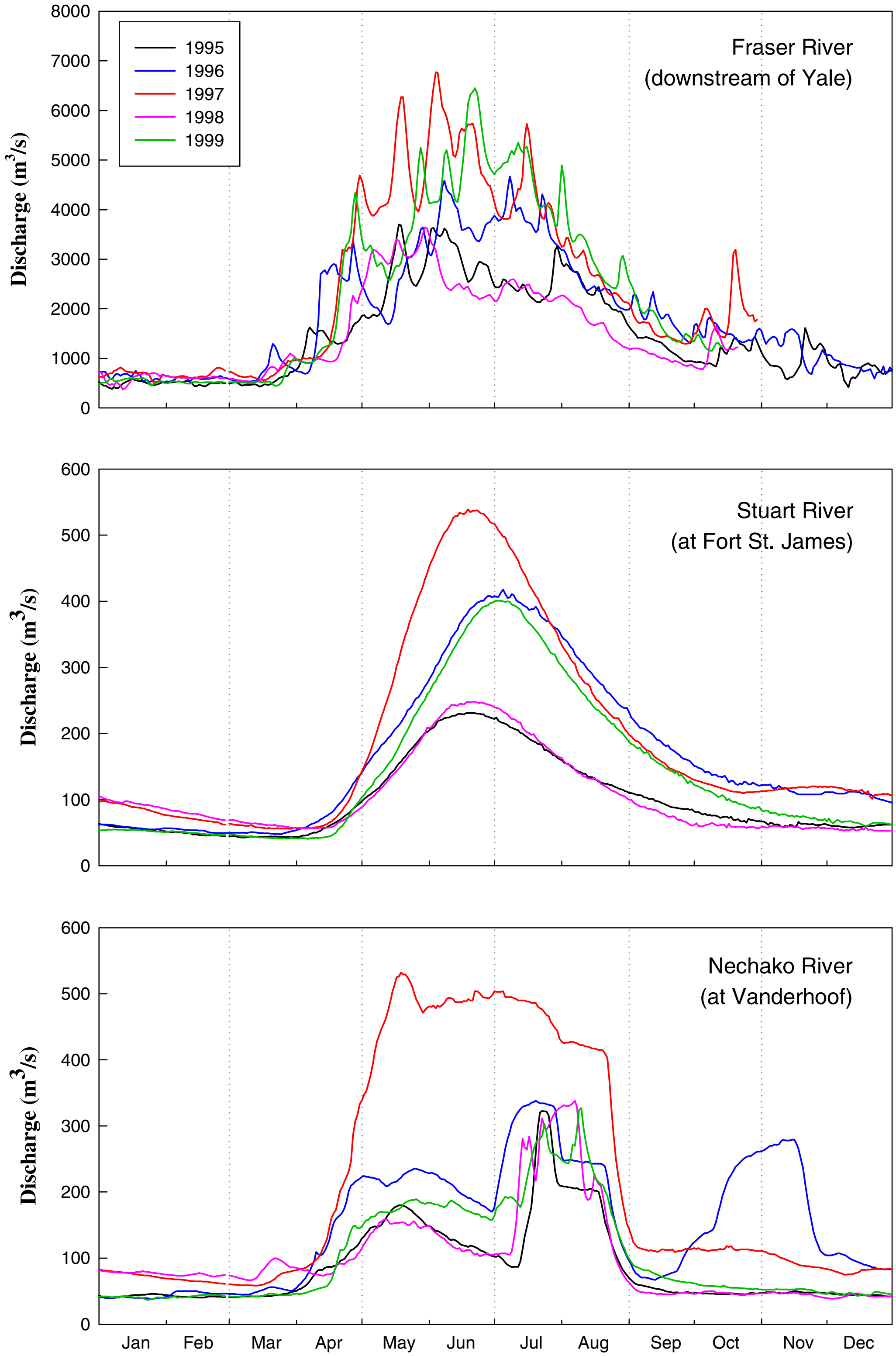

Figure 3.2 Mean Daily Discharges for the Fraser, Stuart, and Nechako Rivers, 1995 to 1999

The hydrograph of the Nechako River below Cheslatta Falls and at Isle Pierre is characteristic of a regulated system with flows moderated by large lakes (i.e., Fraser and Stuart lakes). Flows from late April to June represent the natural spring freshet period, with discharge peaking rapidly, leveling, and reducing gradually (Figure 3.2; RL&L 2000). However, flows from mid-July to late August are normally influenced by releases from Skins Lake Spillway. These releases are regulated as part of a temperature reduction program to provide cooling flows for migrating salmon stocks during the late summer period (RL&L 1997c). Low flows for the Nechako River typically occurred during the January to June period and increased rapidly in mid-July. Extreme fluctuations in releases from Skins Lake Spillway occurred during July and August with a rapid reduction in mainstem Nechako River flows in mid-August that remained low over the fall and winter (RL&L 2000).

3.3 WATER TEMPERATURE

Water temperature of the Fraser and Stuart rivers rose steadily throughout the spring and early summer period and then declined during late summer and fall (Figure 3.3). Peak summer water temperatures in the Fraser River typically did not exceed 20.0 °C (RL&L 1996, 1997a-c, 1998a-d, 1999b-d, 2000a-c), with the exception of the lower Fraser River in 1995 and 1998, and the upper Fraser River in 1999 where water temperatures as high as 22.6 °C were recorded (RL&L 1999a, 2000c). A minimum water temperature of 1.2 °C in January 1998 was reported for the lower Fraser River by RL&L (1999a). Water temperatures in the Stuart River generally peaked just over 20.0 °C, although water temperatures near 23.0 °C were recorded during the monitoring program (Figure 3.3). Seasonal water temperatures for the Fraser River and its tributaries are presented in the annual data reports (Appendix A).

Nechako River water temperatures at Vanderhoof typically ranged from 0 °C during winter ice conditions to more than 20.0 °C during July and August (Figure 3.3). Peak summer temperatures as high as 23 °C have been recorded at other sites in the Nechako River, upstream and downstream of the Stuart River (RL&L 1999d). Water temperatures in the Nechako River were influenced by releases from Skins Lake Spillway and by lake (e.g., Fraser Lake) outflows (RL&L 1998d). The rapid temperature decline in the Nechako River during July and August was attributed to the increased release of cooler water from Skins Lake Spillway. This reduction in water temperature was most apparent in the upper Nechako River, upstream of the Stuart River confluence. RL&L (1997c) noted that water temperatures in the Nechako River downstream of the mouth of the Nautley River were influenced by Fraser Lake. The warmer surface water temperatures in Fraser Lake elevated the water temperature in the Nautley River in late August. Typically, the Nautley River was 0.2 to 0.4 °C warmer than the Nechako River during the July to September period.

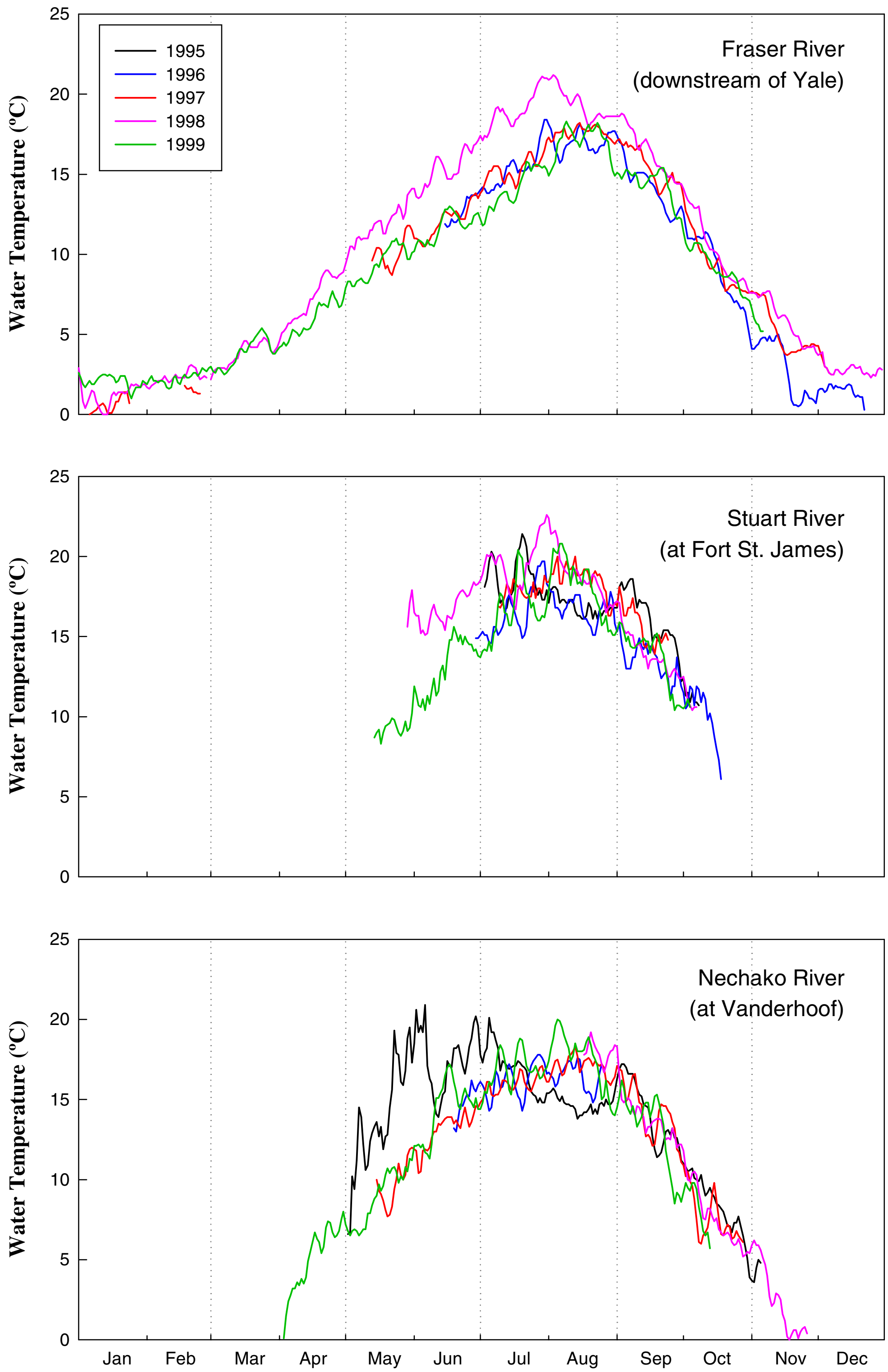

Figure 3.3 Mean Daily Temperatures for the Fraser, Stuart, and Nechako Rivers, 1995 to 1999

CHAPTER 4 DEFINITION OF FRASER STURGEON STOCKS

4.1 INTERPRETATION OF GENETIC RESULTS

Results of the catch and movement data were considered as a starting point for the designation of units to evaluate the genetic population structure of white sturgeon and their geographic ranges in the Fraser River drainage. Movements of tagged fish, potential migratory impediments (velocity barriers), and clusters in distribution were used to identify pooled samples (Nelson et al. 1999; Pollard 2000). The putative groups of white sturgeon used for genetic comparisons are summarized below:

1. Km 78 to 123 (Mission to Chilliwack),
2. Km 169 to 185 (Hope to Yale),
3. Km 220 to 265 (Boston Bar to Lytton),
4. Km 266 to 335 (Lytton to Lillooet),
5. Km 336 to 480 (Lillooet to Chilcotin R.),
6. Km 481 to 554 (Chilcotin R. to Soda Creek),
7. Km 555 to 790 (Soda Creek to Nechako R.),
8. Km 791 to 910 (Nechako R. to Bowron R.), and
9. Nechako River.

DNA analysis of these putative groups provided information on whether there was a genetic distinction among white sturgeon from different geographic areas of the Fraser River drainage and the extent of interbreeding between groups. The genetic study showed that for the most part, the two independent DNA techniques (i.e., mtDNA and microsatellite DNA) supported each other although the mtDNA results provided higher resolution (Nelson et al. 1999; Pollard 2000). Five genetically distinct groups of white sturgeon were identified within the Fraser River drainage. Results showed the two groups of white sturgeon in the lower Fraser River below Hell's Gate (i.e., Km 78 to 123, Km 169 to 185; groups 1 and 2) to be genetically distinct from one another. Furthermore, these groups were found to be more genetically diverse, in terms of the number of different haplotypes, than upstream groups. The greater genetic diversity of lower Fraser River sturgeon was not unexpected and likely reflects the higher density of fish in this section of the river and its accessibility by individuals migrating from other Pacific coast systems (e.g., Columbia River). Bartley et al. (1985) showed that sturgeon populations with access to the ocean exhibited greater genetic diversity than land-locked populations.

Samples from the middle Fraser River (i.e., Km 220 to 554; groups 3 to 6) were not genetically distinct from one another, which suggested there was significant gene flow among white sturgeon within these sections of the

Fraser River mainstem. Consequently, white sturgeon in the middle Fraser River were considered together as a distinct group (Nelson et al. 1999; Pollard 2000). White sturgeon sampled from the upper Fraser River (Km 791 to 910; group 8), above the Nechako River confluence, were the least genetically diverse group of all those tested while Nechako River sturgeon (group 9) were genetically differentiated from all other groups (Nelson et al. 1999; Pollard 2000). White sturgeon sampled in the Fraser River, between Soda Creek and the Nechako River confluence (Km 555 to 790; group 7), were not clearly definable as a genetically discrete group or population (Nelson et al. 1999; Pollard 2000).

4.2 STOCK GROUP BOUNDARIES

Based on the results of the genetic studies and preliminary review of movement and abundance data collected as part of the *FRWSMP*, the five Stock Groups of white sturgeon shown below are illustrated in Figure 1.1 and discussed in the following sections.

- ***Stock Group 1*** (*SG-1*; Km 78 to 153; Lower Fraser Mainstem),
- ***Stock Group 2*** (*SG-2*; Km 154 to 211; Lower Fraser Canyon),
- ***Stock Group 3*** (*SG-3*; Km 212 to 790; Middle Fraser),
- ***Stock Group 4*** (*SG-4*; Km 790 to 1042; Upper Fraser), and
- ***Stock Group 5*** (*SG-5*; Nechako Drainage).

Stock Groups 1 and 2

The boundaries for SG-1 and SG-2 were refined from the putative groups identified in the genetic study to include fish sampled between Chilliwack and Hope (Km 124 to 168) and between Yale and Hell’s Gate (Km 86 to 210). Genetic samples from these two areas were not included in the genetic analysis as it was decided that the two most separated sections below Hell’s Gate would be evaluated first (Nelson et al. 1999; Pollard 2000). If the results suggest further sub-structuring, then additional analysis will be considered in future. To aid in developing a population estimate, RL&L (1999a) separated the lower Fraser River below Hell’s Gate into three reaches based on differing recapture rates of white sturgeon and river morphometry. Reach 3 was termed the Lower Canyon section (Km 154 to 185) and was characterized by a high gradient and confined channel and, since 1996, consistently had a recapture rate greater than 20%. Reach 2 was defined as the Lower Mainland section (Km 92 to 153) and exhibited a low gradient and braided channel. Reach 1 was also located in the Lower Mainland section (Km 78 to 91) with a confined, deep channel and low gradient. As both of the lower reaches had substantially lower recapture rates compared with the uppermost reach, recapture data were pooled (i.e., Km 78 to 153) to provide an estimate of the population size of white sturgeon in the Lower Mainland section.

Data from the capture and telemetry studies were examined to determine if there was support for the groupings used to develop the population estimates. Results suggested few fish in the lower Fraser River exhibit movements between the Lower Mainland (Km 78 to 153) and Lower Canyon (Km 154 to 185) sections. This information suggests limited gene flow between the Lower Mainland and Lower Canyon sections and provides additional evidence to support the use of the boundaries defined by RL&L (1999a). Few white sturgeon were captured upstream of Yale (Km 186 to 211) and none were recaptured during the *FRWSMP*. Based on river conditions being similar and an absence of defined movements, white sturgeon captured above Yale were grouped with fish from the Lower Canyon section.

Results of the *FRWSMP* suggested Hell's Gate may act as a physical barrier to upstream movement by white sturgeon. Capture and movement data provided evidence of downstream movement of white sturgeon from the middle to lower Fraser River (i.e., SG-3 to SG-2) although the frequency at which this occurs appears to be very low. For this reason and because the genetic results showed a distinction between white sturgeon captured in sections of the Fraser River above and below Hell's Gate, the two groups were treated as separate stocks.

Stock Group 3

The boundary of the putative group of white sturgeon in SG-3 was adjusted to include individuals captured downstream of Boston Bar (i.e., Km 212 to 220) and upstream of Soda Creek (Km 555 to 790). Although fish were not captured in the Fraser River between Hell's Gate and Boston Bar, use of this 8 km section of the Fraser River by white sturgeon should not be discounted based on limited sampling effort to date. This section of the Fraser River was included as part of SG-3 based mainly on the assumption that Hell's Gate restricts the upstream transfer of genetic material from stocks in the lower Fraser River.

Catch data from the *FRWSMP* suggests the Fraser River between Soda Creek and the Nechako River confluence most likely does not support significant numbers of white sturgeon. Results of the genetic studies were inconclusive for grouping or differentiating these fish from other putative groups due largely to the low number of samples from this section of the river. In the absence of additional movement or recapture information and because of the genetic distinctness of the upper Fraser River group (SG-5), fish sampled between Soda Creek and the Nechako River confluence were grouped with the middle Fraser River population (SG-3).

Stock Group 4

The upper limit of the boundary for SG-4 was extended to include fish captured in upstream areas that were not included in the genetic analysis (Km 911 to 1042). The upper Fraser group was also adjusted to include white sturgeon captured in the confluence areas and lowermost reaches of tributaries to the upper Fraser River (e.g., Torpy, McGregor, Bowron). The general assumption is that these fish occur in an area that represents the northern extent of their distribution; therefore, they likely exhibit low genetic variability, similar to white sturgeon in other sections of the upper Fraser River. Moreover, there is no information to suggest significant gene flow does not occur among these sections of the upper Fraser River.

Stock Group 5

The genetic results showed white sturgeon from the Nechako River to be clearly distinguishable from all other groups. The boundary of the Nechako group was broadened, however, to include the Stuart River drainage based on the findings of RL&L (1997c, 1998d, 1999d). The documented movements of white sturgeon between the Nechako and Stuart river systems suggested there was the potential for exchange of genetic material between white sturgeon in the two systems.

CHAPTER 5 DISTRIBUTION AND RELATIVE ABUNDANCE

5.1 STOCK GROUP 1

White sturgeon in SG-1 were fairly uniformly distributed in the Fraser River between Mission (rKm 78) and Bristol Island (rKm 154; Figure 5.1). White sturgeon were most commonly captured in the section of the mainstem river between Hatzic Eddy (rKm 81) and rKm 145 (downstream of Bristol Island).

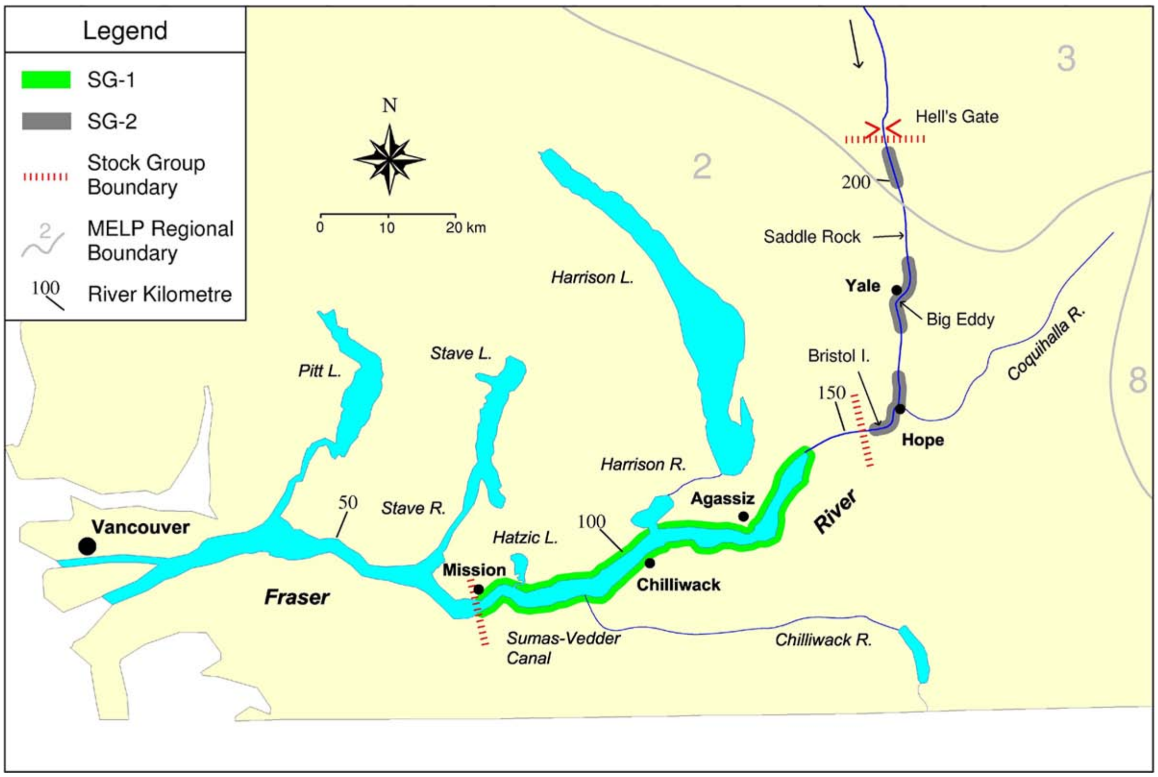

Figure 5.1 White Sturgeon Capture Areas in the Lower Fraser River below Hell's Gate

Based on anecdotal reports from anglers, use of the lower Fraser River by SG-1 is influenced by water levels (RL&L 1999a). Some sections of the lower Fraser River (e.g., Minto Channel, rKm 105; Greyell Channel, rKm 113.5) exhibit low water levels during certain periods of the year that appears to restrict sturgeon use of these areas. Typically, sturgeon use is higher in these channels during spring and summer when water levels are higher.

