Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

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Canadian Science Advisory Secretariat / **Secrétariat canadien de consultation scientifique**

Research Document 2010/081 / **Document de recherche 2010/081**

Information Relevant to a Recovery Potential Assessment of Lake Sturgeon: Saskatchewan River Populations (DU2)

Renseignements pertinents pour l'évaluation du potentiel de rétablissement de l'esturgeon jaune : populations de la rivière Saskatchewan (UD 2)

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ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

Canada

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Correct citation for this publication:

Cleator, H., K.A. Martin, T.C. Pratt, R. Campbell, M. Pollock and D. Watters. 2010. Information relevant to a recovery potential assessment of Lake Sturgeon: Saskatchewan River populations (DU2). DFO Can. Sci. Advis. Sec. Res, Doc. 2010/081. vi + 36 p.

ABSTRACT

The Lake Sturgeon (*Acipenser fulvescens*) was common in nearshore waters across much of Canada in the nineteenth century, but intensive fishing, habitat loss and degraded water quality caused severe reductions in population size or extirpation across their range. Today they remain extant from the North Saskatchewan River in Alberta, to Hudson Bay in the north, and eastward to the St. Lawrence River estuary. In November 2006, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed Lake Sturgeon in Canada. Designatable Unit (DU) 2, the Saskatchewan River populations, includes Lake Sturgeon in the Saskatchewan River upstream of the Grand Rapids Generating Station at Lake Winnipeg and all drainages west to east-central Alberta. COSEWIC assessed and designated DU2 as Endangered. Commercial over-exploitation and the detrimental impacts associated with dams/impoundments and other barriers contributed to the declines in Lake Sturgeon abundance in DU2. Negative impacts associated with fishing and habitat degradation or loss and population fragmentation, resulting from dams/impoundments and other barriers, are ongoing. These, combined with new threats from agriculture, urban development and forestry, currently pose the greatest threats to the survival and recovery of Lake Sturgeon in DU2, although the importance of individual threats vary by Management Unit (MU).

DU2 Lake Sturgeon is being considered for legal listing under the *Species at Risk Act* (SARA). In advance of making a listing decision, Fisheries and Oceans Canada (DFO) has been asked to undertake a Recovery Potential Assessment (RPA). This RPA summarizes the current understanding of the distribution, abundance and population trends of Lake Sturgeon in DU2, along with recovery targets and times. The current state of knowledge about habitat requirements, threats to both habitat and Lake Sturgeon, and measures to mitigate these impacts for DU2 are also included. This information may be used to inform both scientific and socio-economic elements of the listing decision, development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions, as per sections 73, 74, 75, 77 and 78 of SARA.

Six Lake Sturgeon MUs have been identified for DU2. Available data and expert opinion indicate that the current status and population trajectory of MUs 1, 2 and 4 is cautious and stable or increasing, respectively. Abundance in MUs 1 and 4 is probably low to moderate while MU2 appears to be somewhat higher. MU5 is thought to be cautious though its trajectory is unknown. The status of MUs 3 and 6 is deemed to be critical with a stable trajectory in MU6 and unknown trajectory in MU3. Available data and expert opinion suggest that Lake Sturgeon abundance in DU2 ranges from very low to moderate. The long-term recovery goal for DU2 is to protect and maintain healthy, viable populations of Lake Sturgeon in all MUs.

RÉSUMÉ

L’esturgeon jaune (*Acipenser fulvescens*) était abondant dans les eaux côtières de la majeure partie du Canada au dix-neuvième siècle, mais la pêche intensive, la perte d’habitat et la dégradation de la qualité de l’eau ont entraîné de graves diminutions de la taille de la population ou, encore, sa disparition dans l’ensemble de son aire de répartition. Aujourd’hui, les populations subsistent de la rivière Saskatchewan Nord en Alberta à la baie d’Hudson au nord et à l’estuaire du fleuve Saint-Laurent à l’est. En novembre 2006, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a évalué l’esturgeon jaune au Canada. L’unité désignable (UD) 2, à savoir les populations de la rivière Saskatchewan, comprend les esturgeons jaunes présents dans la rivière Saskatchewan en amont de la centrale de Grand Rapids au lac Winnipeg ainsi que dans tous les bassins hydrographiques à l’ouest du centre-est de l’Alberta. Le COSEPAC a évalué l’UD 2 et l’a désignée comme étant en voie de disparition. La surexploitation par la pêche commerciale ainsi que les impacts négatifs causés par les barrages, les ouvrages de retenue et autres obstacles ont contribué au déclin de l’abondance des esturgeons jaunes dans l’UD 2. Les effets négatifs liés à la pêche et à la dégradation ou à la perte de l’habitat ainsi qu’à la fragmentation de la population causées par les barrages, les ouvrages de retenue et autres obstacles se poursuivent. Ceux-ci, combinés à de nouvelles menaces comme l’agriculture, le développement urbain et l’exploitation forestière, constituent actuellement les menaces les plus importantes pesant sur la survie et le rétablissement de l’esturgeon jaune dans l’UD 2, bien que l’importance de chacune de ces menaces varie selon l’unité de gestion (UG).

On étudie la possibilité d’inscrire l’esturgeon jaune de l’UD 2 à la liste de la *Loi sur les espèces en péril* (LEP). Avant de prendre une décision quant à l’inscription, on a demandé à Pêches et Océans Canada (MPO) d’effectuer une évaluation du potentiel de rétablissement (EPR). Cette EPR résume les connaissances actuelles associées à la répartition, à l’abondance et aux tendances relatives aux populations d’esturgeons jaunes dans l’UD 2 et propose des cibles et des délais de rétablissement. On présente également l’état actuel des connaissances sur les exigences en matière d’habitat, les menaces pesant sur l’habitat et sur l’esturgeon jaune ainsi que les mesures d’atténuation à mettre en œuvre dans l’UD 2. Cette information peut être utilisée pour éclairer les volets scientifiques et socio-économiques des processus décisionnels relatifs à l’inscription ainsi que l’élaboration d’un programme de rétablissement et d’un plan d’action et, finalement, pour soutenir les processus décisionnels concernant la délivrance de permis, la conclusion d’accords et l’établissement de conditions connexes en vertu des articles 73, 74, 75, 77 et 78 de la LEP.

On a relevé six UG de l’esturgeon jaune pour l’UD 2. Selon les données disponibles ainsi que les opinions d’experts, l’état actuel des UG 1, 2 et 4 se situe dans la zone de prudence et la trajectoire de la population est stable ou à la hausse. L’abondance dans l’UG 1 et l’UG 4 va probablement de faible à modérée, tandis que dans l’UG 2, l’abondance semble être passablement plus élevée. On estime que l’UG 5 se situe dans la zone de prudence, mais la trajectoire est inconnue. L’état des UG 3 et 6 est considérée comme critique; la trajectoire est stable dans l’UG 6 et inconnue dans l’UG 3. Les données disponibles ainsi que les opinions d’experts laissent sous-entendre que l’abondance de l’esturgeon jaune dans l’UD 2 varie de très faible à modérée. Dans l’UD 2, le but du rétablissement à long terme est de protéger et de maintenir des populations d’esturgeons jaunes en santé et viables dans l’ensemble des UG.

INTRODUCTION

The Lake Sturgeon (*Acipenser fulvescens*) is part of an evolutionarily ancient, temperate freshwater fish family. They are slow-growing and long-lived, and their extended reproductive cycles make them vulnerable to human-induced population declines. The Lake Sturgeon was common in nearshore waters across much of Canada in the nineteenth century, but over the past century have undergone severe reductions in population size, or extirpation, in response to intensive fishing habitat loss and degraded water quality. Eight Canadian designatable units (DUs) of Lake Sturgeon are recognized by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2006). DU2 includes Lake Sturgeon in the Saskatchewan River upstream of the Grand Rapids Generating Station (GS) at Lake Winnipeg and all drainages west to east-central Alberta (Figure 1). COSEWIC assessed and designated this DU as Endangered in November 2006 (COSEWIC 2006). The Lake Sturgeon has cultural significance and importance for subsistence harvesting to First Nations peoples. This species is valued by recreational fishers for catch-and-release and is of value to the tourist industry. Maintaining Lake Sturgeon populations in Canada, including DU2, is important for the long-term survival and recovery of this species.

SPECIES BIOLOGY AND ECOLOGY

The Lake Sturgeon is a bottom-dwelling freshwater fish that is heavy, cartilaginous and torpedo-shaped with an extended, hard snout and shark-like caudal fin. Larval and juvenile fish have conspicuous bony plates (scutes) in five rows along the body which become less obvious with age as they embed in the body wall. The pointed snout has four prominent barbels located ventrally and well in front of the mouth. The Lake Sturgeon is typically light to dark brown or grey in colour on the back and sides with a lighter-coloured belly. They can attain over 3 m in length and 180 kg in weight, though they mostly range about 0.9-1.5 m in length and about 5-35 kg in weight (Scott and Crossman 1973). Historically, Lake Sturgeon taken in Saskatchewan typically weighed up to 30 kg (Houston 1987) while weights now typically range up to 14 kg (Smith 2003). In the Alberta portion of the South Saskatchewan River, angled Lake Sturgeon typically average 1.1 m (range: 0.4-1.7 m) in length and 8.4 kg (range: 0.2-29.0 kg) in weight (Saunders 2006). In 1996-97, the largest Lake Sturgeon caught from the lower Saskatchewan River measured 1.5 m in length and weighed 33 kg (Wallace and Leroux 1999). A study conducted in the Saskatchewan River delta in the mid-1960s found Lake Sturgeon growth rates were faster than those reported for the Nelson River (DU3), Ontario and Quebec, but slower than in Wisconsin (Royer *et al.* 1968). Females are usually larger than males (Harkness and Dymond 1961, Mosindy and Rusak 1991).

This species is found in large rivers and lakes. To date, most Lake Sturgeon research has been conducted in riverine rather than lacustrine systems so most of the available data presented reflect this.

The Lake Sturgeon usually occurs at depths of 5-10 m or more over mud, clay, sand or gravel substrates in water temperatures within the range of 3-24°C (COSEWIC 2006). In the Winnipeg River, juvenile Lake Sturgeon prefer deep water areas greater than 13.7 m (Barth *et al.* 2009), while most adults were captured in 4-19 m depths (D. MacDonell, pers. comm.). The Lake Sturgeon has been described as largely sedentary (Threader and Brousseau 1986, Fortin *et al.* 1993, Haxton 2003) with high site fidelity except to move over longer distances for spawning. A low proportion of adult fish migrate long distances, sometimes in excess of hundreds of km, but most make localized (1-20 km) seasonal movements between feeding areas in large rivers or lakes and spawning areas, and typically exhibit site fidelity to spawning areas and sometimes to “home” or “activity” centres for feeding and/or overwintering (Sandilands 1987, Kempinger 1988, Fortin *et al.* 1993, Auer 1996, Rusak and Mosindy 1997, Borkholder *et al.* 2002, Knights *et al.* 2002, Barth and

Ambrose 2006). Tagging studies indicate that in contiguous lake-river systems, basin-wide movement patterns may be the most prevalent during the ice-free season, especially during the spawning and post-spawning period when water temperatures increase, while fairly limited movements are typical during the winter months (Mosindy and Rusak 1991, Rusak and Mosindy 1997, Borkholder *et al.* 2002). Tagging studies also indicate that younger, smaller Lake Sturgeon do not move as far as older, larger individuals (Mosindy and Rusak 1991, Swanson *et al.* 1991, Holtgren and Auer 2004, Benson *et al.* 2005, Smith and King 2005). Further, some mark-recapture and acoustic telemetry data from DU5 indicate that habitat transitions, specifically areas characterized by shallow water depths (1-5 m) and fast moving (> 1.0 $m \cdot s^{-1}$) water, may limit or restrict juvenile movement (Barth, unpubl. data).

The importance of migration to Lake Sturgeon extends beyond feeding and spawning. It is also critical for the recolonization of areas that are subject to freezing, drought or other seasonal changes or catastrophic events (Aadland, as cited in DFO 2007).

Adult Lake Sturgeon spawn in swift current after moving upstream to suitable areas containing rapids or below barriers (e.g., falls or dams) (Harkness and Dymond 1961, Scott and Crossman 1973, Priegel and Wirth 1974, Baker 1980, Mosindy and Rusak 1991, Lyons and Kempinger 1992, Auer 1996). They return downstream following spawning (Mosindy and Rusak 1991, Lyons and Kempinger 1992) to replenish energy stores before the next spawning cycle.

Sexual maturity in Lake Sturgeon typically occurs between 14 and 33 years of age in females and between 14 and 22 years in males (Harkness and Dymond 1961). Age at first spawning may occur several years after eggs first start to develop. Historically, age at maturity was determined from egg development when fish were collected for caviar. Today, sexual maturity is based on the age at which Lake Sturgeon are first observed spawning. Therefore, comparisons between historical and current age at maturity should be made with caution as they may reflect differences in methods rather than changes in population characteristics. In the Saskatchewan River, females reach sexual maturity at about 25 years (length and weight: 127 cm and 13.6 kg) and males at 18-20 years (97.8 cm) (Wallace 1991).

Spawning occurs in May and/or June, once waters are free of ice. The maximum number of females and heaviest spawning activity usually occurs when water temperature reaches 11.5-16.0°C (Bruch and Binkowski 2002). Individual spawning females are surrounded by 2-8 males in fast current, often near shore though not always, and release about 1,000 eggs into a cloud of sperm during 2-4 spawning events (Bruch and Binkowski 2002, D. MacDonell, pers. comm.). Females may contain between about 50,000 and > 1,000,000 eggs with heavier females producing more eggs (Scott and Crossman 1973). A female will continue spawning for about 8-12 hours and spawning typically occurs for 2-4 days at each site depending on the number of spawning females. Spawning periodicity has been estimated to be 3-7 years for females and 2-3 years for males (Sunde 1959, Mosindy and Rusak 1991, Wallace 1991). In DU2, females spawn every 4-8 years (Wallace 1991). Reproductive senescence has not been reported. Lake Sturgeon scatter their eggs and move quickly downstream after spawning, providing no parental care to the eggs or fry.

