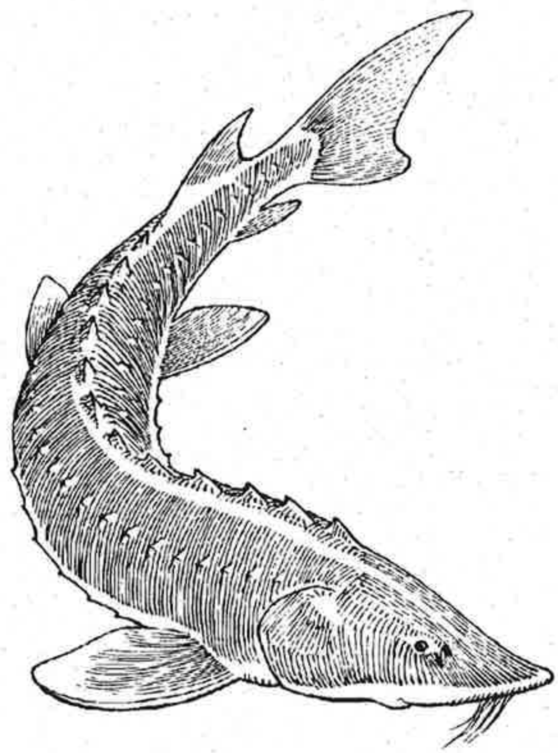
Fish & Wildlife Division

WILDLIFE CONSERVATION AND BIODIVERSITY BRANCH

Status of the Lake Sturgeon (*Acipenser fulvescens*) in Alberta



Alberta Wildlife Status Report No. 46

Alberta Conservation Association®

Funded by Alberta Anglers, Hunters, and Other Conservationists

Alberta SUSTAINABLE RESOURCE DEVELOPMENT

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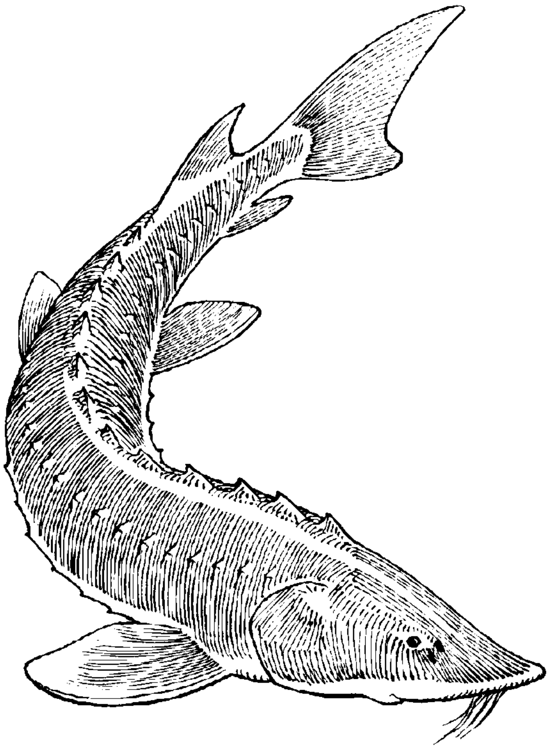

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Alberta Conservation Association (ACA)

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PREFACE

Every five years, the Fish and Wildlife Division of Alberta Sustainable Resource Development reviews the status of wildlife species in Alberta. These overviews, which have been conducted in 1991, 1996 and 2000, assign individual species "ranks" that reflect the perceived level of risk to populations that occur in the province. Such designations are determined from extensive consultations with professional and amateur biologists, and from a variety of readily available sources of population data. A primary objective of these reviews is to identify species that may be considered for more detailed status determinations.

The Alberta Wildlife Status Report Series is an extension of the general statusing exercises (1996 *Status of Alberta Wildlife, The General Status of Alberta Wild Species* 2000*)*, and provides comprehensive current summaries of the biological status of selected wildlife species in Alberta. Priority is given to species that are potentially at risk in the province ("At Risk," "May Be At Risk"), that are of uncertain status ("Undetermined"), or those considered to be at risk at a national level by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Reports in this series are published and distributed by the Alberta Conservation Association and the Fish and Wildlife Division of Alberta Sustainable Resource Development. They are intended to provide detailed and up-to-date information which will be useful to resource professionals for managing populations of species and their habitats in the province. The reports are also designed to provide current information which will assist the Alberta Endangered Species Conservation Committee to identify species that may be formally designated as "Endangered" or "Threatened" under Alberta's *Wildlife Act*. To achieve these goals, the reports have been authored and/or reviewed by individuals with unique local expertise in the biology and management of each species.

EXECUTIVE SUMMARY

Lake sturgeon (*Acipenser fulvescens*) populations have declined dramatically throughout the species' North American range. Inherent biological characteristics of longevity, delayed maturity and infrequent spawning make this species highly susceptible to losses and slow to rebound from low population levels. Substantial commercial fisheries in the early 20th century led to severe overharvest of lake sturgeon, from which many populations have not yet recovered. Habitat fragmentation from dams, as well as water manipulation and pollution, has also contributed to a decline in numbers.

The status of lake sturgeon in Alberta is currently "Undetermined," according to *The General Status of Alberta Wild Species 2000* (Alberta Sustainable Resource Development 2001). Alberta lake sturgeon occur at the westernmost portion of their North American range in two isolated subpopulations in the North Saskatchewan and South Saskatchewan river systems. Commercial and recreational lake sturgeon fishing were closed from 1940 to 1968 in Alberta, followed by the opening of a sport fishery. Today, sturgeon are harvested on the South Saskatchewan River whereas the North Saskatchewan River is a catch-and-release fishery. In 2000, the population of sturgeon was estimated at fewer than 200 mature fish in the North Saskatchewan River. The most recent population estimate for the South Saskatchewan River system in Alberta was approximately 500 mature fish in 1986. Mortality rates of lake sturgeon appear to be at or above maximum sustainable levels, suggesting that current levels of harvest may be too great to maintain a healthy sturgeon population. The continuation of long-term research initiatives will be required to adequately assess future population levels and to monitor trends.

ACKNOWLEDGEMENTS

Many individuals provided information and comments to help in the preparation of this report and all assistance was greatly appreciated. Special thanks to Daryl Watters (Alberta Sustainable Resource Development) for making available his extensive population data for the North Saskatchewan River and for sharing his sturgeon expertise to aid in the writing of this report. The hard work of Daryl and his group of dedicated volunteers in gathering data throughout the last decade has contributed to a solid data set used in the quantitative analysis of the North Saskatchewan River lake sturgeon population.

I would like to extend my appreciation to Vytenis Gotceitas (Lakeland College), Susan Pollard, Sherry Feser (Alberta Conservation Association), Sue Peters (Alberta Conservation Association) and Susan Cotterill (Alberta Sustainable Resource Development) who reviewed this report and provided many helpful comments and editing. Thanks also go to Mike Sullivan (Alberta Sustainable Resource Development) for answering many questions and for the insightful discussions, and Stuart Nadeau (Alberta Sustainable Resource Development) for facilitating access to the FMIS database. Terry Clayton and Glen Clements (Alberta Sustainable Resource Development) supplied annual harvest records. Karl Scheidegger (Wisconsin Department of Natural Resources) provided information on lake sturgeon management initiatives in Wisconsin. Thanks to Curtiss McLeod (R.L.&L. Environmental Services Ltd., now a member of the Golder Group of Companies) who provided reports and information from an assessment of the South Saskatchewan River.

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INTRODUCTION

A relict of the dinosaur age, possessing no teeth, calcified bones or scales, the lake sturgeon (*Acipenser fulvescens*) has survived a history of overharvest, habitat disturbance and population fragmentation. Extensive population decline has been apparent throughout its North American range (Haugen 1969, Houston 1987, Beamesderfer and Farr 1997). Highly valued for both flesh and eggs, lake sturgeon have been overexploited since the initiation of significant commercial fisheries in 1860. Declines as a result of overfishing have been compounded by the effects of dams and other environmental disturbances (Scott and Crossman 1973, Nelson and Paetz 1992). Life history characteristics including delayed maturity, longevity and low reproductive output increase their susceptibility to decline (Haugen 1969, Beamesderfer and Farr 1997).

In Alberta, sturgeon populations are resident in both the North Saskatchewan and South Saskatchewan river systems (Nelson and Paetz 1992). According to *The General Status of Alberta Wild Species 2000*, lake sturgeon are currently ranked "Undetermined"* in the province (Alberta Sustainable Resource Development 2001). Further research and information are required to ensure sustainable populations in the future. This report reviews and summarizes current and historical information and provides a quantitative analysis of population data collected over the past decade as a step in updating the status of this species in Alberta.

HABITAT

Sturgeon require the large-scale conditions of a functioning river system including large areas of diverse habitat, natural variation in flow, high water quality and a broad prey base (Beamesderfer and Farr 1997). Different types of habitat are required for spawning, development of eggs and larvae, growth of juveniles, as well as feeding and overwintering of adults (Auer 1996). Spawning occurs during the spring and requires fast-flowing rocky areas (Scott and Crossman 1973, R.L.&L. 1991). After hatching, juveniles disperse downstream and generally prefer habitat with flat sandy bottoms (Kempinger 1996, Peake 1999). As adults, lake sturgeon often congregate in deep (4 m - 7 m), slow-velocity pools with silt/rock substrate located in the thalweg (the line defining the deepest point) of the channel (Haugen 1969). These locations provide suitable habitat for overwinter use and for cover during the summer (McLeod et al. 1999).

In Alberta, several key areas are known for relatively high sturgeon abundance and the majority of captures occur within these locations (Watters 1993a, Watters 1993b). Protection of these key areas may be crucial to the long-term sustainability of lake sturgeon. Identifying and protecting critical juvenile and spawning habitat in the North Saskatchewan and South Saskatchewan rivers is also important (Auer 1996, Beamesderfer and Farr 1997). Water diversion, land use, hydroelectric dams, pulp and paper mills, agricultural operations and industrial discharge all negatively affect habitat quality in Alberta. In particular, the large mainstem river environment has been significantly affected by dams. Sturgeon populations in Alberta have been isolated from the remainder of the river system, reducing the extent of river habitat.

CONSERVATION BIOLOGY

1. General Biology. - The lake sturgeon is a living fossil that has retained many of its primitive morphological characteristics. Sturgeon-like fossils have been dated to approximately 100 million years ago (Houston 1987). Sturgeon possess vestigial (ancestral) traits including an outer armour of bony plates,

* See Appendix 1 for definitions of selected status designations.

a shark-like (heterocercal) caudal fin and cartilaginous skeleton (Scott and Crossman 1973). Instead of scales, the body is covered with five rows of bony plates called "scutes," which are prominent and sharp in young sturgeon and are worn away as the fish ages. Juvenile fish are protected from predators by these sharp scutes.

Sensory barbels or feelers are present on the lower side of the snout, and are used to help search for food during movement along the bottom (Harkness and Dymond 1961, Scott and Crossman 1973). With their sensory barbels and a protrusible suction-like mouth, lake sturgeon are well adapted for a benthic feeding strategy. They are opportunistic predators and are not selective during food consumption, eating whatever prey are available (Beamesderfer and Farr 1997, Chiasson et al. 1997). Diet composition depends largely on food type availability. Analysis of stomach contents has detected mayfly nymphs, chironomid larvae, caddisfly larvae, molluscs, crayfish, crustaceans, nematodes, leeches, plants, fish and fish eggs (Harkness and Dymond 1961, Scott and Crossman 1973).