Catch-per-unit-effort (*CPUE*) by set lining (fish per 100 hook-hours) and angling (fish per hook-hour) were somewhat variable among years for SG-1 (Table 5.1), which may have reflected between year differences in the seasonal timing of field programs and associated changes in physical river conditions (e.g., flow, temperature). Set lines were used to sample white sturgeon in 1995 and 1997 and the relative abundance of white sturgeon was 0.12 and 0.37 fish/100 hook-hours, respectively. Twenty white sturgeon were captured by set line during this period. Set line sampling was also conducted in the lower reaches of the Harrison River in 1995 but white sturgeon were not encountered. Overall, the catch rate for setline sampling was 0.11 white sturgeon/100 hook-hours.

Table 5.1 Summary of Total Catch, Effort, and Catch Rate (*CPUE*) by Set Line and Angling in the Lower Mainland Section of the Fraser River

Stock Group	Sample Method	Waterbody	Year	Effort (hk-hrs)	Catch	*CPUE*[1]
SG-1	Angling	Fraser River	1995	200.3	16	*0.08*
			1996	641.8	161	*0.25*
			1997	219.7	76	*0.35*
			1998	364.2	141	*0.39*
	Angling Total			**1425.9**	**394**	***0.28***
	Set Line	Fraser River	1995	16146.2	19	*0.12*
			1997	272.4	1	*0.37*
		Harrison River	1995	1349.2	0	*0*
	Set Line Total			**17767.8**	**20**	***0.11***

[1] *CPUE*=catch-per-unit-effort; Angling *CPUE*=No. fish/hook-hour; Set Line *CPUE*=No. fish/100 hook-hours.

Sampling by angling from 1995 to 1998 resulted in the capture of 394 white sturgeon in the Lower Mainland section of the Fraser River. The catch rate of white sturgeon during this period ranged from 0.08 fish/hook-hour in 1995 to 0.39 fish/hook-hour in 1997 (Table 5.1). For all years and locations combined, the catch rate for angling was 0.28 white sturgeon/hook-hour.

Spatially, the relative abundance of white sturgeon was noticeably higher in the Mission (rKm 76) to Sumas-Vedder Canal (rKm 92) area compared with other areas (Figure 5.2). Angling catch rates ranged from 0.44 to 0.51 white sturgeon/hook-hour in this section of the lower Fraser River; set line catch rate peaked at 0.41 white sturgeon/100 hook-hours in the Sumas-Vedder Canal area.

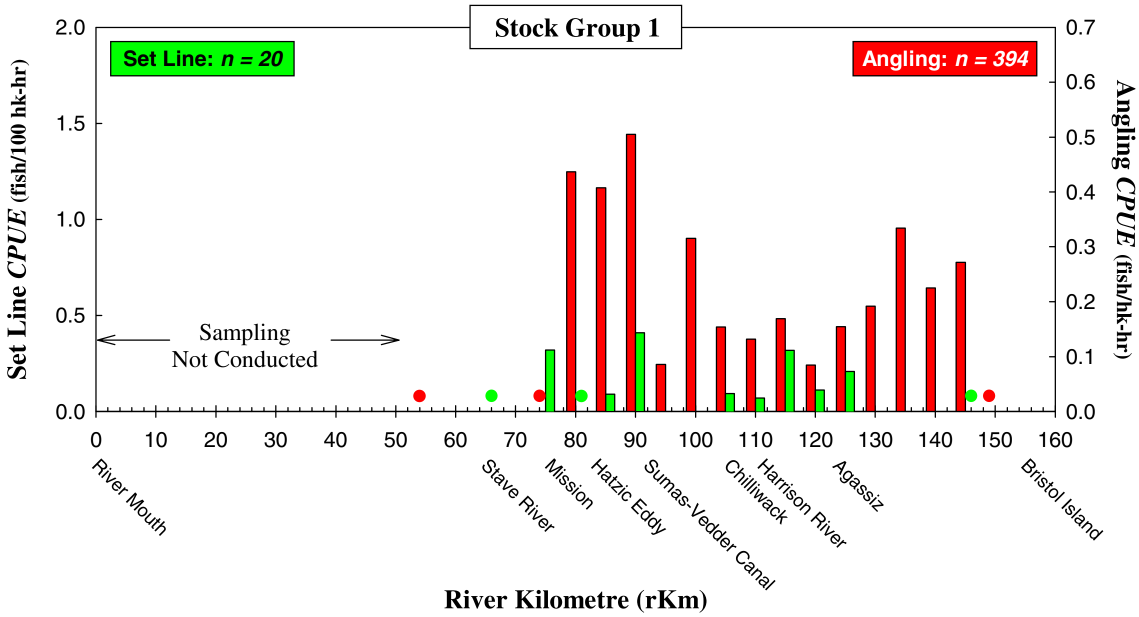

Figure 5.2 Relative Abundance of White Sturgeon by Two Kilometre River Section in the Lower Mainland Section of the Fraser River (colored circles denote river sections where sampling yielded zero catch)

White sturgeon egg and larval capture programs were conducted in the Lower Mainland section. These programs, implemented in 1997 and continued through to 1999, involved the use of egg collection mats and drift nets. Approximately 14 636 hours of egg collection mat effort (i.e., mat-hours) occurred in SG-1, which resulted in the capture of 47 white sturgeon eggs (RL&L 1998a; Perrin et al. 1999, 2000). The catch rate ranged from zero in 1997 to 0.51 white sturgeon eggs/100 mat-hours in 1999. Drift net sampling was done for more than 568 hours, with 74 white sturgeon larvae and three white sturgeon eggs recorded during the 1998 and 1999 programs (Perrin et al. 1999, 2000). This catch and effort corresponded to a catch rate of 0.07 and 0.19 white sturgeon/net-hour in 1998 and 1999, respectively. White sturgeon eggs and larvae were collected in main channel (Hope Slough) and side channel (Minto, Jespersons, Herrling, and Herrling and Peters islands) areas.

5.2 STOCK GROUP 2

Three main areas of sturgeon use were identified in the Lower Canyon section of the lower Fraser River (Figure 5.1). White sturgeon were captured in the vicinity of Hope (includes the confluence area of the Coquihalla River; rKm 159), Yale (includes Big Eddy; rKm 183), and downstream of Hell's Gate (between Alexandra Bridge and Blackwater Canyon; rKm 200 to 208; RL&L 1996a, 1997a, 1998a, 1999a).

Nineteen white sturgeon were captured by set line in the Lower Canyon section of the Fraser River mainstem (Table 5.2). White sturgeon were only encountered, however, in 1995 and 1999. The catch rates during this period were 0.33 and 0.15 white sturgeon/100 hook-hours, respectively, with a combined catch rate of 0.21 fish/100 hook-hours. The absence of white sturgeon in set line catches from 1997 and 1998 may be partly attributed to sample effort, which was substantially lower compared with other years.

Table 5.2 Summary of Total Catch, Effort, and Catch Rate (*CPUE*) by Set Line and Angling in the Lower Canyon Section of the Fraser River

Stock Group	Sample Method	Waterbody	Year	Effort (hk-hrs)	Catch	*CPUE*[1]
SG-2	Angling	Fraser River	1995	63.8	7	*0.11*
			1996	302.2	186	*0.62*
			1997	420.6	159	*0.38*
			1998	86.4	22	*0.25*
			1999	101.7	2	*0.02*
	Angling Total			**974.6**	**376**	***0.39***
	Set Line	Fraser River	1995	3304.9	11	*0.33*
			1997	245.6	0	*0*
			1998	387.7	0	*0*
			1999	5303.7	8	*0.15*
	Set Line Total			**9241.9**	**19**	***0.21***

[1] *CPUE*=catch-per-unit-effort; Angling *CPUE*=No. fish/hook-hour; Set Line *CPUE*=No. fish/100 hook-hours.

Considerably more white sturgeon in SG-2 were captured by angling than by set lines between 1995 and 1999. The 974.6 hook-hours of effort resulted in the capture of 376 white sturgeon; catch rate was 0.39 white sturgeon/hook-hour (Table 5.2). Catch rate varied among years with the highest catch rate recorded in 1996. The lowest catch was recorded in 1999 although sampling was restricted to the upper reaches of the Lower Canyon section, between Hell's Gate and Yale.

The highest set line catch rate (0.52 white sturgeon/100 hook-hours) was recorded in the vicinity of Big Eddy (rKm 182), downstream of Lady Franklin Rapids (rKm 183; Figure 5.3). Angling captures of white sturgeon were most common in the Lower Canyon section of the Fraser River between the confluence of the Coquihalla River (rKm 160) and Big Eddy.

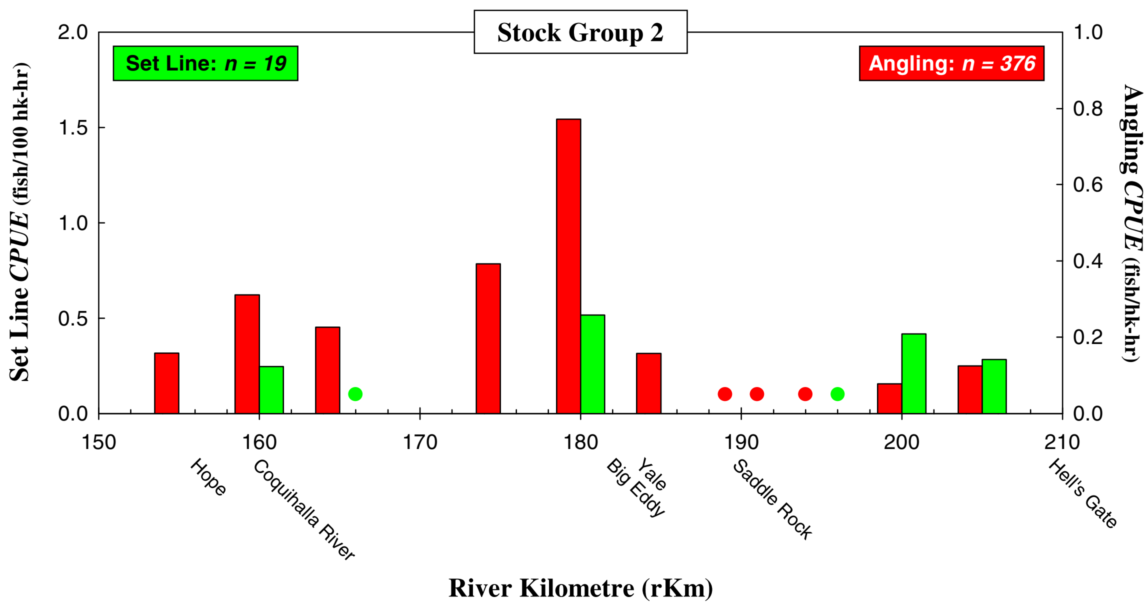

Figure 5.3 Relative Abundance of White Sturgeon by Two Kilometre River Section in the Lower Canyon Section of the Fraser River (colored circles denote river sections where sampling yielded zero catch)

Sample effort was expended to capture white eggs and larvae in the canyon section of the lower Fraser River during the 1997 to 1999 period. A total of 8760.2 hours of egg collection mat and 114.7 hours of drift net sampling resulted in the capture of 33 white sturgeon eggs and 29 white sturgeon larvae (RL&L 1998a; Perrin et al. 1999, 2000). The catch rate using egg collection mats was 2.01 white sturgeon/100 mat-hours, whereas the catch rate using drift nets varied from 0.04 white sturgeon/net-hour in 1997 to 0.76 white sturgeon/net-hour in 1999.

5.3 STOCK GROUP 3

Figure 5.4 depicts the broad distribution of white sturgeon between Boston Bar (rKm 220) and Prince George (rKm 790). Distribution varied, however, with sturgeon being more uniformly distributed between Boston Bar and the Chilcotin River confluence (rKm 479; RL&L 1998b-c, 1999b-c, 2000b-c). White sturgeon were commonly recorded near the confluences of tributaries to the mainstem Fraser River (e.g., Nahatlach, Stein, Seton, and Chilcotin rivers) and in the French Bar Canyon (rKm 409) and Powerline Rapids (rKm 359 to 365) areas. White sturgeon were encountered more sporadically upstream of the Chilcotin River confluence, with areas of higher use noted in the vicinity of Hawks Creek (rKm 550), Australian Creek (rKm 615), and the confluence area of the Cottonwood River (rKm 670).

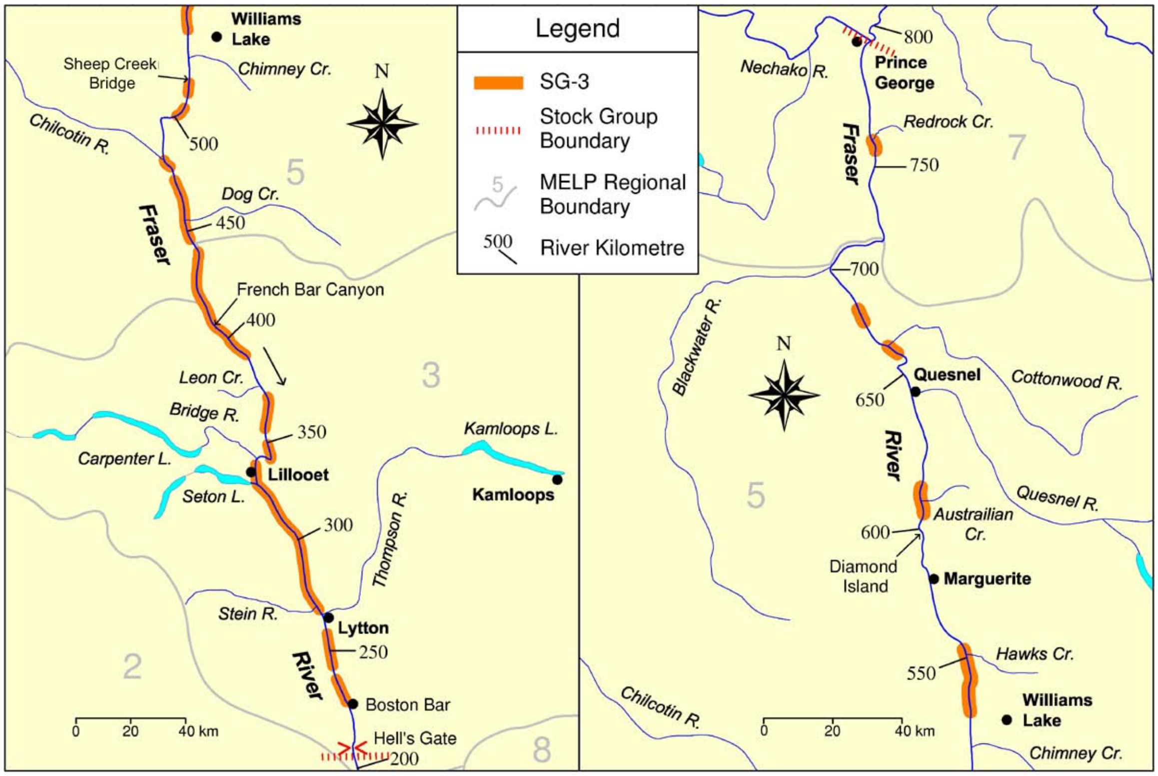

Figure 5.4 White Sturgeon Capture Areas in the Middle Fraser River between Hell's Gate and Prince George

Within the middle section of the Fraser River, 657 white sturgeon were captured by angling and set lining (Table 5.3). Despite efforts to capture individuals in the Quesnel River, and in Quesnel, Seton, and Kamloops lakes, white sturgeon were only encountered in the mainstem of the Fraser River. A total of 517 white sturgeon were captured by angling for a catch rate of 0.18 fish per hook-hour; annual catch rate ranged from 0.05 to 0.30 white sturgeon/hook-hour.

Fewer white sturgeon (n=281) were captured in the middle Fraser River by set lining compared with angling. On a temporal scale, the annual catch rate of white sturgeon was similar from 1997 to 1999 where it ranged from 0.46 to 0.65 white sturgeon/100 hook-hours (Table 5.3). The highest annual catch rate of white sturgeon was recorded in 1996 (1.16 white sturgeon/100 hook-hours) and the lowest catch rate occurred in 1995 (0.39 white sturgeon/100 hook-hours). For all years combined, the catch rate was 0.38 white sturgeon/100 hook-hours.

Table 5.3 Summary of Total Catch, Effort, and Catch Rate (*CPUE*) by Set Line and Angling in the Middle Fraser River

Stock Group	Sample Method	Waterbody	Year	Effort (hk-hrs)	Catch	*CPUE*[1]
SG-3	Angling	Fraser River	1995	80.6	4	*0.05*
			1996	272.3	66	*0.24*
			1997	898.4	160	*0.18*
			1998	1059.6	120	*0.11*
			1999	564.9	167	*0.30*
		Fraser River Total		**2875.8**	**517**	***0.18***
		Seton Lake	1997	43.0	0	*0*
	Angling Total			**2918.8**	**517**	***0.18***
	Set Line	Fraser River	1995	7110.3	28	*0.39*
			1996	1379.9	16	*1.16*
			1997	20 674.0	105	*0.51*
			1998	16 243.7	75	*0.46*
			1999	8789.7	57	*0.65*
		Fraser River Total		**54 197.6**	**281**	***0.52***
		Quesnel River	1995	310.0	0	*0*
		Quesnel Lake	1995	231.8	0	*0*
		Kamloops Lake	1995	808.2	0	*0*
		Seton Lake	1997	17 604.3	0	*0*
	Set Line Total			**73 151.9**	**281**	***0.38***

[1] *CPUE*=catch-per-unit-effort; Angling *CPUE*=No. fish/hook-hour; Set Line *CPUE*=No. fish/100 hook-hours.

As illustrated in Figure 5.5, the spatial trend in the relative abundance of white sturgeon within the middle section of the Fraser River was similar for set line and angling catches. Although physical river conditions (e.g., flow, temperature) and sample periods did not precisely overlap among years, results generally indicated white sturgeon were more common in the Boston Bar to Bridge River Rapids (rKm 337), and French Bar to Chilcotin River confluence sections than in the other sections of the middle Fraser River. Upstream of the Chilcotin River confluence, catch rates declined sharply, and the distribution of white sturgeon was more sporadic. Catches of white sturgeon were restricted to localized areas in the vicinity of Australian, Hawks, Cottonwood, and Red Rock creeks.

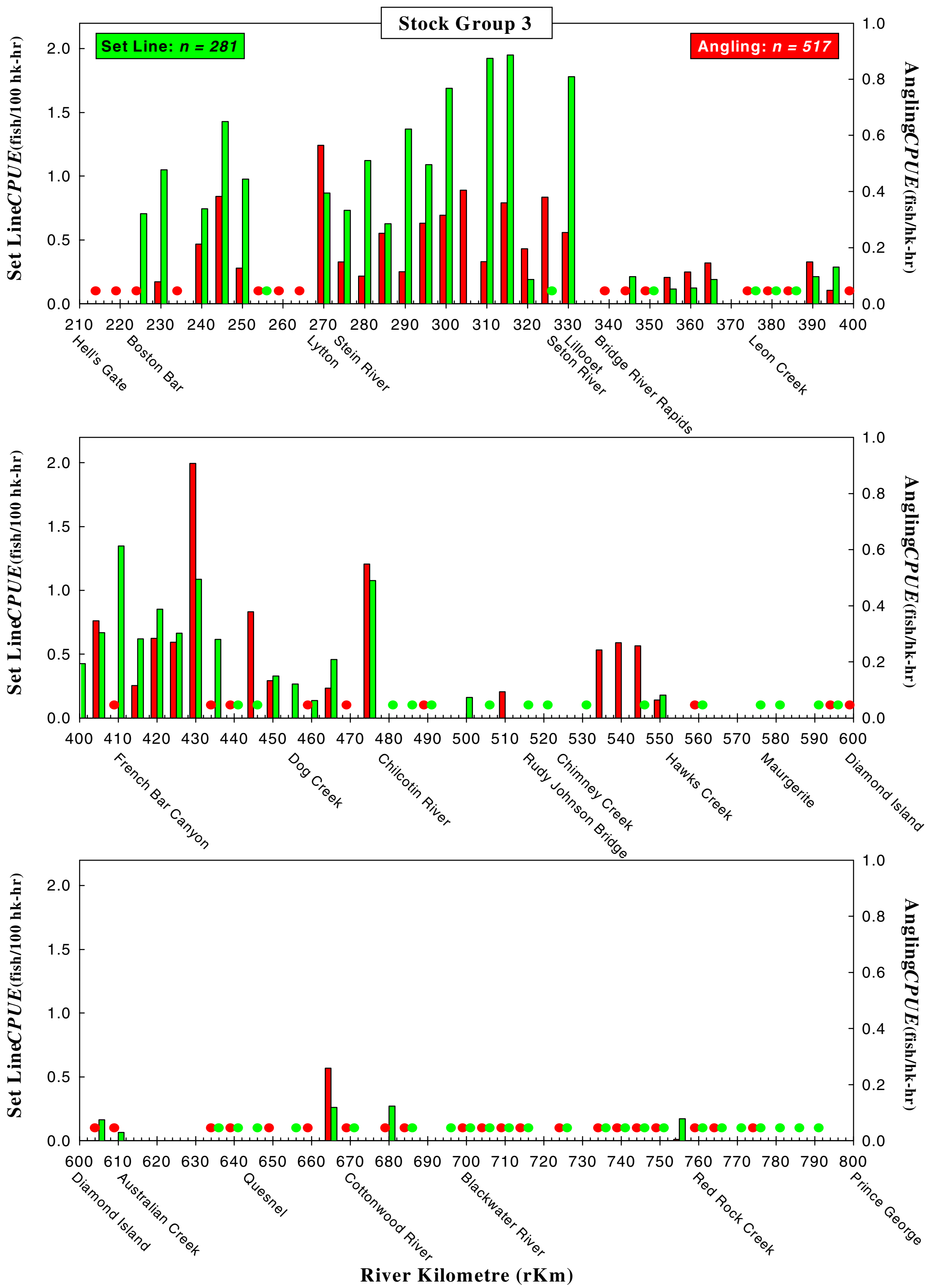

Figure 5.5 Relative Abundance of White Sturgeon by Four Kilometre River Section in the Middle Fraser River (colored circles denote river sections where sampling yielded zero catch)

5.4 STOCK GROUP 4

Studies to investigate the distribution of white sturgeon in the upper Fraser River above Prince George (SG-4) were not as intensive as in other portions of the drainage. White sturgeon were most commonly found near the confluence areas of the major tributaries such as the McGregor (rKm 890), Willow (rKm 827), Bowron (rKm 908 to 911), and Torpy (rKm 1035) rivers and in the Grand Canyon area (rKm 944 to 946; RL&L 1998d; LTFN 2000). Individuals were also documented in the lowermost reaches of tributaries to the upper mainstem, including the Torpy, Bowron, and McGregor rivers (Figure 5.6).