The eggs hatch in 5-10 days, depending on water temperature. Newly-hatched young are negatively phototactic, and remain burrowed in the interstitial spaces of the substrate until the yolk sac is absorbed. Typically they emerge at night within 13-19 days after hatching and disperse downstream with the current (up to 40 kilometers) before returning to a benthic habitat (Seyler 1997). By that time they resemble miniature adults and start feeding. The early age-0 stage (i.e., the transition from larvae to exogenous feeding) is a critical life history stage for Lake Sturgeon. Age-0 fish grow rapidly from 1.7-1.8 cm at emergence to approximately 11-20 cm total length (TL) by the end of the first summer (COSEWIC 2006, C. Barth, pers. comm.). Up to five years of age, they grow more rapidly in length than weight, whereas from 5-15 years of age they grow more rapidly in weight than length. In general, growth rate and body condition in Lake Sturgeon have been found to vary in relation to mean annual air temperature, latitude and region of Canada (east versus west portion of the range) and water properties such as pH and conductivity (Fortin *et al.* 1996).

The sex ratio at birth is unknown but assumed to be 1:1 based on data from populations with little or no anthropogenic mortality (Threader and Brousseau 1986, Nowak and Jessop 1987). Following maturation, the sex ratio can favour either females or males as a result of targeted exploitation. For example, in the St. Lawrence the sex ratio shifted in favour of females reaching 6:1 by age 40 (Fortin *et al.* 1993). In the Lake Winnebago system it shifted in favour of males due to targeted exploitation of females (Bruch 1999). Information about survival is limited. Survival and mortality rates in Lake Winnebago in 1936-52 were 0.946 and 0.054 for ages 16-36 years and 0.866 and 0.134 for ages older than 36 years, respectively (Priegel and Wirth 1975). The estimate of survivorship of adult and sub-adult Lake Sturgeon below the St. Lawrence FDR Power Project at Massena, New York, was 0.86 (Hayes and Werner 1997). Recruitment (i.e., the number of fish which grow into the catchable size range in a year) in populations which are self sustaining is reported to be in the range of 4.7-5.4% (Priegel and Wirth 1975, Baker 1980). In the lower Saskatchewan River, total annual mortality rate was about 4.8% and annual recruitment about 3.5% in 1958. By 1975, the total annual mortality had increased to 18.9% (Wallace 1991). Natural survival of adult Lake Sturgeon is high (Vélez-Espino and Koops 2009), but adults are particularly vulnerable to exploitation.

There are historic records of Lake Sturgeon living up to 150 years of age (Scott and Crossman 1973, Stewart and Watkinson 2004) however the typical lifespan in western Canada was about 80 years for females and 55 years for males (Choudhury and Dick 1993). Maximum ages were higher in the more northern, slower-growing populations (Scott and Crossman 1973). Lifespan today is more in the range of 25-50 years with an average generation time of about 26-30 years (Fortin *et al.* 1996, Scott and Crossman 1973), but lifespan is population specific. Shorter average lifespan today may reflect current and/or past effects of harvest rather than natural longevity. In the South Saskatchewan River (MU2), 12% of Lake Sturgeon are older than 25 years and 1% older than 33 years (Saunders 2006).

The Lake Sturgeon follows a benthic generalist feeding strategy. Age-0 fish mostly feed on amphipods and chironomid larvae while the diet of juveniles also includes oligocheates, aquatic insects (e.g., ephemeroptera nymphs, trichoptera larvae) mollusks and fish eggs (Peterson *et al.* 2007, Randall 2008). A shift in diet has been reported to occur when Lake Sturgeon reach about 70-80 cm TL, from a diet comprised mainly of soft bodied insects to a wide range of benthic organisms including bivalves or crayfish (Sandilands 1987, Werner and Hayes 2005). Some pelagic feeding has also been reported (Dick 2004). The Lake Sturgeon feeds actively throughout the year, though consumption may decline in the fall and winter (DFO 2008).

ASSESSMENT

HISTORIC AND CURRENT DISTRIBUTION AND TRENDS

DU2 includes the Saskatchewan rivers system, upstream of the Grand Rapids GS at Lake Winnipeg, in southern and central Alberta and Saskatchewan and far west-central Manitoba (Figure 1). The Lake Sturgeon in this region is considered a distinct designatable unit on the basis of distinguishable variation in three nuclear microsatellite loci (Robinson and Ferguson 2001, COSEWIC 2006).

A number of hydroelectric GSs and impoundments interspersed with river sections currently exist on the North Saskatchewan, South Saskatchewan and Saskatchewan rivers. Some tributaries also have barriers to historically available reaches. Six Lake Sturgeon MUs have been identified for DU2 (Figure 1): (1) the North Saskatchewan River downstream of the Bighorn GS, (2) the South Saskatchewan River upstream of Gardiner GS, (3) the South Saskatchewan River from Gardiner GS to the forks (referred to as "The Forks") of the North Saskatchewan and South Saskatchewan rivers, (4) from The Forks to François-Finley GS, (5) from François-Finley GS to E.B. Campbell GS and (6) from E.B. Campbell GS to Grand Rapids GS. The man-made barrier at the start (i.e., upstream end) of an MU is included in the MU. For example, the E.B. Campbell GS is included in MU6. Within each of these MUs there may be one or more spawning stocks.

The Lake Sturgeon currently occurs in all six MUs and their area of occupancy in DU2 is estimated to be < 400,000 km^2 (COSEWIC 2006).

North Saskatchewan River: Bighorn GS – The Forks (MU1)

Historical records and anecdotal information indicate that Lake Sturgeon were harvested in the North Saskatchewan River (MU1) and its tributaries, including the Battle River (Nelson and Paetz 1992, Smith 2003).

The North Saskatchewan River originates in the Rocky Mountains of Alberta and is impounded in the headwater reach by the Bighorn GS. A major headwater tributary, Brazeau River, is also dammed for hydroelectric generation. The current distribution of Lake Sturgeon in MU1 extends as far upstream as these GSs and downstream about 1,195 river km, unimpeded by barriers, to The Forks east of Prince Albert in Saskatchewan.

The upper 240 km below Bighorn GS is characterized by cold water habitat with shallow depth, moderate to high water velocity, abundant rock and gravel substrate and braided channel morphology. The fish community is dominated by salmonids. The distribution of Lake Sturgeon is generally limited to the lower 475 km of the North Saskatchewan River in Alberta which transitions to cool water depositional habitat with slower water velocity in a single channel. In Saskatchewan, Lake Sturgeon are commonly reported in the Lloydminster, Battleford and Prince Albert areas (Smith 2003).

South Saskatchewan River: upstream of Gardiner GS (MU2)

The South Saskatchewan River from its headwaters at the confluence of the Bow and Oldman rivers in Alberta downstream to the Gardiner GS (MU2) in Saskatchewan, at the northern outlet of Lake Diefenbaker, is about 602 river km. Many of the historic locations for Lake Sturgeon in the Alberta portion of the South Saskatchewan River (MU2) were located in upstream areas (Smith 2003). One of the earliest accounts was a Lake Sturgeon harvested in the Bow River near Bassano in 1915 or 1916 (Whitehouse 1919). Today, the Lake Sturgeon is found in the lower portions of the Red Deer, Bow and Oldman rivers and the South Saskatchewan River (Nelson and Paetz 1992) downstream to Gardiner GS. In Saskatchewan, most reports are from the Leader area (Smith 2003).

South Saskatchewan River: Gardiner GS – The Forks (MU3)

The South Saskatchewan River from the Gardiner GS to The Forks (MU3) is 358 river km in length. No historic scientific information about Lake Sturgeon distribution is available for MU3. This species may now be absent between Gardiner GS and Saskatoon and sparsely distributed between Saskatoon and The Forks (Smith 2003).

Saskatchewan River: The Forks – François-Finley GS (MU4)

The Saskatchewan River from The Forks downstream to the François-Finley GS (MU4), upstream of Nipawin, is 103 river km in length. The impounded waters immediately upstream of the François-Finley GS are known as Codette Lake. Historically, the Lake Sturgeon was reported to occur at ferry crossings and in the Fort-a-la-Corne area (Smith 2003), about 25 river km downstream of The Forks. Today, the Lake Sturgeon is frequently seen in two areas located roughly 20 km (M. Pollock, pers. comm.) and 67 km (Smith 2003) downstream of The Forks.

Saskatchewan River: François-Finley GS – E.B. Campbell GS (MU5)

The Saskatchewan River from the François-Finley GS downstream to the E.B. Campbell GS (MU5) is 70 river km in length. Lake Tobin, the impounded waters upstream of the E.B. Campbell GS that went into operation in 1962, represents about 75% of this MU. No historic or current information about Lake Sturgeon distribution and trends is available for this MU.

Saskatchewan River: E.B. Campbell GS – Grand Rapids GS (MU6)

The Saskatchewan River below E.B. Campbell GS flows downstream through Cedar Lake to the Grand Rapids GS at Lake Winnipeg. This stretch of the Saskatchewan River (MU6) is about 427 river km in length. Historically, the Lake Sturgeon was known to occur in Cumberland Lake, the Torch and Tearing rivers and Namew Lake in Saskatchewan, and downstream to Lake Winnipeg at Grand Rapids, including Moose and Cedar lakes, in Manitoba (Skaptason 1926, Smith 2003, Stewart 2009). Lake Sturgeon may continue to be distributed throughout this MU but in much smaller numbers.

There were 111 historic Lake Sturgeon fishing sites identified in Saskatchewan based on anecdotal information collected during interviews and questionnaires about where Lake Sturgeon were known to occur historically and currently (Smith 2003). Of those, only 35 were also identified as “present” fishing sites: 7 of 30 in the South Saskatchewan River, 16 of 48 in the North Saskatchewan River and 12 of 33 in the Saskatchewan River (Smith 2003). Whether the drop in numbers of sites represented an actual decline in distribution, changes in fishing patterns or something else is unknown.

HISTORIC AND CURRENT ABUNDANCE AND TRENDS

Historical harvests of Lake Sturgeon in the Alberta portion of the Saskatchewan rivers system were small relative to those in Saskatchewan and Manitoba. In Alberta, small commercial fisheries for Lake Sturgeon began in the late 1800s and closed in 1940 (Stewart 2009). Larger commercial fisheries in Saskatchewan and Manitoba began in the 1890s in Saskatchewan and in the 1880s in Manitoba, and continued intermittently until the mid-1990s when they were closed (Stewart 2009). Over the past 50 years, several dams were built on the Saskatchewan rivers system for hydroelectric power generation and other purposes. Commercial over-exploitation and the detrimental impacts associated with dams/impoundments and other barriers contributed to the declines in Lake Sturgeon abundance in DU2.

The current conservation status (Figure 2), based on the precautionary framework (DFO 2005), of each of the MUs in DU2 was evaluated on the basis of available information and expert opinion (Table 1).

North Saskatchewan River: Bighorn GS – The Forks (MU1)

The Lake Sturgeon was probably more abundant in this MU in the early 1900s than now though they are reported at numerous locations along the North Saskatchewan River in the provinces of Alberta and Saskatchewan (Smith 2003). Population estimates derived from Lake Sturgeon mark-recapture studies conducted in the Alberta portion of the North Saskatchewan River, using a closed population model, indicate that there may have been between 700 and 2,000 fish older than three years of age in 1990-93, although uncertainty around this estimate is high (Watters 1993a and b). Alberta Sustainable Resource Development (ASRD) has analyzed more recent Lake Sturgeon tagging data from the Alberta portion of MU1 using open population models. The results indicate that Lake Sturgeon greater than three years of age may have fluctuated between 700 and 1,600 individuals between 1993 and 2007 (ASRD, unpubl. data). The mean estimate for that period was 1,062 Lake Sturgeon with no detectable trend. Several important uncertainties surrounding the model assumptions have been identified (e.g., whether capture probability is the same for all individuals).

All population estimates from the Alberta portion of MU1 only include Lake Sturgeon older than three years of age, the time at which they first become vulnerable to the gear. In 2007, 18 of 69 (26%) Lake Sturgeon sampled and aged from MU1 were older than age 20 years. Using the 2007 abundance estimate of 1,463 (95% CI: 785-2,725) (ASRD, unpubl. data) and assuming a 1:1 sex ratio and spawning interval of 4-7 years, suggests there may be about 27-48 females spawning each year in the Alberta portion of MU1.

The status of Lake Sturgeon in MU1 is cautious (Table 1). The population trajectory is thought to be stable in Alberta (ASRD, unpubl. data) and, based on anecdotal evidence, stable or increasing in Saskatchewan.

South Saskatchewan River: upstream of Gardiner GS (MU2)

In Alberta, population estimates derived from Lake Sturgeon mark-recapture studies conducted in the South Saskatchewan River in 1968-78, 1985-86 and 2003, and analyzed using a closed population model, indicate that the population ranged from less than 3,000 to about 4,500 fish older than age 3 years and that it increased over that period (Radford 1980, R.L. & L. Environmental Services Ltd 1991, Saunders 2006). None of the population estimates included the Bow, Red Deer or Oldman rivers. ASRD has analyzed more recent Lake Sturgeon tagging data from the Alberta portion of MU2 using open population models. The results indicate that Lake Sturgeon greater than three years of age may have increased from 3,644 (95% CI: 2,362-5,621) in 2003 to 8,681 (95% CI: 5,881-12,815) in 2009 and that the potential increase may have been driven by recruitment (ASRD, unpubl. data). Comparison of the recent results with the 1968-78 abundance estimate indicates that the population has increased from 1970 to present day. While these data are the best available, several important uncertainties have been identified (e.g., whether capture probability is the same for all individuals).