There is potential for interspecific competition with other bottom feeders including lake whitefish (*Coregonus clupeaformis*), shorthead redhorse (*Moxostoma macrolepidotum*), longnose suckers (*Catostomus catostomus*) and white suckers (*Catostomus commersoni*); however, these species tend to feed in different locations. Therefore, this type of competition is likely minimal (Scott and Crossman 1973).

2. Growth. - Despite feeding on small prey, lake sturgeon grow to extremely large sizes and may weigh upwards of 45 kg (Nelson and Paetz 1992). A rapid increase in length and weight early in life, followed by a decline in growth rate around age 20 has been attributed to sexual maturity, when more energy is allocated to gonad development (Harkness and Dymond 1961, Royer et al. 1968, R.L.&L. 1991). Attacks by predators are unlikely because of the large size of an adult sturgeon, thus lowering natural mortality and increasing longevity (Harkness and Dymond 1961, Beamesderfer and Farr 1997). Males generally live to 55 years and females can live up to 80 years or more (Scott and Crossman 1973).

From August 1990 to August 2001, Fish and Wildlife Division staff and public angler volunteers sampled lake sturgeon at various locations on the North Saskatchewan River (Watters 1993a, Watters 1993b). The general objective was to gain baseline data on the distribution, life history and population parameters of lake sturgeon. A study conducted by R.L.&L. Environmental Services (R.L.&L. 1991), during the summer seasons of 1985, 1986 and 1987, provided information on abundance, movement patterns and critical habitat in the South Saskatchewan River. Lengths, weights and some age data were collected and individual fish tagged.

Growth rates of sturgeon in the North Saskatchewan River appeared to decrease slightly between 1993 and 2000 (Figure 1). In addition, this reduced growth rate was accompanied by a slightly decreasing trend in weight-at-length (Figure 2). Growth has been observed to vary depending on the availability of food (Houston 1987, R.L.&L. 1991, Noakes et al. 1999). The relationship between length and weight also changes depending on the suitability of the environment (Cuerrier and Roussow 1951, Harkness and Dymond 1961). A decreasing growth rate combined with decreasing weight are both indicative of density-dependent interactions and may suggest that more sturgeon are exploiting a limited food source. A decrease in growth rate may also indicate environmental problems rather than a density-dependent response (Noakes et al. 1999).

Northern populations have shorter growing seasons, and northern lake sturgeon typically have lower growth rates than populations to the

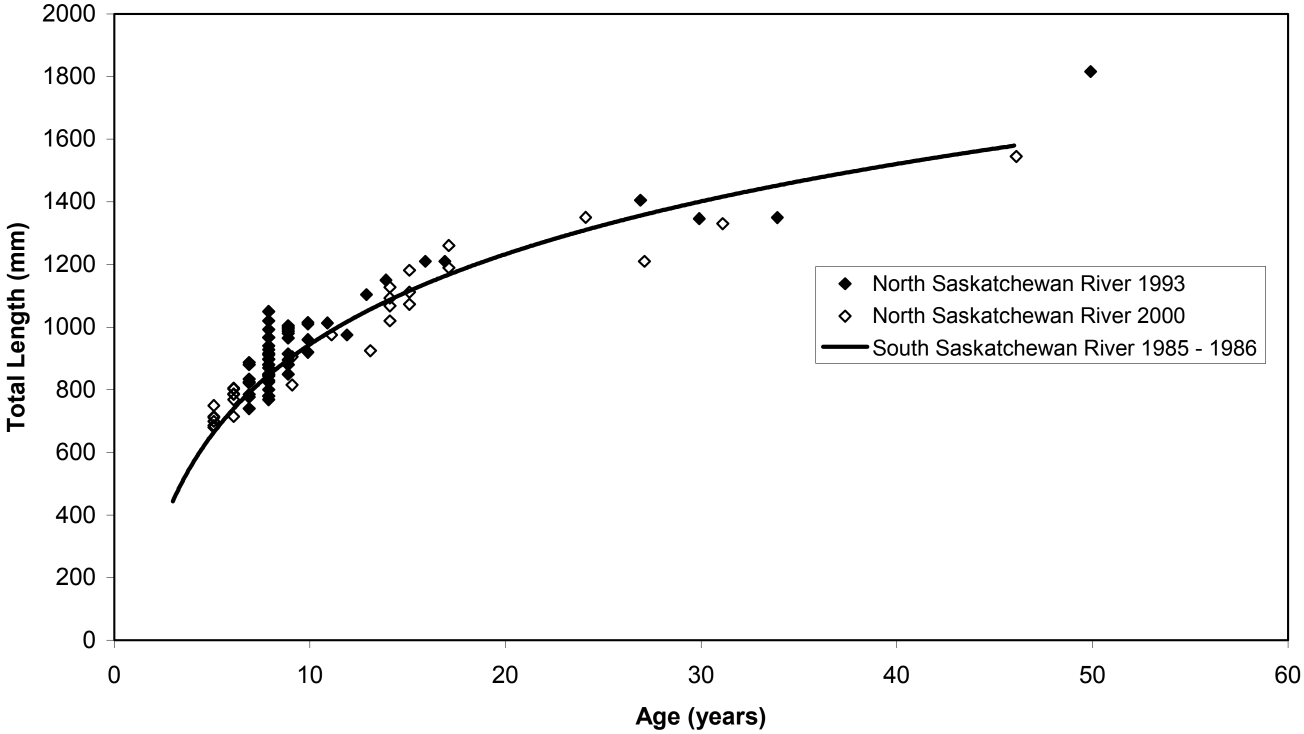

Figure 1: Length at age of lake sturgeon from the North Saskatchewan River during 1993 and 2000 (Fisheries Management and Information System [FMIS] data) and from the South Saskatchewan River during 1985 and 1986 (R.L.&L. 1991). (Data points are offset for clarity)

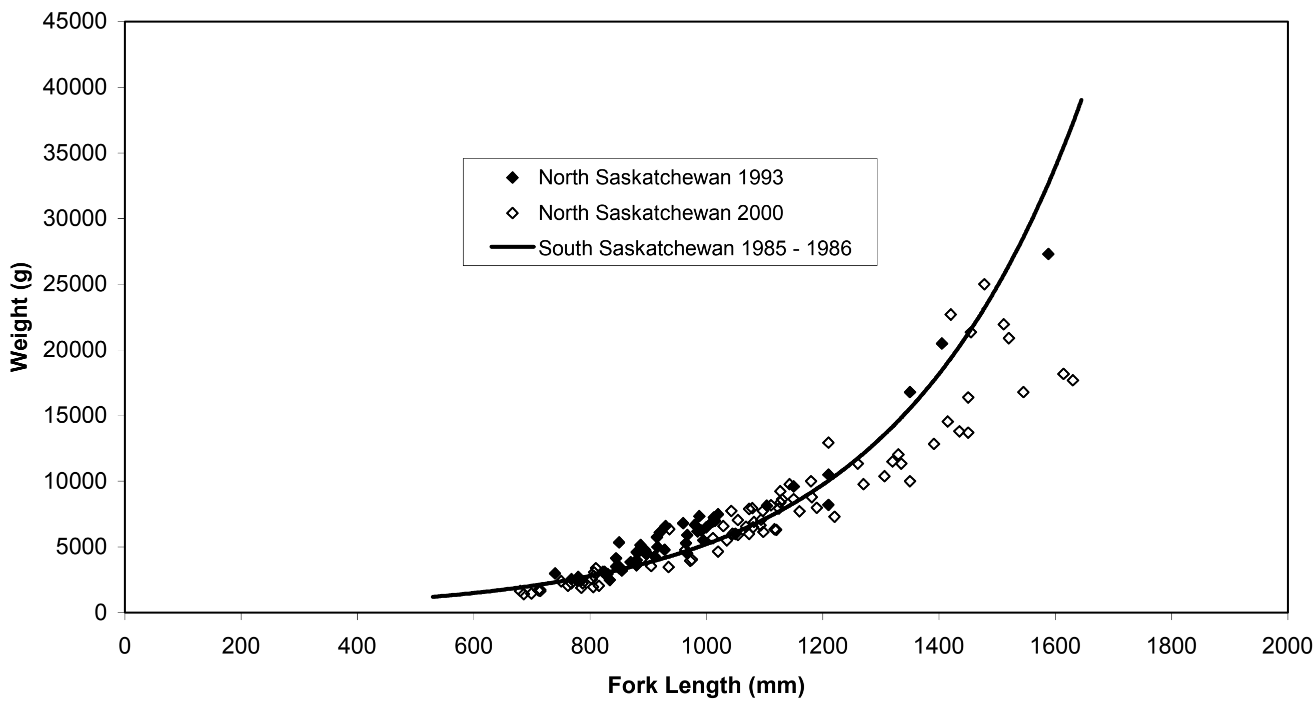

Figure 2: Length - weight relationship for lake sturgeon from the North Saskatchewan River during 1993 and 2000 (FMIS data) and from the South Saskatchewan River during 1985 and 1986 (R.L.&L. 1991). (Data points are offset for clarity)

south (Beamish et al. 1996, Fortin et al. 1996, Noakes et al. 1999). Annual growing degree days (an index of growth potential defined as the number of degrees by which the mean daily air temperature is greater than 5°C; GDD>5°C) in 2002 for Stony Plain and Elk Point on the North Saskatchewan River are 1453 and 1353, respectively (Environment Canada 2002). These are considerably lower than the average GDD for the South Saskatchewan River of 1799 near Lethbridge and 1971 at Medicine Hat. Therefore, a lower growth rate is expected in the North Saskatchewan because of less productive growing conditions when compared to the warmer system of the South Saskatchewan. However, these two systems are similar in growth rate and weight-at-length (Figures 1 and 2). While the data suggest the size of the North Saskatchewan population is increasing, the population may be well below its potential carrying capacity because the fish are growing at rates comparable to fish in a more productive southern environment.

3. Reproductive Biology. - Lake sturgeon exhibit delayed maturation, allowing energy to be devoted to somatic rather than gonadal development until sexual maturity. Sexual maturity for males is approximately 14 to 25 years and 14 to 33 years for females, but these ages vary with location from north to south (Houston 1987). Maximum lifespan in Alberta has been recorded at 78 years, whereas maximum lifespan in Canada is 154 years (Scott and Crossman 1973). In a survey on the South Saskatchewan River, males matured by age 19 and females by 22 to 26 years (R.L.&L. 1992, McLeod et al. 1999). Specific maturity data are unavailable for the North Saskatchewan River; however, maturation is thought to be comparable to the South Saskatchewan River (D. Watters, pers. comm.). Delayed maturation may exist because of colder annual temperatures (Fortin et al. 1996). In general, there are slightly more females than males in age groups exceeding 20 years (R.L.&L. 1991). Both males and females spawn multiple times throughout their lifetimes. However, spawning is intermittent with females generally spawning only every four to seven years (Roussow 1957, Harkness and Dymond 1961). Males spawn more frequently at every two to three years (Scott and Crossman 1973). Delayed maturation and periodic spawning in lake sturgeon limit the recruitment potential of a population, which contributes to their susceptibility to declines (R.L.&L. 1991). Age-at-maturity and spawning information is important for analyzing future recruitment and population viability models.

Spawning occurs in spring from early May to late June, depending on latitude, and requires fast-flowing rapids and a hard substrate (Scott and Crossman 1973, LaHaye et al. 1992). The timing of spawning is triggered by volume of water discharge (Auer 1994) and temperature, with peak spawning between 10°C and 14°C (Harkness and Dymond 1961, Houston 1987). Males arrive at the spawning area first and congregate until suitable spawning temperatures are reached (Houston 1987). Sturgeon are broadcast spawners. Females release their eggs into the water column and one or more males may fertilize the eggs. The number of eggs a female releases generally increases with age and size. Fecundity ranged from 117 450 eggs (for 135-cm, 15.5-kg females) to 607 400 eggs (for 170-cm, 45.5-kg females) in a South Saskatchewan River Study (R.L.&L. 1992). The eggs are demersal (sink to the bottom) and adhesive. Eggs are scattered by the current and adhere to rocks and logs downstream (LaHaye et al. 1992).