White sturgeon were sampled in the upper Fraser River from 1997 to 1999, mainly by set line and angling. Total set line effort in the mainstem during this period was 37 135.2 hook-hours that resulted in the capture of forty-five white sturgeon; catch rate was 0.11 white sturgeon/100 hook-hours (Table 5.4). Set lining was also conducted in the lower reaches of the McGregor (1606 hook-hours) and Bowron (2510.7 hook-hours) rivers. White sturgeon were captured in each of these systems with corresponding catch rates of 0.28 and 0.06 white sturgeon/100 hook-hours, respectively.

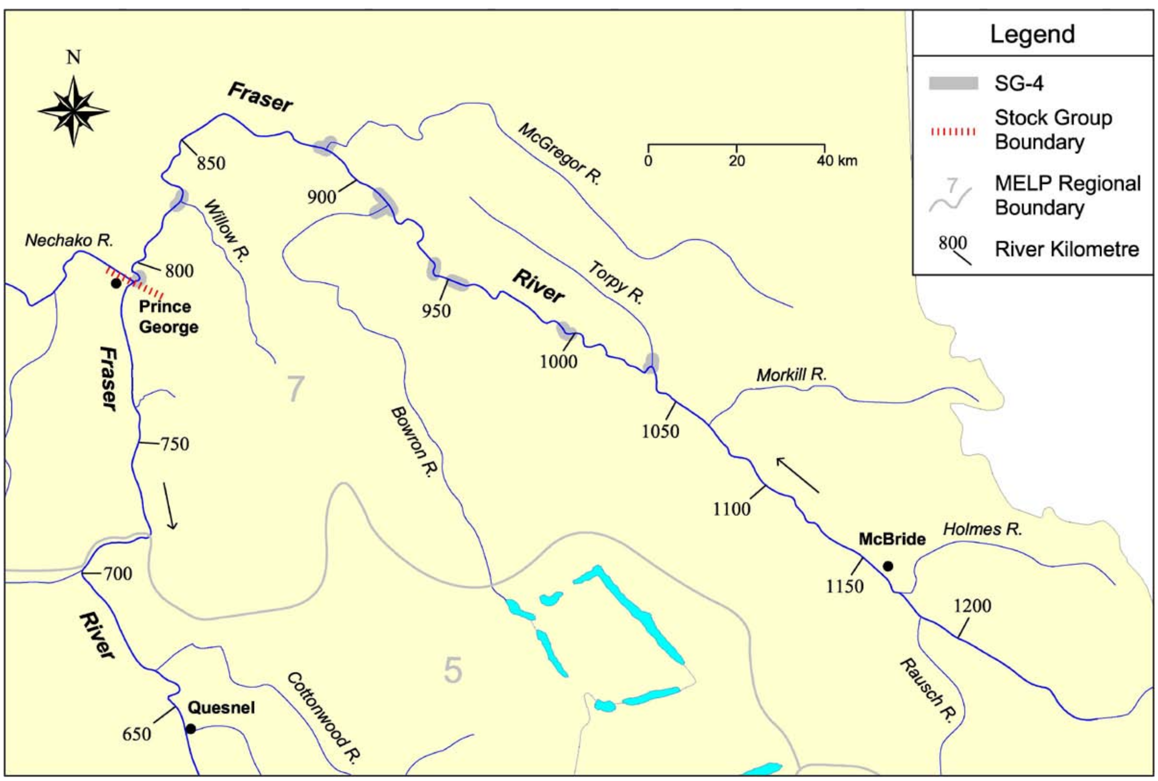

Figure 5.6 White Sturgeon Capture Areas in the Upper Fraser River, upstream of Prince George

The number of white sturgeon captured by angling (*n*=7) was considerably lower than the number of fish captured by set line. The angling catch rate was 0.01 white sturgeon/hook-hour. Most of the sampling effort occurred in 1998, which resulted in the capture of six white sturgeon (Table 5.4). A modest amount of angling effort was also expended in the lower reaches of the Torpy, McGregor, and Bowron rivers. However, white sturgeon were only angled in the Torpy River.

Gill nets were used to sample white sturgeon in the upper Fraser River mainstem and in the confluence areas of tributaries in 1997 and 1999. A total of 62.8 net-days of effort was applied and no white sturgeon were captured. A modest amount of boat electrofishing effort (102.5 minutes) was also expended within side channel and snye-type habitats in the upper Fraser River mainstem near the Nechako River confluence; white sturgeon were not encountered.

Table 5.4 Summary of Total Catch, Effort, and Catch Rate (*CPUE*) by Set Line and Angling in the upper Fraser River

Stock Group	Sample Method	Waterbody	Year	Effort (hk-hrs)	Catch	*CPUE*[1]
SG-4	Angling	Fraser River	1997	2.0	0	*0*
			1998	1013.4	6	*0.01*
			1999[2]	29.8	0	*0*
		Fraser River Total		**1045.2**	**6**	***0.01***
		McGregor River	1998	19.3	0	*0*
		Torpy River	1998	10.9	1	*0.09*
		Bowron River	1998	57.3	0	*0*
		Blackwater River	1998	62.0	0	*0*
	Angling Total			**1194.7**	**7**	***0.01***
	Set Line	Fraser River	1997	5031.2	1	*0.02*
			1999[2]	32 104.0	36	*0.11*
		Fraser River Total		**37 135.2**	**37**	***0.10***
		McGregor River	1997	711.6	0	*0*
			1999[2]	894.4	1	*0.11*
		Bowron River	1999[2]	2510.7	7	*0.28*
	Set Line Total			**41 251.9**	**45**	***0.11***

[1] *CPUE*=catch-per-unit-effort; Angling *CPUE*=No. fish/hook-hour; Set Line *CPUE*=No. fish/100 hook-hours.

[2] Data obtained from LTFN (2000).

Within the upper Fraser River mainstem, highest catch rates were recorded in the vicinity of the McGregor River confluence (rKm 860 to 900; Figure 5.7). Generally, catch rates were higher near the confluence areas of tributaries than in other areas of the upper Fraser River mainstem.

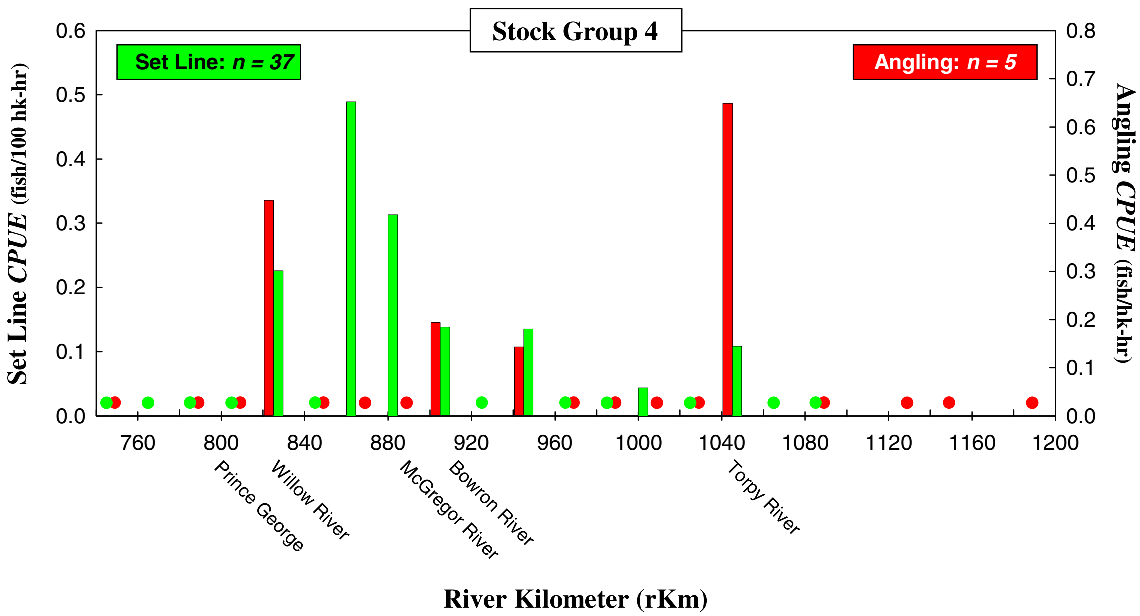

Figure 5.7 Relative Abundance of White Sturgeon by Twenty Kilometre River Section in the Upper Fraser River (colored circles denote river sections where sampling yielded zero catch; tributary catches are not illustrated)

5.5 STOCK GROUP 5

The distribution of white sturgeon in the Nechako River and its tributaries (SG-5) has been well documented (Dixon 1986; RL&L 1996a, 1997c, 1998d, 1999d, 2000d; Triton 2000). White sturgeon occurred most commonly in the mainstem Nechako River with individuals captured between Isle Pierre (rKm 67) and the Nautley River (rKm 192; RL&L 2000d; Figure 5.8). RL&L (1998d, 1999d, 2000d) identified areas of high use by white sturgeon in the Nechako River that included the section between Isle Pierre and the Stuart River (rKm 67 to 79), the Sinkut area (rKm 115 to 117), and downstream of Vanderhoof (rKm 122 to 127). The areas of the Nechako River near Leduc Creek (rKm 117 to 122), immediately downstream of Vanderhoof (rKm 128 to 175) were rated a low to moderate use, as defined by RL&L (1997c, 1998d).

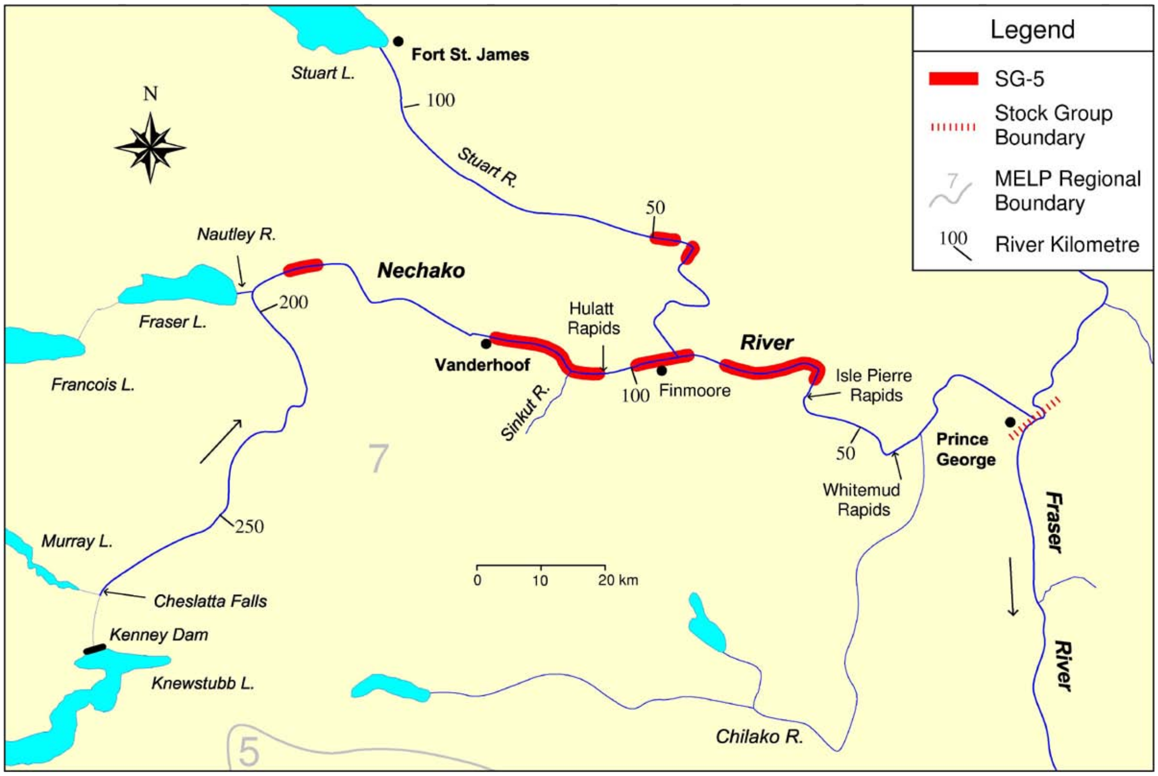

Figure 5.8 White Sturgeon Capture Areas in the Nechako River Drainage

The distribution of white sturgeon in the Stuart River system is less well understood. Sturgeon were only captured in the middle portion of the system near "Sturgeon Point" (rKm 50; Figure 5.8). Data from mark-recapture and movement studies, and anecdotal information from First Nations and others, however, suggest white sturgeon use of the system, including Stuart and Trembleur lakes, may be greater than the capture results indicate to date.

The Nechako River drainage was intensively sampled from 1995 to 1999. Set lining was the most common technique used to capture white sturgeon in SG-5. Within the Nechako River mainstem, 123 728.7 hook-hours of set line effort was expended to capture of 182 white sturgeon; catch rate was 0.15 white sturgeon/100 hook-hours (Table 5.5). The catch rate varied among sample years and ranged from 0.08 white sturgeon/100 hook-hours in 1997 to 0.44 white sturgeon/100 hook-hours in 1999.

Four white sturgeon were also captured by angling in the Nechako River (Table 5.5). White sturgeon were not captured by angling during sampling in the Stuart River or Fraser Lake.

Table 5.5 Summary of Total Catch, Effort, and Catch Rate (*CPUE*) by Set Line and Angling in the Nechako River Drainage

Stock Group	Sample Method	Waterbody	Year	Effort (hk-hrs)	Catch	*CPUE*[1]
SG-5	Angling	Nechako River	1996	29.4	0	*0*
			1997	21.5	2	*0.09*
			1998	72.0	2	*0.03*
			1999	12.9	0	*0*
		Nechako River Total		**135.8**	**4**	***0.03***
		Stuart River	1996	9.6	0	*0*
			1997	6.3	0	*0*
			1998	3.4	0	*0*
			1999	2.0	0	*0*
		Fraser Lake	1996	1.7	0	*0*
	Angling Total			**158.8**	**4**	***0.03***
	Set Line	Nechako River	1995	23 498.5	36	*0.15*
			1996	33 639.9	36	*0.11*
			1997	37 580.1	28	*0.08*
			1998	20 589.6	45	*0.22*
			1999	8420.6	37	*0.44*
		Nechako River Total		**123 728.7**	**182**	***0.15***
		Stuart River	1996	9044.9	1	*0.01*
			1997	2987.9	1	*0.03*
			1998	3799.1	0	*0*
		Tachie River	1996	4145.5	0	*0*
		Nautley River	1995	438.9	0	*0*
			1997	136.3	0	*0*
		Fraser Lake	1995	648.9	0	*0*
			1996	1684.0	0	*0*
			1997	570.8	0	*0*
	Set Line Total			**147 184.9**	**184**	***0.13***

[1] *CPUE*=catch-per-unit-effort; Angling *CPUE*=No. fish/hook-hour; Set Line *CPUE*=No. fish/100 hook-hours.

The highest catch rates of white sturgeon were recorded in the Sinkut River area (rKm 115 to 117) of the Nechako River mainstem (Figure 5.9). Capture data indicated the relative abundance of white sturgeon in the Nechako River, between the Fraser River confluence and Isle Pierre and between Vanderhoof and Cheslatta Falls, was extremely low. The relative use of these areas of the Nechako River by white sturgeon is discussed in more detail in Chapter 7.

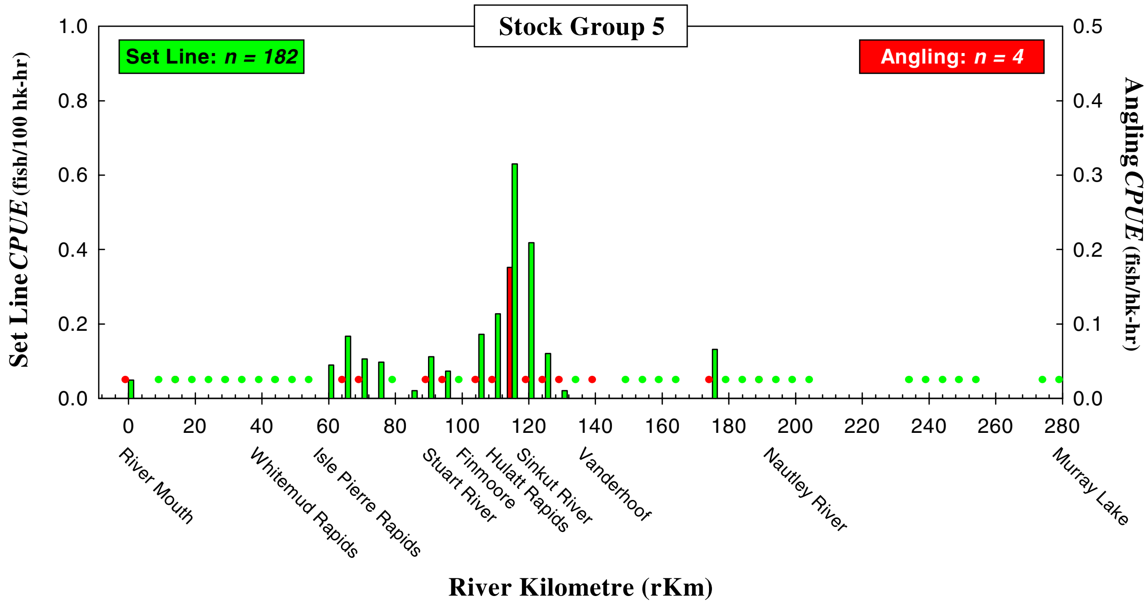

Figure 5.9 Relative Abundance of White Sturgeon by Four Kilometre River Section in the Nechako River (colored circles denote river sections where sampling yielded zero catch)

From 1996 to 1999, the program included juvenile sampling components to gather information on the early life history of white sturgeon. Small mesh gill nets were deployed in the Nechako and Stuart rivers and in Fraser Lake to target juvenile white sturgeon. Approximately 107 net-days (one net-day is equivalent to 100 m^2 of net set for a 24 h period) of effort were expended in the Nechako River (RL&L 1997c, 1998d, 1999d, 2000d; Triton 2000). Eight white sturgeon were captured, of which, five were juveniles. The catch rates varied annually from 0.06 to 0.12 white sturgeon/net-day. White sturgeon were not captured by netting in the Stuart River (1.32 net-days of effort) or in Fraser Lake (16 net-days of effort).

To confirm spawning activity by white sturgeon in the Nechako River drainage, early life history sampling was conducted in potential spawning habitats during the spring spawning period (i.e., May to July flows; 12 to 18 °C). Eggs or larval stages of white sturgeon were not collected despite 15 716.6 mat-hours of effort in the Nechako River and 6242.8 mat-hours of effort in the lower Stuart River (RL&L 1998d, 1999d, 2000d). Drift netting (17.3 net-hours in Nechako River; 23.6 net-hours in Stuart River) also failed to confirm spawning.

Boat electofishing was conducted in the Nechako and Stuart rivers. The catch rate was low with only two white sturgeon observed in the Nechako River mainstem after more than 10 hours of electrofishing effort. White sturgeon were not captured or observed after nearly 40 minutes of boat electrofishing in the Stuart River.

CHAPTER 6 POPULATION DYNAMICS

6.1 STOCK SIZE ESTIMATES

A population estimate was generated for each Stock Group using data collected from all years of monitoring (1995 to 1999; Table 6.1) by applying the modified Schnabel Estimation Technique. In the lower Fraser River a population estimate of 17 259 fish (95% *CI*=6118 to 64 338) in SG-1 and 976 fish (95% *CI*=601 to 1598) in SG-2 was determined. The density of white sturgeon in the lower Fraser River is also shown in Table 6.1 as the estimated size of the Stock Group divided by its geographic range. These estimates represented the approximate size and density of the population of fish greater than 50 cm FL. The analysis for these Stock Groups excluded multiple recaptures of fish within years and recaptures among Stock Groups.

Table 6.1 Population and Density Estimates for Stock Groups of White Sturgeon in the Fraser River drainage

Stock Group	Density (fish/km)	Population Estimate	95%*CI*
SG-1	230.1	17 259	6118 to 64 338
SG-2	17.1	976	601 to 1598
SG-3	6.5	3745	3064 to 4813
SG-4	n/a	n/a	n/a
SG-5	1.5	571	421 to 890

Note: n/a=not available due to insufficient recaptures.

The population estimate for the Lower Canyon section (SG-2) may be more robust than the estimate for the Lower Mainland section (SG-1) due mainly to the higher recapture rate for SG-2 (12.5%) than SG-1 (2.4%) which was reflected in the tighter confidence interval for the SG-2 estimate (RL&L 1999a). The population of white sturgeon in SG-1 undoubtedly extends to below Mission but information on the size and distribution of white sturgeon in the tidal zone of the Fraser River was not collected as part of the *FRWSMP*. Consequently, the population estimate for SG-1 was considered preliminary and additional mark-recapture sampling was recommended to increase confidence in the estimate.

The size of the white sturgeon population in SG-3 was estimated at 3745 fish (95% *CI*=3064 to 4813), with a density of 6.5 fish/km (Table 6.1). Because of the differences in sample effort and associated recapture rates among river sections, and the large segment of the Fraser River that is occupied by SG-3, this estimate does not reflect the apparent localized variability in stock density. Examples of localized areas in SG-3 where capture data indicated higher densities of white sturgeon included the confluence areas of some of the larger tributaries (e.g., Stein, Seton, Chilcotin rivers) as well as French Bar Canyon and Powerline Rapids.