In Saskatchewan, the abundance of Lake Sturgeon in MU2 has not been estimated but this species is reported to frequent the Leader area, near the border with Alberta (Smith 2003) where higher catches have occurred since 2000.

The status of Lake Sturgeon in MU2 is cautious (Table 1). The population trajectory is thought to be increasing in Alberta and, based on anecdotal evidence, stable or increasing in Saskatchewan.

South Saskatchewan River: Gardiner GS – The Forks (MU3)

Little is known about Lake Sturgeon abundance in this MU but no recent occurrences have been reported upstream of Saskatoon and only a few have been reported downstream, thus it appears Lake Sturgeon abundance is very low. Population status and trajectory are critical and unknown, respectively (Table 1).

Saskatchewan River: The Forks – François-Finley GS (MU4)

Little is known about numbers of Lake Sturgeon in this MU. Historically, Lake Sturgeon occurred at ferry crossings and in the Fort-a-la-Corne area but no estimates of abundance are available. In recent years, they seem to be increasing in abundance about 20 km downstream of The Forks. The status of Lake Sturgeon in this MU is thought to be cautious and anecdotal evidence suggests the population trajectory may be stable or increasing (Table 1).

Saskatchewan River: François-Finley GS – E.B. Campbell GS (MU5)

This MU served as an egg supply source for provincial stocking from 2003 to 2007. All the fry and fingerlings were stocked into MU6, usually below E.B. Campbell GS or Bigstone Rapids (near Cumberland House), except in 2006 and 2007 when 10% were returned to Tobin Lake (MU5). During the recent mark-recapture study in MU5, a variety of age classes were captured and there were few recaptures from year to year, thus moderate numbers of Lake Sturgeon may be present. However, since the early 1960s most of this 70-km MU has been a reservoir so population status is deemed to be cautious (Table 1). Population trend is unknown.

Saskatchewan River: E.B. Campbell GS – Grand Rapids GS (MU6)

In this MU, Lake Sturgeon declined in abundance by more than 80% from an estimated 10,000-16,000 fish to less than an estimated 1,300 fish between 1960 and 2001 (Wallace 1991). A loss of half the mature Lake Sturgeon in a five year period occurred during construction of the E.B. Campbell GS in about 1960 (Wallace 1991). Between Cumberland House (Saskatchewan) and Cedar Lake (Manitoba), Lake Sturgeon abundance may have declined by 50% between 1998 and 2003 (COSEWIC 2006). Catch per unit effort (CPUE) data showed similar severe declines in Lake Sturgeon abundance in this MU between the mid-1970s and mid-1990s (Findlay 1995, Findlay *et al.* 1995). By 2000, very low Lake Sturgeon abundance (e.g., 0.002 Lake Sturgeon/yard of net/day) was reported for the waters between Cumberland House and The Pas (Wallace and Leroux 1999, Bretecher and MacDonell 2001). Stocking activities were undertaken in 1999-2001 to artificially increase recruitment. Eggs and milt were collected from Bigstone Rapids in 1999 and 2000 (North/South Consultants Inc. 2002). In 1999, a total of 33,000 fry were stocked near Cumberland House during summer and 7,000 fingerlings near The Pas (Manitoba) in September. In 2000, 22,000 fry and 300 fingerlings were stocked near Cumberland House in June and September, respectively. Success of the stocking programs is unknown. Little is known about Lake Sturgeon in Cedar Lake and contiguous waters though local knowledge reports that incidental catches do occur there on an annual basis. Based on available information, including 15 years of tagging data, population status and trend in MU6 are thought to be critical and stable, respectively (Table 1).

INFORMATION TO SUPPORT IDENTIFICATION OF CRITICAL HABITAT

Survival and recovery of Lake Sturgeon depend on the availability of habitat for key components of the life cycle: spawning, rearing, summer feeding, overwintering and migration. In general, the Lake Sturgeon is found in water depths of at least 5 m except during spawning. However, anglers regularly catch Lake Sturgeon in water depths of 3-5 m in the Alberta portion of MU1. They are thought to move to deeper waters during warmer periods and return to shallower waters when temperatures decline. This may reflect seasonal or diel changes in distribution and also may vary by waterbody. Movements appear to be limited, except for spawning migrations (Fortin *et al.* 1993). Research indicates that habitat preferences may vary between waterbodies.

The earliest age-0 stage, from hatch to first feeding (about 7-10 days), is assumed to be critical for survival and recovery of Lake Sturgeon but research on this life stage is only now underway. Age-0 fish have been captured in a variety of habitat types. In small tributaries of the Great Lakes, age-0 fish use shallow riverine areas with low current velocity, sand substrates and an abundance of dipteran larvae (Benson *et al.* 2005). In large rivers, they have been captured in habitat characterized by depths > 10 m, water velocities ranging from 0.1-0.3 $m \cdot s^{-1}$ and substrates comprised of clay, sand and gravel/cobble (C. Barth, unpubl. data).

Finer substrate types, like clay and sand, are reported to be preferred habitat for juvenile Lake Sturgeon as they contain larger amounts of small benthic prey (see review by Barth *et al*. 2009), however juvenile rearing habitat has also been reported to include areas of coarse-sand and pea-sized gravel (Smith 2003). In the St. Lawrence River, juveniles were most abundant in areas with water depths of 3-6 m, currents of 0.25-0.50 $m \cdot s^{-1}$ and silt/sand substrates (Hayes and Werner 2002, Randall 2008). In the Winnipeg River, juvenile Lake Sturgeon preferred deep water areas greater than 13.7 m with detectable currents (i.e., greater than 0.2 $m \cdot s^{-1}$) over a variety of substrate types between June and November (Barth *et al.* 2009). Depth was shown to be the primary abiotic factor influencing habitat selection in juvenile Lake Sturgeon from the Winnipeg River (Barth *et al.* 2009).

Some evidence indicates that after their first year, juveniles are found in the same habitats as adults (Priegel and Wirth 1974). Other evidence indicates that age-0 and juvenile Lake Sturgeon may occupy habitats different than those of adults to avoid competition and that younger fish use individual areas of activity rather than the core areas used by adult groups in riverine environments (Smith and King 2005). The habitat requirements of young Lake Sturgeon appear to be more restricted (Chiasson *et al.* 1997) and, thus, availability of suitable habitat may be more limiting for age-0 and early juvenile life stages than for adults. Adult life stages tend to be more plastic, adapting to various habitat conditions (Werner and Hayes 2005). Juvenile rearing areas have been identified in the Alberta portion of MU1 but not in the Saskatchewan portion. Potential juvenile rearing areas have been identified in parts of the Alberta portion of MU2, in at least four locations in MUs 2 and 3 within Saskatchewan and at three sites in MUs 4 and 5 (Smith 2003), as well as between Cumberland House and Big Bend in MU6 (Bretecher and MacDonell 2001).

Migration of adult Lake Sturgeon is functionally linked to movement between the adult feeding and spawning habitat. Open connections between these habitats are necessary, as adults may be required to migrate considerable distances to find suitable spawning habitat (Randall 2008).

Adults typically spawn in late spring, in water temperatures of 11.5-16°C in high-gradient reaches of large rivers, often below rapids or dams, with current velocities of 0.5-1.3 $m \cdot s^{-1}$, water depths of

0.5-10 m, and over substrates of cobble, boulders, coarse gravel, hardpan, or sand (McKinley *et al*. 1998, Peterson *et al.* 2007, Randall 2008, R. Wallace, pers. comm.). Cascades and/or suitable water flows are necessary to keep the eggs healthy by ensuring strong oxygenation and cleaning action preventing sediment deposition while eggs incubate. Conditions necessary for successful spawning are typically found below dams and other barriers. During the incubation period, eggs adhere to the substrate. Spawning success is dependent on the availability of prime substrates, as sub-optimal substrates can significantly reduce spawning success if flushing flows occur during the incubation period and carry eggs downstream. Spawning habitat is also used for hatching and by the newly-hatched young for a period of about one month before larval drift occurs (Randall 2008). Fidelity to spawning sites is known in Lake Sturgeon though these may vary among years in response to flow conditions (Barth and MacDonell 1999). A number of potential spawning sites have been reported for DU2 (Smith 2003). In addition to historic spawning sites, four sites have been noted for the North Saskatchewan River (MU1) including the old Maymont Ferry crossing and upstream of the Cecil Ferry to The Forks. An artificial spawning area was developed within Edmonton city limits using methods and materials recommended by the Wisconsin Department of Natural Resources (D. Watters, pers. comm.). Several sites have been identified in the South Saskatchewan River (MU2), including the confluences of the tributaries of the Oldman and Bow rivers in Alberta, and the confluence of the Red Deer River in Saskatchewan. Ferry locations between Saskatoon and The Forks have been reported as potentially suitable spawning sites in MU3. Four sites have been identified for the Saskatchewan River. At least two are located above the E.B. Campbell GS, including the Fort-a-la-Corne Rapids in MU4 and farther downstream in MU5, and four downstream of the GS (MU6). In MU6, potential and actual spawning locations include the rapids in the Torch River, E.B. Campbell GS tailrace and Bigstone Rapids (Wallace 1991, Smith 2003). The former Tobin and Iskwao rapids, located at the site of the E.B. Campbell GS, contain suitable spawning substrate but are now dry (Wallace 1991). Potential spawning sites may exist downstream of the Pas in a 10 km stretch of river between Bucks Island and Wooden Tent (R. Campbell, pers. comm.).

Tagging studies have documented that Lake Sturgeon movements are complex. Some individuals may move substantial distances away from core areas and then return weeks or months later, while others will remain in the core area or leave and not return. Regardless, many or most Lake Sturgeon groups demonstrate a preference for certain areas, at least in riverine environments (Fortin *et al.* 1993, Rusak and Mosindy 1997, Knights *et al.* 2002, Barth and Ambrose 2006).These areas appear to contain hydraulic features characterized by transition from high-current velocities to slower velocities (e.g., the confluence of the main river channel with a tributary). These local changes in size and shape of the river result in depositional substrates where silt accumulates, providing good habitat for invertebrates which, in turn, provides good feeding habitat for Lake Sturgeon. Core areas of activity for groups of Lake Sturgeon may be more important in flowing (i.e., lotic) than lake (i.e., lentic) environments (Smith and King 2005).

Current velocity also appears to be an important variable in determining preferred habitat of Lake Sturgeon throughout the year (Rusak and Mosindy 1997). Juveniles are reported to use areas with detectable currents (i.e., greater than 0.2 $m \cdot s^{-1}$) (Barth *et al.* 2009). Adults prefer habitats with moderate water flow (< 0.6 $m \cdot s^{-1}$) (Benson *et al.* 2005). They appear to avoid areas with high current velocity, except during spawning, which are typically associated with increased energy costs and diminished food resources (Knights *et al.* 2002). Seasonal and annual changes in flow may affect fidelity to specific spawning and feeding areas.

Not as much is known about habitat preferences during winter. Burton *et al.* (2004) and Environnement Illimité inc. (2007) found that during winter, adult Lake Sturgeon tended to gather at water depths of 6-8 m (max. depth 20 m), and water velocities of 0.2 $m \cdot s^{-1}$ or less (max. velocity:

0.4 $m \cdot s^{-1}$) (Burton *et al.* 2004, Environnement Illimité inc. 2007). Overwintering substrate was typically silt and sand (Environnement Illimité inc. 2007). Juvenile Lake Sturgeon tended to congregate at the same depths as adults (max. depth 12 m). They also appeared to prefer the same flow velocities although some juveniles were observed at flow velocities as high as 0.4-0.6 $m \cdot s^{-1}$ (Environnement Illimité inc. 2007). Juveniles often spend the winter over silt and sand substrates and less so over gravel (Environnement Illimité inc. 2007). Overwintering habitat occupied by Lake Sturgeon in the North Saskatchewan River in the Alberta portion of MU1 is typically characterised by deep (> 3 m depth) outside bends with an upstream inflowing tributary on the mainstem river (D. Watters, pers. comm.). Occasionally, shallower (< 3 m depth) habitat may be used during the closed-water season. Lake Sturgeon typically occupy these habitats in late fall (October) and remain until the onset of ice break-up in April. Subsequent to identification of important Lake Sturgeon overwintering, foraging and spawning habitats in the Alberta portions of MUs 1 and 2, these habitats were designated as Class A “No Touch” areas and were afforded protection from any new development (Figures 3 and 4). Maintenance of existing facilities is permitted with rigorous operating conditions. On the Saskatchewan River, overwintering habitat of tagged Lake Sturgeon has only been reported in the mainstem, perhaps because winter flows in secondary channels and some lakes (e.g., Cumberland Lake) may not provide sufficient depths or levels of oxygenation (Wallace and Leroux 1999).

In summary, maintaining the functional attributes of habitat, including the ecologically-based flow regimes, needed for spawning, egg incubation, juvenile rearing, summer feeding and overwintering, as well as migration routes between these habitats, is critical to the survival and recovery of Lake Sturgeon. The current distribution of Lake Sturgeon in the Saskatchewan rivers system (DU2) is fragmented by dams, which may be limiting the availability of spawning habitat in some MUs. It is essential that conditions that optimize the survival and recovery of Lake Sturgeon be maintained in DU2, especially during the spawning and incubation periods.

RESIDENCE

SARA defines a *residence* as “a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating”. Residence is interpreted by DFO as being a *constructed* place (e.g., a spawning redd). The Lake Sturgeon does not change its physical environment or invest in a structure during any part of its life cycle, therefore no biological feature of this species meets the SARA definition of residence as interpreted by DFO.