Seasonal floods may also provide cues for spawning and scour substrates free of sand and silt, which otherwise might suffocate eggs (Beamesderfer and Farr 1997). Higher flows also increase dispersion of eggs and larvae, which helps the young fish to reach a greater range of suitable habitat downstream (Beamesderfer and Farr 1997, Nilo et al. 1997). Hatching occurs one week after fertilization (Scott and Crossman 1973, Nelson and Paetz

1992, R.L.&L. 1992). Optimal survival of lake sturgeon embryos occurs between 12°C and 16°C (Wang et al. 1985, Nilo et al. 1997).

4. Recruitment. - Density-independent factors are important in determining the reproductive success of sturgeon species (Nilo et al. 1997). Flow volumes and temperature can be major determinants of year-class strength (Beamesderfer and Farr 1997, Nilo et al. 1997). Increased temperatures stimulate growth, and the rapid attainment of larger larval sizes increases the survival rate throughout the vulnerable larval stage. Higher flows encourage greater dispersal of juveniles and reduce density-dependent mortality. Density-dependent interactions have also been observed between consecutive year classes (Nilo et al. 1997).

Recruitment patterns in the North Saskatchewan River have been irregular, with two large year classes and several recruitment failures dominating the age structure recently (Appendix 2). Such erratic patterns can be a result of extremely low spawning numbers, but other factors such as variable environmental conditions may also be responsible. Consistent recruitment is essential to maintain a healthy population that can withstand some losses to harvest. For example, the St. Lawrence River supports one of North America's most important commercial fisheries for lake sturgeon and has regular and sustained recruitment (Nilo et al. 1997).

5. Movement. - Sturgeon species are generally sedentary in nature and movements associated with feeding and overwintering tend to be relatively localized. However, lake sturgeon do undergo long migrations usually related to spawning (Harkness and Dymond 1961, Haugen 1969, Fortin et al. 1993). North Saskatchewan River tag-return data show downstream movement of over 500 km and upstream movement of 400 km (D. Watters, unpubl. data). Telemetry data show significant site fidelity for extended periods (up to two years), occasionally followed by extensive movements of over 100 km (D. Watters, unpubl. data). In the South Saskatchewan River, radio-tagged fish travelled up to 210 km for spawning-related movements (R.L.&L. 1991). Transboundary movements of lake sturgeon have been identified between Alberta and Saskatchewan populations (R.L.&L. 1991). These distances may have been truncated in the Saskatchewan River system because of the presence of several dams blocking sturgeon movements. Short-term movements in some sturgeon species have also been observed for feeding (Beamesderfer and Farr 1997).

DISTRIBUTION

1. Alberta. - There are two subpopulations of lake sturgeon in Alberta (Figure 3). One subpopulation (isolated because movements, and therefore, genetic exchange are prevented by the Gardiner Dam in southern Saskatchewan) is found in the South Saskatchewan River and its tributaries, the Red Deer River, Bow River and Oldman River. The other subpopulation lives in the North Saskatchewan River system (Haugen 1969, Nelson and Paetz 1992). Populations in these Alberta rivers occur at the westernmost portion of this species' North American range (Scott and Crossman 1973). The majority of Alberta's annual catch is taken from the South Saskatchewan River at the junction of the Bow and Oldman rivers (Nelson and Paetz 1992), although the catch-and-release sport fishery on the North Saskatchewan has gained popularity (Watters 1993a). Lake sturgeon populations generally exhibit a clumped distribution congregating in pools along the length of the river (D.Watters, unpubl. data).

2. Other Areas. - The lake sturgeon has a wide geographic range in North America comprising three drainage basins: the Great Lakes and the Hudson-James Bay in Canada, and the Mississippi River drainage in the United States (Harkness and Dymond 1961, Houston 1987) (Figure 4). The species has exhibited dramatic

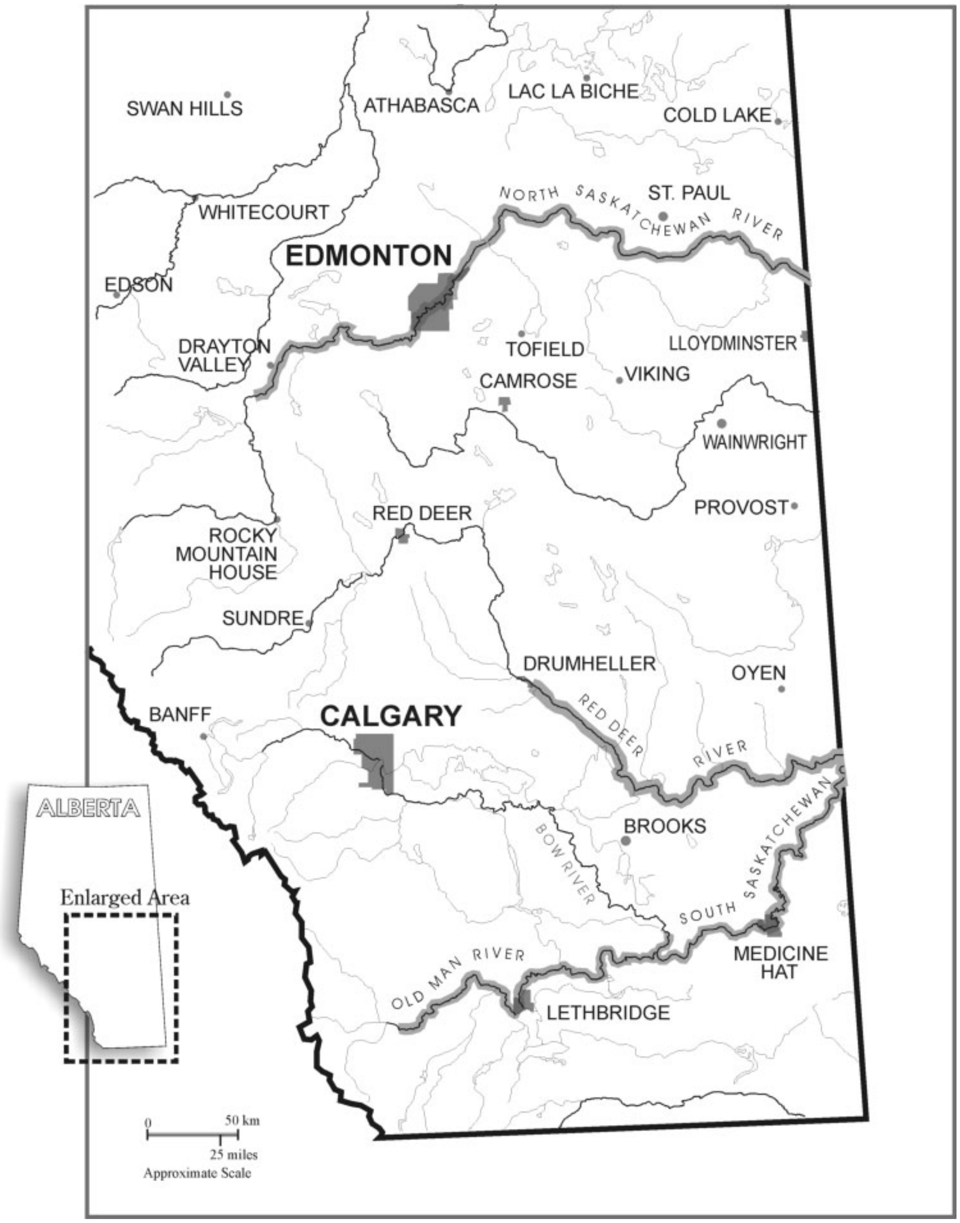

Figure 3: Distribution of the lake sturgeon (*Acipenser fulvescens*) in Alberta, as indicated by rivers outlined in grey.

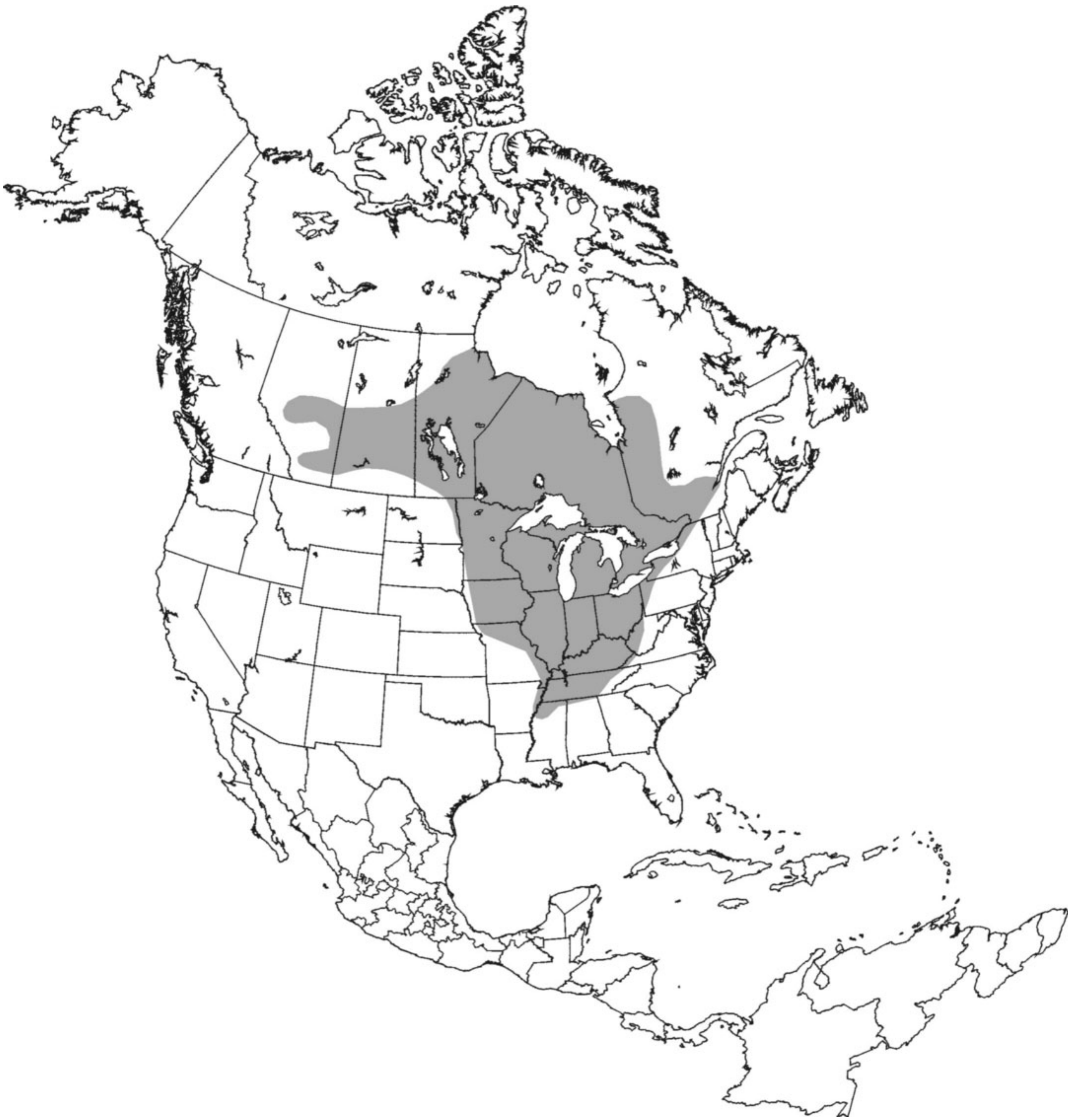

Figure 4: Distribution of the lake sturgeon (*Acipenser fulvescens*) in North America (adapted from Scott and Crossman 1973, Fish and Wildlife data for Alberta, and state and provincial websites).

declines over much of its range and populations remain smaller than historical numbers. Lake sturgeon historically occurred in larger rivers and lakes from the St. Lawrence River to the Hudson Bay (Houston 1987); however, populations have mostly disappeared from large lake systems in Ontario and Manitoba (T. Dick, in prep.).

