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[Article]

Population Status of White Sturgeon in the Lower Columbia River within Canada

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Abstract.—The subpopulation of white sturgeon *Acipenser transmontanus* in the Canadian portion of the Columbia River between Hugh L. Keenleyside Dam and the U.S.–Canada border has been identified as endangered, with nearly 30 consecutive years of consistent recruitment failure. The objectives of this study were to determine the status and population attributes of this subpopulation. We estimated survival rates and abundance using catch-curve analysis and mark–recapture models. An annual survival rate of 89% (95% confidence interval [CI], 88–90%) was estimated for the subpopulation using catch-curve analysis for the time period 1993–2004. The survival rates estimated from the mark–recapture data were obtained using model-averaged parameter estimates from a multistrata Cormack–Jolly–Seber model. The annual survival rate from the mark–recapture model was estimated at 97% (95% CI, 92–99%) from 1993 to 2004. The mark–recapture methods estimated abundance for 2004 to be 1,157 individuals (95% CI, 414–1,900). The mark–recapture data suggest that the white sturgeon have low migration rates, ranging from 3% to 5% among sections of the river. Despite high estimated survival, high uncertainty as to the future viability of the white sturgeon subpopulation in this portion of the river remains, as natural recruitment is poor. The fish continue to age, and size and age-frequency data suggest that recruitment failure continues in this subpopulation with minimal presence of wild juvenile or subadult white sturgeon detected.

The white sturgeon *Acipenser transmontanus* is the largest freshwater fish in North America and an integral component of the ecological and cultural heritage of the Columbia, Fraser, and Sacramento–San Joaquin river systems. Historically, white sturgeon populations of the Columbia River supported important commercial and recreational fisheries (PSMFC 1992). However, studies conducted since the early 1990s have provided strong evidence that some of its populations have been in decline since the 1970s (Hildebrand et al. 1999; UCWSRI 2002). A Columbia River white sturgeon subpopulation resides between Hugh L. Keenleyside (HLK) Dam in southern British Columbia, Canada and the U.S.–Canada border (Figure 1).

This lower Columbia River, Canada (LCR-Can), subpopulation has been identified as highly imperiled (Hildebrand et al. 1999) and in 2006, it was listed as endangered by the Canadian Species at Risk Act. It was first isolated from the downstream subpopulation in the U.S. portion of the Columbia River by the construction of Grand Coulee Dam in 1941 and was later isolated from the upstream subpopulation by the construction of HLK Dam in 1968 (Hildebrand et al. 1999). The Canadian reach of the Columbia River containing the LCR-Can subpopulation spans approximately 56 km of unimpounded river. Although the LCR-Can subpopulation is contiguous with the U.S. component of the subpopulation from the border to Grand Coulee Dam, there were insufficient data on the U.S. subpopulation for inclusion in this analysis.

In 1995 the LCR-Can subpopulation was estimated at 1,120 individuals (R.L. & L. Environmental Services 1996). Length-frequency distributions revealed the presence of approximately 30 consecutive years of near total recruitment failure (Figure 2). The lack of juvenile or subadult white sturgeon captured by gear that would not have a size-selected bias against the capture of younger fish led to the conclusion that recruitment was either completely nonexistent or present only at very low levels (Hildebrand et al. 1999). The setline and gill-net gear used for sampling from 1990 to 2004 in the LCR-Can reach of the Columbia River catches white sturgeon juveniles and subadults in other locations (Beamesderfer et al. 1989). Additional evidence for extremely low recruitment levels was obtained from another study that assessed the population characteristics of hatchery-reared juvenile sturgeon that were stocked in the LCR-Can reach annually since 2002 (UCWSRI 2002).