RECOVERY TARGETS

DFO has determined that Population Viability Analysis (e.g., minimum viable population (MVP)) is a good approach for setting recovery targets for species at risk (DFO 2010) and meets the SARA requirement for demographic sustainability. MVP size has often been used as the abundance target. Vélez-Espino and Koops (in prep.) used MVP analysis of stage-structure demographic matrices to calculate recovery targets for Lake Sturgeon in DUs 1-5. They calculated that each MU in DU2 would need at least 586 spawning females per year (i.e., 5,860 adults) to achieve a 99% probability of persistence of Lake Sturgeon over 250 years, given a probability of catastrophe (50% decrease in the abundance of all life stages in one year) of 14% per generation, and assuming a balanced sex ratio and 5-year spawning periodicity and a sufficient number of juveniles to support the adult population goal. Using MVP combined with information on area per individual and stable stage distributions, Vélez-Espino and Koops (in prep.) calculated that at least 974 ha of Lake Sturgeon habitat for lotic (riverine) environments, or approximately twice as much for lentic (lake) environments, is needed to support all life stages of a viable MU in DU2 at the recommended recovery target. On average, age-0 individuals would require 2.3% of the total area of required habitat, juveniles 45.3% and adults 52.3%.

The MVP modelling uses vital rates as inputs, and it is important to note that there are uncertainties associated with these vital rates. For example, the vital rates data may not have been specific to the DU being modelled, recent unpublished data may not be available or assumptions used in the model (e.g., a balanced sex ratio) may not accurately represent current conditions for that DU. Additionally, the recovery target may not reflect historic Lake Sturgeon abundance before over-exploitation and habitat degradation or loss began. In spite of uncertainty around the model output, its results are still useful and provide a recovery target to work towards. The model can be updated once new information comes available.

On the basis of this information, a minimum recovery goal and population and distribution objectives were developed. The long-term recovery goal for DU2 is to protect and maintain healthy, viable populations of Lake Sturgeon in all MUs within the Saskatchewan rivers system. To reach this goal, each MU must have at least 586 spawning females each year (i.e., 5,860 adults) and at least 974 ha of suitable riverine habitat or 1,948 ha of suitable lake habitat. The aim is to reach these population and distribution objectives within three generations (i.e., about 108 years).

Vélez-Espino and Koops (in prep.) chose a recovery target that, if undertaken, would achieve a significant reduction in the probability of extinction of Lake Sturgeon in DU2. If a less precautionary recovery target is chosen, the number of spawning females per year would be reduced and years to recovery increased accordingly.

Vélez-Espino and Koops (2009) modelled recovery efforts combined with recovery targets to project recovery timeframes as a stochastic process under a number of management scenarios targeting different combinations of Lake Sturgeon vital rates. They estimated MVP as the number of adults required for a 99% chance of persistence over 40 generations (> 1,000 years). Vélez-Espino and Koops (in prep.) re-calculated MVP as the number of adults required for a 99% chance of persistence over 250 years. Regardless of the change in some parameters, the long-term projections and timeframes for recovery reported by Vélez-Espino and Koops in 2009 do not change given that initial population sizes used in the model simulations are relative (1-10%) to the recovery target (M. Koops, pers. comm.). When current abundances are assumed to be 10% of the recovery target, the times-to-recovery range from about 20 years to around 95 years (i.e., about 1-3 generations), depending on the recovery actions implemented (Vélez-Espino and Koops 2009) (Figure 5). Recovery timeframes diminish if Lake Sturgeon spawning periodicity is shorter or reproductive effort is higher than expected and, conversely, will lengthen if spawning periodicity is longer or reproductive effort is lower than expected (Vélez-Espino and Koops 2009).

The recovery potential and importance to recovery of each of the six Lake Sturgeon MUs in DU2 was evaluated on the basis of available information (e.g., quantitative population data) and expert opinion (Table 1). Recovery potential is high for MUs 1 and 2. MU1 may currently contain no more than 50-100 annual female spawners but current population numbers are thought to be stable in Alberta and stable or increasing in Saskatchewan so recovery is possible though likely protracted. MU2 likely has no more than 300-500 female spawners each year but the population is thought to be increasing, at least in Alberta, thus recovery should be attainable with appropriate management and/or recovery efforts. MU3 is negatively impacted by Gardiner GS upstream and Lake Sturgeon numbers are low thus recovery potential is low. In MU4, recovery potential is moderate as anecdotal information suggests that Lake Sturgeon numbers are stable or increasing at one or more locations. While it appears that moderate numbers of Lake Sturgeon currently exist in MU5, serious habitat degradation resulting from the construction and operation of the François-Finley GS and E.B. Campbell GS, at either end of the MU, restricts the potential for recovery to low. MU6 may contain only about 100 spawning females each year but population numbers are thought to be stable and recovery efforts are underway, thus recovery potential is rated as high. The importance of MUs 1, 2, 4 and 6 to species recovery in DU2 are thought to be high while the importance of MUs 3 and 5 are low.

In order to meet the recovery goal and recommended population and habitat objectives, within the suggested timeline, threats must be identified and removed or mitigated.

THREATS TO SURVIVAL AND RECOVERY

The life history traits of Lake Sturgeon, including large size, delayed maturation, low natural adult mortality and high fecundity, allow this species to be successful when facing extremes in environmental conditions and consequently have contributed to the long-term success of the species. Unfortunately, many of these traits became disadvantageous when faced with human-induced mortality and habitat changes (Beamesderfer and Farr 1997).

In Alberta, commercial and recreational fisheries for Lake Sturgeon were closed from 1940 to 1968, followed by the opening of a sport fishery which continues today as a catch-and-release fishery in the North Saskatchewan River (MU1). Total mortality rate including this fishery is estimated at 10% (ASRD 2002); a more recent estimate is not available. Poaching is occurring in MU1 (D. Watters, pers. comm.). As of 2004, harvesting of Lake Sturgeon in the Alberta portion of the South Saskatchewan River (MU2) is no longer permitted. The mortality rate associated with fishery may have been upwards of 20% (ASRD 2002). A conservation closure is in place for subsistence fishing and only a catch-and-release fishery is currently allowed. While mortality from illegal harvest and poor fish handling is known or likely occurring, increased enforcement effort and angler education through signage and media releases is also happening (D. Watters, pers. comm.).

In Saskatchewan, the Lake Sturgeon was harvested for subsistence until around 1890 when the arrival of the railway improved export opportunities. Substantial harvests were recorded as early as 1892 (Dominion of Canada, Department of Fisheries (Dom. Can. Dep. Fish.) 1892). A voluntary moratorium on the commercial fishery commenced in 1996. Up until 1999, the angling limit had been one Lake Sturgeon daily and two in possession. Since then, anglers who catch Lake Sturgeon are required to release them immediately (Smith 2003). The Aboriginal domestic fishery is the only remaining legal harvest of Lake Sturgeon in Saskatchewan and those levels have not been reported for any of the MUs except MU6.

In Manitoba, commercial harvests of Lake Sturgeon from the Saskatchewan River system were first reported in the 1880s (Stewart 2009). Fish were taken from Cedar Lake as well as the Saskatchewan River. Commercial and sport harvests of Lake Sturgeon were discontinued by 1996 and 1999, respectively, leaving the Aboriginal domestic fishery as the remaining legal harvest for Lake Sturgeon in the Lower Saskatchewan River and Cedar Lake area. Some evidence in recent years indicates that Lake Sturgeon are incidentally captured and released by commercial fishers and anglers (R. Campbell, pers. comm.).

Harvest studies were conducted downstream of the E.B. Campbell GS, in Saskatchewan and Manitoba (MU6), in 2001 and 2002. Over the two summers, the harvest surveys estimated that 75-320 Lake Sturgeon were harvested by aboriginal fishers, though the sampling methods were not well documented so the estimates should be viewed with caution (North/South Consultants Inc.

2003). Extrapolated harvest estimates indicated that the harvest of Lake Sturgeon weighing 8 kg or more may have represented as much as 12.3% of the population estimate. At least 50% of the population weighed less than 8 kg therefore a similar percentage of smaller Lake Sturgeon was also being harvested. Annual harvest rates that are thought to be sustainable for Lake Sturgeon are typically 5% or less (Threader and Brousseau 1986, Beamesderfer and Farr 1997, Secor *et al.* 2002, Auer 2003, Bruch 2008). A guideline developed for rehabilitation of Lake Sturgeon in the State of Michigan, for populations that currently exist, specifies maintaining fishing mortality below 3% for an expanding population and below 6% to maintain Lake Sturgeon abundance (Hay-Chmielewski and Whelan 1997). If the actual MU6 harvest rates in 2001-02 were close to 12.3% or more, then they were unsustainable (North/South Consultants Inc. 2003).

Six hydroelectric GSs (Bighorn, Brazeau, E.B. Campbell, Grand Rapids, Gardiner and François-Finley) and other man-made barriers were developed on the Saskatchewan rivers system and its tributaries in the latter half of the twentieth century (Figure 1). Others have been, or may be, considered in the future (e.g., the Meridian GS). Dams and control structures elsewhere have been shown to alter the natural flow regime and fragment habitat resulting in degradation and/or loss of Lake Sturgeon habitat, loss of genetic diversity, reduced spawning success, reduced prey availability (through removal of prey items by flushing flows and entrainment or exposure during low flows) and mortality (e.g., excessive siltation leading to loss of critical age-0 fish) (see review in Pratt 2008). Dam construction can extirpate local Lake Sturgeon populations (Dumont *et al.* 1987) by preventing fish from accessing spawning areas and stranding fish between impassable barriers. There is some evidence that at least the dams on the South Saskatchewan and Saskatchewan rivers caused fragmentation of habitat and, thus, isolation of Lake Sturgeon (Findlay *et al.* 1995), as well as considerable loss and degradation of important habitat that resulted in reduced recruitment (Findlay *et al.* 1997). Larger structures, like hydroelectric dams, can also cause injury or direct mortality from exposure to rapid and extreme water pressure changes, cavitation, shear, turbulence and/or mechanical injuries (Cada 1998) through entrainment[1], impingement[2] and fish passing downstream through the turbines (Hay-Chmielewski and Whelan 1997, McKinley *et al.* 1998). However, the intakes of most hydroelectric GSs are covered by bars or grates spaced such that they prevent passage of adult Lake Sturgeon through turbines.

Other human activities have also contributed to the degradation of Lake Sturgeon habitat in DU2. Over the past century, quality of water and substrate in the Saskatchewan rivers system have deteriorated due to agricultural activities and, in the North and South Saskatchewan rivers, forestry and urban development. These activities are known to cause a variety of habitat effects including erosion, suspended sediments, the addition of sewage effluents and nutrients and water withdrawals, all of which contribute to the degradation or loss of Lake Sturgeon habitat.

In summary, the most important current threats to survival and recovery of Lake Sturgeon in DU2 are habitat degradation or loss resulting from dams/impoundments and other barriers, agriculture, urban development and forestry, mortality, injury or reduced survival resulting from fishing, and population fragmentation resulting from dams/impoundments and other barriers (Table 2). The likelihood and severity of individual threats may vary by MU. All other threats that have been identified for other DUs in Canada are relatively unimportant or their impacts are unknown in DU2. The timeframe and impacts of climate change are unknown.

[1] Entrainment occurs when fish eggs and larvae are taken into a facility's water-intake systems, pass through and back to the water body.
[2] Impingement occurs when fish are trapped or pinned by the force of the intake flow against the intake.

LIMITING FACTORS FOR POPULATION RECOVERY

The Lake Sturgeon possesses several intrinsic or evolved biological characteristics that make this species susceptible to over-exploitation and habitat changes and may naturally influence or limit potential for recovery: (1) slow growth and late maturation, (2) intermittent spawning intervals, (3) specific temperature, flow velocities and substrate requirements to ensure uniform hatching and high survival of eggs and (4) high fidelity to spawning areas. The early age-0 stage (transition from larvae to exogenous feeding) is a critical life stage for Lake Sturgeon.

MITIGATION, ALTERNATIVES AND ENHANCEMENTS

As with the impacts of threats, suggested mitigations and alternatives can also differentially affect survival or productivity of certain life stages. Vélez-Espino and Koops (2009) examined the effects of five hypothetical recovery scenarios that represented positive and increasing impacts on the Lake Sturgeon vital rates derived from habitat rehabilitation, stocking, modified fishing regulations, and improved fish passage at barriers. They used a stage-structured projection matrix with five life stages. Young-of-the-year, referred to as age-0 in this document, was the stage from eggs to age-1. The juvenile stage was defined as the period from the end of the first year to the mean age at first maturity, with the early and late juvenile stages being the first and second half of this period. The early and late adult stages referred to the first and second half of the adult period, respectively, and covered the period from mean age at first maturity to maximum reproductive age where total length is 95% of asymptotic length. Their modelling results indicated that even if the main causes of population decline are removed from Lake Sturgeon in DU2, geometric mean population growth rates will continue to show declining abundances. The Lake Sturgeon in this DU is highly sensitive to harm with early adults most sensitive, followed by late juveniles, early juveniles, age-0 and late adults (in decreasing order).

Fishing mortality, one of the main causes of population decline in DU2, has been largely eliminated over the past few decades. Contrary to the modelling results, recent research in DU2 indicates that Lake Sturgeon may be showing signs of recovery in at least three MUs (i.e., 1, 2 and 4). While this is encouraging, the modelling results highlight the importance of reducing mortality on adults and late juveniles (e.g., from fishing) as the key to recovering this DU, and indicate that any recovery measures that maximize survival of these stages will increase the likelihood of, or shorten the time to, recovery (Vélez-Espino and Koops 2009). While elimination of mortality to early adults and late juveniles can produce significant improvements in recovery timeframes, the potential for improving survival of early adults is low relative to the potential in age-0 and young juveniles (Table 3) (Vélez-Espino and Koops 2009). Therefore, the possibility of implementing recovery strategies that improve age-0 and juvenile survival (e.g., habitat rehabilitation) should also be considered. For example, in some circumstances it may be possible and desirable to improve age-0 and young juvenile survival by capturing pre-spawn adult Lake Sturgeon, stripping them of their eggs and sperm, fertilizing and hatching the eggs, and raising the larvae to fingerlings before releasing them back into their natal waters. Conservation stocking programs must address potential impacts on genetic variability, artificial selection and transmission of disease from cultured to native fish (LaPatra *et al.* 1999). In an effort to conserve genetic variability in the native population, a better alternative would be to capture drifting larval fish or fertilized eggs and raise them in onsite facilities prior to release. While conservation stocking using fish from the same genetic stock has the potential to improve survival of age-0 and young juvenile fish, it should be undertaken only after careful consideration and as part of a comprehensive conservation stocking strategy for the DU, not a substitute for other effective mitigation measures or alternates outlined in this document.