POPULATION SIZE AND TRENDS

When assessing the sustainability of a population it is important to consider effective population size (N_e) (Rieman and Allandorf 2001). If N_e is less than 50, the population is vulnerable to the effects of inbreeding depression. A population of at least 500 breeding individuals is necessary to maintain adaptive genetic variation, which is known as the 50/500 rule and is often used to guide conservation management (Rieman and Allandorf 2001). These numbers assume an ideal population with an equal sex ratio and equal contribution to the next generation. These are minimum values for genetic conservation and should not be mistaken as a goal for a sustainable population. The actual population size equivalent will be much greater. In defining a population goal, genetics, small population demographics and harvest rates need to be assessed.

The population estimate of importance for lake sturgeon is that of mature fish (age > 20), which have the potential to contribute offspring to the population. As a result of a high degree of uncertainty in fisheries management science, a precautionary approach needs to be applied to the analysis and the lower 95% confidence interval of the population estimate should be used for management purposes (Richards and Maguire 1998). For example, if the population was estimated at 1000 fish, with upper and lower confidence limits of 800 and 1200 fish, the estimate of 800 fish would be used.

1. Alberta. - The population densities of lake sturgeon in Alberta are extremely low and recent trends indicate no substantial increase. A total of 824 fish was tagged during a continuous mark-recapture experiment in the North Saskatchewan baseline study (D. Watters, unpubl. data). This estimate encompasses a 540-km long reach (160 km upstream of Edmonton to 380 km downstream) and includes all fish greater than age 3 (D. Watters, unpubl. data). Using a Jolly-Seber population estimate (Appendix 3A, Ricker 1958), the lake sturgeon population in the North Saskatchewan River varied between 835 and 2115 total individuals (age > 3), and between 38 and 200 mature individuals over a 10-year period (Figure 5).

The entire sturgeon population in the North Saskatchewan River (including young fish) was estimated to be below 1000 individuals in 1992, and thereafter displays an increasing trend in population size, primarily because of the recruitment of two stronger year classes (born during 1986 and 1994). In 1999, the population was estimated at approximately 1830 individuals with age > 3, using the Jolly-Seber method (Appendix 3A). Bailey's formula (Ricker 1958) was then used to confirm this estimate and to determine accurate confidence intervals for the estimate. In 2000, the population was estimated at 1902 sturgeon, using the Bailey method. Using the lower 95% confidence limit as a precautionary principle results in a population estimate of 1360 fish (1360 to 2689, 95% C.I., Appendix 3B). In 2000, 14% of the population was greater than 20 years old (approximate age at maturity) and longer than 130 cm (minimum legal harvest length) (Figure 6). The estimated number of mature sturgeon present in the North Saskatchewan River in 2000 was therefore 190 fish. With a sex ratio of 50:50, the number of mature females may be under 100 fish. Because females spawn every 4 to 7 years, the annual spawning population may be as low as 14 to 25 female sturgeon.

Compared to the sturgeon management goal in Wisconsin of 250 fish/mile (156 fish/km, Wisconsin Department of Natural Resources 2000), the North Saskatchewan River population

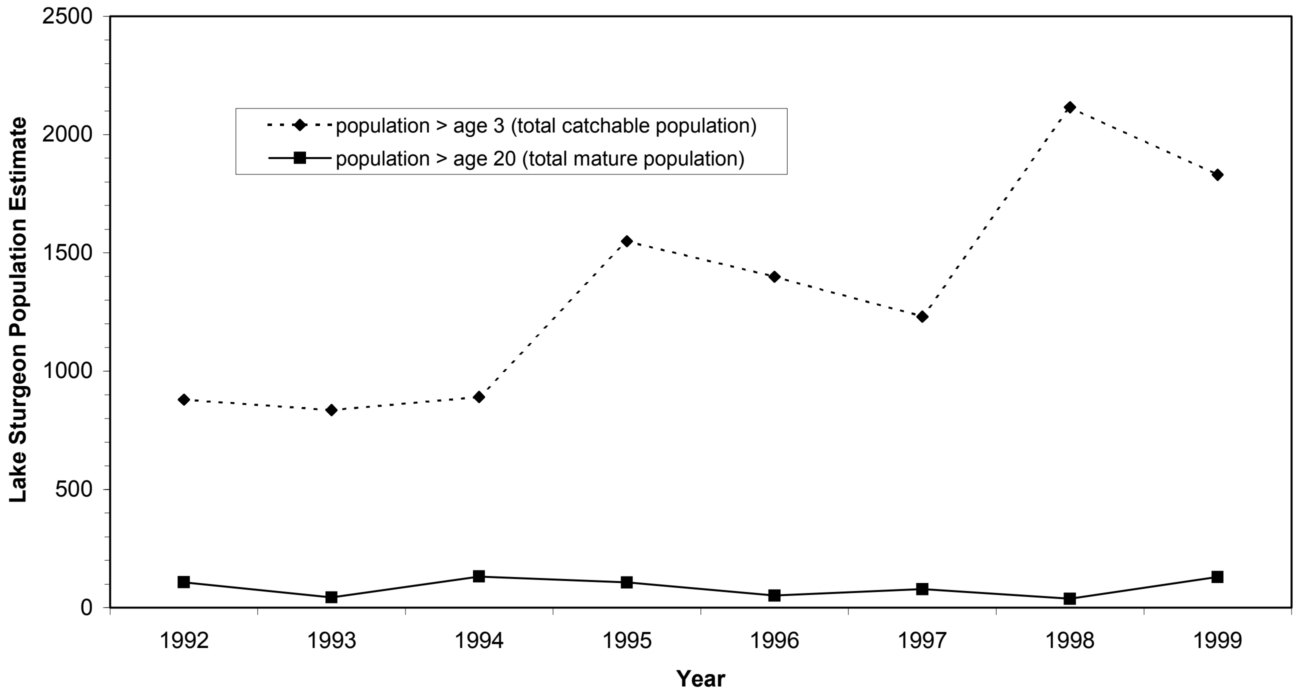

Figure 5: The lake sturgeon population (using a Jolly-Seber population estimation method from mark-recapture data, for fish at age > 3 and age > 20) for a 540-km long reach of the North Saskatchewan River over the years of 1992 to 1999 (data from FMIS).

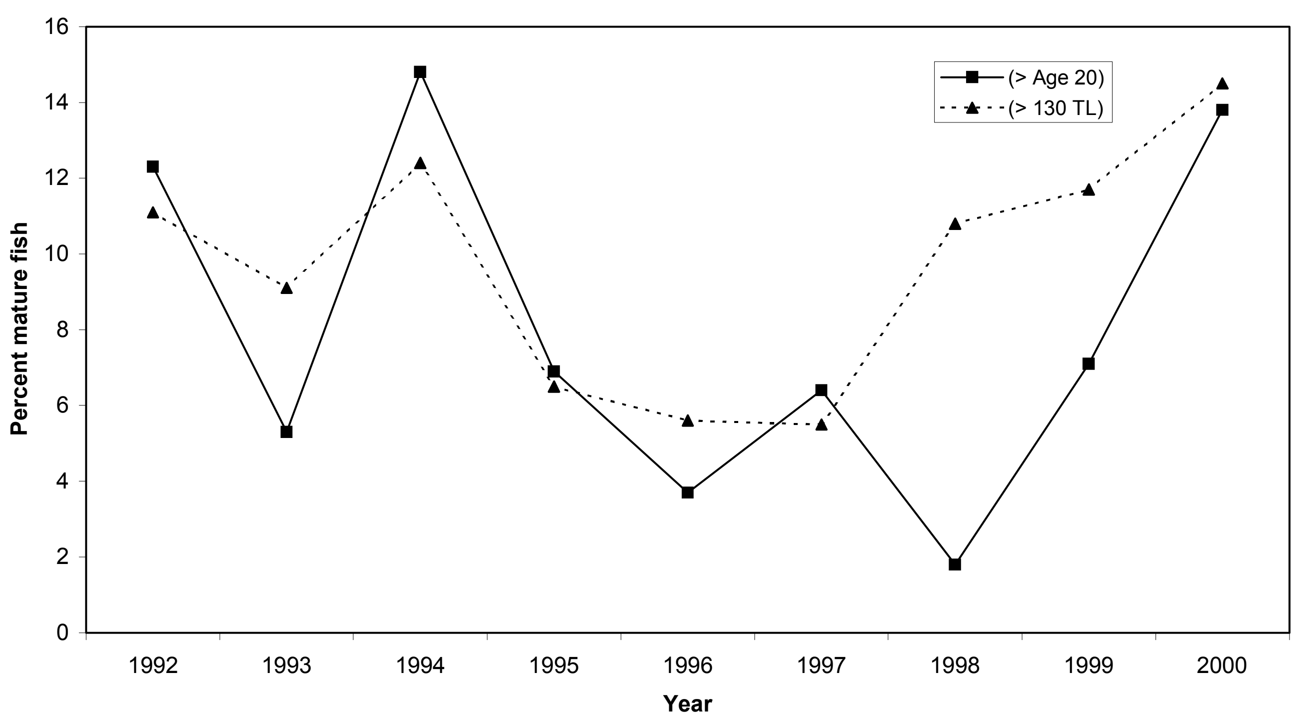

Figure 6: Percent mature fish (>130 cm in total length and age > 20) of the total lake sturgeon caught in each year from the North Saskatchewan River (data from FMIS).

has an extremely low density of only 2.5 fish/km.

The angling data from the North Saskatchewan River baseline study display a slightly increasing trend in Catch per Unit Effort (CUE) over the past decade (Figure 7). This increase may be the result of increased angler knowledge on how and where to catch sturgeon; however, this trend might also suggest that the lake sturgeon population in the North Saskatchewan River is slowly increasing.

Age structure in the North Saskatchewan River lake sturgeon population reflects an irregular recruitment pattern. The age structure from 1998 to 2000 displays a bimodal distribution with peaks for the 1985 and 1986 cohorts as well as increased recruitment from the 1994 and 1995 year classes (Appendix 2) (Watters 1993b). These pulses in year-class strength should not be considered a sign of constant increased production of the population (Watters 1993a). Although it is positive to have years of high recruitment, a population with insufficient breeding individuals is nevertheless ultimately doomed, as are populations with numerous recruitment failures.

In 1986, the sturgeon population estimate on the South Saskatchewan River was 4718 ± 2660 fish (R.L.&L. 1991), but the population was likely overestimated because of emigration and tag loss (R.L.&L. 1991). Using the lower 95% confidence interval in the assessment as a precautionary measure yields a population of 2058 fish (age > 3) within a 300-km study area. A length-age relationship was calculated from the 1986 R.L.&L. field data to obtain an appropriate age structure for this population (Appendix 2). Approximately 25% of the population in 1986 was mature (age > 20) generating an estimate of 510 potential spawners. With an equal sex ratio and a spawning frequency of 4 to 7 years, the number of females spawning each year may be only 36 to 63 sturgeon in the South Saskatchewan River system. The lack of current data from the South Saskatchewan River prevents further analysis of the population.