We used mark–recapture data to assess the current population status of the white sturgeon subpopulation in the LCR-Can reach. In particular, we estimated the abundance and survival rates and assessed the degree to which white sturgeon migrate within this reach of river. We discuss the implications of our estimates for the future of this white sturgeon subpopulation. The overall recovery objective for this subpopulation is to

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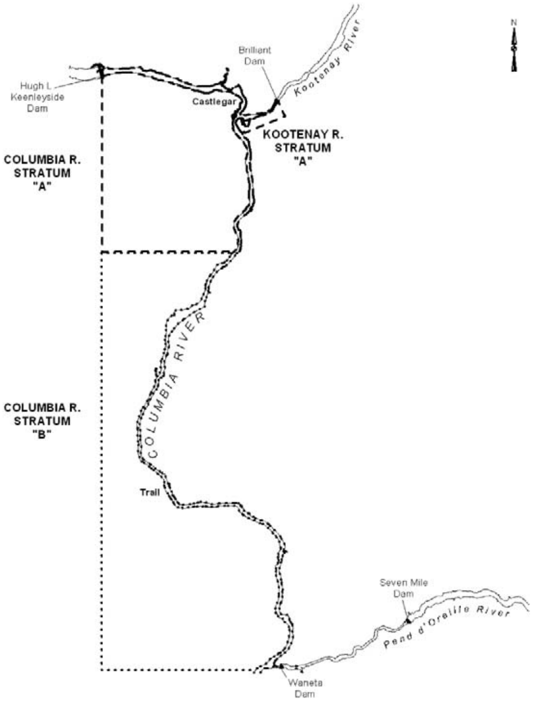

FIGURE 1.—The lower Columbia River within Canada, in which white sturgeon population analyses were carried out, extends from Hugh L. Keenleyside Dam in southern British Columbia to the U.S.–Canada border. The strata used in the multistrata analysis, dams, and relevant towns are provided for orientation.

reestablish a self-sustaining population of white sturgeon within this section of the Columbia River (UCWSRI 2002).

Study Site

The headwaters of the Columbia River flow from Columbia Lake northwards to Kinbasket Reservoir, British Columbia. The river then turns southward and flows through the Arrow Lakes region where it is joined by the Kootenay River and the Pend d'Oreille River. After leaving Canada, the Columbia River flows through the northwestern USA before entering the Pacific Ocean in Washington–Oregon. White sturgeon in the LCR-Can subpopulation range from HLK Dam, which forms Arrow Lakes Reservoir, to the U.S.–Canada border. This subpopulation also includes the white sturgeon that frequent the lower 3.4 km of the Kootenay River below Brilliant Dam (Hildebrand et al. 1999) (Figure 1). The LCR-Can subpopulation is part of the transboundary subpopulation that ranges from HLK Dam to Grand Coulee Dam at the southern end of Lake Roosevelt in the USA (UCWSRI 2002).

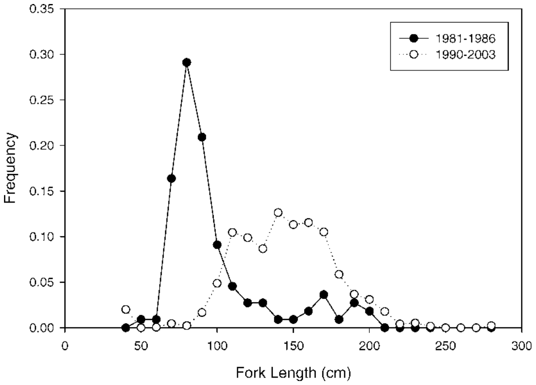

FIGURE 2.—Comparison of the length-frequencies of white sturgeon collected from the Canadian subpopulation of the Columbia River between Hugh L. Keenleyside Dam and the U.S.–Canada border during 1981–1986 and 1990–2003.

Methods

Field sampling.—From 1990 to 2004 white sturgeon were caught in the LCR-Can reach. The sampled area was then divided into two spatially delimited strata of the river for the population analyses. The first stratum (A) extends from HLK Dam (river kilometer [rkm] 0) downstream to rkm 20 and includes the lowermost section of the Kootenay River (Figure 1). The second stratum (B) extends from rkm 20.1 to the U.S. border at rkm 56.5. In this analysis the term stratum only refers to the spatial dimension. This stratification allowed overall subpopulation parameters to be estimated as well as migration rates between areas of high year-round sturgeon concentration that had previously been identified (R.L. & L. Environmental Services 1994). These "high-use" areas, as they are referred to in this paper, are areas where sturgeon have been consistently observed and captured over 15 years. They are areas with deep (>15 m) water and lower velocity relative to average main-stem flows, and four of them have been found in the LCR-Can reach (Hildebrand et al. 1999).