Fertility rates in both early and late adult stages are less sensitive to perturbation. Although eliminating or mitigating threats to adult mortality would have a substantially greater impact on recovery than threats that cause impacts on reproduction (e.g., denial of access to spawning through dams and barriers) (Vélez-Espino and Koops 2009), continuous and intense recruitment failure caused by blocking spawning migration by dams and barriers or habitat degradation can still produce more apparent population constraints than adult mortality (Jager *et al.* 2007). Complete blockage of spawners at barriers can eradicate a population in a generation from continuous reproductive failure and strong site fidelity for spawning (Swanson *et al.* 1991, Rusak and Mosindy 1997).

Table 4 provides an inventory of possible mitigation measures, alternatives and enhancements to anthropogenic activities that pose threats to Lake Sturgeon survival and recovery. The mitigations/alternatives/enhancements for the most important threats for DU2, as identified in Table 2, are explained more fully below.

Mitigations and Alternatives

Habitat degradation or loss: dams/impoundments and other barriers

- Adjust water management operating conditions of dams/impoundments and other barriers for those currently in place and those planned in the future to optimize the survival and recovery of Lake Sturgeon, especially during the spawning and incubation periods.
- Rehabilitate habitat in key areas to mitigate habitat degradation or loss of important habitat (e.g., spawning sites) and to improve age-0 and juvenile survival.
- Ensure design of new dams and modernization of existing dams does not jeopardize the survival and recovery of Lake Sturgeon (e.g., consider possible need for fish passage).
- Protect spawning and rearing habitat.

Habitat degradation or loss: agricultural activities

- Prevent significant sedimentation, especially during winter or spring.
- Minimize release of contaminants.
- Prevent significant changes in water temperature, total gas pressure, salinity or nutrient concentrations.
- Prevent removal of substrates of coarse gravel, cobble, boulders, hardpan or sand in known or suspected spawning areas.
- Prevent significant changes in water flow, especially during spring (when spawning and rearing occur).
- Advocate proper drainage (properly maintained functional drains will reduce direct loading to streams).
- Protect spawning and rearing habitat.
- Rehabilitate habitat in key areas to mitigate habitat degradation or loss of important habitat (e.g., spawning sites) and to improve age-0 and juvenile survival.

Habitat degradation or loss: urban development

- Enforce discharge limits on potential pollutants (e.g., effluent from water treatment plants, pollution point sources).
- Improve effluent from water treatment plants.
- Increase protection during work permit reviews.

- Rehabilitate habitat in key areas to mitigate habitat degradation or loss of important habitat (e.g., spawning sites) and to improve age-0 and juvenile survival.
- Protect spawning and rearing habitat.

Habitat degradation or loss: forestry exploration/extraction

- Prevent significant sedimentation, especially during winter or spring.
- Minimize release of contaminants.
- Prevent significant changes in water temperature, total gas pressure, salinity or nutrient concentrations.
- Prevent removal of substrates of coarse gravel, cobble, boulders, hardpan or sand in known or suspected spawning areas.
- Prevent significant changes in water flow, especially during spring (when spawning and rearing occur).
- Protect spawning and rearing habitat.
- Rehabilitate habitat in key areas to mitigate habitat degradation or loss of important habitat (e.g., spawning sites) and to improve age-0 and juvenile survival.

Mortality, injury or reduced survival: fishing

- Immediate release of bycatch to promote survivability.
- Examine ways and means of altering commercial net fisheries to reduce impacts on recovering Lake Sturgeon populations (e.g., trapnets versus gillnets, netting off the bottom, area closures such as limiting fishing near river mouths, close fishery).
- Regulate or encourage fishing practices that improve fish survival for catch-and-release fisheries, such as cutting lines of deeply-hooked fish, tight-line fishing, and minimizing "playing" and handling of hooked fish.
- Consider closure (e.g., conservation closures, closed seasons and areas), or at least reduce mortality, for adults through the use of legal size limits.
- Educate the public about the importance of Lake Sturgeon and what measures they can take to prevent over-exploitation.
- Ensure effective enforcement of regulations.

Mortality, injury or reduced survival: population fragmentation

- Prevent any additional fragmentation.
- Provide effective upstream and downstream fish passage for Lake Sturgeon at new dams and modernization of existing dams if necessary.
- Remove barriers that prevent Lake Sturgeon from migrating to known historical spawning sites, or provide effective upstream and downstream fish passage at current barriers if necessary.
- Rehabilitate habitat in key areas to mitigate habitat degradation or loss of important habitat (e.g., spawning sites) and to improve age-0 and juvenile survival.
- Select the most appropriate design option for new dams and modernization of existing dams to ensure Lake Sturgeon survival and recovery are not jeopardized.

Enhancements

The following population enhancements could be considered supplementary measures to the mitigations and alternatives indicated above.

- Enhance age-0 and young juvenile survival through a conservation stocking program that does not introduce disease or reduce the genetic fitness of naturally-reproducing Lake Sturgeon.

ALLOWABLE HARM

Decisions about whether harm from human-induced mortality and habitat modifications is allowable are informed by the potential for recovery and the impact of human activities as well as alternate and mitigation measures to those activities. Vélez-Espino and Koops (2009) modelled allowable harm for DU2. They reported that even if the main causes of population decline are removed, the minimum recovery efforts for individual vital rates that would be necessary to reverse declines in abundance would be approximately 6.0-28.7% increments in adult survival, 11.3-27.3% in juvenile survival, 29.6% in age-0 survival and 59.4-91.9% in fertility rates (Table 3). Lake Sturgeon populations are most sensitive to early adult survival and a minimum increase of 6% in this vital rate, or close to zero mortality depending on which is more feasible, would be required to achieve recovery targets for abundance. Further, it may be necessary to simultaneously improve other vital rates, in addition to early adult survival, in order achieve target population growth rates. However, it is not feasible to increase survival rates sufficiently for late adults and fertility rates for early and late adults to achieve recovery (Table 3).

Negative impacts associated with habitat degradation or loss from dams/impoundments and other barriers, agriculture, urban development and forestry, as well as fishing and population fragmentation associated with dams/impoundments and other barriers, currently pose the most significant threats to the long-term survival and recovery of Lake Sturgeon in DU2, although their importance varies by MU. Dams and other barriers, and habitat degradation, have the potential to negatively impact all three life stages while fishing focuses on juveniles and adults. It may be possible to estimate harm resulting from threats such as entrainment, impingement, turbine mortality and fishing but assessing the levels of harm resulting from threats such as changes in flow regime, and habitat fragmentation and degradation, are more difficult to quantify.

While modelling allowable harm at the DU level provides useful information, careful examination of conditions within an MU is necessary to fully assess the level of risk posed by harm from human-induced mortality and habitat modifications. Available data and expert opinion indicate that survival and recovery would be, at best, very slow in MU3 and likely restricted in MU5. Thus, activities that damage or destroy functional components of habitat or key life components of the life cycle (e.g., spawning, recruitment and survival) pose a very high risk to survival or recovery of any remaining Lake Sturgeon populations in those two MUs. Recovery in MUs 1, 4 and 6 is deemed possible but may be protracted given current knowledge of population abundance and trajectory, so harmful activities pose a moderate to high risk to survival or recovery there. The Lake Sturgeon seems to be most abundant in MU2 and the population trajectory appears to be increasing, at least in Alberta. Activities that damage or destroy habitat or key life components there pose a moderate risk to survival or recovery. Allowable harm in DU2 should be assessed on a case-by-case basis, keeping in mind the cumulative effects of all threats to the DU, to ensure that survival and recovery of Lake Sturgeon are not jeopardized.

Research activities should be allowed if they are beneficial to the species and would not jeopardize the survival or recovery of an MU.

DATA AND KNOWLEDGE GAPS

The relationship between key life history stages and habitat in DU2 needs to be better understood, as does the current level of domestic harvest. Obtaining reliable estimates of population size, population growth rate and harvest in each MU is a high priority. Surveys are needed to identify where spawning and feeding occur and whether access to, and the quantity and quality of spawning habitat for, individual MUs is sufficient. The habitat needs of age-0 and juvenile Lake Sturgeon should be better understood. Determination of the impact of altered flow regimes and other environmental factors on egg, larval and juvenile survival, and corresponding mitigation measures would be useful. The additive or cumulative effects of multiple dams/impoundments and barriers on Lake Sturgeon populations also should be investigated. MVP modelling needs to be updated as new knowledge about vital rates is obtained for each MU.

SOURCES OF UNCERTAINTY

For almost a century, Lake Sturgeon ages have been estimated by counting annuli in transverse sections of pectoral fin rays. Recently the accuracy of this ageing technique and others were tested using bomb radiocarbon (^{14}C) assays (Bruch *et al.* 2009). Age estimates made using growth increments on pectoral fin spine cross sections were found to underestimate the true age of fish older than 14 years and error increased with age; the average difference was -4.96 ± 4.57 years, and ranged from +2 to -17 years (Bruch *et al.* 2009). A correction factor has been developed to correct existing age estimates obtained using this method, though validation studies are needed to determine whether there are differences among populations.

Some uncertainties may exist regarding the Lake Sturgeon vital rates used in the MVP modelling. For example, the vital rates data may not have been specific to the DU being modelled, recent unpublished data may not be available or assumptions used in the model (e.g., a balanced sex ratio) may not accurately represent current conditions for that DU.

Assessing population size for Lake Sturgeon is difficult given the behaviour and ecology of the species. This makes it difficult to determine whether recovery targets are being met.

CONCLUSIONS

Six MUs have been identified for DU2: MU1 is located on the North Saskatchewan River downstream of the Bighorn GS, MU2 on the South Saskatchewan River upstream of Gardiner GS, MU3 on the South Saskatchewan River downstream of Gardiner GS, MU4 between the forks of the North Saskatchewan and South Saskatchewan rivers and François-Finley GS, MU5 between François-Finley GS and E.B. Campbell GS and MU6 between E.B. Campbell GS and Grand Rapids GS.

Over the past century, Lake Sturgeon in DU2 declined primarily as a result of over-exploitation from commercial fisheries and degradation or loss of a significant portion of their habitat as a result of dams/impoundments and other barriers. Available data and expert opinion suggest that Lake Sturgeon abundance in DU2 ranges from very low to moderate.

Available data and expert opinion indicate that the current status and population trajectory of MUs 1, 2 and 4 are cautious and stable or increasing, respectively. Abundance in MUs 1 and 4 is probably low to moderate while MU2 appears to be somewhat higher. MU5 is thought to be cautious though its trajectory is unknown. The status of MUs 3 and 6 is deemed to be critical with an unknown trajectory in MU3 and a stable trajectory in MU6.

Survival and recovery of Lake Sturgeon in DU2 depends on maintaining the functional attributes of habitat, including the ecologically-based flow regimes, needed for spawning, egg incubation, juvenile rearing, summer feeding and overwintering, as well as migration routes between these habitats. It is essential that conditions that optimize the survival and recovery of Lake Sturgeon be maintained, especially during the spawning and incubation periods.

The long-term recovery goal for DU2 is to protect and maintain healthy, viable populations of Lake Sturgeon in all MUs within the Saskatchewan rivers system. To reach this goal it will be necessary for each MU to have at least 586 spawning females (i.e., 5,860 adults) each year and at least 974 ha of suitable riverine habitat or 1,948 ha of suitable lake habitat. The aim is to reach these population and distribution objectives within three generations (i.e., about 108 years). If a less precautionary recovery target is chosen, the number of spawning females per year would be reduced and years to recovery increased accordingly.

The most important current threats to survival and recovery of Lake Sturgeon in DU2 are habitat degradation or loss resulting from dams/impoundments and other barriers, agriculture, urban development and forestry, mortality, injury or reduced survival resulting from fishing, and population fragmentation resulting from dams/impoundments and other barriers. The likelihood and severity of individual threats may vary by MU. The timeframe and impacts of climate change are unknown.

A variety of mitigation measures and alternatives could be implemented to aid in the survival and recovery of Lake Sturgeon in DU2 including protecting spawning and rearing habitat, minimizing activities that cause habitat degradation or loss, rehabilitating habitat in key areas and reducing impacts of the fishery through education and effective enforcement. Conservation stocking using fish from the same genetic stock may be a useful enhancement tool as part of a comprehensive conservation stocking strategy for the DU and when combined with mitigation measures and alternatives.

Activities that damage or destroy functional components of habitat or key life components of the life cycle pose a very high risk to the survival or recovery of Lake Sturgeon in MUs 3 and 5, a moderate to high risk in MUs 1, 4 and 6 and a moderate risk in MU2. Research activities should be allowed in DU2 if they are beneficial to the species and would not jeopardize the survival or recovery of an MU.

ACKNOWLEDGEMENTS

A background document prepared by Darren Derbowka was used in the development of this report.

LITERATURE CITED

ASRD. 2002. The status of the Lake Sturgeon (*Acipenser fulvescens*) in Alberta. Alberta Sustainable Res. Dev., Fish and Wildl. Div., and Alberta Conservation Assoc., Edmonton, AB. Alberta Wildlife Status Rep. No. 46. 30 p.

Auer, N.A. 1996. Importance of habitat and migration to Lake Sturgeons with emphasis on Lake Sturgeon. Can. J. Fish. Aquat. Sci. 53(Suppl. 1): 152-160.

Auer, N.A. 2003. A Lake Sturgeon rehabilitation plan for Lake Superior. Misc. Public. 2003-02. Great Lakes Fishery Comm., Ann Arbour, MI. 27 p.