An estimate of the population size of SG-4 was not generated due to the low number of recaptures. The size and density of SG-5 was estimated at 571 fish (*CI*=421 to 890) and 1.5 fish/km, respectively, which was representative of the population in the Nechako River from the mouth to the confluence of the Nautley River, and from the Stuart River below Stuart Lake. The estimate includes fish captured by all agencies in the drainage but may not accurately reflect the size of the population in the Stuart River because of limited sampling effort and few recaptures in this system.

6.2 STOCK CHARACTERISTICS

6.2.1 Size and Growth Characteristics

Life history information gathered during the *FRWSMP* is summarized in the following sections along with a general comparison of differences in size and age-class composition and growth characteristics among Stock Groups. Life history information (e.g., length, weight, age) on white sturgeon in the Fraser River drainage, collected and presented by other researchers since the onset of the *FRWSMP* (LTFN 2000; Triton 2000), were included in the following analysis of age-frequency distribution and age-growth characteristics.

Length-Weight

The length-weight regression equations for each of the five Stock Groups indicated the relationship between fork length and weight was logarithmic (Table 6.2) and growth was isometric (Figure 6.1). White sturgeon captured in the Fraser River drainage ranged in fork length from 38.5 to 320.0 cm and in weight from 0.3 to 151.6 kg. Figure 6.1 illustrates that the observed differences in length-weight among stocks were visible yet relatively small. Because of the large sample sizes, there were significant differences among the stocks with respect to weight-length coefficients (ANCOVA; $p<0.01$) that were described by the equation [*Log W=b0 + (b1*log FL) + (b2*Stock Group) + error*] for common slopes and different intercepts. Generally, comparison probabilities (*T-Method*; $p<0.01$) suggested the more southern Stock Groups were heavier at a given length than their more northern counterparts. Interpreting the biological reasons for such small differences with such great overlap are difficult, however, and more likely attributable to stock differences in such factors as population structure (e.g., sex and maturity) and sampling design (e.g., capture season and year).

Table 6.2 Length-Weight Regressions of White Sturgeon Stock Groups in the Fraser River Drainage

Stock Group	Regression Equation	Linear Regression Equation	r^2	*n*
SG-1	$W = 2.789 \times 10^{-6} \times FL^{3.185}$	Log W = -5.667 + 3.185(Log FL)	*0.98*	*553*
SG-2	$W = 5.284 \times 10^{-6} \times FL^{3.091}$	Log W = -5.369 + 3.092(Log FL)	*0.97*	*346*
SG-3	$W = 3.221 \times 10^{-6} \times FL^{3.231}$	Log W = -5.785 + 3.230(Log FL)	*0.94*	*613*
SG-4	$W = 1.098 \times 10^{-6} \times FL^{3.397}$	Log W = -6.357 + 3.397(Log FL)	*0.98*	*44*
SG-5	$W = 2.463 \times 10^{-6} \times FL^{3.226}$	Log W = -5.835 + 3.226(Log FL)	*0.97*	*187*

Note: W=weight in grams; FL=fork length in millimeters.

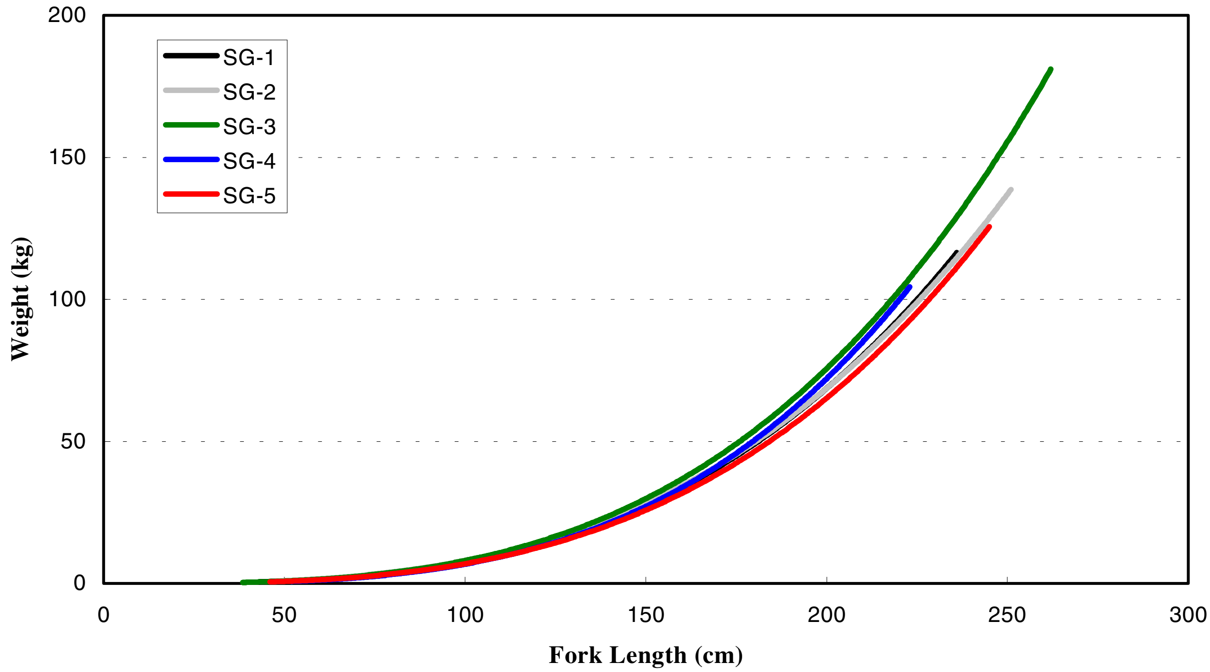

Figure 6.1 Length-Weight Regressions of White Sturgeon Stock Groups in the Fraser River Drainage

RL&L (1996a) showed that the length-weight relationships documented for other populations of white sturgeon in the Columbia (RL&L 1994), Snake (Cochnauer 1983), Kootenai (Apperson and Anders 1991), and Sacramento (Kohlhorst et al. 1980) rivers were generally similar to those identified in the Fraser River drainage.

Fork Length-Total Length

The linear relationship between fork length and total length of white sturgeon was examined for each of the five Stock Groups. As a general linear model comparison of this linear relationship did not show significant difference among Stock Groups (ANOVA; $p>0.01$), a single regression equation was generated to represent all stocks of white sturgeon in the Fraser River drainage (Figure 6.2). The predictive model resembled the regression equations previously documented for white sturgeon populations in the Nechako (Dixon 1986) and Fraser (Lane and Rosenau 1993) rivers, and in the Columbia River (RL&L 1994).

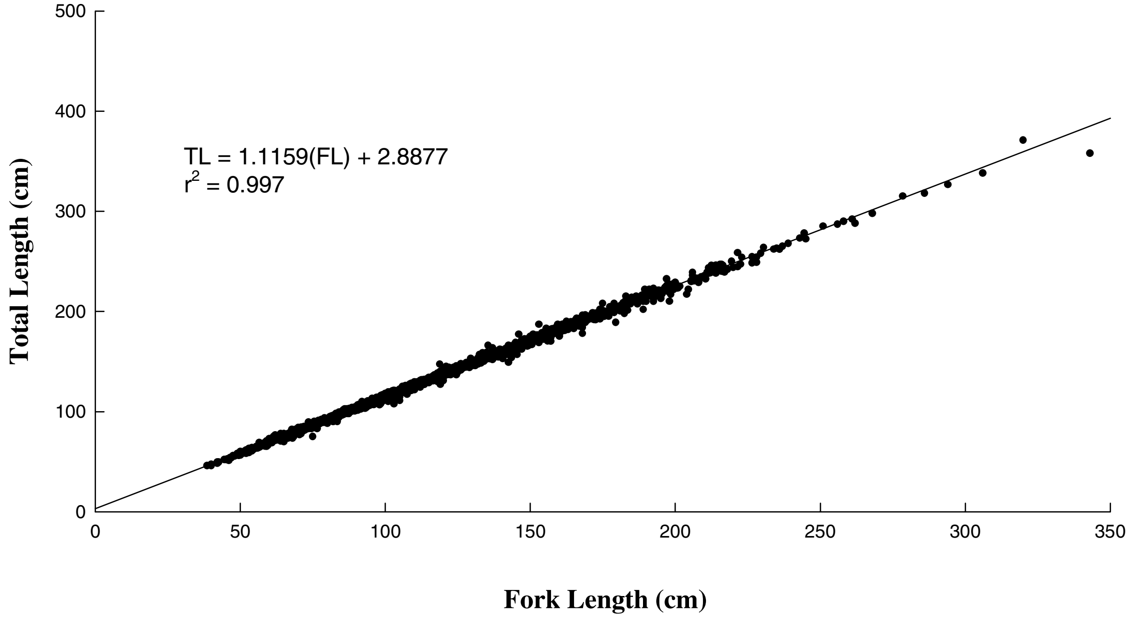

Figure 6.2 Fork Length versus Total Length of White Sturgeon Captured in the Fraser River Drainage

Snout Length-Fork Length

A regression equation was developed to describe the linear relationship between snout length (SL) and fork length (FL) of white sturgeon from the five Stock Groups (Table 6.3). Statistical comparisons of snout length-fork length regressions (Figure 6.3) showed significant differences among Stock Groups (ANCOVA; $p<0.01$). For fish greater than 1 m in total length, the observed differences in snout-fork length coefficients were described by the equation [*SL=b0 + (b1*FL) + (b2*Stock Group) + (b3*Stock Group*FL) + error*] for different slopes and intercepts. More specifically, white sturgeon below Hell's Gate (i.e., SG-1 and SG-2) had a significantly shorter snout length at a given fork length than stocks above Hell's Gate (i.e., SG-3 and SG-5), with the exception of SG-4 (Upper Fraser Group; Tukey Multiple Comparison Test; $p<0.01$). The size of the sample from SG-4, however, was substantially lower than the other Stock Groups, which may have reduced the probability of detecting a difference.

Table 6.3 Snout Length-Fork Length Regressions of White Sturgeon Stock Groups in the Fraser River Drainage

Stock Group	Linear Regression Equation	r^2	*n*
SG-1	SL=3.053 + 4.228(FL)	*0.95*	*557*
SG-2	SL=3.053 + 4.228(FL)	*0.92*	*357*
SG-3	SL=3.053 + 4.228(FL)	*0.96*	*769*
SG-4	SL=3.053 + 4.228(FL)	*0.97*	*50*
SG-5	SL=3.053 + 4.228(FL)	*0.95*	*192*

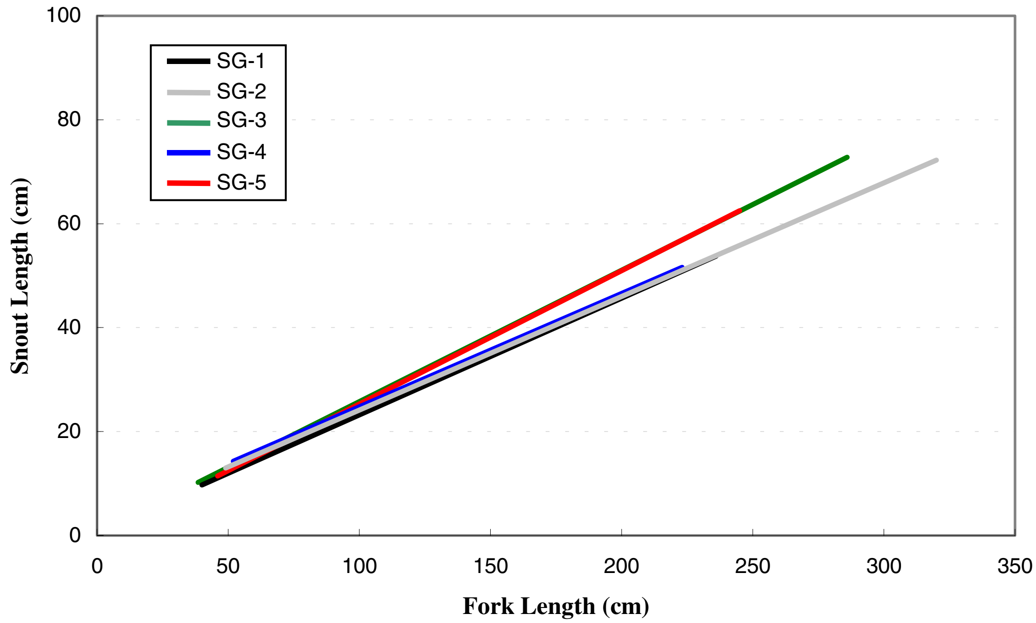

Figure 6.3 Snout Length-Fork Length Regressions of White Sturgeon Stock Groups in the Fraser River Drainage

Further comparison of SG-2 with SG-3 suggested that as white sturgeon increased in age, the relationship between snout length and fork length became stronger. Consequently, a regression model was developed that combined Stock Groups downstream of Hell's Gate (i.e., SG-1 and SG-2) and compared these combined Stock Groups with those upstream of Hell's Gate (i.e., SG-3, SG-4, and SG-5). Examination of the residuals from the analysis indicated a similar normal distribution between the "upstream" and "downstream" groupings (Figure 6.4a). However, further examination of the residuals from each Stock Group suggested that at least SG-2 may have been composed of two morphologically separable groups of snout types (Figure 6.4b).

To further evaluate this effect, the technique of discriminate functions (Sokal and Rohlf 1981) was applied using the upstream and downstream groups and the variables fork length and snout length. The frequency distributions of the canonical scores of the upstream and downstream groups, and of each Stock Group are illustrated in Figure 6.5. Table 6.4 provides a classification accuracy table of white sturgeon based on snout length and fork length. The percentages indicate the proportion of white sturgeon from each Stock Group that were correctly assigned to the upstream or downstream morphological group based on the canonical scores generated from the snout length and fork length variables.

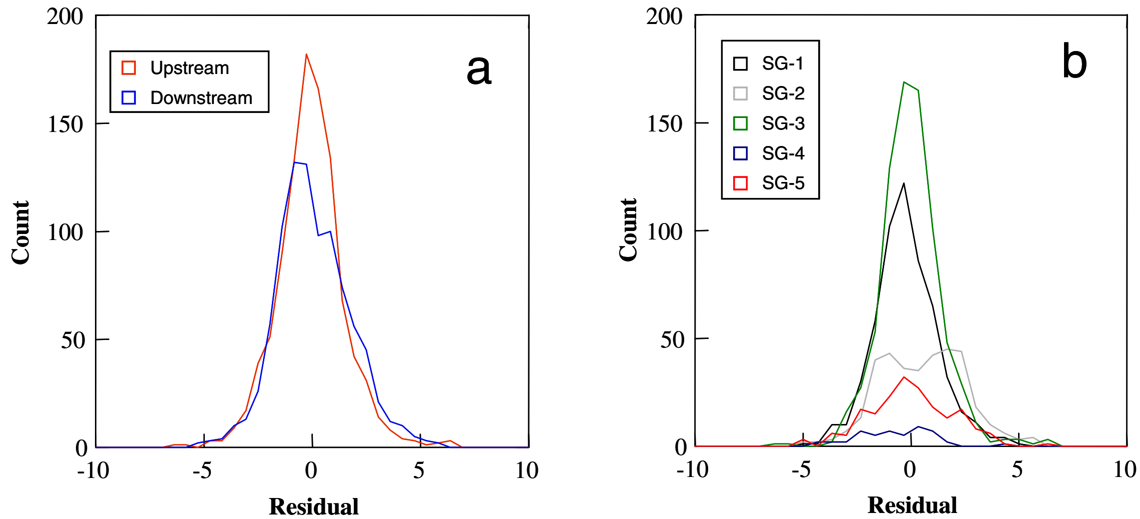

Figure 6.4 Residual Frequency Plot of Snout Length Regression Analysis for Downstream (SG-1 and SG-2) and Upstream (SG-3, SG-4, and SG-5) Stock Groups (a) and for each Stock Group (b)

Based on these analyses, white sturgeon upstream of Hell's Gate can be correctly assigned approximately 84% of the time, whereas individuals downstream of Hell's Gate are correctly assigned approximately 76% of the time, with an overall classification accuracy of 80% (Table 6.4). SG-2 and SG-4 had substantially lower classification accuracies (i.e., 59% and 57% respectively). Based on the bimodal frequency distribution (Figures 6.4 and 6.5), at least SG-2 was composed of both the upstream and downstream morphological groups. The small sample size for SG-4 and the relatively narrow range of the canonical scores provides less certainty as to morphological snout type found in the upper Fraser River. Although there is significant overlap in the morphological characteristics of white sturgeon snout types from the various Stock Groups, the bimodal distribution may suggest at least two phenotypic snout types of white sturgeon that are somewhat identifiable based on combined snout length and fork length characteristics, with the blunt snout type being most prevalent downstream of Hell's Gate.

Table 6.4 Classification Accuracy of White Sturgeon Stock Groups to Upstream or Downstream Morphological Groups based on Discriminant Analysis of Snout Length and Fork Length Variables

Classification Accuracy	Stock Group					Total
	Downstream		Upstream			
	SG-1	SG-2	SG-3	SG-4	SG-5	
% Correct	87%	59%	86%	57%	81%	**80%**
	76%		84%			
n	553	353	764	49	192	**1911**

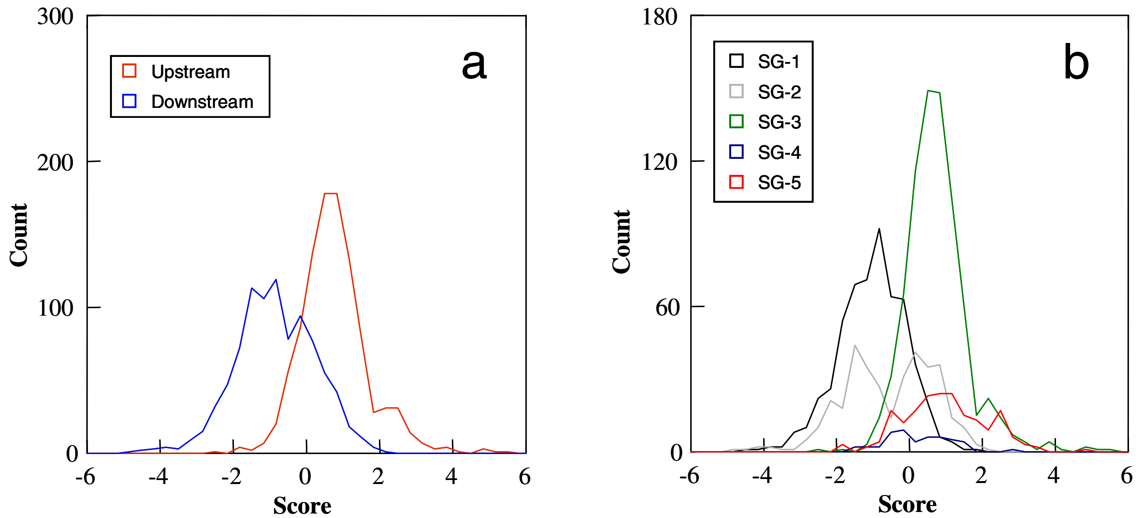

Figure 6.5 Frequency Plots of Discriminant Analysis Canonical Scores for the Variables Snout Length and Fork Length from Downstream (SG-1 and SG-2) and Upstream (SG-3, SG-4, and SG-5) Stock Groups (a) and from each Stock Group (b)

Snout dimorphism of white sturgeon has been reported by Crass and Gray (1980) and Brannon et al. (1986) in the Columbia River. Differences in snout shape were also recorded in the Siberian sturgeon (*A. baeri*) by Sokolov et al. (1986) and in the pallid (*Scaphirhynchus albus*) and shovelnose (*S. platorynchus*) sturgeon by Carlson et al. (1985). Brannon et al. (1986) suggested snout dimorphism may be common for sturgeon species. In the Columbia River system, blunt nose populations were found mainly in the mid and lower reaches whereas longer snouts occurred predominately in upriver areas (Brannon et al. 1986). Other authors have stated that snout shape may be linked to water temperature or other factors experienced by an individual during development (Brannon et al. 1986; Crass and Gray 1982); however, whether these dimorphisms were associated with different races or subspecies was unclear.

There was no DNA evidence, however, from the *FRWSMP* that suggested white sturgeon with long or short snouts were separate stocks. Despite the apparent absence of a genetic basis for the dimorphism, Brannon et al. (1986) recommended that enhancement measures on the Columbia River be undertaken in a manner that would maintain any observed discreteness that populations of white sturgeon have acquired. This discreteness could include snout dimorphism, which may be linked to rare alleles or gene frequency differences not yet distinguishable within a population.

Length-Frequency

To explore the stock differences in size classes, individuals were categorized as undersize, mid-size, or oversize. These groupings represented fish less than 100 cm in total length (TL), between 100 and 150 cm TL, and greater than 150cm TL. This definition was somewhat arbitrary and reflected an estimate that was used by RL&L (1996a) to classify juvenile, sub-adult and adult cohorts of white sturgeon in the Fraser River drainage. Although some contrast is apparent between length frequency plots of each of the Stock Groups (Figure 6.6), these observations may be gear dependent in some cases since not all sample techniques were used in similar proportions of effort in all stocks. Furthermore, data was collected over more than one year and sometimes during different seasons and river conditions.