White sturgeon caught before 1993 were marked with T-anchor and fin-band tags and fin-clipped before being released. The 2-cm-wide section of fin, which was used for aging and provided a permanent mark, was clipped from the first pectoral fin ray from either the left or the right pectoral fin. From 1993 onward all fish were marked using passive integrated transponder (PIT) tags; fin-clipping continued to provide material for age determination and to provide a second mark. The PIT tags were injected subcutaneously on the left side of the fish at a point halfway between the insertion of the dorsal fin and lateral line. The use of PIT tags was necessary due to concerns about tag loss and infection of the T-anchor and fin-band tags. The

TABLE 1.—Annual estimates of effort (hook-hours) and white sturgeon caught on the lower Columbia River in Canada.

			Fish caught	
Year	Hook-hours	Mean CPUE[a]	Setlines	Incidental methods[b]
1990	12,746.9	1.08	131	5
1991	33,680.7	0.6	188	1
1992	47,674.6	0.57	272	13
1993	42,036.7	0.5	199	4
1994	40,364.0	0.4	148	2
1995	14,273.8	0.5	77	2
1996	20,152.0	0.5	97	0
1997	[c]	[c]	34	0
1998	[c]	[c]	56	0
1999	[c]	[c]	1	4
2000	0	0	0	3
2001	967.2	20.1	194	1
2002	605.1	22.6	137	2
2003	521.6	21.3	111	1
2004	657.6	18.1	119	0

[a] Fish/100 hook-hours.

[b] Pre-1996 creel surveys, boat electrofishing, gill netting, or found dead.

[c] No estimate.

recapture of individuals using setlines may have contributed to losses of the T-anchor tags. Observations by divers indicated a rolling behavior once a sturgeon was hooked and in the process, the mainline occasionally wrapped around the body of the fish and pulled out the tag (R.L. & L. Environmental Services 1994).

The sampling methods used to capture sturgeon in the LCR-Can reach were based on previous studies on the lower Columbia River in the USA that showed setlines to be more productive, more species specific, and less size selective than other gear for white sturgeon (Nigro et al. 1988; Beamesderfer et al. 1989; Elliot and Beamesderfer 1990).

Setlines also proved more effective than gillnetting or boat electrofishing for white sturgeon on the LCR-Can reach (R.L. & L. Environmental Services 1994), and the majority of captures and recaptures were made with setlines. In the USA, 50% of the setline catch was composed of juvenile and subadult white sturgeon that ranged from 340 to 2,740 mm in fork length (FL) (Beamesderfer et al. 1989). The same setline configuration as used in the USA was used to sample the LCR-Can subpopulation, but the catch in the first 3 years of sampling using setlines consisted predominantly (98.5%) of adult fish (R.L. & L. Environmental Services 1994; Hildebrand et al. 1999). Annual sampling efforts varied throughout the 15 years of sampling (Table 1).

Aging.—Fin rays collected in the field were stored frozen and then thawed, air-dried, and embedded in epoxy resin. The rays were sectioned in 0.5–1.0-mm-thick slices with a jeweler's saw and mounted on glass slides using a synthetic mounting medium. Fish were aged by counting growth rings in the basal cross sections using the methods described by Cuerrier (1951), Beamesderfer et al. (1989), and Brennan and Cailliet (1989). Fish collected in early spring before annulus formation were assigned an annulus on the outer edge of the ray and a January 1 birthday was assumed for all fish.

Statistical analysis.—Survival (S) was estimated using both catch-curve analysis and a multistratum Cormack–Jolly–Seber (CJS) model (Cormack 1964; Jolly 1965; Seber 1965; Hestbeck et al. 1991; Brownie et al. 1993). The migration parameters (ψ) between the spatial strata were estimated using the multistrata CJS model as were the probabilities of capture or recapture (p). The abundance of the subpopulation was estimated using a robust parameterization of the Jolly–Seber model, which is known within MARK (White and Burnham 1999) as the POPAN model type (Jolly 1965; Seber 1965; Schwarz and Arnason 1996).