Baker, J.P. 1980. The distribution, ecology, and management of the Lake Sturgeon (*Acipenser fulvescens* Rafinesque) in Michigan. Michigan Dep. Nat. Res., Fisheries Division. Fish. Res. Rep. No. 1883. 95 p.

Barth, C.C. and K.M. Ambrose. 2006. Lake Sturgeon investigations in the Keeysak study area, 2004. Keeyask Project Environmental Studies Program, Report 04-05. North/South Consultants Inc., Winnipeg, Manitoba. 86 p.

Barth, C.C. and D.S. MacDonell. 1999. Lower Nelson River Lake Sturgeon spawning study Weir River 1998. Unpubl rep. prep. for Manitoba Hydro by North/South Consultants Inc., Winnipeg, MB. 59 p.

Barth, C.C., S.J. Peake, P.J. Allen and W.G. Anderson. 2009. Habitat utilization of juvenile Lake Sturgeon, *Acipenser fulvescens*, in a large Canadian river. J. Appl. Ichthyol. 25(supp. 2): 18-26.

Beamesderfer, R.C.P. and R.A. Farr. 1997. Alternatives for the protection and restoration of sturgeons and their habitat. Environ. Biol. Fishes 48: 407-417.

Benson, A.C., T.M. Sutton, R.F. Elliott and T.G. Meronek. 2005. Seasonal movement patterns and habitat preference of age-0 Lake Sturgeon in the lower Peshtigo River, Wisconsin. Trans. Am. Fish. Soc. 134: 1400-1409.

Borkholder, B.D., D.S. Morse, H.T. Weaver, R.A. Hugill, A.T. Linder, L.M. Schwarzkopf, T.E. Perrault, M.J. Zacher and J.A. Frank. 2002. Evidence of a year-round population of Lake Sturgeon in the Kettle River, Minnesota, based on radio-telemetry and tagging. N. Am. J. Fish. Manage. 22: 888-894.

Bretecher, R.L. and D.S. MacDonell. 2001. Saskatchewan River Lake Sturgeon habitat investigation Cumberland House, Saskatchewan to The Pas, Manitoba, June 2000. Unpubl. rep. prep. Manitoba Hydro and Saskatchewan River Lake Sturgeon Co-management Board. 124 p.

Bruch, R.M. 1999. Management of Lake Sturgeon in the Winnebago system: long-term impacts of harvest and regulations on population structure. J. Appl. Ichthyol. 15: 142–152.

Bruch, R.M. 2008. Modelling the population dynamics and sustainability of Lake Sturgeon in the Winnebago system, Wisconsin. PhD. Dissertation. Univ. of Wisconsin, Milwaukee, WI. 247 p.

Bruch, R.M. and F.P. Binkowski. 2002. Spawning behaviour of Lake Sturgeon (*Acipenser* *fulvescens*). J. Appl. Ichthyol. 18: 570-579.

Bruch, R.M., S.E. Campana, S.L. Davis-Foust, M.J. Hansen and J. Janssen. 2009. Lake Sturgeon age validation using bomb radiocarbon and known-age fish. Trans. Am. Fish. Soc. 138: 361-372.

Burton, F., M. Gendron, G. Guay and J. Gingras. 2004. Aménagement hydroélectrique de l'eastmain-1-charactérisation de la population d'esturgeon jaune. Rapport sectoriel 2002-2003. Rapport présenté à la société d'énergie de la baie James (SEBJ), Montréal, QC. 137 p.

Cada, G.F. 1998. Better science supports fish-friendly turbine designs. Hydro Review / Nov. 1998: 52-61.

Chiasson, W.B., D.L.G. Noakes and F.W.H. Beamish. 1997. Habitat, benthic prey and distribution of juvenile Lake Sturgeon (*Acipenser fulvescens*) in northern Ontario rivers. Can. J. Fish. Aquat. Sci. 54: 2866-2871.

Choudhury, A. and T.A. Dick. 1993. Parasites of Lake Sturgeon, *Acipenser fulvescens* (Chondrostei: Acipenseridae), from central Canada. J. Fish Biol. 42: 571-584.

COSEWIC 2006. COSEWIC assessment and update status report on the Lake Sturgeon *Acipenser fulvescens* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 107 p.

DFO. 2005. A framework for developing science advice on recovery targets for aquatic species in the context of the *Species At Risk Act*. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/054.

DFO. 2007. Proceedings of the Lake Sturgeon recovery planning workshop; 28 February to 1 March 2006. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2007/030.

DFO. 2008. Recovery potential assessment of Great Lakes and St. Lawrence River watersheds (designatable unit 8) Lake Sturgeon (*Acipenser fulvescens*) population. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/042.

DFO. 2010. Guidelines for terms and concepts used in the species at risk program. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/065.

Dick, T.A. 2004. Lake Sturgeon studies in the Pigeon and Winnipeg rivers and biota indicators. Unpubl. rep. prep. by Dep. Zool., Univ. Manitoba, Winnipeg, MB. 429 p.

Dom. Can. Dep. Fish. 1892. Annual report of the Department of Fisheries, Dominion of Canada for the year 1891. 511 p.

Dumont, P., R. Fortin, G. Desjardins and M. Bernard. 1987. Biology and exploitation of Lake Sturgeon in the Quebec waters of the Saint-Laurent River. *In* Proceedings of a workshop on the Lake Sturgeon (*Acipenser fulvescens*). *Edited by* C.H Oliver. Ont. Fish. Tech. Rep. Ser. No. 2. Queen's Printers, ON. p. 57-76.

Environnement Illimité inc. 2007. Eastmain-1 hydroelectric development - findings of 2002-2005 Lake Sturgeon studies. Unpubl. rep. prep. for Société d'énergie de la Baie James by Environnement Illimité inc., Montreal, QC. 23 p.

Findlay, C.S. 1995. A retrospective assessment of the risks to Lake Sturgeon (*Acipenser fulvescens*) in the vicinity of The Pas, Manitoba: Briefing Report. Inst. Research Environ. Economy, Univ. of Ottawa, Ottawa, ON. 7 p.

Findlay, C.S., S. Lagarec, R. McGillvery, J. Houlahan and M. Sawada. 1995. An assessment of the risks to Lake Sturgeon (*Acipenser fulvescens*) in the vicinity of The Pas, Manitoba (preliminary interim report). Inst. Research Environ. Economy, Univ. of Ottawa, Ottawa, ON. 21 p.

Findlay, C.S., S. Lagarec, J. Houlahan, M. Sawada, R. McGillvery and G. Haas. 1997. A retrospective assessment of the risks to Lake Sturgeon (*Acipenser fulvescens*) in the lower Saskatchewan River. Ottawa-Carleton Inst. Biol., Univ. Ottawa, Ottawa, ON. 70 p.

Fortin, R., J. Mongeau, G. Desjardins and P. Dumont. 1993. Movements and biological statistics of Lake Sturgeon populations from the St. Lawrence and Ottawa River system, Quebec. Can. J. Zool. 71: 638–650.

Fortin, R., P. Dumont and S. Guénette. 1996. Determinants of growth and body condition of Lake Sturgeon (*Acipenser fulvescens*). Can. J. Fish. Aquat. Sci. 53: 1150-1156.

Harkness, W.J.K. and J.R. Dymond. 1961. The Lake Sturgeon: the history of its fisheries and problems with conservation. Ontario Dep. Lands and Forests, Fish and Wildl. Branch, Toronto, ON. 121 p.

Haxton, T. 2003. Movement of Lake Sturgeon, (*Acipenser fulvescens*), in a natural reach of the Ottawa River. Can. Field-Nat. 117: 541-545.

Hay-Chmielewski, E.M. and G.E. Whelan. 1997. Lake Sturgeon rehabilitation strategy. Fish. Div. Spec. Rep. Number 18. Michigan Dep. Nat. Res., Lansing, MI. 51 p.

Hayes, J.S. and R.G. Werner. 1997. Biology, movements and habitat utilization of Lake Sturgeon (*Acipenser fulvescens*) in the St. Lawrence River. Abstract from the 59th Midwest Fish and Wildlife Conference, Managing natural resources: integrating ecology and society, Milwaukee, WI, Dec. 7-10, 1997.

Hayes, J. and R. Werner. 2002. Contributing factors in habitat selection by Lake Sturgeon habitat (*Acipenser fulvescens*). The Research Foundation of the State Univ. of New York, Albany, NY. 19 p.

Holtgren, J.M. and N.A. Auer. 2004. Movement and habitat of juvenile Lake Sturgeon (*Acipenser fulvescens*) in the Sturgeon River/Portage Lake system, Michigan. J. Freshwater Ecol. 19: 419-432.

Houston, J.J. 1987. Status of Lake Sturgeon, *Acipenser fulvescens*, in Canada. Can. Field-Nat. 10: 171-185.

Jager, H.I., M.S. Bevelhimer, K.B. Lepla, J.A. Chandler and W. Van Winkle. 2007. Evaluation of reconnection options for White Sturgeon in the Snake River using a population viability model. Am. Fish. Soc. Symp. 56: 319-335.

Kempinger, J.J. 1988. Spawning and early life history of Lake Sturgeon in the Lake Winnebago system, Wisconsin. Am. Fish. Soc. Symp. 5: 110-122.

Knights, B.C., J.M. Vallazza, S.J. Zigler and M.R. Dewey. 2002. Habitat and movements of Lake Sturgeon in the upper Mississippi River system, U.S.A. Trans. Am. Fish. Soc. 131: 507-522.

LaPatra, S.E., S.C. Ireland, J.M. Groff, K.M. Clemens and J.T. Siple. 1999. Adaptive disease management strategies for the endangered population of Kootenai River White Sturgeon. Fisheries 24: 6–13.

Lyons, J. and J.J. Kempinger. 1992. Movements of adult Lake Sturgeon in the Lake Winnebago system. Wisconsin Dep. Nat. Res. Publ. No. RS-156-92. 17 p.

McKinley, S., G.V. Der Kraak and G. Power. 1998. Seasonal migrations and reproductive patterns in the Lake Sturgeon, *Acipenser fulvescens*, in the vicinity of hydroelectric stations in northern Ontario. Environ. Biol. Fishes 51: 245-256.

Mosindy, T. and J. Rusak. 1991. An assessment of the Lake Sturgeon populations in Lake of the Woods and the Rainy River 1987-90. Lake of the Woods Fisheries Assessment Unit Report. Ontario Ministry of Natural Resources, Kenora, ON. 59 p.

Nelson, J.S. and M.J. Paetz. 1992. The fishes of Alberta. University of Alberta Press, Edmonton, AB. 437 p.

North/South Consultants Inc. 2002. Saskatchewan River Sturgeon Management Board Ten-Year Management Plan. Unpubl. rep. prep. by North/South Consultants Inc., Winnipeg, MB, for Sask. R. Sturgeon Manage. Bd. 104 p.

North/South Consultants Inc. 2003. Saskatchewan River Lake Sturgeon harvest surveys 2001-2002. Unpubl. rep. prep. by North/South Consultants Inc., Winnipeg, MB, for Sask. R. Sturgeon Manage. Bd. 42 p.

Nowak, A.M., and C.S. Jessop. 1987. Biology and management of the Lake Sturgeon (*Acipenser fulvescens*) in the Groundhog and Mattagami Rivers, Ontario. *In* Proceedings of a workshop on the Lake Sturgeon (*Acipenser fulvescens*). *Edited by* C.H Oliver. Ont. Fish. Tech. Rep. Ser. No. 23. Queen's Printers, ON. p. 20-32.

Peterson, D., P. Vecsei and C. Jennings. 2007. Ecology and biology of Lake Sturgeon: a synthesis of current knowledge of a threatened North American Acipenseridae. Rev. Fish Biol. Fish. 17: 59-76.

Pratt, T.C. 2008. Population status and threats of Lake Sturgeon in Designatable Unit 8 (Great Lakes / St. Lawrence River Watersheds). DFO. Can. Sci. Adv. Sec. Res. Doc. 2008/043. iv + 33 p.

Priegel, G.R. and T.L. Wirth. 1974. The Lake Sturgeon: it's life history, ecology and management. Wisconsin Dep. Nat. Res. Publ. 4-3600 (74), Madison, WI. 19 p.

Priegel, G.R. and T.L. Wirth. 1975. Lake Sturgeon harvest, growth, and recruitment in Lake Winnebago, Wisconsin. Wisconsin Dep. Nat. Res. Tech. Bull. 83. 25 p.

Radford, D.S. 1980. The harvest of Lake Sturgeon (*Acipenser fulvescens*) from the South Saskatchewan River, Alberta between 1968 and 1978. Alberta Energ. Nat. Res. Fish Wildl. Div. MS. Rep. 35 p.

Randall, R.G. 2008. Narrative description and quantification of the habitat requirements of Lake Sturgeon, *Acipenser fulvescens* in the Great Lakes and upper St. Lawrence River. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/015.

R.L. & L. Environmental Services Ltd. 1991. A study of Lake Sturgeon (*Acipenser fulvescens*) from the South Saskatchewan River. Unpubl. rep. prep. for Alberta Recreation, Parks and Wildl. Foundation and Fish and Wildl. Div., Alberta Sustainable Res. Dev., Edmonton, AB. 56 p.

Robinson, M. and M. Ferguson. 2001. Lake Sturgeon population genetics in the Saskatchewan and Winnipeg rivers. Unpubl. rep. prep. for Fisheries Branch, Manitoba Conservation and SERM Fish and Wildlife Branch. 13 p.

Royer, L.M., F.M. Atton and J.-P. Cuerrier. 1968. Age and growth of Lake Sturgeon in the Saskatchewan River delta. J. Fish. Res. Bd Canada 25: 1511-1516.

Rusak, J.A. and T. Mosindy. 1997. Seasonal movement of Lake Sturgeon in Lake of the Woods and the Rainy River, Ontario. Can. J. Zool. 75: 383-395.