Harvest reports for Alberta are collected annually (since 1968) through annual sturgeon-fishing questionnaires sent to anglers possessing a sturgeon fishing licence (Clayton 2001). CUE on the South Saskatchewan River fluctuates from year to year but displayed a peak in 1996. It has since decreased to the present CUE, which is lower than reported by volunteer research anglers for the fishery in the North Saskatchewan River (Figure 7). Mail survey catch rates can be considerably exaggerated over the actual catch rate (Roach et al. 1999); therefore, catch rates in the South Saskatchewan River may be even lower than they appear in the survey. The harvest survey results need to be interpreted with caution given the nature of the data; however, a decreasing CUE could indicate underlying population stress and may require further biological investigation.

The annual harvest for 2000 was estimated to be 22 fish. Over the past decade the reported annual harvest ranged from 3 to 254 fish (Clayton 2001). A lower proportion of the population is harvested now than in previous years, but the total number of fish caught by anglers throughout the season is increasing. This may be because there are fewer fish of legal size or it may be that anglers are choosing to practise catch-and-release fishing more often. As harvest surpasses recruitment, the surviving population is made up of younger and smaller fish (Houston 1987).

A comparison of the age distribution between the South Saskatchewan and North Saskatchewan systems demonstrates a difference in population structure (Figure 8). Although both systems are similar in that they have large numbers of immature fish with few old age classes represented, the comparatively lower catch rates in the South Saskatchewan River suggest a smaller population than that of the

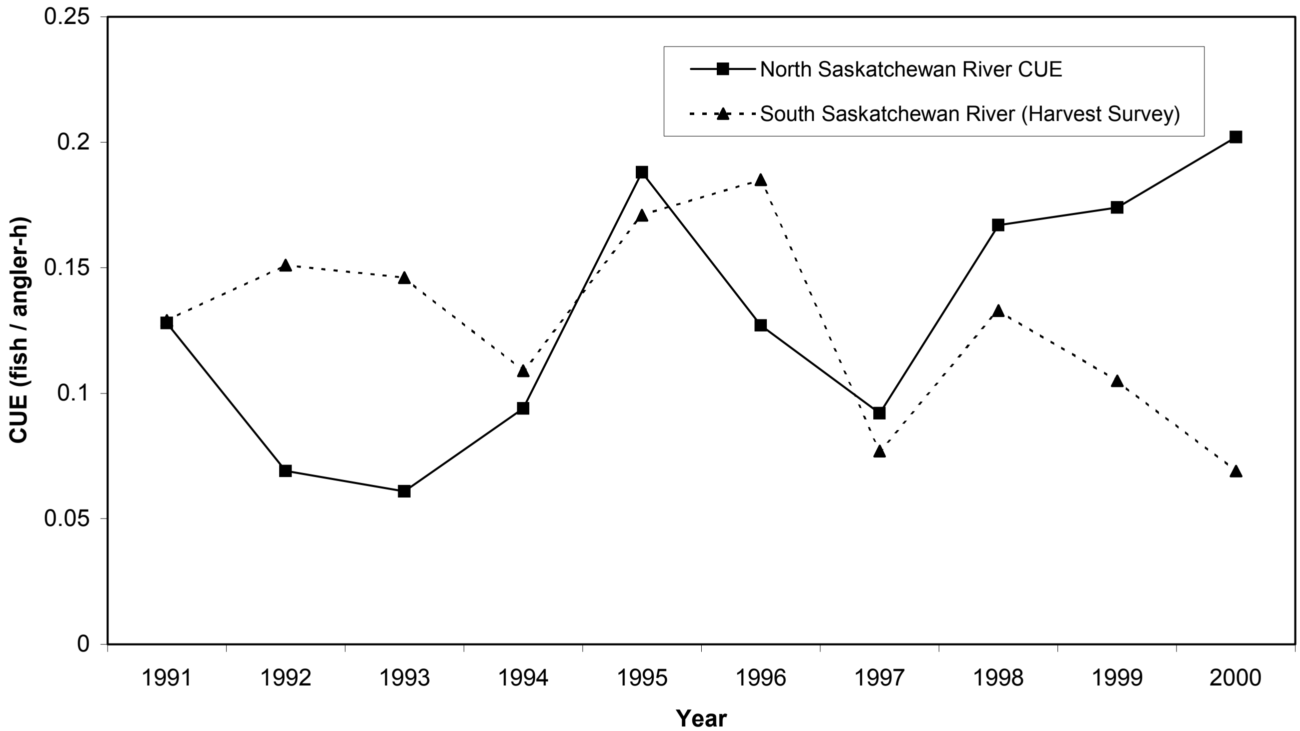

Figure 7: Lake sturgeon caught (kept or released) per hour of angling effort (CUE) in the North Saskatchewan and South Saskatchewan rivers over a 10-year period (1991 to 2000) (data from FMIS and harvest survey data [Clayton 2001]).

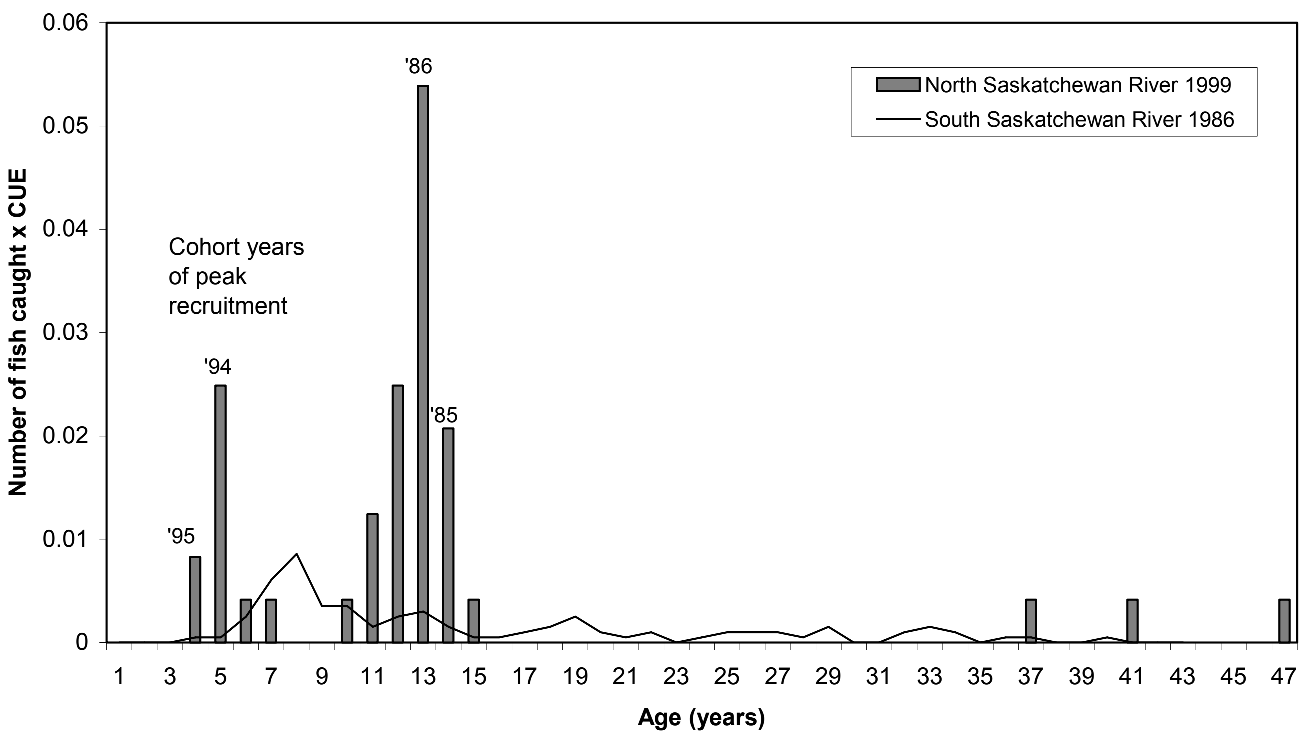

Figure 8: Age-class distribution of lake sturgeon adjusted to angling effort in the North Saskatchewan (1999) and South Saskatchewan river systems (1986) (data from FMIS and R.L.&L. 1991).

North Saskatchewan River. If the population in the South Saskatchewan River has decreased since the most recent population estimate, the system may not be able to sustain the current levels of harvest. In 1986, when the South Saskatchewan population was estimated to have 510 mature fish, the estimated annual harvest was 102 fish. Fishing mortality alone was 20% and when added to natural mortality creates a situation that is likely unsustainable.

As a result of the inherent limitations in capture methods, small-sized fish are inadequately sampled (Ricker 1958). The equipment effectively samples an accurate representation of the sturgeon population at an age greater than or equal to nine years in the North Saskatchewan River. The average mortality rate for the 1985 and 1986 cohorts was estimated to be 10% (Figure 9). The total allowable mortality to maintain a viable sturgeon population in the two Alberta subpopulations, including combined mortality from known harvest, hooking mortality, poaching, and natural mortality, may be extremely low. A healthy population of lake sturgeon should have a sufficient number of 50- to 80-year-olds to sustain any type of harvest without serious impacts (Berry 1996). To achieve this, it is essential to keep fish losses low to allow the fish to live long enough to reach these large sizes and old age. Using a simple age-structured cohort model, mortality must remain below 10% given existing population levels to preserve older individuals (Figure 10, Appendix 4).

In summary, sturgeon subpopulations in both the South Saskatchewan and North Saskatchewan rivers are at or below the critical densities for population sustainability. This unsustainability is further reflected in the irregular recruitment observed in both populations. Trends in population densities do not show substantial increases and fishing mortality rates may exceed rates that would allow for population recovery.

2. Other Areas. - In 1860, a significant commercial fishery for lake sturgeon began in Canada, after which lake sturgeon populations all displayed similar trends (Houston 1987). A high initial yield at the onset of the fishery was consistently followed by rapid declines. Stresses of hydroelectric dam construction and operation have reduced or extirpated populations in the Lake Winnipeg drainage area, lower Laurentian Great Lakes of Lake Ontario and Lake Erie and riverine populations in northern Ontario (Ferguson and Duckworth 1997). Sturgeon populations have been devastated throughout most of its North American range, with a few notable exceptions (Harkness and Dymond 1961). The St. Lawrence River appears to maintain a relatively large and sustainable population (Nilo et al. 1997). A large commercial fishery remains in Quebec and a few small commercial fisheries continue to exist in Ontario. Wisconsin has one of the largest self-sustaining lake sturgeon populations in the world (Wisconsin Department of Natural Resources 2000).

LIMITING FACTORS

1. Habitat Fragmentation and Alteration. - Fragmentation of populations by dams erodes the genetic diversity in fish populations (Ferguson and Duckworth 1997, Rieman and Allandorf 2001) and these newly isolated populations are vulnerable to extinction (Jager et al. 2001). The construction of dams causes a loss of spawning and nursery habitat, creates barriers to migration, changes the natural flow patterns of the river and changes community structure and ecology (R.L.&L. 1992, Auer 1996).