Catch-curve analysis assumes that (1) all age-classes are equally recruited to the sampling gear, (2) the subpopulation size is constant, and (3) survival is independent of age (Ricker 1975; Hilborn and Walters 1992). The abundance of individual brood year-classes was determined from the frequencies of the aged individuals. The slope of the straight line provided an estimate of Z, the instantaneous total mortality rate, and this was converted to a survival estimate by exponentiating the negative value of Z (Ricker 1975). The catch-curve analysis only included fish from brood years before 1970 since these were considered to have recruited at a constant rate. Several of the older brood year-classes (before 1955) were absent or had low frequencies. The catch-curve analysis was, therefore, performed with and without brood years before 1955 to determine if their inclusion would bias the survival estimate. The two slopes were statistically compared using the t-test method outlined in Zar (1998). Catch-curve analyses were conducted using R. 2.4.1 (R Development Core Team 2006).

Program MARK employs an information-theoretic paradigm whereby a plausible set of candidate models is ranked using the second-order Akaike information criterion (AIC_c; Burnham and Anderson 2002). The default model in MARK is a fully time-dependent model where all parameters are estimated in all time periods. Additional plausible biological models were fitted to address likely possibilities for the LCR-Can subpopulation. Tag loss may have affected survival estimates for 1990–1993; consequently, we estimated survival for varying numbers of time periods ranging

TABLE 2.—Release–recapture matrix for white sturgeon in the Canadian subpopulation on the lower Columbia River. Occasions 1–15 equate to 1990–2004. No releases or recaptures were made in 2000.

Release occasion	Number of releases	Recapture occasion														Total
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	123	12	3	2	1	0	1	0	0	0	0	2	0	0	0	21
2	162		22	16	5	0	1	0	0	0	0	1	0	0	0	45
3	253			32	27	10	7	3	6	1	0	9	8	4	6	113
4	188				26	15	4	1	3	0	0	20	11	5	9	94
5	168					13	3	3	7	0	0	27	13	6	6	78
6	82						2	4	0	0	0	6	1	5	4	22
7	21							2	1	0	0	2	2	2	4	13
8	33								1	0	0	3	2	0	3	9
9	56									0	0	6	3	3	6	18
10	1										0	1	0	0	0	1
11	0											0	0	0	0	0
12	177												26	13	8	47
13	133													16	7	23
14	107														8	8

from two periods to the 13 time periods of the fully time-dependent model to separate out the years where the survival estimate was likely to be affected by lost tags. For example, to estimate survival over two time periods, the model was formulated to estimate S for 1990–1993 and then for 1994–2004. The survival parameters were also estimated for each stratum individually or with grouped strata to see which aggregation level best reflected the information in the data. The probability of capture and recapture parameters were estimated for each time period with the strata separated and grouped with the probability set to zero for years in which there was no effort. For all model fits, the logit link function was used. The release and recapture matrix for the data used in both mark–recapture analyses is detailed in Table 2.

The variance inflation factor ($\hat{c}$) estimates the dispersion in the data. If it differs from 1, then the models are ranked using quasi-AIC$_c$ (QAIC$_c$) rather than AIC$_c$ to account for the dispersion (Burnham and Anderson 2002). However, $\hat{c}$ cannot be estimated for multistrata models (Cooch and White 2003). Therefore, the sensitivity of the results to any over- or underdispersion must be assessed by recalculating the model rankings with a range of $\hat{c}$ values and comparing the rankings obtained using QAIC$_c$ with those obtained with AIC$_c$ (when $\hat{c} = 1$) (Cooch and White 2003). The models fitted using the multistrata CJS model were tested with $\hat{c}$ values ranging from 0.5 to 4 to assess the robustness of the model ranking.

The abundance (N) of the LCR-Can subpopulation for the first year with minimal tag loss (1993) was estimated using the POPAN analysis within Program MARK. The POPAN data type is a robust parameterization of the Jolly–Seber model that parameterizes the model in terms of a super population (N) and allows the number of animals in the population to be estimated (Schwarz and Arnason 1996). Since the POPAN model type does not accept stratified data, we conducted a separate analysis for each of the two strata (A and B). White sturgeon recaptured in both strata were assigned to the stratum where they were most frequently captured. If an individual white sturgeon was captured in multiple strata with the same frequency, it was assigned to the strata where it was last caught. The POPAN model type was not used to estimate survival since this model does not account for migration or the existing spatial structure of the white sturgeon subpopulation. It was considered more biologically accurate to represent the data with a model that reflected migration since that model was able to converge.