Sandilands, A.P. 1987. Biology of the Lake Sturgeon (*Acipenser fulvescens*) in the Kenogami River, Ontario. *In* Proceedings of a workshop on the Lake Sturgeon (*Acipenser fulvescens*). *Edited by* C.H. Oliver. Ont. Fish. Tech. Rep. Ser. No. 23. Queen's Printers, ON. p. 33-46.

Saunders, E.J. 2006. Lake Sturgeon in Alberta: a summary of current knowledge. Unpubl. rep. prep. for Fish and Wildlife Div., Alberta Sustainable Res. Dev., Lethbridge, AB. 22 p.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd of Canada Bull. 184. 966 p.

Secor, D.H., P.J. Anders, W. Van Winkle and D.A. Dixon. 2002. Can we study sturgeon to extinction? What we do and don't know about the conservation of North American sturgeons. Am. Fish. Soc. Symp. 28: 3-10.

Seyler, J. 1997. Biology of selected riverine fish species in the Moose River basin. Ontario Ministry of Nat. Res. Northeast Sci. Tech. Info. Rep. IR-024. 100 p.

Skaptason, J.B. 1926. The fish resources of Manitoba. Industrial Dev. Bd of Manitoba. Printed by the Farmer's Advocate of Winnipeg Ltd, MB. 43 p.

Smith, C.G. 2003. Historical and present locations of Lake Sturgeon (*Acipenser fulvescens*) in Saskatchewan. Canadian Plains Res. Centre and Saskatchewan Environ. Fish and Wildl. Branch, Saskatoon, SK. Fish and Wildl. Tech. Rep. 2003-2. 32 p.

Smith, K.M. and D.K. King. 2005. Movement and habitat use of yearling and juvenile Lake Sturgeon in Black Lake, Michigan. Trans. Am. Fish. Soc. 134: 1159-1172.

Stewart, D.B. 2009. Historical harvests of Lake Sturgeon (*Acipenser fulvescens*) from western Canada. Unpubl. rep. prep. by Arctic Biological Consultants, Winnipeg, MB for Fisheries and Oceans Canada, Winnipeg, MB. 41 p.

Stewart, K.W. and D.A. Watkinson. 2004. The freshwater fishes of Manitoba. University of Manitoba Press, Winnipeg, MB. 276 p.

Sunde, L.A. 1959. The royal fish. Fishing, A Bulletin for Commercial Fisherman (Winnipeg) 1: 20-23.

Swanson, G.M., K.R. Kansas, S.M. Matkowski and P. Graveline. 1991. A report on the fisheries resource of the lower Nelson River and the impacts of hydroelectric development, 1989 data. Manitoba Dep. Nat. Res, Fish. Branch, Manuscr. Rep. 91-03. 248 p.

Threader, R.W. and C.S. Brousseau. 1986. Biology and management of the Lake Sturgeon in the Moose River, Ontario. N. Am. J. Fish. Manage. 6: 383-390.

Vélez-Espino, L.A. and M.A. Koops. 2009. Recovery potential assessment for Lake Sturgeon (*Acipenser fulvescens*) in Canadian designatable units. N. Am. J. Fish. Manage. 29: 1065-1090.

Vélez-Espino, L.A. and M.A. Koops. In prep. Lake Sturgeon (*Acipenser fulvescens*) recovery targets in Canadian designatable units. DFO Can. Sci. Advis. Sec. Res. Doc.

Wallace, R.G. 1991. Species recovery plan for Lake Sturgeon on the Lower Saskatchewan River (Cumberland Sound area). Fish. Tech. Rep. 91-3. Fish. Branch, Saskatchewan Parks and Renewable Resources, Regina, SK. 51 p.

Wallace, R.G. and D.R. Leroux. 1999. Lake Sturgeon in the lower Saskatchewan River: radio-tracking and index fishing. 1994-1997. Unpubl. rep. prep. Interprovincial Sturgeon Steering Committee. Fish Wildl. Tech. Rep. 99-4. 83 p.

Watters, D. 1993a. Lake Sturgeon, *Acipenser fulvescens* Rafinesque, in the North Saskatchewan River, Alberta. Fish and Wildl. Serv., Dep. Environ. Prot., Edmonton, AB. 40 p.

Watters, D.V. 1993b. Lake Sturgeon, *Acipenser fulvescens* Rafinesque, in the North Saskatchewan River, Alberta: a summary of activities during 1993. Alberta Environ. Prot. Fish and Wildl. Serv. Manuscr. Rep., Edmonton, AB. 37 p.

Werner, R.G. and J. Hayes. 2005. Contributing factors in habitat selection by Lake Sturgeon (*Acipenser fulvescens*). U.S. Environ. Protect. Agency – Great Lakes Nat. Progr. Office GL 97517201. 24 p.

Whitehouse, F.C. 1919. Notes on some of the fishes of Alberta and adjacent waters. Can. Field-Nat. 33: 50-55.

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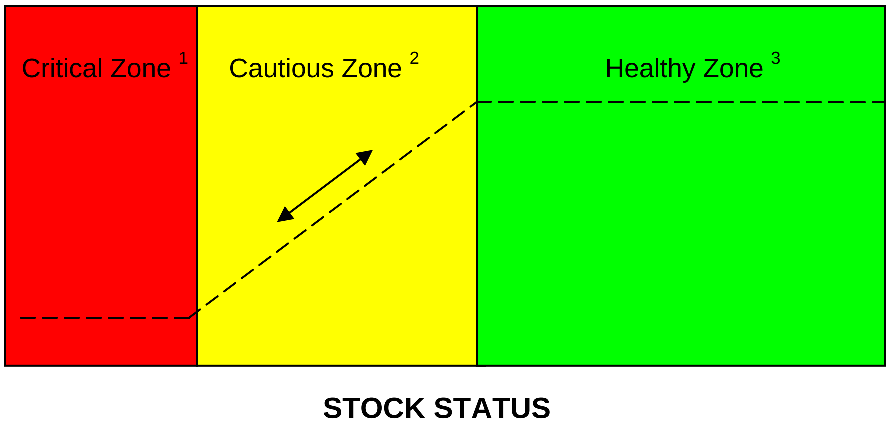
Figure 1. DU2 showing locations of MUs and place names mentioned in the text.



[1] The Critical zone is where stock biomass is evaluated as being at or below a level where there is a high risk of serious or irreversible harm to stock productivity.

[2] The Cautious zone reflects uncertainty about the estimation of annual stock status and the biomasses at which stock productivity begins to decline and becomes at risk of serious or irreversible harm.

[3] The Healthy zone is where stock biomass is evaluated as being within the historical range of the stock when it was healthy.

Figure 2. Conservation status of a stock or population based on the framework for the application of the precautionary approach (adapted from DFO 2005).

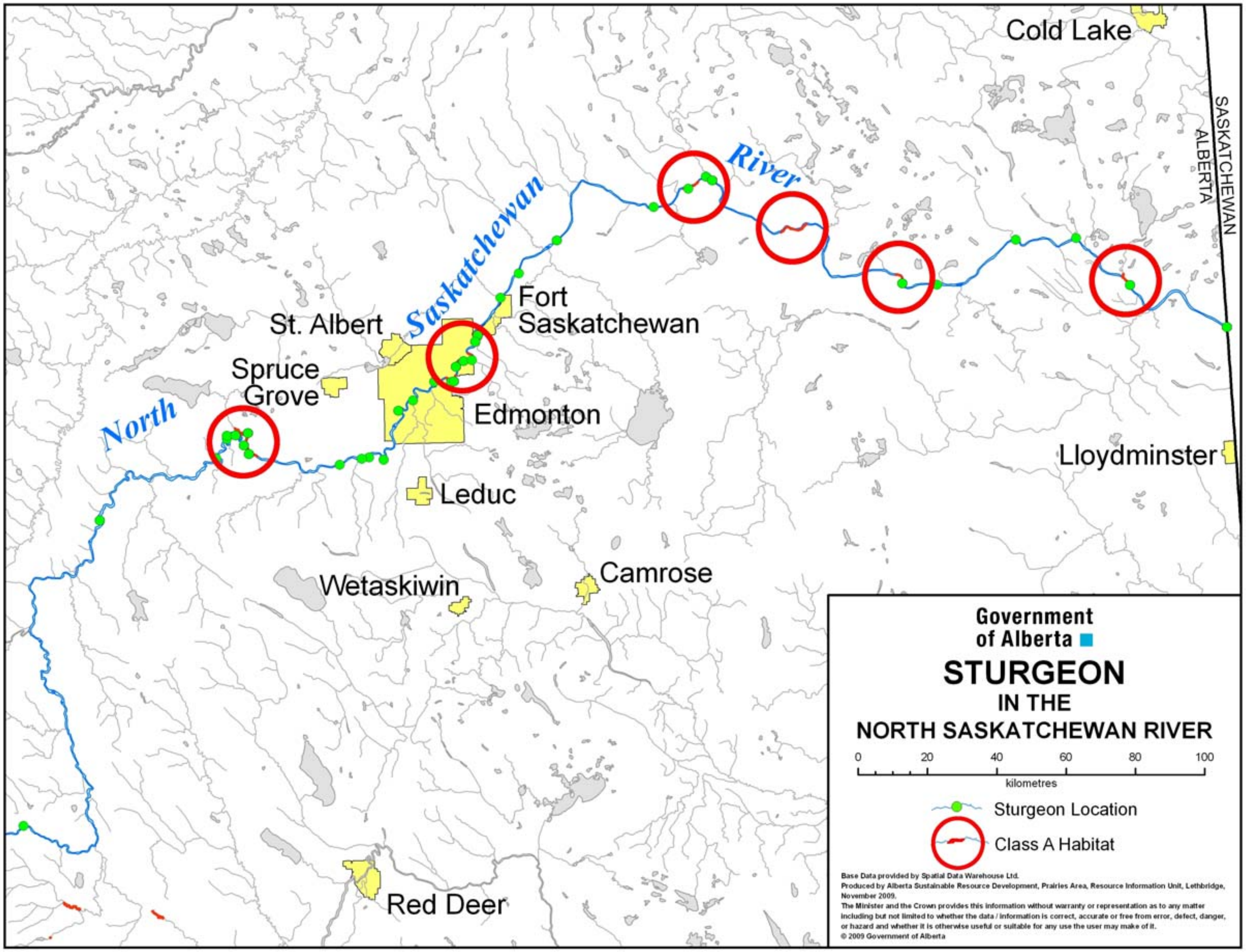


Figure 3. Class A habitat identified for Lake Sturgeon in the Alberta portion of MU1 (ASRD, unpubl. data).

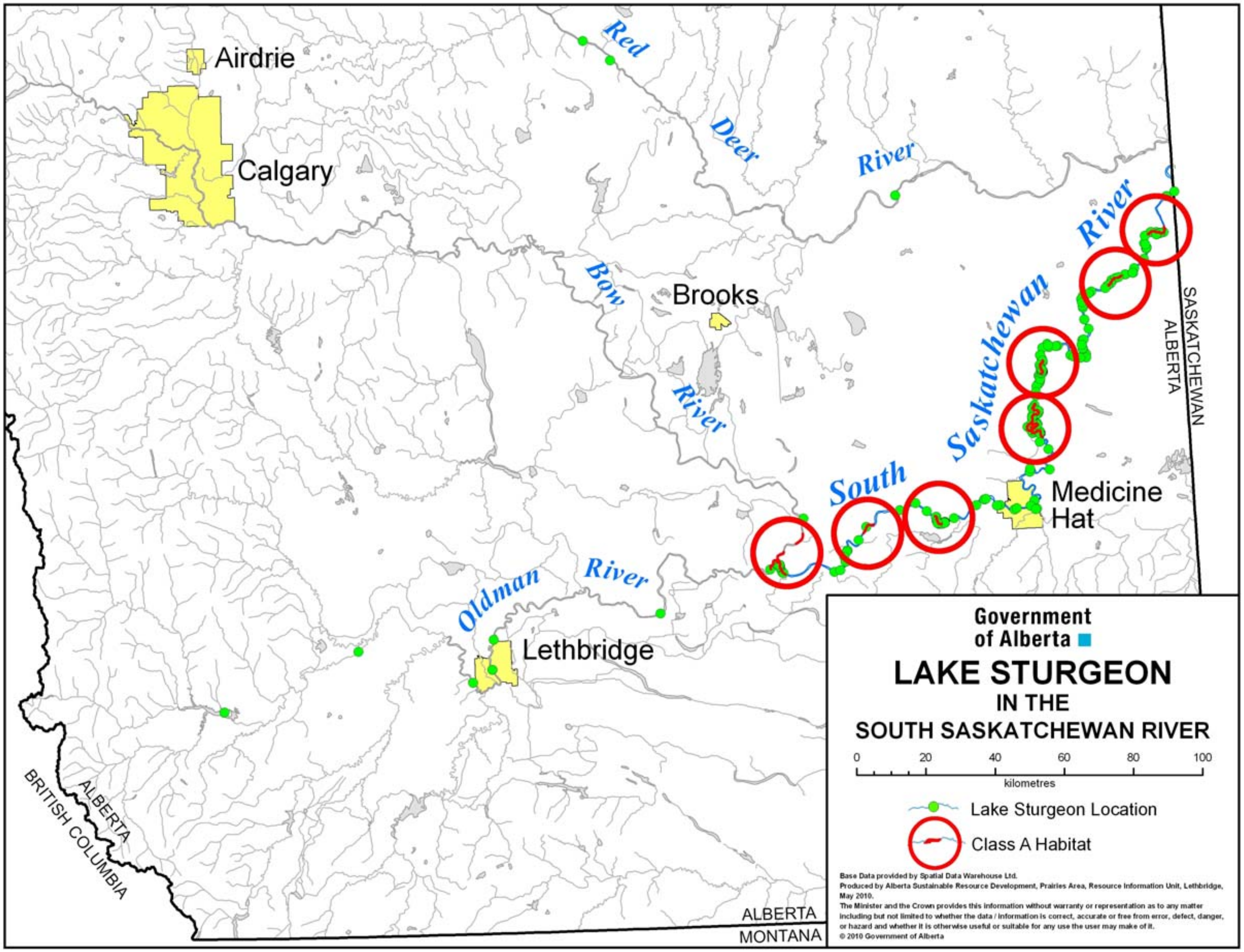


Figure 4. Class A habitat identified for Lake Sturgeon in the Alberta portion of MU2 (ASRD, unpubl. data).