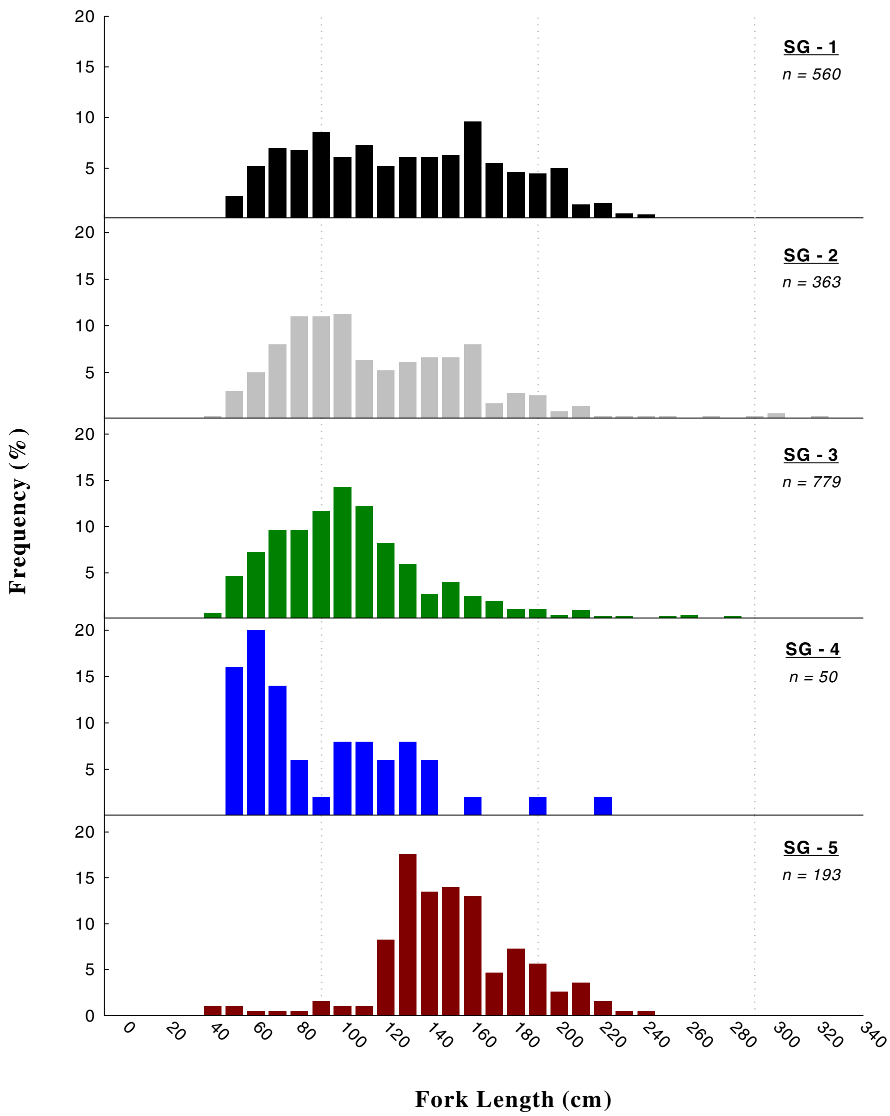

Figure 6.6 Length-Frequency Distribution of White Sturgeon Stock Groups in the Fraser River Drainage

Stock Groups 1 to 3 exhibited a similar range of size classes and were comprised of moderate proportions of undersize to oversize fish (Figure 6.7). The contribution of the undersize cohort to the total catch in Stock Groups 1 to 3 varied from approximately 22% in SG-2 to 29% in SG-3. The percentage composition of the mid-size cohort was lowest in SG-1 (29% of the total catch) and highest in SG-3 (52%). Conversely, oversized individuals were more common in SG-1 (45%) than in either SG-2 (37%) or SG-3 (20%).

The percentage composition of the size classes of white sturgeon in SG-1 and SG-2 may not be an accurate portrayal of the size-class structure of these stocks. From 1996 to 1998, a reward-based program was implemented for the capture of adult white sturgeon. Despite the sampling program being biased towards the capture of adult fish, however, juveniles were more common in catches from 1996 and 1997 (RL&L 1997a, 1998a, 1999a).

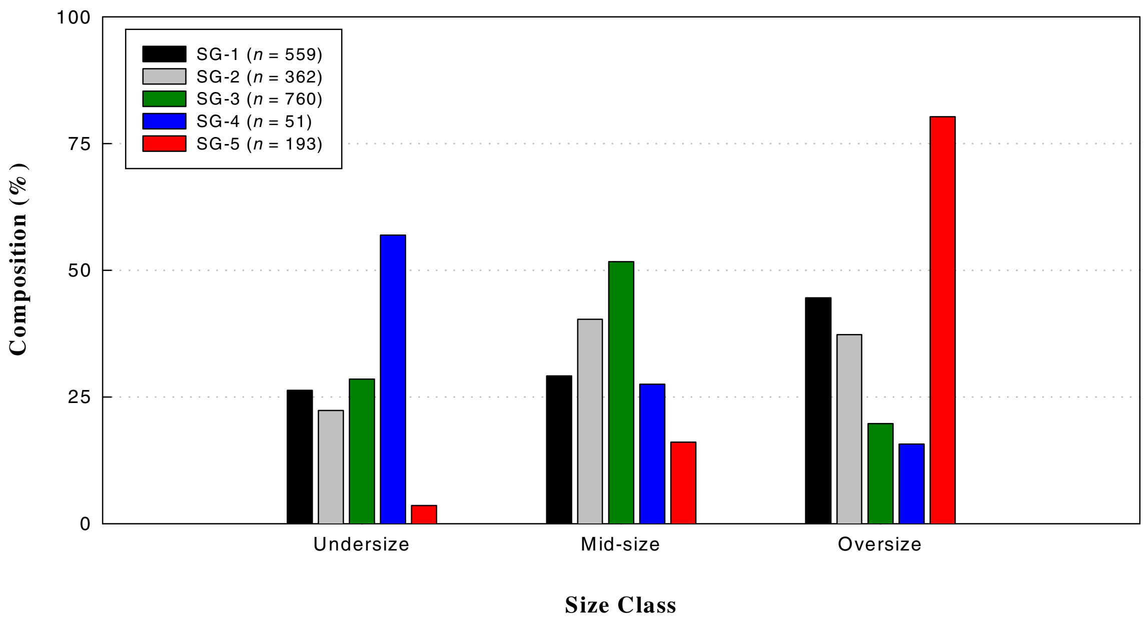

Figure 6.7 Percent Composition of Undersize, Mid-Size, and Oversize White Sturgeon by Stock Group in the Fraser River Drainage

Undersize white sturgeon were the most common in SG-4 (57% of the catch) and the least common in SG-5 (less than 4% of the total catch) compared with all other Stock Groups (Figure 6.7). Furthermore, the oversize cohort comprised the bulk of the catch in SG-5 (80%) whereas this size cohort contributed only 16% to the total catch in SG-4.

Age-Frequency

The age-class structure from each of the five Stock Groups is illustrated in Figure 6.8. With the exception of SG-5, fish between the ages of 6 and 20 years were the most common and contributed between 62.1 to 80.6% of the catch sampled in each Stock Group. The age-frequency distribution of white sturgeon in SG-5 indicated the catch consisted of older fish predominantly between 31 and 50 years-of-age. In sharp contrast to the other stocks groups of white sturgeon in the Fraser River drainage, the most common age cohort of white sturgeon in SG-5 was the 31 to 45 year cohort, which represented 60.3% of the total catch.

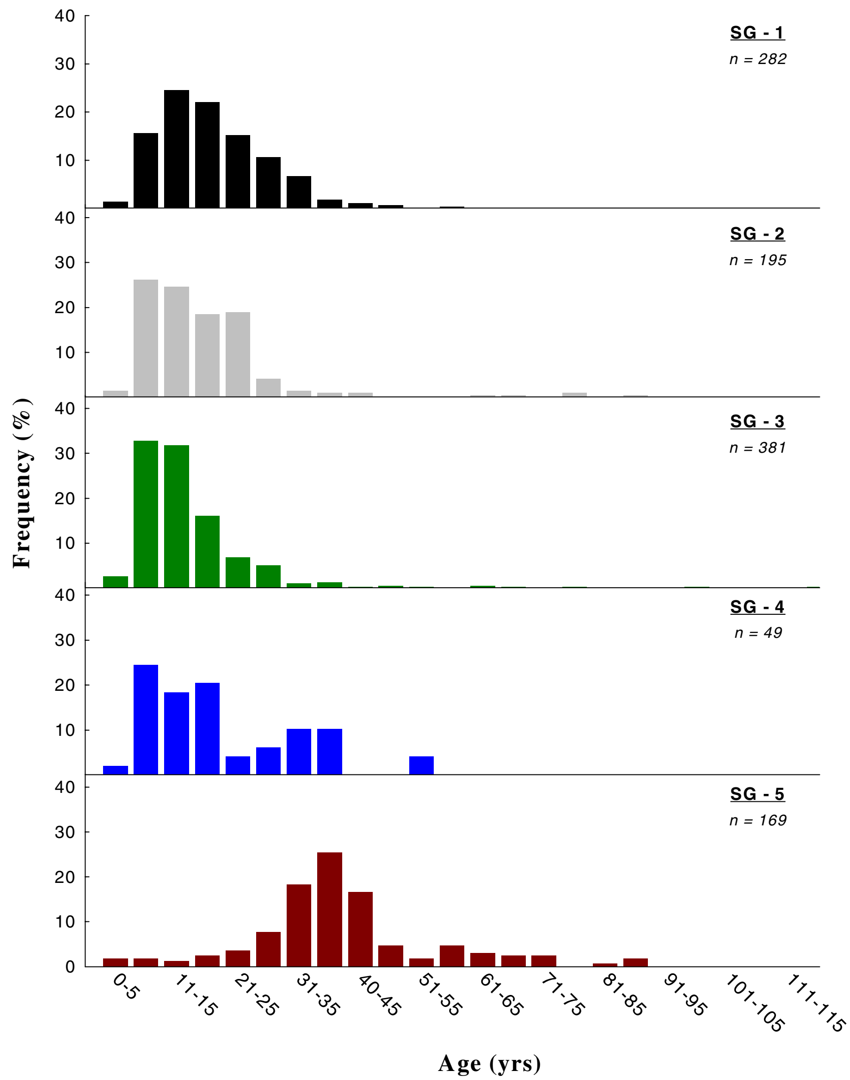

Figure 6.8 Age-Frequency Distribution of White Sturgeon Stock Groups in the Fraser River Drainage

Age-Growth

The age-length relationship for the five Stock Groups of white sturgeon in the Fraser River drainage was determined to be non-linear and best described by the von Bertalanffy growth model (von Bertalanffy 1938) assuming the Y-intercept (length at time 0 or t_o) equaled zero as follows:

$$L_t = L_\infty \left(1 - e^{-k(t-0)}\right)$$

Where : L_t= Fork Length at age t
t=age in years
k= growth constant
L_∞ =Theoretical maximum length of the population

A comparison of single sex and combined sex von Bertalanffy growth models was completed following the analysis used to examine differences in growth rates among stocks (refer to Section 2.5.6). SG-4 had inadequate numbers of white sturgeon with sex determination to make a comparative test of growth rates. Results of the analysis indicated that only in SG-3 were significant improvements to the growth model realized by considering the sexes separately. However, only fourteen female white sturgeon from SG-3 were available for the analysis, which was the smallest of any of the stocks examined. Because of the lack of consistency of this pattern with the other Stock Groups, we suspect this is likely a statistical artifact. Consequently, there was a lack of evidence to suggest significant differences in growth rates in Fraser River Stock Groups occur between the sexes.

Following the above analysis, the sexes were grouped and a matrix of stock comparison probability values was developed that indicated separate models of growth for each Stock Group provided superior estimates of growth than growth models of combined Stock Groups ($p<0.05$; Table 6.5). The exception was Stock Groups 4 and 5 where the results suggested growth was similar between the two stocks. As these Stock Groups were found to be genetically distinct from one another (Pollard 2000), separate Stock Group estimates of model parameters L_∞ and k, and their associated 95% confidence intervals (*CI*) are provided in Table 6.6.

Table 6.5 Matrix of Stock Comparison Probability Values that Reject the Null Hypothesis that the Growth Models of the Combined Stocks are Significantly Better Predictors than the Individual Stock Based Models

Stock Group	SG-1	SG-2	SG-3	SG-4	SG-5
SG-1	1	-	-	-	-
SG-2	0.0260	1	-	-	-
SG-3	1.96×10^{-5}	1.83×10^{-11}	1	-	-
SG-4	7.00×10^{-22}	5.88×10^{-21}	1.43×10^{-11}	1	-
SG-5	5.73×10^{-24}	1.39×10^{-31}	1.49×10^{-13}	0.1159	1

As illustrated in Figure 6.9, the growth rates of the Stock Groups were different. White sturgeon captured in the Lower Mainland section of the Fraser River (SG-1) exhibited the most rapid rate of growth. The growth rates of the southern Stock Groups (SG-1 to 3) were generally similar to that described by Semakula and Larkin (1968). Overall, the growth rate of stocks slowed as their geographic range became more northerly. White sturgeon found in the upper Fraser (SG-4) and Nechako (SG-5) rivers exhibited a notably slower growth, which may be attributable in part to the shorter growing season and/or to differences in the availability of food resources.

Table 6.6 Von Bertalanffy Growth Model Parameter Estimates for White Sturgeon Stock Groups in the Fraser River Drainage

Stock Group	Growth Equation	Growth Model Parameters				
		L_∞ (*CI*)	*k* (*CI*)	t_o	r^2	*n*
SG-1	L_t=370 (1-e$^{-0.025(t+0)}$)	*370.1* (337.9-402.3)	*0.025* (0.021-0.029)	*0*	*0.93*	*308*
SG-2	L_t=315 (1-e$^{-0.032(t+0)}$)	*315.3* (294.7-336.0)	*0.032* (0.028-0.036)	*0*	*0.96*	*195*
SG-3	L_t=251 (1-e$^{-0.038(t+0)}$)	*250.6* (232.2-269.1)	*0.038* (0.032-0.044)	*0*	*0.92*	*380*
SG-4	L_t=237 (1-e$^{-0.027(t+0)}$)	*237.0* (169.4-304.6)	*0.027* (0.015-0.039)	*0*	*0.87*	*49*
SG-5	L_t=228 (1-e$^{-0.032(t+0)}$)	*228.3* (213.0-243.7)	*0.032* (0.027-0.037)	*0*	*0.92*	*169*

Note: *CI* = Wald 95% *CI*.

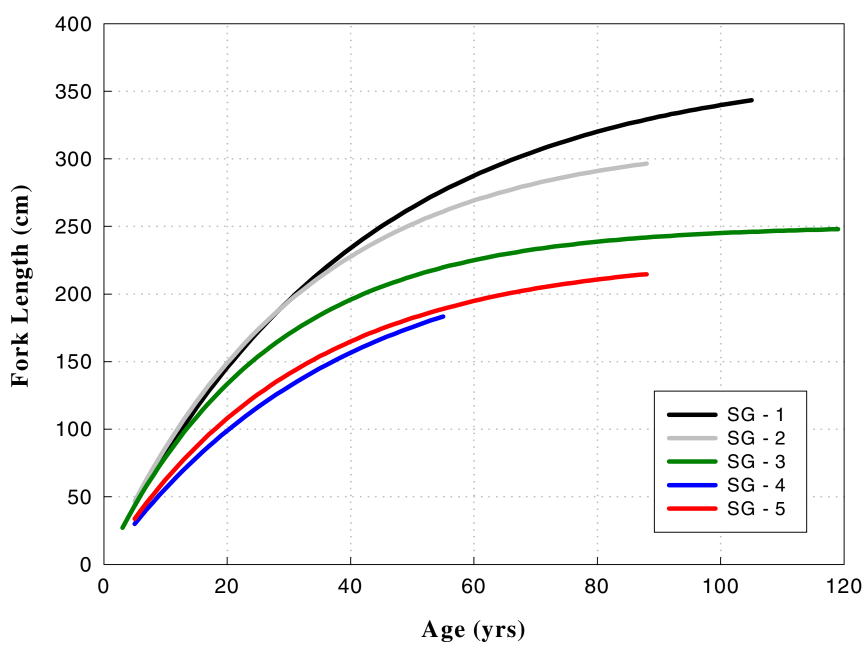

Figure 6.9 Age-Growth Curves of White Sturgeon Stock Groups in the Fraser River Drainage

The growth rate of SG-4 and SG-5 fish were similar to each other and to Kootenai River white sturgeon (Partrige 1980). The Kootenai River and Nechako River are regulated systems with similar habitat characteristics such as channel width and depth, discharge, and reduced nutrient input from upstream impoundments (RL&L 1996). The main difference in the Nechako drainage, however, is the availability of migrating salmon stocks (e.g., sockeye salmon) during summer that serve as a food source for what is believed to be a resident population of white sturgeon.

6.2.2 Sex and Maturity

Stock Group 1

In the Lower Mainland section of the Fraser River, 117 white sturgeon were surgically examined and assigned a sex and maturity stage. The sex ratio of white sturgeon in SG-1 was 94 males:23 females (4.1:1; Table 6.7). Approximately 88% of the male white sturgeon and 91% of females examined were either non-reproductive or in the early stages of reproductive development (i.e., Codes 01 to 03; 11 to 13).

Table 6.7 Length and Age Data for Sexual Maturity Stages of White Sturgeon in the Lower Mainland Section of the Fraser River Drainage

Stock Group	Maturity Code (*State*)[1]	Mean FL (cm)	Age Data			Percent Composition
			n	Mean Age (yrs)	Range	
SG-1	**MALES**					
	01 (*Non-reproductive*)	167.4	*20*	20.1	12-33	21.3
	02 (*Maturing*)	174.7	*40*	23.3	12-58	42.6
	03 (*Early Reproductive*)	175.9	*23*	24.1	17-32	24.4
	04 (*Late Reproductive*)	197.2	*11*	31.2	14-46	11.7
	05 (*Ripe*)					
	06 (*Spent*)					
	FEMALES					
	11 (*Non-reproductive*)	156.6	*5*	21.2	16-29	21.7
	12 (*Pre-vitellogenic*)	175.7	*14*	25.5	19-41	60.9
	13 (*Early vitellogenic*)	194.5	*2*	33.0	26-40	8.7
	14 (*Late vitellogenic*)					
	15 (*Ripe*)					
	16 (*Spent*)					
	17 (*Pre-vitellogenic with attritic oocytes*)	178.0	*2*	22.5	18-27	8.7

Note: Blank cells represent no data.

[1] Description of maturity state classifications adapted from Conte et al. (1988). For a more detailed description of maturity codes, refer to RL&L (1996a).

RL&L (1994) noted that visual determination of the reproductive sex and maturity state of white sturgeon in the early reproductive states, particularly males, can be considerably more difficult compared with individuals with more sexually advanced reproductive organs. Interestingly, the proportion of males to females was not affected by excluding the immature cohorts (i.e., Codes 01 and 11) from the data set used to calculate the sex ratio. Furthermore, the low proportion of sexually mature individuals was unexpected because surgical examinations were restricted mainly to larger fish suspected of being in pre-spawning condition (i.e., length greater than 1.5 m TL, distended abdomen), which should have skewed the results toward an increase in the number of more sexually mature fish.

The average length of white sturgeon in the later stages of reproductive development was larger than for fish in the early stages for both males and females (Table 6.7). Of the 23 ovaries examined, 21.7% were non-reproductive, 60.9% were pre-vitellogenic, 8.7% were either early vitellogenic or pre-vitellogenic with attritic oocytes. Non-reproductive females (Code 11) had a mean length (FL) or 156.5 cm and an average age of 21.2 years. Early vitellogenic females were considerably larger in size, with a mean FL of 175.7 cm; mean age was 25.5 years. White sturgeon in the late vitellogenic stage of reproductive maturity were an average of 194.5 cm in fork length and 33 years-of-age. Female white sturgeon in the more advanced reproductive stages were not encountered in the Lower Mainland section of the Fraser River. Two white sturgeon were classed as post-spawning with ovaries in the pre-vitellogenic stage of development with attritic oocytes. The mean FL of these fish was 178.0 cm and their mean age was 22.5 years. Generally, females were larger than their male counterparts within comparable developmental stages. The results suggest female white sturgeon in SG-1 may spawn as early as 18 years-of-age based on the capture of post-spawning females. Additional information is needed, however, to more accurately define the age-at-maturity for females.

Maturing male white sturgeon were the most common group (42.6%) in the surgically examined portion of the male catch, followed by the early reproductive (24.4%), non-reproductive (21.3%), and late reproductive (11.7%) stages (Table 6.7). Despite the more advanced stages of reproductive development being only a minor component of the male catch, the results suggest some males may be reproductively mature by as early as age 14. The youngest early reproductive male in SG-1 was 12 years-of-age.

Stock Group 2

A sexual maturity stage was determined for 69 white sturgeon in SG-2. The sex ratio of sampled portion of the population was 54 males:15 females (4.5:1; Table 6.8). Male and female white sturgeon in the non-reproductive or early reproductive stages of development were most common (88.9% and 86.7%, respectively). The low number of white sturgeon in the more advanced maturity states was surprising given the emphasis on surgical examinations of fish suspected to be reproductively mature (see Section 6.2.2.1).

Similar to the results obtained in SG-1, both male and female white sturgeon in SG-2 increased in size as their stage of maturity became more advanced (Table 6.8). Furthermore, female white sturgeon were consistently larger and older than males in comparable developmental stages. Non-reproductive female white sturgeon had an average fork length of 177.3 cm; mean age was 25.7 years. Pre- and late vitellogenic females averaged 198.6 cm and 221.5 cm in fork length, respectively. The corresponding average age of these maturity classes was 38.1 years and 43.7 years. Female white sturgeon in more advanced stages of development (i.e., ripe and spent) were not encountered in SG-2. Pre-vitellogenic ovaries with attritic oocytes were, however, identified in a 21 and 25 year old female. Their average length was 190.0 cm FL. Although based on limited information (i.e., post-spawning females), the results suggested the age-at-maturity for females in SG-2 may be as early as 21 years-of-age.

Table 6.8 Length and Age Data for Sexual Maturity Stages of White Sturgeon in the Lower Canyon Section of the Fraser River Drainage

Stock Group	Maturity Code (*State*)[1]	Mean FL (cm)	Age Data			Percent Composition
			n	Mean Age (yrs)	Range	
SG-2	**MALES**					
	01 (*Non-reproductive*)	163.8	*6*	20.8	15-31	11.1
	02 (*Maturing*)	163.3	*27*	21.2	14-43	50.0
	03 (*Early Reproductive*)	181.5	*15*	27.0	17-79	27.8
	04 (*Late Reproductive*)	210.8	*3*	34.3	22-45	5.5
	05 (*Ripe*)					
	06 (*Spent*)	179.5	*3*	24.0	20-30	5.5
	FEMALES					
	11 (*Non-reproductive*)	177.3	*3*	25.7	22-31	20.0
	12 (*Pre-vitellogenic*)	198.6	*7*	38.1	21-88	46.7
	13 (*Early vitellogenic*)	221.5	*3*	43.7	25-76	20.0
	14 (*Late vitellogenic*)					
	15 (*Ripe*)					
	16 (*Spent*)					
	17 (*Pre-vitellogenic with attritic oocytes*)	190.0	*2*	23.0	21-25	13.3

Note: Blank cells represent no data.