All mark–recapture models assumed that survival in the LCR-Can subpopulation was independent of age. This is a plausible assumption given the longevity of the species, their lack of natural predators within the river, and the fact that most angling pressure during the 1990s was catch and release. No plausible covariates (e.g., age) were available for the entire subpopulation so no models with covariates were assessed. We were careful to use only biologically plausible models and not to "data dredge" for best fits, following the advice of Burnham and Anderson (2002).

Results

The estimated annual survival rate using catch-curve analysis was 89.2% (95% confidence interval [CI], 88.2–90.3%; Figure 3). The exclusion of the brood year-classes before 1955 did not significantly affect the estimated annual survival rate (t-test, $P = 0.48$) so they were included in the analysis. The r^2 value for the

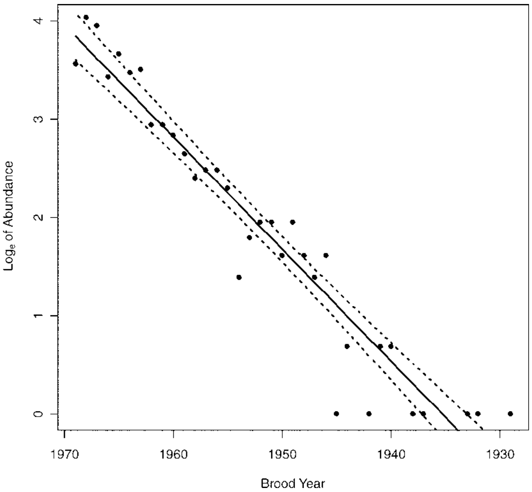

FIGURE 3.—Catch-curve for white sturgeon from the study reach using all available data (year-classes from 1929 to 1969). The dashed lines portray the 95% confidence intervals (CIs) for the fitted model. The absolute value of the slope of the line is the estimate of the annual mortality rate, and the exponentiated negative value of the estimated slope gives the survival estimate of 89.2% (95% CI, 88.2–90.3%).

regression line fitted to all data was 0.92 and the regression slope was 0.11.

For the multistrata CJS model type, we fitted approximately 20 different, biologically plausible models to the data, ranging from a model in which each parameter was considered a constant to a fully time- and stratum-dependent model. The best fit model as ranked by AIC$_c$ estimated migration as a constant value through time, but with separate values estimated for each stratum. Survival in the top model was estimated for the two strata grouped together, but with an estimate for each of four time periods: 1990–1991, 1991–1992, 1992–1993, and 1994–2004. The probability-of-capture parameter in the top model was estimated for each year with the strata grouped. This model had an Akaike weight of 0.81 (Table 3). The second-ranked model was the identical model but the migration parameter was considered a constant over both strata. The third-ranked model had a low Akaike weight of 0.0038, so was not very likely, but was also similar to the top two models though it grouped time differently for the estimation of the survival parameters. Only the three models that converged and had substantive Akaike weights are presented (Table 3). Models were ranked by AIC$_c$ and by QAIC$_c$. Changing the ĉ value did not change which of the array of models were in the top three, but it did alter their relative ranking. Final parameter estimates were extracted using

TABLE 3.—Number of parameters and Akaike information criterion (AIC$_c$) values for the three top-ranked multistrata Cormack–Jolly–Seber models for the subpopulation of white sturgeon in the lower Columbia River in Canada. The model notation follows the conventions recommended by Cooch and White (2003). Survival (*S*[*t*]) was best estimated by grouping the two river strata and various time periods together. The *p*(*t*) notation shows that the (re)capture probability was best estimated in a fully time dependent way with the strata grouped. The ψ(strata * .) notation shows that the migration parameter was estimated for each stratum but held constant through time; the ψ(.) notation means that the migration parameter was held constant across time and space.