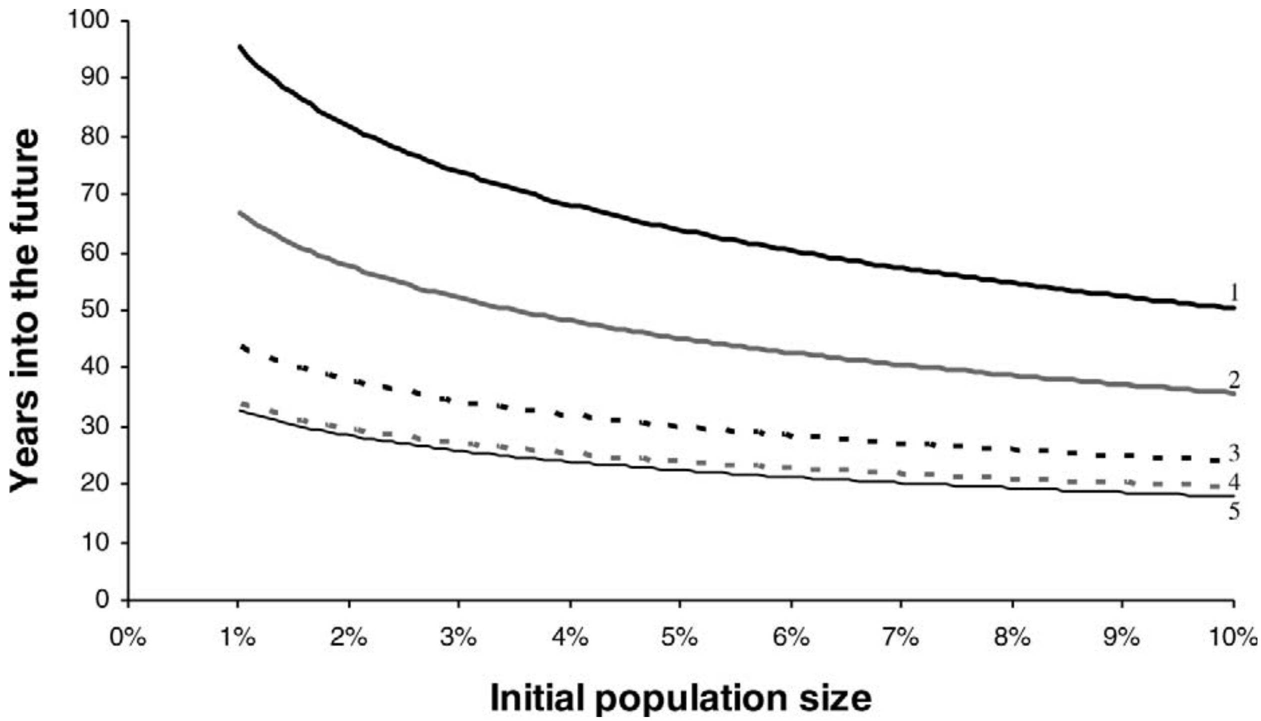


Figure 5. Stochastic projections of times to recovery for Lake Sturgeon based on initial population size (i.e., percentage of MVP) under five different recovery scenarios. Strategy 1 (solid black line) was the maximization of the survival rates of early adults, strategy 2 (solid grey line) added a 10% increase in the survival rates of late juveniles, strategy 3 (black dotted line) added a 20% increase in the survival rates of age-0 and early juveniles, strategy 4 (dotted grey line) added the maximization of the survival rate of late adults, while strategy 5 (black dashed line) added a 20% increase in fertility. Initial population size is expressed as a percentage of the recovery target (from Figure 8 in Vèlez-Espino and Koops 2009).

Table 1. Assessment of the current conservation status, population trajectory, overall importance to species recovery and recovery potential of the six Lake Sturgeon Management Units (MUs) in the Saskatchewan rivers system. Conservation status (Figure 2) was based on the best available information and Precautionary Framework (DFO 2005); population trajectory was rated as Unknown, Stable, Increasing or Decreasing; importance to species recovery evaluates the importance of the MU to the overall recovery of Lake Sturgeon within DU2. For example, if a DU contained only one Lake Sturgeon MU whose conservation status was considered to be Healthy, then its importance to species recovery would be rated High as catastrophic loss of that MU would result in extirpation of the DU. Recovery potential is based on a combination of current conservation status and current threats status. Importance to species recovery and recovery potential were rated as Nil, Low, Moderate, High or Unknown.

MU	Location	Conservation status	Population trajectory	Importance to DU recovery	Recovery potential
1	North Saskatchewan River: Bighorn GS – The Forks	Cautious	Stable (AB), Stable or Increasing (SK)	High	High
2	South Saskatchewan River, upstream of Gardiner GS	Cautious	Increasing (AB), Stable or Increasing (SK)	High	High
3	South Saskatchewan River, Gardiner GS – The Forks	Critical	Unknown	Low	Low
4	The Forks – François-Finley GS	Cautious	Stable or Increasing	High	Moderate
5	François-Finley GS – E.B. Campbell GS	Cautious	Unknown	Low	Low
6	E.B. Campbell GS – Grand Rapids GS	Critical	Stable	High	High

Table 2. Current status of threats to Lake Sturgeon in DU2 by Management Unit (MU), defined in terms of the likelihood of occurrence followed by level of severity, based on current knowledge of the MUs and the areas in which they occur. (0=Nil, L=Low, M=Moderate, H=High, U=Unknown). The most important threats are highlighted. Note: In cases where a man-made barrier occurs at the start (upstream end) of an MU, it is included in the MU. For example, the E.B. Campbell GS is included in MU6.

THREATS	North Saskatchewan River : Bighorn GS – The Forks	South Saskatchewan River, upstream of Gardiner GS	South Saskatchewan River, Gardiner GS- The Forks	The Forks - François-Finley GS	François-Finley GS – E.B. Campbell GS	E.B. Campbell GS – Grand Rapids GS
	MU1	MU2	MU3	MU4	MU5	MU6
Mortality, injury or reduced survival						
Entrainment, impingement and turbine mortality (e.g., from hydroelectric dams and other barriers, urban or irrigation intakes)	L,L	L,L	L,L	L,L	L,L	L,L
Population fragmentation (e.g., from dams/impoundments and other barriers)	L,L	L,L	L,L	L,L	M,M	L,L
Fishing: commercial net (bycatch)	0,0	0,0	0,0	0,0	0,0	M,M
Fishing: domestic / subsistence	0,0	0,0	0,0	0,0	0,0	M,M
Fishing: recreational / commercial tourism	L,L	L,L	L,L	L,L	L,L	L,L
Fishing: illegal harvest	H,M	U,U	U,U	U,U	U,U	L,L
Habitat degradation or loss[1]						
Dams/impoundments and other barriers (e.g., hydroelectric dams or water control structures)	H,H	H,H	H,H	L,L	M,H	H,H
Industrial activities (including oil and gas, and pulp and paper)	H,U	H,U	M,L	L,L	L,L	M,L
Forestry exploration/ extraction	H,M	H,M	L,L	L,L	L,L	L,L
Mining exploration/extraction	L,L	L,L	L,L	L,L	L,L	L,L
Agricultural activities	H,L	H,M	H,H	M,L	M,M	M,M
Urban development	H,M	H,M	M,M	L,L	L,L	L,L
Sturgeon culture						
Genetic contamination	0,0	0,0	0,0	0,0	L,0[2]	L,L
Disease	0,0	0,0	0,0	0,0	0,0	U,U
Non-indigenous and invasive species	H,U	H,U	M,L	M,L	M,L	L,L
Climate change[3]	U,U	U,U	U,U	U,U	U,U	U,U

[1] Examples: changes in flow regime, water temperature, concentrations of sediments, nutrients and contaminants, habitat structure and cover, food supply and migration/access to habitat, surface hardening and pollution.
[2] Stocking occurred here in 2006 and 2007 but the brood stock was from the same MU thus the risk of contamination is thought to be nil.
[3] Examples: changes in water temperature, patterns of precipitation, river morphology and hydrology.

Table 3. Minimum recovery effort and maximum allowable harm with respect to annual survival and fertility of Lake Sturgeon in DU2 based on results of modelling (Vélez-Espino and Koops 2009). Minimum recovery effort indicates the minimum increase in vital rates necessary to stabilize or stimulate population growth. Maximum allowable harm indicates the maximum reduction in survival or fertility rates in a population that can occur while still allowing the population to recover, once the main causes of population decline are removed. These percentages are not additive.

Vital Rates	Minimum Recovery Effort	Maximum Allowable Harm
Age-0 survival	29.6%[1]	0%
Early juvenile survival	27.3%[1]	0%
Late juvenile survival	11.3%[1]	0%
Early adult survival	6%[2]	0%
Late adult survival	28.7[2] (16.1%[3])	0%
Early adult fertility	91.9[1] (8.8%[3])	0%
Late adult fertility	59.4[1] (4.1%[3])	0%

[1] Value generated by the stochastic-generic model, which incorporated values for DUs 2, 4 and 5, resulting in a more precautionary value than was produced by the stochastic DU2 model.

[2] Value generated by the stochastic DU2 model.

[3] Maximum proportional increase possible, thus it is not feasible to increase this vital rate sufficiently for recovery.

Table 4. Possible mitigations and alternatives to threats to ensure that activities (including structures) do not jeopardize the survival and recovery of Lake Sturgeon.

Threats	Mitigations and Alternatives	Life stage enhanced
Habitat degradation or loss[1]		
Dams/impoundments and other barriers	Follow ecologically-based flow regimes for key life stages to optimize conditions especially during spawning, incubation and larval periods	Age-0[2], eggs
	Protect spawning and rearing habitat at new and existing dams and other barriers	Age-0[2], eggs
	Select the most appropriate design option for new structures, or those being modernized, to enhance survival and recovery	All
	Rehabilitate habitat in key areas	All
Industrial activities (including oil and gas), forestry and mining exploration/extraction	Prohibit activities that cause significant sedimentation especially during winter or spring	Age-0[2], eggs
	Prohibit activities that cause removal of substrates in known or suspected spawning areas	Age-0[2], eggs
	Prohibit activities that cause significant changes in water flows especially during spring	Age-0[2], eggs
	Prohibit activities that cause significant changes in water temperature, total gas pressure, salinity or nutrient concentrations	All
Agricultural activities	Prohibit activities that cause significant sedimentation especially during winter or spring	Age-0[2], eggs
	Prohibit activities that cause removal of substrates in known or suspected spawning areas	Age-0[2], eggs
	Prohibit activities that cause significant changes in water flows especially during spring	Age-0[2], eggs
	Prohibit activities that cause significant changes in water temperature, total gas pressure, salinity or nutrient concentrations	All
	Minimize release of contaminants	All
Urbanization	Enforce discharge limits on potential pollutants	All
	Improve effluent from water treatment plants	All
	Increase protection during work permit reviews	All
	Protect spawning and rearing habitat	Age-0[2], eggs
	Rehabilitate habitat in key areas	All

[1] Examples: changes in flow regime, water temperature, concentrations of sediments, nutrients and contaminants, habitat structure and cover, food supply and migration/access to habitat, surface hardening and pollution.

[2] Age-0 survival could also be enhanced through conservation stocking (see Mitigation, Alternatives and Enhancements section for explanation).

Table 4. (Continued)

Threats	Mitigations and Alternatives	Life stage enhanced
Mortality, injury or reduced survival		
Entrainment, impingement and turbine mortality (e.g., from hydroelectric dams and other barriers, urban or irrigation intakes)	Provide protection measures to exclude Lake Sturgeon from passing through facility intakes	All
	Provide effective upstream and downstream passage[3]	All
	Select the most appropriate design option for new structures, or those being modernized, to enhance survival and recovery	All
Population fragmentation (e.g., from dams/impoundments and other barriers)	Prevent any additional fragmentation	All
	Provide effective upstream and downstream passage[3] at new dams and modernization of existing dams if necessary	Age-0[2], eggs
	Remove barriers to migration to known historical spawning sites or provide effective upstream or downstream fish passage at current barriers if necessary	Age-0[2], eggs
	Rehabilitate habitat in key areas	All
Fishing[4]	Regulate or encourage practices that improve fish survival	Late juvenile, both adult stages
	Ensure immediate release of bycatch	All juvenile and adult stages
	Close fishing by season and/or area, or modify fishing practises	All juvenile and adult stages
	Improve public education	Late juvenile, both adult stages
	Ensure effective enforcement of regulations	Late juvenile, both adult stages
Sturgeon culture		
Genetic contamination	Develop effective and controlled stocking policy/plan	All
	Ensure broodstock, fertilized eggs and/or larval fish are from the same genetic stock	All
Disease	Monitor for bacteria and viruses	All
Non-indigenous and invasive species[5]		
	Monitor non-indigenous and invasive species	All
	Ban use of live bait	All
	Establish measures to prevent introduction or spread	All
Climate change[6]		
	Monitor environmental changes	All

[3] Examples: construction of a fishway, partial dismantling or removal of barriers.
[4] Commercial net (bycatch), domestic/subsistence, recreational/commercial tourism and illegal harvest.
[5] Examples: Common Carp (*Cyprinus carpio*), Zebra Mussels (*Dreissena polymorpha*), Rainbow Smelt (*Osmerus mordax*) and Rusty Crayfish (*Orconectes rusticus*).
[6] Examples: changes in water temperature, concentrations of sediments, nutrients and contaminants, habitat structure and cover, food supply and migration/access to habitat, surface hardening and pollution.