[1] Description of maturity state classifications adapted from Conte et al. (1988). For a more detailed description of maturity codes, refer to RL&L (1996a).

White sturgeon males in the maturing stage of development contributed 50% to the surgically examined portion of the catch. Early reproductive males were the next most abundant (27.8%), followed by non-reproductive (11.1%), late reproductive (5.5%) and spent (5.5%) individuals (Table 6.8). Although preliminary, these results suggest male white sturgeon in SG-2 become reproductively mature by 20 years-of-age with maturing males recorded as young as 14 years-of-age.

Semakula and Larkin (1968) assessed age-at-maturity and spawning frequency of white sturgeon in the lower Fraser River by examining banding patterns on fin ray cross sections. Their study area roughly corresponded to the Stock Group boundaries for SG-1 and SG-2. The age at first spawning of white sturgeon in the lower Fraser River was reported as variable, with males first spawning between 11 and 22 years-of-age. These researchers stated that some males may spawn more than once by age 17 and three times by age 22. Female white sturgeon reached sexual maturity at ages ranging from 26 to 34; however, only a few individuals had spawned twice by age 36. Spawning frequency ranged from two to five years for males and three to eight years for females with the frequency of spawning declining in older individuals.

Stock Group 3

The sexual maturity stage of 120 white sturgeon in SG-3 was determined as part of the *FRWSMP*. The sex ratio of the surgically examined portion of the catch was skewed toward males at 7.6:1 (Table 6.9). Similar to the lower Fraser stocks of white sturgeon, individuals in the early stages of reproductive development were most common, comprising 91.5% of the male catch and 92.9% of the female catch.

Table 6.9 Length and Age Data for Sexual Maturity Stages of White Sturgeon in the Middle Section of the Fraser River Drainage

Stock Group	Maturity Code (*State*)[1]	Mean FL (cm)	Age Data			Percent Composition
			n	Mean Age (yrs)	Range	
SG-3	**MALES**					
	01 (*Non-reproductive*)	113.1	*7*	14.1	9-20	6.6
	02 (*Maturing*)	122.4	*49*	18.4	9-100	46.2
	03 (*Early Reproductive*)	149.6	*41*	22.0	13-31	38.7
	04 (*Late Reproductive*)	181.4	*9*	33.4	16-65	8.5
	05 (*Ripe*)					
	06 (*Spent*)					
	FEMALES					
	11 (*Non-reproductive*)	121.3	*2*	15.5	10-21	14.3
	12 (*Pre-vitellogenic*)	145.7	*6*	25.7	15-54	42.9
	13 (*Early vitellogenic*)					
	14 (*Late vitellogenic*)	229.5	*5*	68.2	29-118	35.7
	15 (*Ripe*)	239.0	*1*	62.0	62	7.1
	16 (*Spent*)					
	17 (*Pre-vitellogenic with attritic oocytes*)					

Note: Blank cells represent no data.

[1] Description of maturity state classifications adapted from Conte et al. (1988). For a more detailed description of maturity codes, refer to RL&L (1996a).

In SG-3, white sturgeon in the more advanced stages of reproductive development were larger in size than less mature individuals (Table 6.9). For comparable development stages (e.g., codes 01 and 11), females were larger than males. Non-reproductive females exhibited an average age of 15.5 years, with a mean fork length of 121.3 cm. Pre-vitellogenic females were on average, 24.4 cm larger in fork length than non-reproductive fish and exhibited an average age of 25.7 years. Late vitellogenic females averaged 229.5 cm FL and 68.2 years-of-age. A ripe female, 239.0 cm in fork length and 62 years of age, was also sampled in SG-3. The results provide only limited information on the age-at-maturity of female white sturgeon in SG-3 based on the capture of only one individual in spawning condition. The range of ages for the late vitellogenic maturity stage suggests females may reach sexual maturity by their late 20's, although additional information is needed to provide a more accurate estimate.

Maturing male white sturgeon were frequently encountered in the portion of the catch assessed for gender and sexual maturity stage (46.2% of the male catch; Table 6.9). Early reproductive males were the next most common (38.7%), followed by late reproductive (8.5%), and non-reproductive (6.6%) individuals. Preliminary results suggest male white sturgeon in SG-3 may become reproductively mature before they reach 20 years-of-age; however, the absence of reproductively mature males indicates the need for additional information.

Stock Group 4

Information on the sexual maturity of white sturgeon in the upper Fraser River drainage has not been collected. To date, programs initiated in this section of the Fraser River have only just begun to describe the distribution, life history, and population structure of white sturgeon.

Stock Group 5

The sex ratio of the white sturgeon (*n*=120) in SG-5 was 80 males: 40 females (2:1; Table 6.10). For both sexes, white sturgeon in the later stages of reproductive development contributed less than 10% to the surgically examined portion of the catch.

As in the other Stock Groups, the more advanced maturity stages of white sturgeon in SG-5 were larger in size than less mature individuals, with females being generally larger than males in comparable developmental stages (Table 6.10). The one non-reproductive female examined was 132.0 cm FL and 26 years-of-age. Pre-vitellogenic females were the most abundant maturity stage (72.5% of the examined female catch), with an average fork length of 157.4 cm and an average age of 40.4 years. Early and late vitellogenic females were similar in average size at 193.4 cm and 200.3 cm, respectively, but noticeably larger than pre-vitellogenic females. Despite the similarity in size of the early and late vitellogenic females, they were more than 10 years apart in average age. White sturgeon in the ripe and spent stages of maturity were not encountered in the Nechako River drainage although one specimen was determined to be pre-vitellogenic with attritic oocytes. This female white sturgeon was 230.5 cm FL and 71 years-of-age. Preliminary age-at-maturity information for female white sturgeon in the SG-5 suggested females may not become sexual mature until their late 30's or possibly older. This estimate is based on the observed age range of females staged as early vitellogenic (Code 13) or later with the assumption that early vitellogenic females may reach sexual maturity within 5 years. The observed late age-at-maturity of females in SG-5 may be related to poor recruitment; whereby the population is ageing with younger, mature fish underrepresented in the population. The findings may also be an artifact of low sample sizes and as a result, additional data are recommended to refine the estimate.

Table 6.10 Length and Age Data for Sexual Maturity Stages of White Sturgeon in the Nechako River Drainage

Stock Group	Maturity Code (*State*)[1]	Mean FL (cm)	Age Data			Percent Composition
			n	Mean Age (yrs)	Range	
SG-5	**MALES**					
	01 (*Non-reproductive*)	112.5	*2*	22.0	13-31	2.5
	02 (*Maturing*)	145.6	*42*	37.0	18-67	52.5
	03 (*Early Reproductive*)	155.8	*28*	40.2	32-67	35.0
	04 (*Late Reproductive*)	205.4	*7*	64.4	40-88	8.8
	05 (*Ripe*)	193.0	*1*	62.0	62	1.2
	06 (*Spent*)					
	FEMALES					
	11 (*Non-reproductive*)	132.0	*1*	26.0	26	2.5
	12 (*Pre-vitellogenic*)	157.4	*29*	40.4	24-62	72.5
	13 (*Early vitellogenic*)	193.4	*6*	56.5	35-83	15.0
	14 (*Late vitellogenic*)	200.3	*3*	67.0	65-71	7.5
	15 (*Ripe*)					
	16 (*Spent*)					
	17 (*Pre-vitellogenic with attritic oocytes*)	230.5	*1*	71.0	71	2.5

Note: Blank cells represent no data.

[1] Description of maturity state classifications adapted from Conte et al. (1988). For a more detailed description of maturity codes, refer to RL&L (1996a).

Maturing and early reproductive males were frequently encountered in SG-5, contributing 52.5% and 35.0% to the male portion of the catch (Table 6.10). Late reproductive males were less common (8.8%), followed by males in the non-reproductive (2.5%) and ripe (1.2%) maturity stages. Base on age estimates of late reproductive male white sturgeon in SG-5 and the assumption that this mature cohort may be capable of spawning within one to three years, males may exhibit a similar age-at-maturity as the females and may not become sexually mature until their early 40's. This estimate of age-at-maturity for male white sturgeon is significantly older than has been reported elsewhere and should only be considered as preliminary since few mature male white sturgeon were captured and examined in SG-5. The observed age-at-maturity may also be attributable to poor recruitment as described for the female portion of the population.

Based on the perceived similar growth rate of Lower Fraser and Nechako River sturgeon, Dixon (1986) used the length-at-maturity information gather by Semakula and Larkin (1968) for lower Fraser River sturgeon to state that male white sturgeon in the Nechako River may spawn twice before they reach 100 cm FL or 17 years-of-age. Dixon (1986) further commented that females could potentially be part of the spawning population at approximately 137 to 169 cm FL. Results of the *FRWSMP* indicated white sturgeon in SG-5 had a noticeably slower rate of growth and later age-at-maturity than that predicted by Dixon (1986) and by Semakula and Larkin (1968). Length-at-maturity estimates from the *FRWSMP* suggested both sexes of white sturgeon in the Nechako River may not spawn until age 40 or later, which translates to approximately 165 cm FL or larger based on their predicted length-at-age. These results may be skewed, however, by the possibility that the population is ageing from poor recruitment and that the younger cohorts were not present to determine the “true” age-at-maturity.

CHAPTER 7 CRITICAL HABITAT AND LIFE HISTORY

7.1 MOVEMENTS AND MIGRATIONS

The general movement patterns of white sturgeon in each Stock Group are summarized in this section. Detailed information on the movement and behavior of individual fish can be found in the annual data reports (Appendix A). A review of the possible life history functions attributable to the observed movement patterns is provided in subsequent sections of this chapter, with the exception of SG-4, where this information has not been collected to date.

Information on the movement patterns of white sturgeon was gathered by mark-recapture and telemetry programs. The telemetry monitoring components of the studies conducted within each Stock Group were considered robust in that regular tracking programs were conducted by boat, ground, air and fixed remote ground stations (refer to Chapter 2). The design of the telemetry programs (e.g., design and frequency of monitoring) were specific to the study objectives in each Stock Group, with a consistent theme being the detection of large-scale, significant movements (e.g., spawning migrations, fall migrations for overwintering).

Despite the wealth of behavioral information provided by the results of the movement studies, there were problems encountered in the radio telemetry program. There were several radio tagged white sturgeon in each Stock Group that were never located after their release. It is unclear whether these fish moved out of the study area undetected or their radio tag malfunctioned. There were also instances where radio tags were confirmed shed, while other radio tags were suspected to have been shed. RL&L (1998a) noted several possible causes for tag loss that included the effects of physical habitat conditions (submerged debris, high river flows) as well as the size, shape, and design of the radio tags on tag retention.

7.1.1 Movement Trends

Stock Group 1

The main objective of monitoring movements of white sturgeon in SG-1 was to define areas used for spawning. Radio tagging was used as the primary method to assess the behavior of potential spawners although additional movement information was gathered from mark-recapture data. The distribution of radio tags and summary of movements by maturity stage are presented in Table 7.1.

Thirty-six white sturgeon were equipped with radio tags in SG-1. The sex and maturity of four radio tagged individuals could not be determined and they were subjectively classed as either adult (Code 97; TL>150 cm) or juvenile (Code 98; TL<150 cm) based on size. The largest mean movement was recorded for pre-vitellogenic female white sturgeon (Code 12), which also exhibited the greatest range of movements from their release locations (Table 7.1). Generally, there appeared to be little difference between the average distance moved by males and females, with localized movements of less than 5 rkm being most common. However, several early to late reproductive males and pre-vitellogenic females exhibited extensive movements that exceeded 40 rkm and in some instances were more than 70 rkm between tracking events. Examples of larger-scale movements included two long-distance movements of late reproductive males after the spawning period; both were upstream movements of more than 40 rkm prior to October (RL&L 1999a). Perrin et al. (1999) documented movements of late reproductive males in excess of 40 rkm in September when they moved upstream and then returned to their original locations in October. McDonald et al. (1987) recorded similar results that showed that the movements of white sturgeon in the lower reaches of the Fraser River can be extensive, particularly downstream of Mission Bridge. ECL (1992) observed 60 rkm upstream and 61 rkm downstream migrations of white sturgeon in the lower Fraser River at rates in excess of 2 rkm/day. Their research also showed movement of white sturgeon between the Harrison and Fraser rivers.

Table 7.1 Distribution of Radio Tags and Movements for Sexual Maturity Stages of White Sturgeon in the Lower Mainland Section of the Fraser River Drainage

Stock Group	Maturity Code (*State*)[1]	*n*	Mean Movement (rkm)	Movement Range (rkm)[2]		Movement (%)[3]		
				d/s	u/s	Loc.	Int.	Ext.
SG-1	**MALES**							
	01 (*Non-reproductive*)	*3*	2.2	13.0	13.0	5.5	0.0	0.6
	02 (*Maturing*)	*6*	0.6	4.4	2.0	10.0	0.0	0.0
	03 (*Early Reproductive*)	*4*	4.3	42.3	11.0	7.5	0.6	1.4
	04 (*Late Reproductive*)	*12*	3.8	46.3	40.5	35.7	3.6	4.7
	05 (*Ripe*)							
	06 (*Spent*)							
	FEMALES							
	11 (*Non-reproductive*)	*1*	0.8	1.5	2.0	2.2	0.0	0.0
	12 (*Pre-vitellogenic*)	*5*	5.3	95.4	41.4	13.0	0.3	1.9
	13 (*Early vitellogenic*)	*1*	2.8	8.6	8.6	3.0	1.1	0.0
	14 (*Late vitellogenic*)							
	15 (*Ripe*)							
	16 (*Spent*)							
	17 (*Pre-vitellogenic with attritic oocytes*)							
	97 (*Adult based on size*)	2[4]	1.4	6.2	6.2	3.3	0.6	0.0
	98 (*Juvenile based on size*)	2	1.0	4.0	4.5	5.0	0.0	0.0

Note: Blank cells represent no data.

[1] Description of maturity state classifications adapted from Conte et al. (1988). For a more detailed description of maturity codes, refer to RL&L (1996a).

[2] u/s=upstream; d/s=downstream.

[3] Movement category where Loc.=local <5rkm; Int.=intermediate 5-10 rkm; Ext.=extended >10rkm. Represents the percentage of net movements, by movement category, based on the total number of radio tagged fish within the Stock Group.

[4] One individual moved to SG-2; refer to Table 7.2 for movement summary of this fish.

Stock Group 2

A total of seventeen white sturgeon were radio tagged in SG-2. Two of these individuals were subjectively classed as juveniles according to the criteria previously described in Section 7.1.1 (Table 7.2). Larger-scale movements between tracking events were less evident in SG-2 than in SG-1. Average distances moved between tracking events did not exceed 3 rkm and localized movements were most prevalent for all maturity classes. Several white sturgeon males (Codes 03 and 04), however, moved at least 35 rkm between tracking events.

Table 7.2 Distribution of Radio Tags and Movements for Sexual Maturity Stages of White Sturgeon in the Lower Canyon Section of Fraser River Drainage

Stock Group	Maturity Code (*State*)[1]	*n*	Mean Movement (rkm)	Movement Range (rkm)[2]		Movement (%)[3]		
				d/s	u/s	Loc.	Int.	Ext.
SG-2	**MALES**							
	01 (*Non-reproductive*)	*1*	0.9	5.0	0.0	2.5	0.5	0.0
	02 (*Maturing*)	*3*	0.2	4.8	0.1	16.8	0.0	0.0
	03 (*Early Reproductive*)	*2*	2.7	19.4	19.4	7.6	0.0	1.0
	04 (*Late Reproductive*)	*3*	2.1	4.8	42.3	12.2	0.0	0.5
	05 (*Ripe*)	*1*	0.1	0.8	0.5	12.7	0.0	0.0
	06 (*Spent*)							
	FEMALES							
	11 (*Non-reproductive*)							
	12 (*Pre-vitellogenic*)	*2*	0.2	2.8	1.6	22.3	0.0	0.0
	13 (*Early vitellogenic*)	*2*	0.6	4.0	4.0	13.7	0.0	0.0
	14 (*Late vitellogenic*)	*1*	0.0	0.0	0.0	2.0	0.0	0.0
	15 (*Ripe*)							
	16 (*Spent*)							
	17 (*Pre-vitellogenic with attritic oocytes*)							
	97 (*Adult based on size*)	*1*[4]	0.0	0.0	0.0	1.0	0.0	0.0
	98 (*Juvenile based on size*)	*2*	0.7	6.9	0.0	6.6	0.5	0.0

Note: Blank cells represent no data.

[1] Description of maturity state classifications adapted from Conte et al. (1988). For a more detailed description of maturity codes, refer to RL&L (1996a).

[2] u/s=upstream; d/s=downstream

[3] Movement category where Loc.=local <5rkm; Int.=intermediate 5-10 rkm; Ext.=extended >10rkm. Represents the percentage of net movements, by movement category, based on the total number of radio tagged fish within the Stock Group.

[4] Individual originally tagged in SG-1 and subsequently located in SG-2 where it exhibited localized movements (<0.1rkm).

Stock Group 3

White sturgeon radio tagged in SG-3 (*n*=60) exhibited a wide range of movements between tracking events; nine individuals were classed as adult (TL>150 cm) and seven were classed as juveniles (TL<150 cm). Table 7.3 shows that the average movement of white sturgeon remained below 5 rkm, with the exception of late reproductive males (Code 04) that displayed a mean individual movement of more than 10 rkm between tracking events. This maturity class also displayed the greatest range of movements, with the 75 rkm downstream migration of an individual from below Lillooet to an area of the Fraser River above the mouth of the Nahatlach River (RL&L 1999b). Some notable movements were also observed in the less reproductively advanced males (Codes 02 and 03), which surpassed 50 rkm.

Table 7.3 Distribution of Radio Tags and Movements for Sexual Maturity Stages of White Sturgeon in the Middle Section of Fraser River Drainage

Stock Group	Maturity Code (*State*)[1]	*n*	Mean Movement (rkm)	Movement Range (rkm)[2]		Movement (%)[3]		
				d/s	u/s	Loc.	Int.	Ext.
SG-3	**MALES**							
	01 (*Non-reproductive*)	*3*	0.3	2.3	1.6	5.1	0.0	0.0
	02 (*Maturing*)	*17*	2.5	22.6	27.5	24.6	1.4	2.7
	03 (*Early Reproductive*)	*17*	2.0	23.0	36.6	22.9	1.4	1.7
	04 (*Late Reproductive*)	*4*	10.9	78.3	4.0	1.7	0.0	0.2
	05 (*Ripe*)							
	06 (*Spent*)							
	FEMALES							
	11 (*Non-reproductive*)							
	12 (*Pre-vitellogenic*)	*1*	1.1	3.3	0.0	0.7	0.0	0.0
	13 (*Early vitellogenic*)							
	14 (*Late vitellogenic*)	*2*	1.6	11.3	0.7	2.7	0.2	0.2
	15 (*Ripe*)							
	16 (*Spent*)							
	17 (*Pre-vitellogenic with attritic oocytes*)							
	97 (*Adult based on size*)	*9*	0.9	20.0	4.3	21.3	0.5	0.5
	98 (*Juvenile based on size*)	*7*	1.7	13.0	11.7	10.6	1.0	0.5

Note: Blank cells represent no data.

[1] Description of maturity state classifications adapted from Conte et al. (1988). For a more detailed description of maturity codes, refer to RL&L (1996a).

[2] u/s=upstream; d/s=downstream

[3] Movement category where Loc.=local <5rkm; Int.=intermediate 5-10 rkm; Ext.=extended >10rkm. Represents the percentage of net movements, by movement category, based on the total number of radio tagged fish within the Stock Group.

Stock Group 4

Efforts to radio tag white sturgeon in the upper Fraser River and monitor their movements were not as intensive as in other areas of the Fraser River drainage. An early reproductive male was the only fish radio tagged in the upper Fraser River. This fish was tagged in September 1997 at rKm 888.6 (McGregor River confluence area) and subsequently located on only three separate occasions (twice in fall 1997, once in spring 1999). During this period, this individual exhibited a net downstream movement of 25 rKm from its initial release location (RL&L 1998d, 1999d).

Only two fish have been recaptured in the upper Fraser River. The first individual was a non-reproductive male, initially tagged (conventional and radio tag) by RL&L at the confluence of the Nechako and Fraser rivers in June 1996. This fish was not located until September 1999 when it was recaptured 35.2 rkm upstream in the upper Fraser River (rKm 826.6), after 1176 days-at-large (LTFN 2000).

Stock Group 5

All maturity stages of white sturgeon radio tagged in SG-5 exhibited mainly localized movements with average movements being well below one river kilometre between tracking events (Table 7.4). The results also indicated, however, that a portion of the individuals within each maturity class displayed extended movements. An example was the large-scale movement (i.e., total distance traveled of more than 200 rkm) of a maturing male that provided evidence that white sturgeon used both the Stuart and Nechako rivers (RL&L 1999d). Generally, maturing individuals exhibited the greatest range of movements. Females in the late stages of reproductive development (Code 14) traveled, on average, more than 35 rkm between tracking events compared with late reproductive males (Code 04) that traveled less than 20 rkm.

Table 7.4 Distribution of Radio Tags and Movements for Sexual Maturity Stages of White Sturgeon in the Nechako River Drainage

Stock Group	Maturity Code (*State*)[1]	*n*	Mean Movement (rkm)	Movement Range (rkm)[2]		Movement (%)[3]		
				d/s	u/s	Loc.	Int.	Ext.
SG-5	**MALES**							
	01 (*Non-reproductive*)	*1*	0.4	19.5	16.0	1.9	0.1	0.4
	02 (*Maturing*)	*10*	0.2	61.5	52.5	22.5	1.2	1.3
	03 (*Early Reproductive*)	*9*	0.4	13.4	42.0	17.7	0.8	0.5
	04 (*Late Reproductive*)	*7*	0.2	9.3	15.5	11.5	0.4	0.1
	05 (*Ripe*)	*1*	0.1	16.5	22.2	2.2	0.1	0.2
	06 (*Spent*)							
	FEMALES							
	11 (*Non-reproductive*)							
	12 (*Pre-vitellogenic*)	*12*	0.2	42.9	56.7	18.4	0.7	1.0
	13 (*Early vitellogenic*)	*5*	0.7	51.5	27.7	9.9	0.4	0.4
	14 (*Late vitellogenic*)	*4*	0.2	38.5	45.6	7.1	0.8	0.6
	15 (*Ripe*)							
	16 (*Spent*)							
	17 (*Pre-vitellogenic with attritic oocytes*)							
	97 (*Adult based on size*)							
	98 (*Juvenile based on size*)							

Note: Blank cells represent no data.

