RECOVERY POTENTIAL ASSESSMENT OF LAKE STURGEON: SASKATCHEWAN RIVER POPULATIONS (DESIGNATABLE UNIT 2)

Lake Sturgeon Acipenser fulvescens
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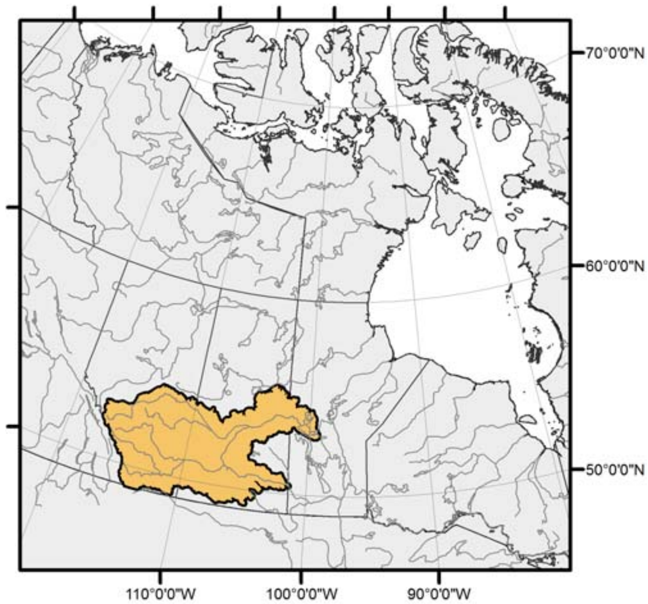

Figure 1. DU2 for Lake Sturgeon (coloured area).

Context:

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 the Saskatchewan River upstream of the Grand Rapids Generating Station at Lake Winnipeg and all drainages west to east-central Alberta. The Lake Sturgeon in this region is considered a distinct DU on the basis of distinguishable variation in three nuclear microsatellite loci. 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.

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.*

SUMMARY

- Six Management Units (MUs) have been identified for DU2: MU1 is located on the North Saskatchewan River downstream of the Bighorn Generating Station (GS), MU2 on the South Saskatchewan River upstream of Gardiner GS, MU3 on the South Saskatchewan River downstream of Gardiner GS to the forks of the North Saskatchewan and South Saskatchewan rivers, MU4 between the forks and François-Finley GS on the Saskatchewan River, MU5 between François-Finley GS and E.B. Campbell GS and MU6 between E.B. Campbell GS and Grand Rapids GS.
- Available data and expert opinion indicate that Lake Sturgeon abundance in DU2 ranges from very low to moderate.
- In MUs 1, 2 and 4, the current status is cautious, population trajectory is stable or increasing and potential for recovery is high.
- The status of MU5 is thought to be cautious though its trajectory is unknown.
- The status of MUs 3 and 6 is deemed critical with an unknown trajectory in MU3 and stable trajectory in MU6.
- Survival and recovery of Lake Sturgeon in DU2 depend 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.
- The long-term recovery goal for DU2 is to protect and maintain healthy, viable populations of Lake Sturgeon in all six MUs in the Saskatchewan rivers system.
- 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.
- Mitigation measures that would aid recovery include protection of habitat, prevention of mortality and public education.
- Activities that damage or destroy functional components of habitat or negatively affect 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.

BACKGROUND

Rationale for Assessment

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the Lake Sturgeon in DU2 as Endangered in 2006 (COSEWIC 2006) and it is now being considered for listing under the *Species at Risk Act* (SARA). When COSEWIC designates an aquatic species as Threatened or Endangered and the Governor in Council decides to list it, the Minister of Fisheries and Oceans Canada (DFO) is required by the SARA to undertake a number of actions. Many of these actions require scientific information such as the current status of the DU, the threats to its survival and recovery, and the feasibility of its recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA). This allows for the consideration of peer-reviewed scientific analyses in subsequent SARA processes, including recovery planning. If listed, decisions made on permitting of harm and in support of recovery planning need to be informed by the impact of human activities on the species, mitigation measures and alternative to these activities, and the potential for recovery. The information and scientific advice provided in this document 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.

Species Biology and Ecology

The Lake Sturgeon is a large bottom-dwelling freshwater fish. 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 (Cleator *et al.* 2010). In the Alberta portion of MU2, 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 (Cleator *et al.* 2010). The largest Lake Sturgeon caught from MU6 in 1996-97 measured 1.5 m in length and weighed 33 kg (Cleator *et al.* 2010). Females are usually heavier than males.