Since the 1960s, hydroelectric operations in Saskatchewan have fragmented the larger lake sturgeon population in the North Saskatchewan and South Saskatchewan rivers (Royer et al. 1968, Berry 1996). Construction of the Squaw Rapids Dam in 1962 eliminated large spawning areas for North Saskatchewan sturgeon on the lower Saskatchewan River (R.L.&L. 1992,

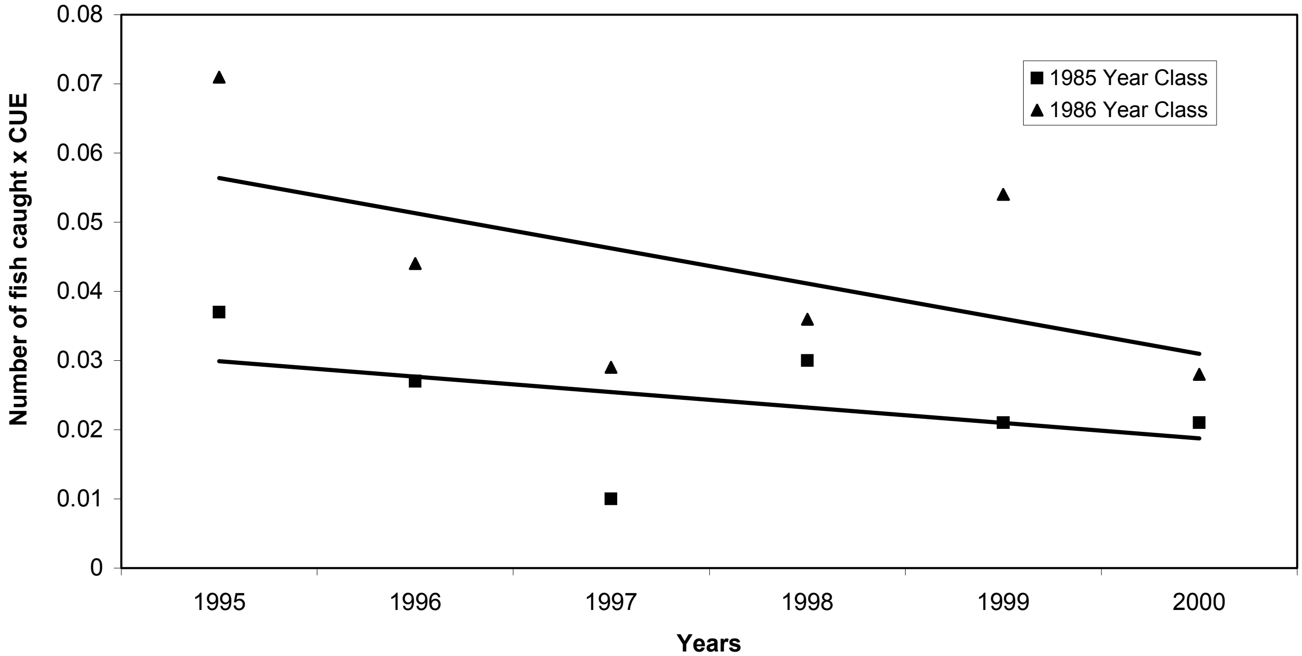

Figure 9: Mortality rate of lake sturgeon in the North Saskatchewan River for 1985 and 1986 year class after full recruitment to the sampling gear (data from FMIS) (the average mortality rate taken from these lines is 10%).

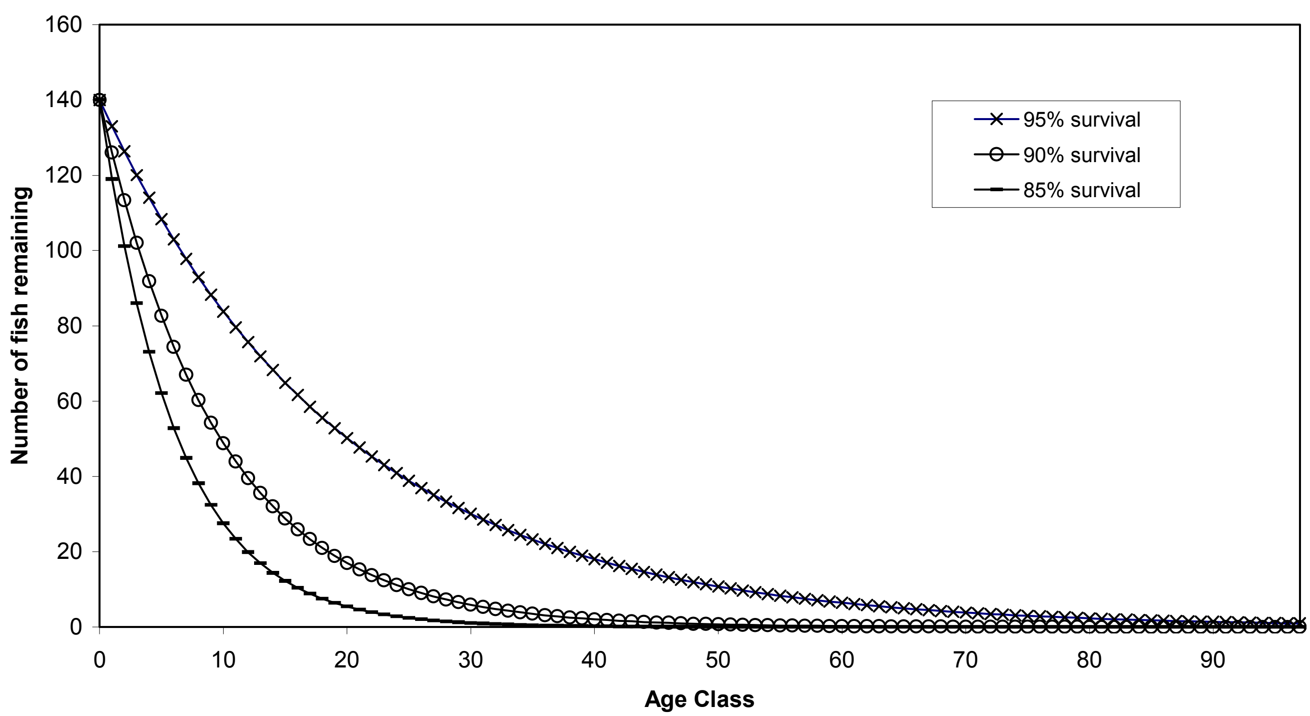

Figure 10: Age-structured cohort model to determine survival of lake sturgeon in each age class with 95-, 90- and 85-percent survival rates.

McLeod et al. 1999). On the South Saskatchewan River, Gardiner Dam, constructed in 1967 (forming Lake Diefenbaker), has blocked free river access and isolated the populations above the dam from the rest of the river system (R.L.&L. 1991, R.L.&L. 1992). The effects of this fragmentation are still not fully understood.

Barriers to migration can affect genetic integrity, which may result in a population less able to withstand future environmental stresses (Ferguson and Duckworth 1997, Rieman and Allandorf 2001). Dam operations also affect food availability, nutrient status, and predator/prey relationships (Noakes et al. 1999). Dam outflows warm the river during the winter and cool it during summer (Lehmkuhl 1972). As a result, the seasonal temperature requirements of many invertebrates are not met and a large-scale macro-invertebrate depletion is common downstream of dams. Lehmkuhl (1972) documented a marked reduction in invertebrates downstream of Gardiner Dam on the South Saskatchewan River. Invertebrates are an important food source for lake sturgeon; therefore, low prey densities make foraging difficult and have detrimental effects on the growth rates of sturgeon (Chiasson et al.1997). Changes in the annual hydrologic profile can also affect the cues used to trigger spawning (Harkness and Dymond 1961, Auer 1994). Natural flow regimes are important for maintaining healthy and productive river communities (Noakes et al. 1999).

The proposal for the Meridian dam on the South Saskatchewan River in Alberta has been rejected after undergoing a pre-feasibility study to determine whether the project would go forward (Golder Associates Ltd. 2002). Large-scale destruction of spawning habitat and additional fragmentation of sturgeon habitat has been avoided; however, it will be important to ensure that future endeavors to deal with water shortages in southern Alberta and Saskatchewan do not serve to further stress and isolate this vulnerable sturgeon population.

2. Water Use and Pollutants. - Demands on water in Alberta river systems include hydroelectric development, storage reservoirs for irrigation and discharge of domestic, municipal and industrial effluents, all of which contribute to depletion of fish and invertebrate habitat (R.L.&L. 1991, Watters 1993a,b). Discharge from wastewater treatment plants affects rivers through increases in bacteria levels and nutrients. Excessive plant growth as a result of increased nutrient levels blocks sunlight, decreases the available oxygen and alters the composition of the natural river ecosystem. The City of Edmonton significantly affects water quality downstream on the North Saskatchewan River (Watters 1993a,b). However, the introduction of discharge disinfection and nutrient reduction in 1998 has resulted in reduced bacteria and phosphorus levels downstream of the City of Edmonton (Alberta Environment 2001). Calgary, Lethbridge, Medicine Hat and Red Deer are all located on the South Saskatchewan River system and extensively manipulate waters for consumptive uses (R.L.&L. 1991). High water demands on the South Saskatchewan River may lead to increasingly low water levels which would reduce the amount of suitable overwintering habitat, deep congregation pools and high-velocity spawning habitat (R.L.&L. 1991).

Low water levels, variable water temperatures and low oxygen concentrations can negatively affect spawning and success of embryo survival. Changes in flow and sediment distribution alter macrobenthos abundance (Trotzky and Gregory 1974) and have detrimental effects on the growth and reproduction of lake sturgeon (Chiasson et al. 1997). Altered aquatic systems develop a new array of prey, predators and competitors (Beamesderfer and Farr 1997). Pulp and paper mill effluent deposits organic debris, reduces dissolved oxygen and disrupts benthic communities (Ferguson and Duckworth 1997). Gas supersaturation below dams can cause significant mortality of sturgeon because of gas bubble disease (Counihan et al. 1998).

Juvenile sturgeon are known to be sensitive to chemical pollutants (Peake 1999). Their benthic feeding strategy coupled with the longevity of lake sturgeon increases vulnerability to bioaccumulation of toxic pollutants (Beamesderfer and Farr 1997). High contaminant levels have resulted in closure of some commercial fisheries on the St. Lawrence and Ottawa rivers (R.L.&L. 1992).

3. Overharvest. - The lake sturgeon sport fishery remains popular despite the low density and low catch rates, likely a result of the unique nature of the fish (Watters 1993b). Impacts of the current fish loss resulting from hooking mortality and illegal harvest need to be assessed to ensure the sustainability of the population and to enable implementation of informed management decisions. Educating anglers about the status of sturgeon may help to decrease accidental or illegal harvests.

Providing an environment where fish can survive for 80 years requires accounting for all potential harvest and ensuring minimal losses. Annual harvest rates greater than 5%-10% are thought to exceed sustainable yields (Beamesderfer and Farr 1997). The North Saskatchewan River, while maintaining exclusively a catch-and-release fishery, still has an estimated 10% total mortality rate. The majority of fishing pressure in Alberta has been concentrated on the South Saskatchewan River (R.L.&L. 1991), where adult mortality may be upwards of 20% from harvest alone. Biologists from R.L.&L. Environmental Consulting suggested that the South Saskatchewan River lake sturgeon harvests between 1980 and 1990 were at or near maximum allowable levels. If mortality of breeding individuals remains close to 20%, this may place a great deal of stress on future recruitment to the population. An up-to-date population estimate will be necessary to assess current harvest levels and total mortality in the South Saskatchewan River.

4. Biological Limitations. - Inherent biological characteristics of lake sturgeon make them particularly susceptible to declines. Sturgeons have evolved a strategy of slow growth, delayed maturity and periodic spawning that has been successful for millions of years. They have overcome predation risks and kept natural mortality low after the first year of life (Houston 1987). However, in the face of intensive overexploitation, sturgeon populations are unable to rebound quickly and may remain depleted for decades (Houston 1987, T. Dick, in prep.).