[1] Description of maturity state classifications adapted from Conte et al. (1988). For a more detailed description of maturity codes, refer to RL&L (1996a).

[2] u/s=upstream; d/s=downstream

[3] Movement category where Loc.=local <5rkm; Int.=intermediate 5-10 rkm; Ext.=extended >10rkm. Represents the percentage of net movements, by movement category, based on the total number of radio tagged fish within the Stock Group.

7.1.2 Life History Functions

Rearing

The objectives of the *FRWSMP* in SG-1 and SG-2 were not directed towards the capture of juvenile white sturgeon or an assessment of habitat used for rearing by this life requisite. However, Lane and Rosenau (1993) have described areas used for rearing by juvenile white sturgeon in the lower Fraser River below Hell's Gate. They documented concentrations of juvenile white sturgeon throughout the lower Fraser River below Hope that included the lower reaches of tributaries to the mainstem as well as large backwaters, side channels, and sloughs. Large numbers of juveniles were documented in the Lower Hatzic Slough, Nicomen Slough, and Big Eddy Backwater. Lane and Rosenau (1993) suggested water depth greater than 5 m, slow and variable current, high turbidity, and perhaps warmer summer water temperatures than in mainstem areas may be important criteria for determining the potential suitability of habitat for rearing by juvenile white sturgeon. Parsley and Beckman (1994) noted that high salinity in estuary environments precluded use by young-of-the-year and smaller juvenile white sturgeon. The ability of white sturgeon to tolerate brackish and saline waters increases with size (McEnroe and Cech 1985) which is why only adult white sturgeon have been documented moving freely between freshwater and estuary environments.

During studies of white sturgeon in the unimpounded section of the lower Columbia River below Bonneville Dam, Parsley et al. (1993) documented juveniles (0.15 to 1.03 m FL) at depths of 2 to 58 m, at mean column and near substrate velocities of 0.1 to 1.2 and 0.1 to 0.8 m/s, and in areas dominated by fine substrate material (i.e., sand). Using this information, Parsley et al. (1993) developed microhabitat criteria curves that describe the suitability of water depths, mean column velocities, and substrate composition for young-of-the-year and juvenile white sturgeon. Their investigations indicated juvenile white sturgeon could generally tolerate but did not necessarily prefer a wide range of environmental conditions.

Juvenile white sturgeon (TL<100 cm) were sporadically collected throughout the portion of the middle Fraser River (SG-3) between Boston Bar and French Bar Canyon. Capture data suggested larger juvenile white sturgeon occupied the same areas as those used by adult fish which were typically nearshore areas defined by depositional habitat (sand, fine gravels) with backwater and eddy flow characteristics (RL&L 1998b, 1999b). Catches of white sturgeon in the French Bar to Chilcotin River confluence area of the mainstem Fraser River consisted mainly of juvenile fish that suggested this section of the river was also used for rearing purposes (RL&L 2000c).

Information on the habitat used for rearing by juvenile white sturgeon, less than 100 cm TL, in the upper Fraser River upstream of Prince George (SG-4), is limited. Capture and life history information suggests this section of the Fraser River is used mainly by juvenile white sturgeon with individuals between the ages of 11 and 20 being most common (RL&L 1999d; RL&L 2000d; LTFN 2000). This cohort was sporadically distributed throughout the upper Fraser River, with highest catches occurring from the confluence of the Willow River (rKm 831) upstream to the confluence of the Bowron River (rKm 910; LTFN 2000). White sturgeon were most commonly recorded near tributary confluences although individuals were also documented in the lowermost reaches of the some of the major tributaries such as the Bowron, McGregor, and Torpy rivers (RL&L 1999d; LTFN 2000). The habitat within the areas used by white sturgeon has been described as backwater eddies with low velocity laminar flow and depositional type habitat units (LTFN 2000).

Juvenile white sturgeon under 100 cm TL were infrequently encountered in the Nechako River drainage (SG-5). Juveniles were captured within the same areas of the Nechako River mainstem as adult fish, including the confluences of Neuco Creek and the Sinkut River, and the Finmoore area (RL&L 1999d, 2000d; Triton 2000). During an earlier investigation of the Nechako River, Envirocon (1984) also captured white sturgeon between 5 and 20 years-of-age in the Sinkut River confluence area and near Vanderhoof. Both areas are known to be used by adults (RL&L 1999d, 2000d). Areas where juvenile white sturgeon were documented in the Nechako River were defined by low velocities, laminar flow or backwater eddies, and fine substrate material (e.g., silt, sand). These areas were often associated with deep pools, calm nearshore areas with low to moderate growth of aquatic macrophytes, and tributary confluences (Envirocon 1984; RL&L 1999d, 2000d).

Spring Movements to Feeding Areas

Information on the spring feeding movements of white sturgeon in the Fraser River drainage was gathered directly or indirectly (depending on regional objectives) as part of the *FRWSMP*. The intent of this section is to provide a general summary of the spring feeding behavior of white sturgeon in each Stock Group (with the exception of SG-4), as determined from radio telemetry and mark-recapture data. A more detailed discussion of the movement and behavior of white sturgeon in the Fraser River is provided in the annual data reports (Appendix A).

Within the Fraser River drainage, a defined movement of white sturgeon was documented during the spring period. Based on available information, spring feeding movements were considered to typically occur between March and July although additional criteria were used to determine if the movements were feeding related and to distinguish feeding behavior from spawning behavior. These criteria included, but were not necessarily limited to, sex and maturity stage (if known), movement timing and destination, physical river conditions, and the behavior of other white sturgeon in the general area. During investigations of white sturgeon in the lower Columbia, Haynes et al. (1978) observed a heightened frequency of movements in mid-June when water temperatures were 12 to 14 °C and flows were high.

Within the lower Fraser River (SG-1 and SG-2), information on the feeding behavior of white sturgeon is limited as the main objective of the movement studies was to gather information on the movements of the sexually mature cohort to identify potential spawning areas. Movement information collected for the non-spawning adult portion of the Stock Groups, however, suggested spring feeding movements were localized and typically less than 10 km (RL&L 1998a, 1999a). Generally, movements were initiated as early as April and were typically in a downstream direction. These results suggest white sturgeon in the lower Fraser River may not migrate large distances to acquire food with some individuals initiating downstream movements (i.e., possibly to exploit potential food sources such as eulachon that enter the lower Fraser River from the Pacific Ocean) early in the year. White sturgeon are known to feed on eulachon (Scott and Crossman 1985). Swiatkiewicz (1989) reported observations of white sturgeon gathering in the lower Fraser River during April and May that suggested these fish were intercepting the eulachon spawning migration. Generally, the distribution of fish that provided information on feeding behavior and their predominately localized movements suggested areas potentially suitable for feeding by adult white sturgeon are widely available in the lower Fraser River.

As shown in Table 7.5, spring feeding movements of maturing adult white sturgeon were documented in SG-3. To facilitate a summary of the movements of the white sturgeon in SG-3, the middle section of the Fraser River was divided into 100 km sections within which the movements of radio tagged white sturgeon were grouped according to their capture location and movement category.

Most of the movements of white sturgeon in SG-3 were localized although several individuals exhibited downstream movements during spring, from areas such as Texas Creek and near Lillooet, that exceeded 20 rkm. Often, these same individuals exhibited return migrations during the fall for overwintering purposes. RL&L (1999b) indicated that the predominance of movements under 10 rkm suggested discrete sections of the middle Fraser River may provide suitable habitat for several life history functions that included overwintering and feeding. Most notable were the Texas Creek, Lillooet, French Bar, Chilcotin confluence, and Hawks Creek areas, although based on capture information, there are likely other areas within this section of the Fraser River that serve a similar function.

Table 7.5 Summary of the Groupings and Range of Movements of White Sturgeon in the Middle Section of the Fraser River

Stock Group	River Section (rkm)	*n*	Movement Category[1]	Movement Range (rkm)[2]	
				d/s	u/s
SG-3	212-299.9	*8*	SM		
			SR	6.1	3.8
			FM	3.3	10.5
			O	0.6	1.0
			S	78.3	
	300-399.9	*10*	SM	27.2	0.7
			SR	5.9	4.0
			FM	3.3	11.7
			O	0.9	1.9
			S	14.3	
	400-499.9	*9*	SM	20.0	3.0
			SR	9.5	0.5
			FM	19.0	36.6
			O	1.7	1.1
			S		
	500-599.9	*5*	SM	22.0	3.2
			SR	20.0	1.0
			FM	0.0	7.9
			O	1.4	1.2
			S		

Note: Blank cells represent no data.

[1] SM=spring movements to feeding areas; SR=summer residency; FM=fall movements to overwintering areas; O=overwintering; S=spawning.

[2] u/s=upstream; d/s=downstream.

The movements of white sturgeon in SG-5 have been intensively monitored since 1995. The movements of white sturgeon radio tagged in the Nechako River drainage are grouped in Table 7.6 according to movement category to facilitate a discussion of their spring feeding, summer residency, fall migration, overwintering, and spawning behavior.

Table 7.6 Summary of the Groupings and Range of Movements of White Sturgeon in the Nechako River Drainage

Stock Group	River Section (rkm)	*n*	Movement Category[1]	Movement Range (rkm)[2]	
				d/s	u/s
SG-5	65-178	*49*	SM	73.2	61.6
			SR	16.5	22.6
			FM	38.0	56.7
			O	9.3	4.0
			S	64.5	47.0

[1] SM=spring movements to feeding areas; SR=summer residency; FM=fall movements to overwintering areas; O=overwintering; S=spawning.

[2] u/s=upstream; d/s=downstream.

Movements related to spring feeding of maturing white sturgeon in the Nechako River system were considerably more extensive and were more common compared with sturgeon stocks in the Fraser River (Table 7.6). Generally, individuals in the Nechako River exhibited spring movements for feeding as early as March; maximum movements ranged in direction from 61.6 rkm upstream to 73.2 rkm downstream. The majority of the movements that occurred during the spring were classed as extended movements that were more than 10 rkm in distance. Large-scale movements of white sturgeon in Roosevelt Lake (Brannon and Setter 1992) and low gradient systems like the Kootenai River (Apperson and Anders 1991) were thought to be necessitated by considerable geographic separation between suitable habitats required for various life requisite functions such as feeding, spawning, and overwintering.

The area of the Nechako River between Vanderhoof and Whitemud Rapids appeared to be used most extensively for feeding although some individuals exhibited movements into the Stuart River system, as far upstream as near the outlet of Stuart Lake, while others moved upstream in the Nechako River toward Fraser Lake to feed (RL&L 1997c, 1998d, 1999d). The timing of movements of white sturgeon in SG-5 generally commenced prior to the arrival of sockeye salmon, a migratory food source for white sturgeon in the system, and coincided with increasing water temperatures and river discharge in the spring. White sturgeon that overwintered in the mainstem Nechako River upstream of the Stuart River confluence exhibited several noticeable movement trends. Some individuals moved downstream during the spring, possibly to intercept early Stuart sockeye salmon as they migrate upstream and into the Stuart River drainage in early July. Other sturgeon appeared to exhibit only localized movements within the areas used for overwintering purposes. A few individuals initiated upstream movements in the spring toward Fraser Lake, which may be associated with migration of sockeye salmon through the Nechako River and into the Stellako River system, via the Nautley River and Fraser Lake, during late July to August.

Based on the timing and destination of movements of some of the maturing white sturgeon, RL&L (1998d, 1999d, 2000d) noted that some of the spring movements thought to be feeding related may have somehow been connected to the spawning migrations of the reproductively mature portion of the population. This was particularly evident with those maturing fish that exhibited downstream migrations in the spring to the lower Nechako River near Isle Pierre and Whitemud Rapids. Both of these areas are believed to provide suitable spawning habitat for white sturgeon and the behavior of several mature fish suggested they may be used for spawning (RL&L 1998d, 1999d).

Summer Residency

Summer residency of white sturgeon in the Fraser River drainage was defined as the period between spring movements to feeding areas and fall migrations for overwintering that generally encompassed July to September. During this period, the movements of white sturgeon in most stocks were typically frequent but more localized than in the spring or fall. In systems like the lower Columbia River (RL&L 1994; Brannon and Setter 1992) and Kootenai River (Apperson and Anders 1991), white sturgeon were reported using shallower depths during the spring to summer period and exhibited frequent, short distance forays between shallow and deep-water areas to feed.

As stated previously, the main objective of the movement studies in SG-1 and SG-2 was to gather information on the movements of the sexually mature cohort to identify areas potentially used for spawning. As with spring feeding behavior of white sturgeon in the lower Fraser River, information on summer residency is sparse. Generally, the movements of the non-spawning adult cohort in the lower Fraser River were mainly localized and less than 5 rkm (RL&L 1998a, 1999a). These preliminary results suggest that during the summer period, some individuals in the populations may not move large distances to feed and may remain within the areas selected during the spring. Lane and Rosenau (1993), however, documented a distinct movement of juvenile white sturgeon from the sloughs and backwaters they occupied in spring to mainstem areas as summer progressed.

White sturgeon in SG-3 exhibited mainly localized movements during the summer period, with the majority of radio tagged individuals moving less than 5 rkm (Table 7.5). These results provided further evidence to suggest there may not be a large geographic separation between suitable habitats in the middle Fraser River required for such activities as feeding and overwintering.

Generally, white sturgeon in SG-5 exhibited more activity during the summer period than individuals from other areas of the Fraser River drainage, with extended movements in excess of 15 rkm being common (Table 7.6). The behavior of radio tagged white sturgeon in the Nechako River drainage suggested they have adopted a feeding strategy to exploit the sockeye salmon that migrate through the system during the summer.

Fall Movements to Overwintering Areas

The fall migrations of white sturgeon in the Fraser River drainage were defined as sustained, unidirectional movements (a movement in either an upstream or downstream direction but not both) likely for overwintering purposes. These movements were usually exhibited by individuals during the late summer to fall period. The fall migration was typically followed by a period of low activity that appeared to be a dormant season. In other systems, such as the Columbia and Kootenai rivers, white sturgeon have been recorded as initiating movements in spring that continued over the summer period and ceased in fall (Haynes et al. 1978; Apperson and Anders 1991; Brannon and Setter 1992; RL&L 1994).

As the primary objective of movement studies in SG-1 and SG-2 was to gather information on spawning behavior of white sturgeon in the lower Fraser River, information on fall movements is limited. Following the movement results provided for SG-1 and SG-2 in previous sections, the non-spawning adult cohort of white sturgeon in the lower Fraser River exhibited mainly localized movements during the fall (RL&L 1998a, 1999a). These results indicate that areas suitable for feeding and overwintering are likely in close proximity in the lower Fraser River.

Fall movements by white sturgeon in SG-3 were variable with maximum distances traveled from 19.0 rkm downstream to 36.6 rkm upstream (Table 7.5). These larger-scale movements were more common between French Bar and the Chilcotin River confluence areas than in other areas of the middle Fraser River. Most of the fall movements, however, were limited in extent and rarely exceeded 10 rkm. Results of the *FRWSMP* suggest some fish in the middle Fraser River may not move much to feed and overwinter while others may move extensively, possibly between preferred areas. Similar results were recorded during studies of the white sturgeon in the Columbia River (Brannon and Setter 1992; RL&L 1994).

Defined fall movements of white sturgeon in the Nechako River were more common than in Fraser River (Table 7.6; RL&L 1998d). RL&L (1997c) noted that the movements of Nechako River sturgeon to overwintering areas occurred during late summer to fall period as water temperatures and river flows declined and food resources became less abundant. Many of the overwintering areas that white sturgeon moved into during the fall were assigned a high use rating by RL&L (1997c), based on consistent presence of white sturgeon during all seasons (refer to Section 5.5). Evidence was obtained that some white sturgeon move between the Nechako and Stuart rivers. Individuals were documented in the Nechako River during the spring to summer period, followed by a movement to the Stuart River during the fall, presumably to overwinter (RL&L 1999d). These results support the findings of the spring movement studies that suggest a portion of the white sturgeon population in SG-5 may utilize different areas for feeding and overwintering while others may reside within localized areas for extended periods and may use these areas for more than one life requisite function.

Overwintering

Results of telemetry studies conducted during the winter period indicated white sturgeon in the Fraser River drainage generally moved less than 2 rkm during this period, with a few individuals moving more than 5 rkm (Tables 7.5 and 7.6). The period of dormancy generally extended from October to March although movement data suggested the dormant season may vary by Stock Group, possibly due to differences in such factors as physical river conditions (e.g., water temperature and discharge), habitat suitability (e.g., proximity of overwintering habitat), and food availability (e.g., migratory salmon). Within all Stock Groups, however, individuals tended to utilize deep, calm-water areas during the winter period. In some portions of the Fraser River drainage (e.g., Nechako River, Sinkut Ranch area), white sturgeon also used these same areas for feeding activities (RL&L 1999d).

As mentioned in Section 7.5, white sturgeon in other systems have been documented as being inactive during the winter period (Apperson and Anders 1991; Brannon and Setter 1992; RL&L 1994). In the lower Columbia River between Priest Rapids and McNary Dam, activity levels of white sturgeon declined when water temperature fell below 15 °C in October (Haynes et al. 1978). Within the lower Columbia River between Priest Rapids and McNary Dam, white sturgeon moved no more than 0.2 km during the November to May period and appeared to be relatively dormant (Haynes et al. 1978). Apperson and Anders (1991) determined that Kootenai River white sturgeon used deeper, calmer habitats during the winter period to recover metabolic energy expended for spawning and migration. A similar behavior was noted during studies of white sturgeon in the Columbia River in British Columbia (RL&L 1994).

Spawning

This section provides a summary on the movement and behavior of the spawning cohort of white sturgeon within each Stock Group and presents the results of early life history sampling. Spawning migrations of white sturgeon were defined as the sustained, unidirectional movements of the mature spawning cohort of the population either for staging or for spawning purposes. The movements typically occurred either during the fall (staging) or spring (spawning) to areas at or near habitat with characteristics similar to that described in the literature as being potentially suitable for spawning by white sturgeon. In the absence of direct evidence of spawning, the migrations of sexually mature fish during the spring were determined to be spawning-related if they occurred prior to or during the period when river conditions (e.g., river discharge and water temperature) were suitable for spawning. The suitability of spawning habitat was based on available literature describing the characteristics of white sturgeon spawning habitat in the Columbia, Kootenai, and Sacramento rivers.

Annual investigations of the movements of pre-spawning white sturgeon identified the canyon section upstream of Hope, the area near the side channels at Herrling Island, and near Minto Channel as potential spawning areas of white sturgeon (Perrin et al. 1999, 2000; RL&L 1999a). RL&L (1999a) noted that most of the extended movements of white sturgeon in the lower Fraser River were made by white sturgeon in the advanced stages of sexual development. Prior to the spawning period, suspected to be during May to July, many of the late reproductive males exhibited movements greater than 15 rkm. Furthermore, a few late reproductive males displayed large-scale upstream movements after the suspected spawning period followed by return movements in late October to the same areas used the previous summer.

Spawning by white sturgeon was documented in the lower Fraser River based on the capture of white sturgeon eggs and larvae (RL&L 1998a; Perrin et al. 1999, 2000). Most of the spawning evidence was from early life history sampling in the Lower Mainland section of the lower Fraser River (i.e., SG-1) near the Herrling, Jesperson, Minto, and Peters Island side channels, and the Fraser main channel near Hope Slough (Perrin et al. 1999, 2000). However, white sturgeon embryos and larvae were also collected in the Lower Canyon section of the Fraser River (i.e., SG-2) near the Coquihalla River confluence upstream of Hope (RL&L 1998a; Perrin et al. 1999, 2000). The behavior of the spawning cohort of the white sturgeon population in the lower Fraser River and the results of early life history sampling suggested white sturgeon spawning may be widely distributed (Perrin et al. 2000). This is markedly different than in impounded systems like the lower Columbia River where spawning is mainly restricted to tailrace areas of dams (RL&L 1994).

Insight into the physical conditions within areas selected for spawning by white sturgeon in the lower Fraser River was obtained from egg and larvae capture sites (Perrin et al. 2000) and from preliminary evidence of spawning habitat reported by RL&L (1998a) and Perrin et al. (1999). These results suggested white sturgeon spawning may be wide spread in the lower Fraser River and occurs during the declining hydrograph in spring and early summer when water temperatures are between 11.3 and 18.4 °C (Perrin et al. 2000). Spawning areas were thought to be characterized by substrate comprised of pebble sized material intermixed with gravel, cobble and sand. Flow conditions were described as being mainly laminar or backwater eddies although upwelling flows were not always present and surface water velocities ranged from 0.5 to 2.2 m/s. Water depths ranged from 0.5 to 6.5 m, average turbidity values were between 6 and 92 NTU, and suspended solid concentrations ranged from 16 to 222 mg/L (Perrin et al. 2000).

The characteristics of white sturgeon spawning habitat in the lower Fraser River have been compared with the spawning habitat of white sturgeon in the lower Columbia, Sacramento, and Kootenai rivers (Perrin et al. 2000). The results of the comparison suggested white sturgeon in the Fraser River may spawn in areas with velocities that are similar to those documented in other systems, with the exception of the Kootenai River where water velocities were substantially lower. Spawning substrate varied widely in all systems, ranging from fines and gravels to cobbles and boulders. Differences between systems in terms of river discharge was noted although spawning during the declining hydrograph was common in each system. RL&L (1994) noted, however, that in the Columbia River, flows fluctuated widely during the spawning period due to variable releases from dams and that these variable flows may reduce sampling efficiency or preclude successful reproduction of white sturgeon.