Model[a]	Number of parameters	AIC$_c$	ΔAIC$_c$	AIC$_c$ weight
S(*t*), *p*(*t*), ψ(strata * .)	19	3,842.73	0	0.8141
S(*t*), *p*(*t*), ψ(.)	18	3,845.73	2.99	0.1831
S(*t*), *p*(*t*), ψ(.)	17	3,853.47	10.74	0.0038

[a] In the first two models $t = 1, 2, 3, 4+$; in the third model $t = 1, 2, 3+$.

the model averaging technique embedded in Program MARK so that the information contained in each of the top three models was used (Table 4; Burnham and Anderson 2002). The annual survival rate for the years in which T-anchor tags were used (1990–1993) ranged from 36.7% to 73.3% (95% CI, 21.1–83.8) while the estimated survival rate for the 1993–2004 period during which PIT tags were used was substantially higher with an estimated value of 97.3% (Table 4). The mean estimated migration rate between the two strata ranged from 3% to 5.5% (Table 4). This low level of estimated migration is in accord with field observations that were unable to identify seasonal movement patterns within this subpopulation and found that most movements detected by radio and sonic telemetry were less than 10 km in distance and usually involved movement from one high-use area to another (Hildebrand et al. 1999).

The POPAN model estimated the abundance and the survival for the two strata separately. The estimated abundance for the LCR-Can subpopulation in strata A and B combined was 1,157 individuals (95% CI, 414–1,900). The survival parameter from 1993 to 2004 was estimated to be 95.6% (91.1–97.9%) for stratum A, from HLK Dam to rkm 20, and 98.3% (89.0–99.0%) in stratum B, from rkm 20 to the U.S. border.

Over the 15 years of the studies that generated the data used in this analysis, 1,504 fish were captured and marked and 492 were recaptured (Table 2). These recapture counts include multiple recaptures of the same fish. Annually, the highest number of recaptures was 113 fish in 1992 and the lowest number of recaptures (aside from the years in which there was no effort) was 8 fish in 2003.

TABLE 4.—Parameter estimates and 95% confidence intervals derived from model-averaged estimates of parameters over the three top-ranked models.

Parameter	Time frame or location	Estimate	Confidence interval
Survival (*S*)	1990–1991	0.367	0.211–0.559
	1991–1992	0.459	0.334–0.591
	1992–1993	0.733	0.591–0.838
	1993–2004	0.973	0.918–0.991
Probability of capture or recapture (*p*)	1991	0.285	0.141–0.491
	1992	0.278	0.181–0.401
	1993	0.215	0.159–0.281
	1994	0.164	0.127–0.208
	1995	0.083	0.060–0.113
	1996	0.037	0.023–0.058
	1997	0.027	0.016–0.047
	1998	0.037	0.023–0.059
	1999	0.002	0–0.006
	2000	0.155	0.118–0.203
	2001	0.114	0.085–0.151
	2002	0.086	0.062–0.117
	2003	0.092	0.067–0.126
Migration (ψ)	Stratum A to B	0.055	0.040–0.074
	Stratum B to A	0.037	0.023–0.059

Discussion

The mean estimated survival rate of 97.3% from the mark–recapture analysis indicates a rate of population decline of 2.7% per year for the LCR-Can subpopulation of white sturgeon, assuming no recruitment. When the estimate's confidence intervals are considered, the rate of decline could range from 0.9% to 8.2%. This range of decline is lower than the 12% natural mortality rate estimated for this same subpopulation in 1994 (R.L. & L. Environmental Services 1994). The predicted rate of decline for the white sturgeon subpopulation in the Kootenai River (Kootenay in Canada) was 9% (Paragamian et al. 2005), which is similar to the upper range of our estimated rate of decline. However, estimated rates of natural mortality for other white sturgeon populations vary widely. In the Snake River a range of 6–16% was estimated (Cochnauer 1983; Lukens 1985; Lepla and Chandler 1995, 1997), while in the U.S. lower Columbia River the range was lower at 4.2–9.0% (Beamesderfer et al. 1995). Within the Sacramento–San Joaquin Estuary, mortality rate estimates varied from 5% to 16% (Kohlhorst et al. 1980), and in the Fraser River estimates varied from 5% to 19% (Semakula and Larkin 1968).