STATUS DESIGNATIONS

1. Alberta. - According to *The General Status of Alberta Wild Species* 2000, lake sturgeon are considered "Undetermined" in Alberta (Alberta Sustainable Resource Development 2001, Appendix 1).

2. Other Areas. - COSEWIC lists the species as "Not at Risk" (COSEWIC 2002). Lake sturgeon have been identified as "Vulnerable" under the *Manitoba Endangered Species Act* (Ferguson and Duckworth 1997). The US Fish and Wildlife Service has classified lake sturgeon as "Rare" over much of its U.S. range. Wisconsin is the only state where lake sturgeon are considered common (Ferguson and Duckworth 1997).

RECENT MANAGEMENT

1. Alberta. – Commercial and recreational lake sturgeon fishing were prohibited in Alberta from 1940 to 1968 because sturgeon populations were thought to be endangered (Haugen 1969, Houston 1987). The sport fishery was re-opened to anglers in 1968 under a strict management regime promoting angling for trophy fish (Nelson and Paetz 1992, R.L.&L. 1992, Berry 1996). Sportfishing regulations implemented in 1997 set harvest limits to one lake sturgeon greater than 130 cm in length per year from the South Saskatchewan River system between 16 June and 31 March. Harvesting a sturgeon requires a special sturgeon licence in addition to a general angling licence (Berry 1996). The North Saskatchewan River and its tributaries are a catch-and-release fishery open to angling year-round (Berry 1996, Clayton 2001).

Biologists have relied heavily on information gathered from angler survey questionnaires to assess population trends (McLeod et al. 1999). An average of 306 sturgeon licences has been sold annually in Alberta over the past 10 years (Clayton 2001). The number of anglers purchasing a sturgeon licence was 266 in 2000 and resulted in a harvest of 22 fish that year. Illegal harvest of undersized fish may be a problem from this traditional consumptive fishery (D. Watters, pers. comm). Management concerns have focused on the sustainability of the present or increased harvest levels and the ability to maintain populations in the midst of habitat alterations (R.L.&L. 1991, Berry 1996).

2. Other Areas. - Lake sturgeon are protected and managed in Canada under the *Fisheries Act* (Houston 1987). Control is effected through open and closed seasons, size limits, bag limits, means of capture (gear restrictions) and catch-and-release regulations (Houston 1987, Beamesderfer and Farr 1997). In general, management efforts have failed to sustain yields (Houston 1987), although there remains a large commercial fishery in Quebec and a few small commercial fisheries in Ontario that appear to be sustainable (T. Dick, in prep.). Commercial fishing on the St. Lawrence River is regulated by gill net length, mesh size restrictions, minimum size limits and closed seasons (Fortin et al. 1993, Nilo et al. 1997). Management of the fishery is focused on ensuring that a sufficient number of spawners are available for adequate recruitment (Fortin et al. 1993).

A study by Threader and Brousseau (1986) suggested that a management strategy for lake sturgeon in the Moose River in Ontario should be based on protecting sexually mature fish. In this case, they felt that smaller fish with lower mercury levels should be harvested and the remaining population used to encourage a sustainable yield. A reduction in minimum size limit has also been implemented in the Lake Winnebago fishery in Wisconsin to reduce exploitation of adult females (Bruch et al. 2001). In Wisconsin, a Sturgeon Management Assessment Team has been developed to review, evaluate and update the lake sturgeon management plan in Wisconsin (Wisconsin Department of Natural Resources 2000). The goal is to manage the inland river population to maintain densities at 250 fish/mile. On the Menominee River in Wisconsin and Michigan, a mandatory registration system has provided a good account of the harvest and has been effective in aiding a management strategy to restore sturgeon populations (Thuemler 1985). Artificial spawning and rearing of this species as a method of re-establishing sturgeon populations has had limited success (Ceskleba et al. 1985). Through extensive sturgeon research, Beamesderfer and Farr (1997) recommend that only large-scale system-wide habitat protection and improvement programs will provide significant benefits for depleted or threatened populations.

SYNTHESIS

Reduced water quality, habitat loss and degradation, and potential overharvest threaten the survival of lake sturgeon populations in Alberta. Sturgeon are more susceptible than most fish to overharvest because of their longevity, delayed maturation and periodic spawning (Harkness and Dymond 1961, Beamesderfer and Farr 1997). Because of these sensitivities, they may serve as an early indicator to ecosystem health and biodiversity.

Historic population levels in Alberta are largely unknown. Within the past decade, numbers in the North Saskatchewan River appear to have increased. No recent estimates for the South Saskatchewan River are available, but existing numbers suggest the population may not be sustainable in its present state. The number of spawning fish in each subpopulation may be below critical numbers for genetic or demographic stability. Re-establishment of older age classes and consistent annual recruitment are essential for full recovery of the lake sturgeon population in Alberta. Current data including age-at-maturity, length and weight-at-age and a reliable population estimate are required to enable meaningful management decisions (R.L.&L. 1992).

A precautionary management strategy should be followed, using conservative estimates to govern all management decisions for lake sturgeon. Successful management efforts need to examine changes in biological characteristics of adult fish as well as recruitment and juvenile assessments (Auer 1994). Habitat protection must be integrated with harvest restrictions and other management strategies to ensure a sustainable lake sturgeon population.

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APPENDIX 1. Definitions of selected legal and protective designations.

A. The General Status of Alberta Wild Species 2000 (after Alberta Sustainable Resource Development 2001)

2000 Rank	1996 Rank	Definitions
At Risk	Red	Any species known to be "At Risk" after formal detailed status assessment and designation as "Endangered" or "Threatened" in Alberta.
May Be At Risk	Blue	Any species that may be at risk of extinction or extirpation, and is therefore a candidate for detailed risk assessment.
Sensitive	Yellow	Any species that is not at risk of extinction or extirpation but may require special attention or protection to prevent it from becoming at risk.
Secure	Green	Any species that is not "At Risk", "May Be At Risk", or "Sensitive".
Undetermined	Status Undetermined	Any species for which insufficient information, knowledge or data is available to reliably evaluate its general status.
Not Assessed	n/a	Any species known or believed to be present but which has not yet been evaluated.
Exotic/Alien	n/a	Any species that has been introduced as a result of human activities.
Extirpated/Extinct	n/a	Any species no longer thought to be present in Alberta ("Extirpated") or no longer believed to be present anywhere in the world ("Extinct").
Accidental/Vagrant	n/a	Any species occurring infrequently and unpredictably in Alberta, i.e., outside their usual range.

B. Alberta Wildlife Act/Regulation

Species designated as "Endangered" under Alberta's *Wildlife Act* include those listed as "Endangered" or "Threatened" in the Wildlife Regulation.

Endangered	A species facing imminent extirpation or extinction.
Threatened	A species that is likely to become endangered if limiting factors are not reversed.

C. Committee on the Status of Endangered Wildlife in Canada (after COSEWIC 2002)

Extinct	A species that no longer exists.
Extirpated	A species that no longer exists in the wild in Canada, but occurs elsewhere.
Endangered	A species facing imminent extirpation or extinction.
Threatened	A species that is likely to become endangered if limiting factors are not reversed.
Special Concern	A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events.
Not at Risk	A species that has been evaluated and found to be not at risk.
Data Deficient	A species for which there is insufficient scientific information to support status designation.

D. Heritage Status Ranks: Global (G), National (N), Sub-National (S) (after Alberta Natural Heritage Information Centre 2000)

G1/N1/S1	5 or fewer occurrences or only a few remaining individuals. May be especially vulnerable to extirpation because of some factor of its biology.
G2/N2/S2	6-20 or fewer occurrences or with many individuals in fewer locations. May be especially vulnerable to extirpation because of some factor of its biology.
G3/N3/S3	21-100 occurrences, may be rare and local throughout it's range, or in a restricted range (may be abundant in some locations). May be susceptible to extirpation because of large-scale disturbances.
G4/N4/S4	Typically >100 occurrences. Apparently secure.
G5/N5/S5	Typically >100 occurrences. Demonstrably secure.
GX/NX/SX	Believed to be extinct or extirpated, historical records only.
GH/NH/SH	Historically known, may be relocated in future.

E. United States Endangered Species Act (after National Research Council 1995)

Endangered	Any species which is in danger of extinction throughout all or a significant portion of its range.
Threatened	Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

APPENDIX 2. Age structure of the North Saskatchewan River lake sturgeon population.

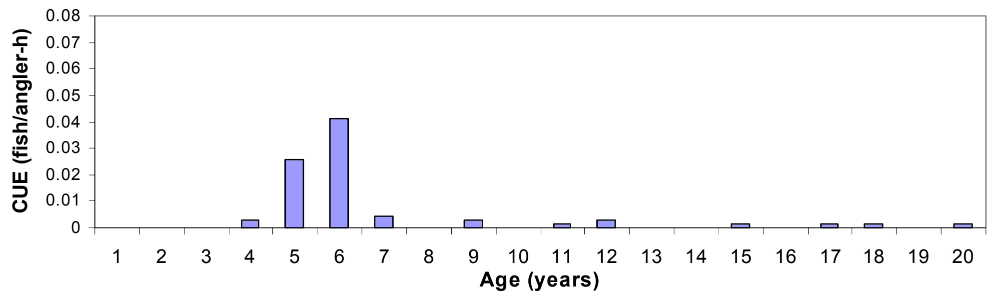

Figure 1: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 1991.

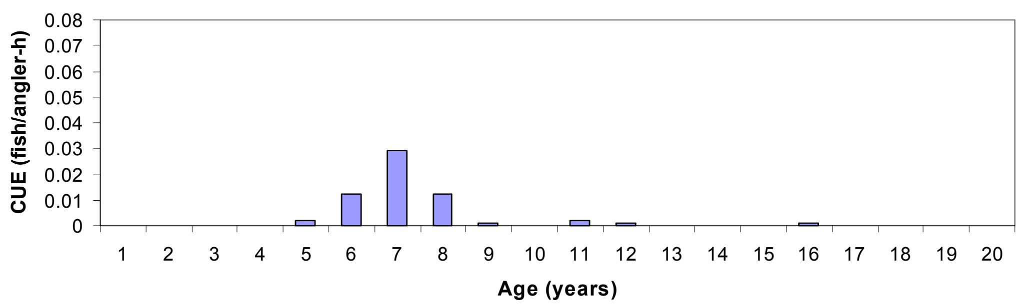

Figure 2: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 1992.

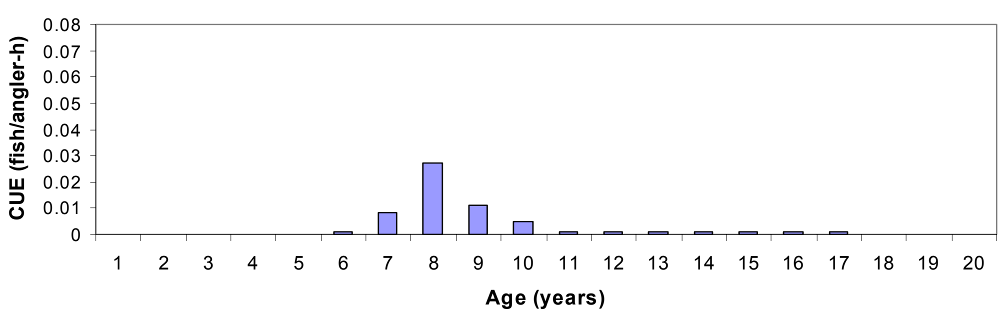

Figure 3: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 1993.