Observations on river flow regimes suggested the Sacramento and lower Fraser River may be similar, with white sturgeon spawning in areas commonly defined by high, laminar flows. In other systems, particularly those that are impounded, white sturgeon spawned in the turbulent flows common in dam tailraces or in the large backwater eddies typically found in confluence areas (Apperson and Anders 1991; Parsley et al. 1993; RL&L 1994). Generally, spawning temperatures were between 10 and 20 °C, with spawning in southern drainages (e.g., Sacramento) commencing as early as February and extending to May. In the more northern portions of the Columbia River (RL&L 1994) and in the Fraser River (PSMFC 1992; Perrin et al. 2000), suitable spawning temperatures occurred during the June to August period.

Direct evidence of white sturgeon spawning was not obtained for white sturgeon in the middle Fraser River (SG-3). The capture and movements of several large, sexually mature fish, however, suggested spawning may occur in this section of the Fraser River. Several white sturgeon in the late stages of reproductive development moved to areas downstream of the Texas Creek confluence (RL&L 1999b). The importance of this area was not clearly understood although it may be used for staging or possibly spawning. The large-scale, downstream movement (75 rkm) of a late reproductive male white sturgeon to the Nahatlach confluence area was considered either an overwintering or pre-spawning movement (RL&L 1999b). Another fish, a pre-spawning female, was radio tagged in the lower reaches of SG-3 and subsequently recorded in SG-2 at Bristol Island. Reasons for this downstream movement were not determined although this behavior provided evidence of white sturgeon movements between SG-3 and SG-2 (RL&L 1998a). Within the upper reaches of SG-3, reproductively mature white sturgeon were captured near the Cottonwood River and Red Rock Creek confluence areas during summer that suggested these areas may be used for staging purposes by pre-spawners (RL&L 1999c).

Surveys were conducted in the Nechako River drainage to identify the spawning behavior of white sturgeon and the characteristics of spawning habitat. Movement and habitat studies provided results that suggested the Hulatt, Isle Pierre, and Whitemud rapids areas of the Nechako River may provide suitable habitat for spawning by white sturgeon. Several mature fish exhibited downstream movements in the spring to the lower Nechako River that coincided with the period when water temperatures and discharge conditions were likely suitable for spawning (RL&L 1999d, 2000d). Movement data also suggested a potential spawning use of the Stuart River and possibly the upper Nechako River near the Nautley River confluence (RL&L 2000d). Evidence of spawning through the capture of white sturgeon eggs and larvae, was not obtained despite considerable sampling effort.

CHAPTER 8 STOCK CONCERNS

8.1 RECRUITMENT FAILURE

Results of efforts to confirm spawning and to collect early life history stages of white sturgeon suggests the reproductive success of Nechako River sturgeon is low and may be insufficient to maintain the population at the low density levels that currently exist. Low numbers of juvenile white sturgeon in the Nechako River (RL&L 1996a, 1997c, 1998d, 1999d, 2000d; Triton 2000) suggests either rearing occurs elsewhere or recruitment of juveniles is low. However, comparisons with results from previous studies of white sturgeon in the Nechako River (Envirocon 1984; Dixon 1986) suggests it is more likely that the population is ageing and recruitment of juveniles to the general population is limited or sporadic (RL&L 2000d).

The spawning period for white sturgeon in the Nechako River mainstem may vary considerably on an annual basis (RL&L 1998d, 1999d, 2000d). Spring water temperatures documented in the literature as being conducive for spawning by white sturgeon in other systems (10 to 20 °C; Parsley and Beckman 1994; RL&L 1994; Perrin et al. 2000) generally occurred in the Nechako River during a one and a half to two month window between May and July (RL&L 1999d, 2000d). Water temperatures conducive for white sturgeon spawning occurred during the June to mid-July period in 1999, which was similar to the spawning window observed in 1997. In 1998, however, spawning temperatures occurred in May and June. During studies of Columbia River sturgeon, researchers noted that dams have reduced the availability of spawning habitat and adversely affected spawning success and recruitment (Reiman and Beamesderfer 1990; Parsley and Beckman 1994; RL&L 1994). Other researchers have documented a similar effect of dams on sturgeon populations in other river systems (Khoroshko 1972; Deacon et al. 1979; Rochard et al. 1990; Apperson and Anders 1991). Reiman and Beamesderfer (1990) stated that the reproductive success of white sturgeon in impounded systems may be sporadic and recruitment failures common. Studies of white sturgeon populations in impounded rivers below dams such as the Kootenai River in Idaho (Apperson and Anders 1991) have documented low to nil spawning success and recruitment.

While there are other factors that may potentially reduce white sturgeon spawning activity or success, there is mounting evidence to suggest alterations to the natural hydrological and thermal regimes of river systems that follow regulation play a significant role. A review of the literature indicates there are a host of factors that, by themselves or in combination, can reduce the white sturgeon reproductive success. Some of these factors include:

- blockage or impediment of spawning migrations to historical spawning areas;

- natural flow regime as a necessary stimulus for egg maturation and ovulation;
- altered temperature regimes preceding or during the spawning period that affect fish migrations, maturation, and egg development;
- decreased volume of the spring freshet coupled with increased water clarity that increases susceptibility of early life stages of white sturgeon to predation during critical downstream dispersal or early benthic stages;
- change in species composition that reduces the abundance of prey species or increases the abundance of potential predators;
- increased total dissolved gas concentrations in waters downstream of dams that may adversely affect larval white sturgeon during critical stages of their life cycle;
- reduced quality or quantity of critical rearing habitats due to mainstem fragmentation and flooding by dams; and
- pollution in the form of pulp mill, smelter, and municipal wastes that may affect sturgeon survival and growth by altering habitat suitability and the composition and abundance of prey species.

The effects of discharge on the spawning success of white sturgeon has been well documented in regulated systems, both impounded and unimpounded. During investigations of Columbia River sturgeon, Hildebrand et al. (1999) only recorded spawning below Waneta Dam at the Pend d'Oreille-Columbia River confluence, despite potentially suitable white sturgeon spawning habitat being available in other areas of the Columbia and Kootenay rivers. They found that the Pend d'Oreille River warmed more rapidly and exhibited a more natural flow pattern in the spring than either of the other two systems. The increase in water temperature was also more gradual and sustained prior to and during the spawning period, and the outflow was more turbulent than in other potentially suitable spawning areas.

Kohlhorst et al. (1991) positively correlated white sturgeon year-class strength with river outflow in the Sacramento-San Joaquin estuary. Anders and Beckman (1993) observed an increased in the number of eggs collected in years of above average discharge than in low discharge years. They also recorded a longer spawning period in years when discharge was above average. A direct relationship between the year-class strength of Siberian sturgeon (*A. baeri*) and water levels in the upper Orb River (in the former USSR) was established by Votinov and Kas'yanov (1978). A shift in the timing of peak flow and reduction in peak flow were correlated to reduced recruitment and spawning efficiency. The intensity and effectiveness of spawning Siberian and Russian sturgeon (*A. guldenstädti*; Khoroshko 1972) were directly dependent not only on the volume of discharge during the spring but also on the timing of increasing water temperatures. Fluctuating discharges also had an adverse effect on the conditions under which sturgeon overwintered and caused important changes in their behavior and maturation.

Habitat suitability criteria curves have been developed by Parsley and Beckman (1994) for white sturgeon spawning and rearing in the lower Columbia River from its mouth to McNary Dam. Habitat suitability curves such as these are being used to assist conservation efforts directed towards enhancing the reproductive success and recruitment of white sturgeon populations in the Columbia and Kootenay Rivers (RL&L 1996b; USFWS 1999). This information may also aid efforts to improve the spawning success and recruitment of Nechako River sturgeon.

8.2 VULNERABILITY TO HARVEST

The effects of overharvest on white sturgeon populations has been well documented in the literature. Semakula and Larkin (1968) noted the crash of the white sturgeon fishery in the lower Fraser River at the turn of the 20th century and the virtual commercial extinction of the population. Catches of white sturgeon exceeded 200 tonnes per year in the late 1800's (Echols 1995) but then declined to less than 20 tonnes per year despite changes in catch regulations (Scott and Crossman 1985). After the collapse of the commercial fishery, but prior to 1994, harvest of white sturgeon in the lower Fraser River occurred as a result of tidal and non-tidal recreational angler fisheries and as incidental catches in the native food fishery and commercial gill net fishery (Inglis and Rosenau 1994). The recreational fishery of white sturgeon in the lower Fraser River began in the early 1900's. Since that time, the increased attraction of sturgeon angling as a recreational sport lead to concerns of potential overharvest of the species and heightened sensitivity to environmental impacts based on their late age-at-maturity and low spawning frequency (Semakula and Larkin 1968). Echols (1995) noted that sport angling regulations for the lower Fraser River tidal and non-tidal waters were markedly different prior to 1994 when non-tidal anglers were required to release sturgeon over 150 cm in length and could only retain one fish per year between 100 and 150 cm in length, whereas tidal anglers were allowed to retain one fish per day over 100 cm in length. These regulation changes were intended to reduce the harvest of mature fish and new recruits to the sport fishery (Echols 1995).

Later in 1994, concerns over the effectiveness of the regulation changes in the sport fishery and the impacts of harvesting of white sturgeon by all sectors in the lower Fraser River, lead to a retention ban on the threatened and endangered populations of white sturgeon in the Fraser River drainage (Echols 1995). More recently, additional measures have been taken by BC Ministry of Environment, Lands and Parks to help recover white sturgeon populations in British Columbia and offset the effects of historical commercial overfishing, habitat loss, and increasing sport fishing pressure. In April 1996, the white sturgeon recreational fishery on the

Columbia River was closed based on the endangered status of the Columbia River population. Catch-and-release remains in place for white sturgeon in the Fraser River drainage, except for the Nechako River and its tributaries, which was closed to angling for white sturgeon in September 2000.

8.3 LOW DENSITY

Results of the *FRWSMP* showed low densities of white sturgeon in the Nechako River drainage with population levels estimated to be below 600 fish. According to Anders (1998), when low density reflects a declining population size due to recruitment failure and natural mortality, the Stock Group may be at high risk of extinction. A comparison of specific population characteristics illustrated how low density populations possessed a lower potential for long-term persistence than large populations, with many recovery options, both natural and artificial, being ineffective when populations declined below a threshold size (Anders 1998). As a population size declines, so does the number of reproducing individuals in a population in a given year, with an increased risk of reduced population viability and persistence.

Relative abundance information also suggested low densities of white sturgeon in the upper Fraser River from Soda Creek, north of Williams Lake, to the confluence of the Torpy River, upstream of Prince George. Presently, there is insufficient data from SG-4 to determine whether the low density of fish upstream of Prince George is at risk. Low numbers of white sturgeon were also documented included the Bridge River Rapids to French Bar Area of SG-3 and between Saddle Rock and Hell's Gate in SG-2. The apparent low density of white sturgeon in the SG-2 and SG-3 areas of the Fraser River was attributed to the quality of available habitat that was markedly less suitable for feeding and overwintering than in other areas of the mainstem (RL&L 2000b).

8.4 MIGRATION BARRIERS

Several points along the mainstem Fraser River may be migration barriers or impediments to white sturgeon, particularly during high flow periods when fish passage of migratory salmon is known to be hampered. These areas include Hell's Gate and Bridge River Rapids, with the effects of the rock slide at Hell's Gate in 1913 on migratory fish passage being well documented (Jackson 1950). RL&L (1996a) commented on the speculation that white sturgeon stocks in the upper and lower Fraser River may represent geographically isolated populations. Results of the *FRWSMP* provided evidence that there is some mixing between the stocks above and below Hell's Gate, but only in a downstream direction from SG-3 to SG-2 and SG-1.

Brown et al. (1992) reported a lower genetic diversity in white sturgeon from above Hell's Gate compared with individuals from the lower Fraser River. Although the observed difference may have been historically present prior to the slide at Hell's Gate based on the probability that upper Fraser River white sturgeon were colonized by upper Columbia white sturgeon, the slide may have accentuated the bottleneck effect through increased isolation of sturgeon in the upper Fraser River. These types of intrariver differences in genetic variability have been observed in populations of white sturgeon in the Columbia River above and below dams.

8.5 HABITAT

8.5.1 Threats to Existing Habitat

Populations of white sturgeon in the Fraser River drainage have historically been impacted by commercial over-harvesting (Semakula and Larkin 1968; Binkowski and Doroshov 1985), sport fishing activity (Dixon 1986), and the loss or alteration of preferred habitat (Deacon et al. 1979; Rochard et al. 1990). Much of the available literature from other area has focused on the impacts to white sturgeon populations from regulated flows and over exploitation. The degradation of white sturgeon habitat through dredging, industrial pollution, and urban development has also been widely recognized as potentially having profound effects on sturgeon populations (Lane and Rosenau 1994; RL&L 1996b; USFWS 1999); however, these effects have not been well documented.

Scuffle dredging in the lower Fraser River between Hope and Mission is believed to interfere with natural white sturgeon spawning and staging habitat, with the potential consequence being a decrease in offspring survival (Laidlaw and Rosenau 1998). Rochard et al. (1990) stated that alterations to the substratum, water flow and other physical factors such as temperature and oxygen, could degrade the spawning habitat of white sturgeon and prevent successful reproduction. According to Rochard et al. (1990), limited regulatory measures have been taken to protect the spawning grounds of Atlantic sturgeon (*A. sturio*) from gravel extraction in the main rivers in France.

Northcote (1974) commented that additional information was needed on the effects of perturbations such as pollutant loadings and habitat destruction by human activity on species like sturgeon that inhabit the lower Fraser River. Pollution and modifications to water flow have had a dramatic effect on sturgeon populations in the Caspian Sea and Danube Basin by limiting trophic potential of areas used for feeding by sturgeon (Rochard et al. 1990).

8.5.2 Areas in Need of Recovery

As discussed in Section 8.1, the population of white sturgeon in the Nechako River is in need of recovery, based on evidence of poor spawning success and recruitment, and low population density. Other populations of white sturgeon that have been provincially listed as critically imperiled or endangered, such as those found in the Columbia and Kootenai rivers, have been selected for recovery efforts to minimize future loss of genetic variability to the population, to re-establish natural recruitment, and to successfully mitigate biological and physical habitat changes caused by dam construction and flow regulation (RL&L 1996b; USFWS 1999).

CHAPTER 9 SUMMARY OF FRASER STURGEON STOCKS

Five years of study of white sturgeon in the Fraser River drainage has provided information to help meet the original program objectives that were developed in 1995. Generally, the results showed that there are at least five Stock Groups of white sturgeon in the Fraser River drainage. Four stocks reside in the Fraser River mainstem with a fifth stock existing in the Nechako River drainage. All white sturgeon stocks were determined to be genetically distinct; stocks in the lower Fraser River had a higher genetic diversity than stocks in the upper Fraser or Nechako rivers. Further, white sturgeon that occupy the area downstream of Hope appear to be part of a stock complex rather than a single stock.

White sturgeon in the lower and middle Fraser River (i.e., SG-1 to SG-3) exhibited what could be considered reasonably healthy population structures. A wide range of size-classes and maturity cohorts of white sturgeon were present from immature juveniles to reproductively mature adults. The population size was highest for the lowermost Stock Group with density of white sturgeon declining markedly in the Lower Canyon. Stock size estimates for SG-3 were higher than in the Lower Canyon (SG-2) but less than in the Lower Mainland (SG-1). The growth model for each stock suggested a reduced growth rate with increased northern geographic range of the Stock Group. Age-at-maturity data indicated the stocks of white sturgeon in the lower and middle Fraser River may become reproductively mature at a later age than previous findings have suggested.

The results of capture and movement studies indicated most white sturgeon movements were localized (i.e., less than 5 rkm), although larger-scale movements (i.e., in excess of 10 rkm) were observed for feeding, overwintering and spawning. Data were also collected that provided evidence of limited white sturgeon movement from the middle to lower Fraser River through Hell’s Gate which suggested some exchange of genetic material between these stocks may occur.

Evidence of spawning by white sturgeon in the Lower Mainland and Lower Canyon sections of the Fraser River mainstem suggests white sturgeon spawning may be wide spread in the gravel reach of the lower Fraser River and occurs during the declining hydrograph when water temperatures are between 11 and 18 °C. Spawning was thought to occur over a relatively broad range of substratum and in a wide range of water velocities and depths. White sturgeon spawning was not confirmed in SG-3 although the capture of fish in pre-spawning condition suggested spawning may occur in the middle Fraser River near the Texas and Red Rock creeks, and the confluences of the Nahatlach and Cottonwood rivers.

Information on the movement, abundance, behavior, and population structure of white sturgeon in the upper Fraser River is not as complete as in other areas of the Fraser River drainage. Information collected to date suggests the density of white sturgeon in the area is low, with the area predominately being used by juvenile and sub-adult white sturgeon. White sturgeon were most commonly found near the confluences of major tributaries to the upper Fraser River, with individuals also recorded in the lowermost reaches of the Bowron, McGregor, and Torpy rivers. The growth rate of the population was similar to that recorded for Nechako River sturgeon but significantly slower than more the more southern populations of the white sturgeon in the Fraser River.

Nechako River white sturgeon displayed a population structure that was similar to that described for other white sturgeon populations in regulated systems. Results of the *FRWSMP* suggested the population consisted predominately of older fish and that spawning success and recruitment were low. The size of the stock in the Nechako and lower Stuart rivers was estimated at less than 600 fish. Movement data indicated the population moved extensively within the mainstem Nechako River for feeding, overwintering, and possibly spawning purposes, with some individuals moving between the Nechako and Stuart rivers. Movements were generally more frequent and of a larger-scale than in other areas of the Fraser River drainage. Some of the large-scale movements were thought to be spawning related and occurred to areas with potentially suitable spawning habitat in the lower Nechako River near Isle Pierre and Whitemud rapids. Several other areas also were identified as being potentially suitable for spawning (Hulatt Rapids, Nautley River – Fraser Lake outflow, lower Stuart River). The maturation and growth of the population was slow which may be attributed in part to factors such as the short growing season and food abundance.

Available information on the critically imperiled population of white sturgeon in the Nechako River drainage suggests the population may not be capable of sustaining itself naturally under current conditions and that additional conservation measures are needed for its recovery. Conservation efforts should initially focus on development of a recovery plan to mitigate existing impacts to the population and to enable natural recruitment as a means to minimize the potential for future loss of genetic variability.

CHAPTER 10 DATA GAPS AND ADDITIONAL RESEARCH NEEDS

10.1 DATA GAPS

Several deficiencies in information were noted in the *FRWSMP*. For the lower Fraser River below Hell's Gate, genetic results were not available to determine the extent of genetic variability in the lower Fraser River that would facilitate a refinement in the geographic boundaries of white sturgeon stocks within this area. Furthermore, information on the density, behavior, and population structure of white sturgeon in the lower Fraser River below Mission is very limited, and the habitat parameters that dictate areas selected by white sturgeon for spawning in the lower Fraser River have only indirectly been defined.

Information on spawning by white sturgeon in the middle Fraser River was not obtained during the *FRWSMP*, which limited discussion of the habitat required for spawning and conditions necessary to stimulate spawning activity for this Stock Group. The upper boundary of the Stock Group in the middle Fraser River is also poorly defined based on the low number of fish captured between Soda Creek and Prince George. This information will also assist in determining whether white sturgeon in the middle Fraser interact with upper Fraser River sturgeon.

As previously mentioned in this report, information on the movement, behavior, size, and structure of the white sturgeon population in the upper Fraser River is limited. Information collected on upper Fraser River sturgeon may have important implications to planning recovery efforts of white sturgeon in the Nechako River.

Knowledge of the dynamics of the white sturgeon population in the Nechako River has substantially improved because of recent research efforts, including the *FRWSMP*. Recovery of Nechako River sturgeon, however, will require a thorough understanding of reproductive strategies and early life history survival, the importance of systems like the Stuart River, Fraser Lake, and Stuart Lake, and the habitat requirements of all life stages.

10.2 ADDITIONAL RESEARCH NEEDS

Based on information deficiencies identified in the previous section, it is recommended that future programs focus on the following:

Stock Groups 1 and 2

- Conduct additional sampling for white sturgeon in the Lower Mainland and Canyon sections of the lower Fraser River, to determine the extent of genetic variability;
- Initiate sampling of white sturgeon below Mission to gather information on density, behavior and population structure; and

- Continue research efforts to determine the habitat requirements and locations selected by white sturgeon for spawning in the lower Fraser River and the habitat requirements of the early life history stages.

Stock Group 3

- Conduct studies to identify white sturgeon spawning locations in the middle Fraser River and the habitat requirements of the spawning cohort; and

- Conduct further sampling of white sturgeon in the upper reaches of the middle Fraser River to determine whether white sturgeon in the middle Fraser River interact with upper Fraser River sturgeon, and to collect additional tissue samples for genetic analysis to refine Stock Group boundaries.

Stock Group 4

- Continue inventory of the white sturgeon in the upper Fraser River to strengthen knowledge of their distribution, behavior, habitat use, abundance, and population structure.

Stock Group 5

- Continue to assess spawning and early life history of white sturgeon in the Nechako River drainage through intensive monitoring of spring migrations of mature fish, and mark-recapture, egg-larval, and juvenile sturgeon studies;

- Obtain additional information on habitat requirements of all life-stages of white sturgeon;

- Develop a juvenile white sturgeon year-class abundance index;

- Initiate a detailed examination of the effects of regulated river flow and temperature on the spawning and early life history of Nechako River sturgeon using results of white sturgeon studies conducted to date in the system;

- Define the requirements to promote natural spawning, incubation, rearing, recruitment, and survival of Nechako River sturgeon;

- Conduct additional studies of white sturgeon in the Stuart River drainage, including Stuart Lake, to ascertain the role this system plays in the life history strategies of Nechako River sturgeon; and

- Conduct periodic surveys of the Nechako River sturgeon to monitor population size and dynamics, and habitat suitability.

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APPENDIX A – LIST OF ANNUAL REPORTS

- Lheidli T'enneh First Nation (LTFN). 2000. 1999/2000 Assessment of Upper Fraser River White Sturgeon.
- Nelson, J., C. Smith, E. Rubidge, and B. Koop. 1999. Genetic Analysis of D-Loop Region and Microsatellite DNA of White Sturgeon from British Columbia - Population Structure and Genetic Diversity.
- Perrin, C.J., A Heaton, and M.A. Laynes. 1999. White Sturgeon (*Acipenser transmontanus*) spawning habitat in the lower Fraser River, 1998.
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