This species is found in large rivers and lakes usually 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). The Lake Sturgeon has been described as largely sedentary, making localized (1-20 km) seasonal movements, with high site fidelity except to move over longer distances for spawning. Tagging studies indicate that younger, smaller Lake Sturgeon do not move as far as older, larger individuals (Cleator *et al.* 2010).

Sexual maturity (i.e., the age at which spawning is first observed) typically occurs between 14 and 33 years of age in females and between 14 and 22 years in males (Cleator *et al.* 2010). 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) (Cleator *et al.* 2010). Spawning occurs in May and June, once the river is free of ice and water temperatures are in the range of 11.5-16°C (Cleator *et al.* 2010). Adults move upstream to suitable areas containing rapids or below barriers (e.g., falls or dams) where they typically spawn in swift current near shore with individual spawning females surrounded by several males (Cleator *et al.* 2010). Females may contain between about 50,000 and > 1,000,000 eggs, with heavier individuals producing more eggs. The interval between successive spawnings is estimated to be 3-7 years for females and 2-3 years for males (Cleator *et al.* 2010). In DU2, females spawn every 4-8 years (Cleator *et al.* 2010). 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, and remained burrowed in the substrate until the yolk sac is absorbed. The young typically emerge at night within 13-19 days after hatching, and disperse downstream with the current (up to 40 km) before returning to a benthic habitat. By that time they resemble miniature adults and start feeding. 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).

The sex ratio at birth is assumed to be 1:1, based on data from populations with little or no anthropogenic mortality, but following maturation can favour either females or males as a result of targeted exploitation. Information about survival is limited. In Lake Winnebago during 1936-1952, survival of Lake Sturgeon aged 16-36 years was 0.946 and older than 36 years was 0.866 (Cleator *et al.* 2010). 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 (Cleator *et al.* 2010). 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% (Cleator *et al.* 2010). In MU6, 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% (Cleator *et al.* 2010).

There are historic records of Lake Sturgeon living up to 150 years of age. Lifespan today is typically more in the range of 25-50 years, with an average generation time of about 26-30 years (Cleator *et al.* 2010). Shorter average lifespan today may reflect current and/or past effects of harvest. In MU2, 12% of Lake Sturgeon are older than 25 years and 1% older than 33 years (Cleator *et al.* 2010).

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 (Cleator *et al.* 2010). 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 (Cleator *et al.* 2010). Some pelagic feeding has also been reported. The Lake Sturgeon feeds actively throughout the year, though consumption may decline in the fall and winter.

ASSESSMENT

Historic and Current Distribution and Trends

DU2 includes the Saskatchewan River system in southern and central Alberta and Saskatchewan and upstream of the Grand Rapids Generating Station (GS), at Lake Winnipeg, in far west-central Manitoba (Figure 1). 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 2): (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) the Saskatchewan River 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. 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, in Alberta and Saskatchewan (Cleator *et al.* 2010). The current distribution of Lake Sturgeon in MU1 extends as far upstream as the Bighorn GS, and the Brazeau GS on the Brazeau River, in Alberta downstream to The Forks in Saskatchewan.

South Saskatchewan River: upstream of Gardiner GS (MU2)

Many historic locations for Lake Sturgeon in the Alberta portion of MU2 were located upstream of the South Saskatchewan River (Cleator *et al.* 2010). The South Saskatchewan River is known to have dried up at least twice since 1930 (DFO 2010). Today Lake Sturgeon are found in the lower portions of the Red Deer, Bow and Oldman rivers and the South Saskatchewan River downstream to Gardiner GS (Cleator *et al.* 2010). In Saskatchewan, most reports are from the Leader area (Cleator *et al.* 2010).

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

No historic 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 (Cleator *et al.* 2010). There may be little suitable habitat for Lake Sturgeon in this MU (DFO 2010).

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

Historically, Lake Sturgeon in this MU were reported to occur at ferry crossings and in the Fort-a-la-Corne area, about 25 river km downstream of The Forks (Cleator *et al.* 2010). Today, Lake Sturgeon are frequently seen in two areas which are located about 20 km and 67 km downstream of The Forks (Cleator *et al.* 2010).

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

Lake Tobin, the impounded waters upstream of the E.B. Campbell GS, represents about 75% of this MU. No historic or current information about Lake Sturgeon distribution and trends is available for this portion of the Saskatchewan River.

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

Historically, Lake Sturgeon were 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 (Cleator *et al.* 2010). Lake Sturgeon may continue to be distributed throughout this MU but in much smaller numbers.