APPENDIX 2 continued

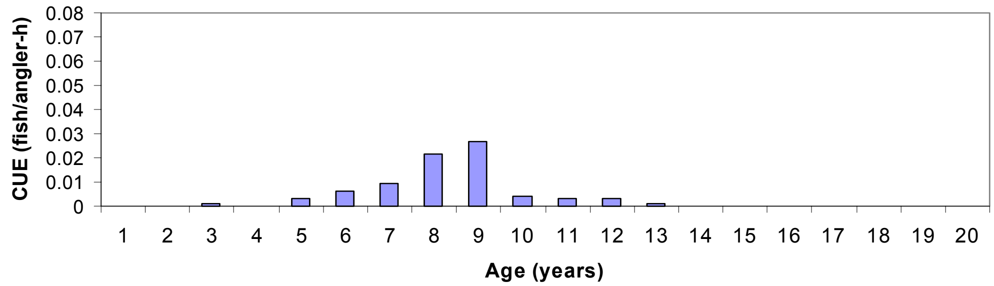

Figure 4: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 1994.

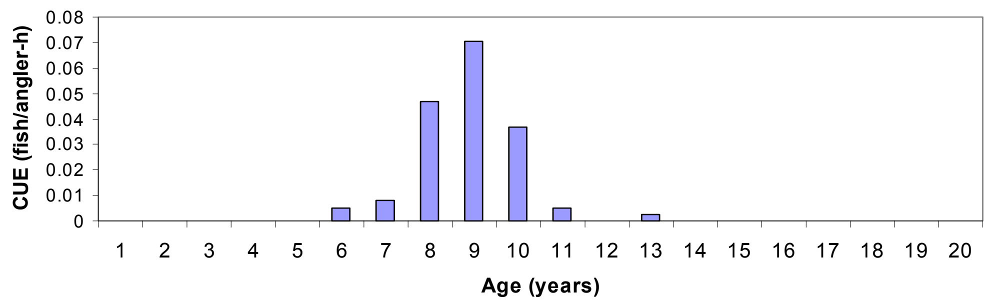

Figure 5: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 1995.

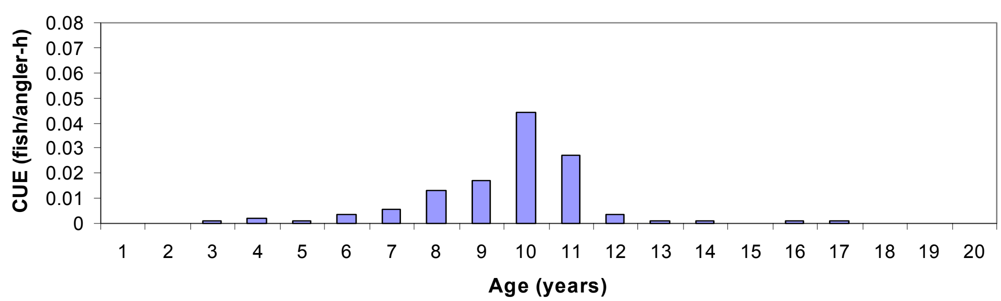

Figure 6: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 1996.

APPENDIX 2 continued

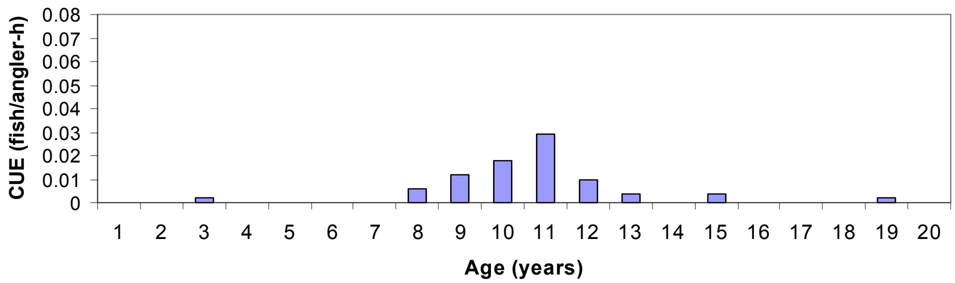

Figure 7: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 1997.

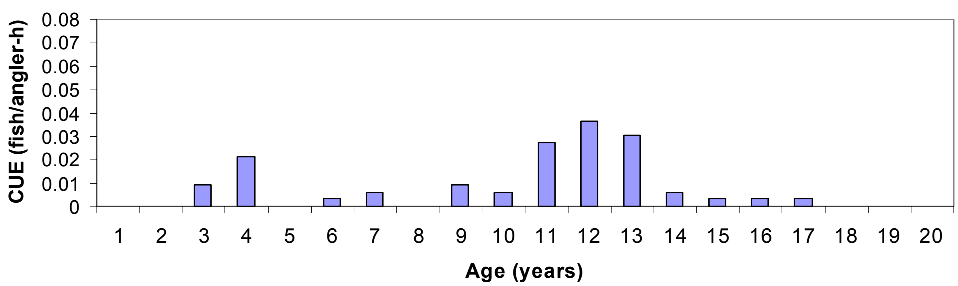

Figure 8: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 1998.

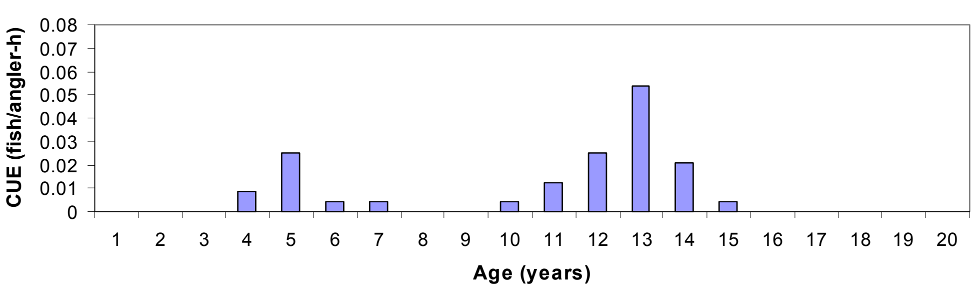

Figure 9: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 1999.

APPENDIX 2 continued

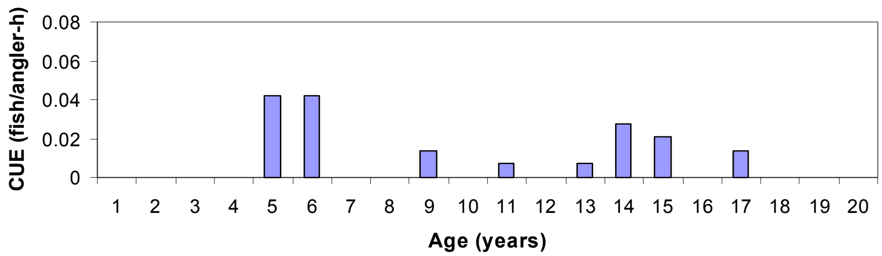

Figure 10: Age Frequency Distribution of Lake Sturgeon in the North Saskatchewan River for 2000.

Figure 11: Age Frequency Distribution of Lake Sturgeon in the South Saskatchewan River from 1985 Field Data.

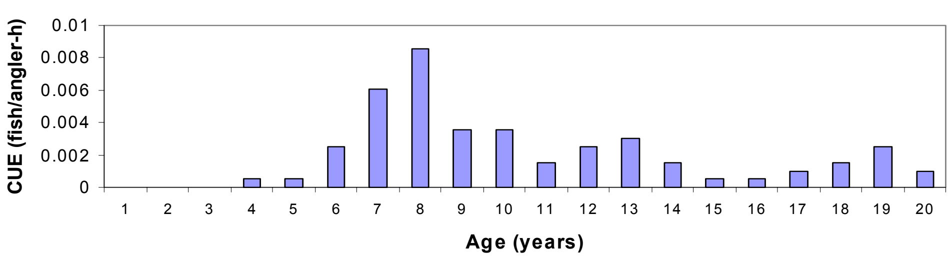

Figure 12: Age Frequency Distribution of Lake Sturgeon in the South Saskatchewan from 1986 Field Data.

APPENDIX 3A. Jolly-Seber population estimate technique.

M_i = marked population size at time i

m_i = marked fish actually caught at time i

S_i = total fish released at time i

Z_i = number of individuals before time i, not caught in the ith sample but caught in a sample after time i

R_i = number of the S_i individuals released at time i that are caught in a later sample.

$M_i = ((S_i Z_i) / R_i) + m_i$

Total population size = marked population size ÷ proportion of animals marked

Number of Fish Captured in Year X

Number of Fish Marked or Recaptured from Year Y

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1990		1	2	0	2	1	3	0	3	0	3
1991		1	4	5	3	3	6	4	0	3	1
1992			0	11	9	6	11	5	3	2	5
1993				9	15	4	13	6	5	2	0
1994					4	9	25	9	12	7	2
1995						0	22	6	6	5	0
1996							15	17	18	19	9
1997								0	10	12	4
1998									5	4	6
1999										7	4
2000											0

	Z	R	S	m	M	tot pop
1990						
1991	14	29	89	2	45	2001*
1992	37	52	82	6	64	879
1993	73	45	106	25	197	835
1994	89	64	134	33	219	891
1995	130	39	100	23	356	1549
1996	89	63	275	95	483	1400
1997	105	26	114	47	507	1231
1998	74	10	129	62	1017	2115
1999	30	4	118	61	946	1830
2000			121	34		

note 1991 estimate was discarded due to a small sample size of marked fish in 1990

APPENDIX 3B. Bailey's population estimate for North Saskatchewan River lake sturgeon in 2000.

Formula:

Pop = (m+1) (c+1)/r

m (total tagged fish alive in 2000, using an annual mortality rate of 10%) = 529
c (fish captured in 2000) = 121
r (tagged fish recaptured) = 34

Pop = 1902 (includes sturgeon at age > 3)

Binomial exact confidence limits (Zar 1999)
Binomial = 34 / 529 = 0.064
Lower 95% CI (proportion) = 0.089
Upper 95% CI (proportion) = 0.045
Lower 95% CI (population) = 121 / 0.089 = 1360 fish
Upper 95% CI (population) = 121 / 0.045 = 2689 fish

Estimate of mature sturgeon population (age > 20):

Proportion age > 20 in year 2000 = 4 / 29 = 0.14
Proportion mature x lower 95% CI = 0.14 x 1360 fish = 190 mature sturgeon

APPENDIX 4. Age-Structured Cohort Model

Model Example:

N(t+1)=N(t)S

Model Variables:

Survival(S)	Total Pop.
0.85	933
Min N at >age 50	
1	

Age Class	# Fish (N)
0	-
1	-
2	-
3	140
4	119
5	101
6	86
7	73
8	62
9	53
10	45
11	38
12	32
13	28
14	23
15	20
16	17
17	14
18	12
19	10
20	9
21	8
22	6
23	5
24	5
25	4
26	3
27	3
28	2
29	2
30	2
con't	
97	0
98	0
99	0
100	0

Simulation Results:

Age-Class Numbers at Different Mortalities

Age Class	Survival Rates		
	85%	90%	95%
3	140	140	140
4	119	126	133
5	101	113	126
6	86	102	120
7	73	92	114
8	62	83	108
9	53	74	103
10	45	67	98
11	38	60	93
12	32	54	88
13	28	49	84
14	23	44	80
15	20	40	76
16	17	36	72
17	14	32	68
18	12	29	65
19	10	26	62
20	9	23	59
21	8	21	56
22	6	19	53
23	5	17	50
24	5	15	48
25	4	14	45
26	3	12	43
27	3	11	41
28	2	10	39
29	2	9	37
30	2	8	35
31	1	7	33
32	1	7	32
con't			
99	0	0	1
100	0	0	1

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