The mean survival rate estimated by catch-curve analysis (89.2%) was 8% lower than the estimate derived from mark–recapture analysis (97.3%). There are multiple causes that could contribute to this difference between the two methods. Aging error is one potential contributing cause for this difference since fin-ray reading tends to underage older fish (Rien and Beamesderfer 1994; Rossiter et al. 1995). Errors in aging sturgeon can occur due to clustering of annuli caused by slower growth (Rien and Beamesderfer 1994; Rossiter et al. 1995) or the occurrence of multiple annuli being laid down in a single year (Sokolov and Malyutin 1978). An aging verification study by Paragamian and Beamesderfer (2003) on white sturgeon in the Kootenai River suggested that ages could be underestimated by as much as 30–60%. If the error in aging the white sturgeon from the LCR-Can reach was as high as 30–60%, the catch-curve analysis would underestimate the survival rate. To test whether this subpopulation could be affected by aging error to the 30–60% level estimated by Paragamian and Beamesderfer (2003), the catch-curve was reanalyzed after adding in aging error to the 60% level. The aging error was distributed among the ages so that an age-0 fish was assumed to have no error and a 70-year-old fish was assumed to have 60% aging error, with the aging error increasing linearly through time. When the regression was run with these data, the estimated survival rate was 96.9% (95% CI, 96.4–97.3%). This survival estimate is extremely close to the mark–recapture estimate, suggesting that it is possible that aging error to the maximum level identified by Paragamian and Beamesderfer (2003) is the sole cause for the difference in survival estimates between the two methods, although a different sole cause or multiple causes are also possible. For example, the difference in the two estimated survival rates may be partly due to historically higher mortality rates. A catch-and-release fishery was introduced in 1993 and angling for white sturgeon was banned in 1996. The subpopulation structure before 1990 was much different, smaller fish dominating (Figure 2) and probably having significantly higher abundances; both of these differences may have contributed to density- or size-based increases in historical mortality rates of the sampled subpopulation.

Migration between the two strata of this subpopulation occurs at a relatively low rate, ranging from approximately 3% to 5%. These migration rates were estimated as constant through time; therefore, they may be biased slightly low due to tag loss in the first 3 years of the sampling program. These model-estimated migration rates were in accord with previous findings from telemetry studies that indicated only occasional migrations for feeding or spawning between high-use sites on the river (R.L. & L. Environmental Services 1994; Hildebrand et al. 1999). Although these studies are limited to the subpopulation of Columbia River white sturgeon that occurs north of the U.S.–Canada boundary, there is evidence through telemetry and tag recovery of sturgeon movements across the border. However, because of a relatively high degree of site fidelity and the low estimates of migration movements between the major concentrations within our study area, we believe such movements are unlikely to significantly affect parameter estimates.

The predicted rate of decline for white sturgeon is of concern owing to the lack of recruitment in the LCR-Can subpopulation, as indicated by the comparison of length–frequencies collected in the 1980s with those from 1990 to 2003 (Figure 2). The lack of small young fish and the continued aging of this subpopulation are striking.

The lack of natural recruitment indicated by the length-frequency plots is supported by evidence from another study that has assessed population parameters of hatchery-reared juvenile white sturgeon stocked in the LCR-Can reach annually since 2002 (UCWSRI 2002). In 5 years of fall gill-net sampling using 5.2-, 10.2-, and 15.1-cm stretched-measure mesh, 1,095 hatchery juveniles have been captured. Over this same period only 19 wild juveniles were captured, which represents only 1.7% of the total juveniles captured and only 1.6% of the estimated adult subpopulation (Golder Associates 2006).

The abundance estimate for the Canadian subpopulation of white sturgeon found in the LCR-Can reach was 1,157 fish, with a 95% CI of 414–1,900. This estimate is very similar to previous studies, which have estimated the abundance in this reach to range between 980 and 1,300 fish (Hildebrand et al. 1999). If the worst-case scenario is projected (i.e., 414 fish with a mortality rate of 8.2%) and mortality is considered age independent, there would be fewer than 50 white sturgeon left in the LCR-Can reach in 25 years. These concerns about the persistence of the existing subpopulation led to the implementation of a conservation aquaculture program whereby juvenile white sturgeon are raised in the hatchery to age 1 and then released into the transboundary reach. Initial survival rates of hatchery releases appear to be high, but these fish are not expected to reach maturity until they are 20 to 30 years old. Consequently, both the collection of broodstock for future hatchery supplementation programs and any natural recruitment that might occur will depend upon the viability and persistence of the existing adults. High uncertainty as to the future viability of this Canadian subpopulation of white sturgeon remains.

Acknowledgments

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