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 (Cleator *et al.* 2010). 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 (Cleator *et al.* 2010). 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, based on the precautionary framework (see Cleator *et al.* 2010 for explanation), 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)

Lake Sturgeon were 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 (Cleator *et al.* 2010). Analysis of recent tagging data from the Alberta portion of MU1 using open population models indicate that Lake Sturgeon greater than three years of age may have fluctuated between 700 and 1,600 (mean estimate: 1,062) individuals between 1993 and 2007, with no detectable trend (Cleator *et al.* 2010). Several important uncertainties surrounding the model assumptions have been identified (e.g., whether capture probability is the same for all individuals). 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) (Cleator *et al.* 2010), 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). Based on available information, the population trajectory is thought to be stable in Alberta and stable or increasing in Saskatchewan (Cleator *et al.* 2010).

South Saskatchewan River: upstream of Gardiner GS (MU2)

Analysis of recent tagging data from the Alberta portion of MU2 using open population models 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 (Cleator *et al.* 2010). Comparison of the recent results with an earlier abundance estimate indicates 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, where higher catches have occurred since 2000 (Cleator *et al.* 2010).

The status of Lake Sturgeon in MU2 is cautious (Table 1). Based on available information, the population trajectory is thought to be increasing in Alberta and stable or increasing in Saskatchewan (Cleator *et al.,* 2010).

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

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)

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 except in 2006 and 2007 when 10% were returned to Tobin Lake (MU5). During a 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 (Cleator *et al.* 2010). Stocking activities were undertaken in 1999-2001 to artificially increase recruitment. 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

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, from shallow water to depths > 10 m, substrates comprised of clay, sand and gravel/cobble, and water velocities of 0.1-0.3 $m \cdot s^{-1}$ (Cleator *et al.* 2010). 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, however they have also been found in areas of coarse-sand and pea-sized gravel. Juveniles use water depths ranging from 3-6 m to > 14 m and currents of 0.25-0.50 $m \cdot s^{-1}$ (Cleator *et al.* 2010). Depth was shown to be the primary abiotic factor influencing habitat selection in juveniles from the Winnipeg River (Cleator *et al.* 2010). A number of potential and actual juvenile rearing areas have been reported throughout DU2 (Cleator *et al.* 2010).

The habitat requirements of young Lake Sturgeon appear to be more restricted, 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 (Cleator *et al.* 2010).

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, that 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. In riverine environments, adults generally prefer water depths of ≥ 5 m with moderate water flow (< 0.6 $m \cdot s^{-1}$), and appear to avoid areas with high current velocity, except during spawning (Cleator *et al.* 2010). However, anglers regularly catch Lake Sturgeon in water depths of 3-5 m in the Alberta portion of MU1.

The Lake Sturgeon is 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. Migration 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.

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 (Cleator *et al.* 2010). Cascades and/or suitable water flows are necessary to keep the eggs and newly-hatched young healthy yet prevent them from being carried downstream before larval drift occurs. Seasonal and annual changes in flow may affect fidelity to specific spawning and feeding areas. A number of potential and actual spawning sites have been reported throughout DU2 (Cleator *et al.* 2010).

Not as much is known about the habitat preferences of Lake Sturgeon during winter. One study reported that adults spend the winter at water depths of 6-8 m (max. 20 m) and water velocities of ≤ 0.2 $m \cdot s^{-1}$ (max. 0.4 $m \cdot s^{-1}$), over silt and sand substrate (Cleator *et al.* 2010). Juveniles tended to congregate at approximately the same depths, substrate types and flow velocities, although some were observed at flow velocities as high as 0.4-0.6 $m \cdot s^{-1}$ (Cleator *et al.* 2010). 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 (Cleator *et al.* 2010). 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. Important Lake Sturgeon overwintering, foraging and spawning habitats in the Alberta portions of MUs 1 and 2 have been designated Class A “No Touch” areas and afforded protection (Cleator *et al.* 2010). 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 (Cleator *et al.* 2010).

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

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[1]. The aim is to reach these population and distribution objectives within three generations (i.e., 3 x 36 years = about 108 years) (Cleator *et al.* 2010). If undertaken, this recovery target 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.

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.

Modelling indicates that when current abundances are assumed to be 10% of the recovery target, times-to-recovery range from about 20 years to around 95 years (i.e., about 1-3 generations), depending on the recovery actions implemented (Cleator *et al.* 2010) (Figure 3). 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. Without recovery actions, time to recovery would be significantly longer.

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 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

[1]Population viability analysis of stage-structure demographic matrices was used to determine recovery targets (Cleator *et al.* 2010). Minimum viable population (MVP) was defined as the number of adults necessary 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, 5-year spawning periodicity and a sufficient number of juveniles to support the adult population goal.

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.

Threats to Survival and Recovery

Mortality, injury or reduced survival resulting from fishing activities can pose a threat to Lake Sturgeon. In the Alberta, a catch-and-release fishery is currently allowed. Poaching is occurring in MU1 (Cleator *et al.* 2010). In Saskatchewan, anglers who catch Lake Sturgeon are required to release them immediately. The aboriginal domestic fishery is the only remaining legal harvest of Lake Sturgeon and those levels have not been reported for any of the MUs except MU6 (Cleator *et al.* 2010). In Manitoba, some evidence in recent years indicates that Lake Sturgeon are incidentally captured and released by commercial fishers and anglers (Cleator *et al.* 2010). Harvest studies were conducted in MU6 in summer 2001 and 2002. Allthough the sampling methods were not well documented, so the estimates should be viewed with caution, 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 and a similar percentage of smaller individuals was also being harvested (Cleator *et al.* 2010). Annual harvest rates that are thought to be sustainable for Lake Sturgeon are typically 5% or less (Cleator *et al.* 2010). 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 (Cleator *et al.* 2010). If the actual MU6 harvest rates in 2001-02 were close to 12.3% or more, then they were unsustainable (Cleator *et al.* 2010).

Six hydroelectric generating stations (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 2). Some dams, such as Gardiner GS, were built to provide other services (e.g., flood control and irrigation for agriculture) in addition to hydroelectric power or for purposes other than hydroelectric power. Other man-made barriers 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 and mortality (Cleator *et al.* 2010). Dam construction can extirpate local Lake Sturgeon populations (Cleator *et al.* 2010) by preventing fish from accessing spawning areas and stranding fish between impassable barriers. Larger structures, like hydroelectric dams, can also cause direct mortality, injury or reduced survival by entrainment[2], impingement[3] and fish passing downstream through the turbines. 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. There is some

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

evidence that GSs on the South Saskatchewan and Saskatchewan rivers caused fragmentation of habitat and, thus, isolation of Lake Sturgeon, as well as considerable loss and degradation of important habitat that resulted in reduced recruitment (Cleator *et al.* 2010).

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.

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

The Lake Sturgeon in DU2 is most sensitive to harm on early adults, followed by late juveniles, early juveniles, age-0 and then late adults (in decreasing order) (Cleator *et al.* 2010). 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, and maximizing survival of, adults and late juveniles as the key to recovering this DU. However, the potential for improving survival of adults is low relative to the potential in age-0 and young juveniles (Table 3), therefore the possibility of implementing recovery strategies that improve age-0 and juvenile survival (e.g., habitat rehabilitation) should also be considered. For example, conservation stocking using fish from the same genetic stock has the potential to improve survival of age-0 and young juvenile fish so long as it also addresses potential impacts on genetic variability, artificial selection and transmission of disease from cultured to native fish. Conservation stocking 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 or alternate measures outlined in this document.

Fertility rates in both early and late adult stages are less sensitive to perturbation (Cleator *et al.* 2010). Regardless, 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 (Cleator *et al.* 2010). Complete blockage of spawners at barriers can eradicate a population in a generation from continuous reproductive failure and strong site fidelity for spawning (Cleator *et al.* 2010).

Table 4 provides an inventory of possible mitigation measures, alternatives and enhancements to anthropogenic activities that pose threats to Lake Sturgeon survival and recovery. Mitigations, alternatives and enhancements for the most important threats for DU2, as identified in Table 2, are shown 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

Modelling analyses for DU2 indicate 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).

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. Lake Sturgeon seem 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

Age estimates for Lake Sturgeon made using a longstanding technique (i.e., counting growth increments on pectoral fin spine cross sections) were recently 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 (Cleator *et al.* 2010). 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 to the forks of the North Saskatchewan and South Saskatchewan rivers, MU4 between the forks and François-Finley GS on the Saskatchewan River, 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 in number primarily as a result of over-exploitation from commercial fisheries and degradation of loss of a significant portion of their habitat. Current information suggests 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 a stable trajectory in MU6 and unknown trajectory in MU3.

Survival and recovery of Lake Sturgeon in DU2 depend 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 River 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). 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 protection of 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.

OTHER CONSIDERATIONS

There are several jurisdictions involved in the management and recovery of Lake Sturgeon in DU2 including the Saskatchewan River Sturgeon Management Board, the governments of Alberta, Saskatchewan and Manitoba and DFO.

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Figure 2. DU2 showing locations of MUs and place names mentioned in the text.

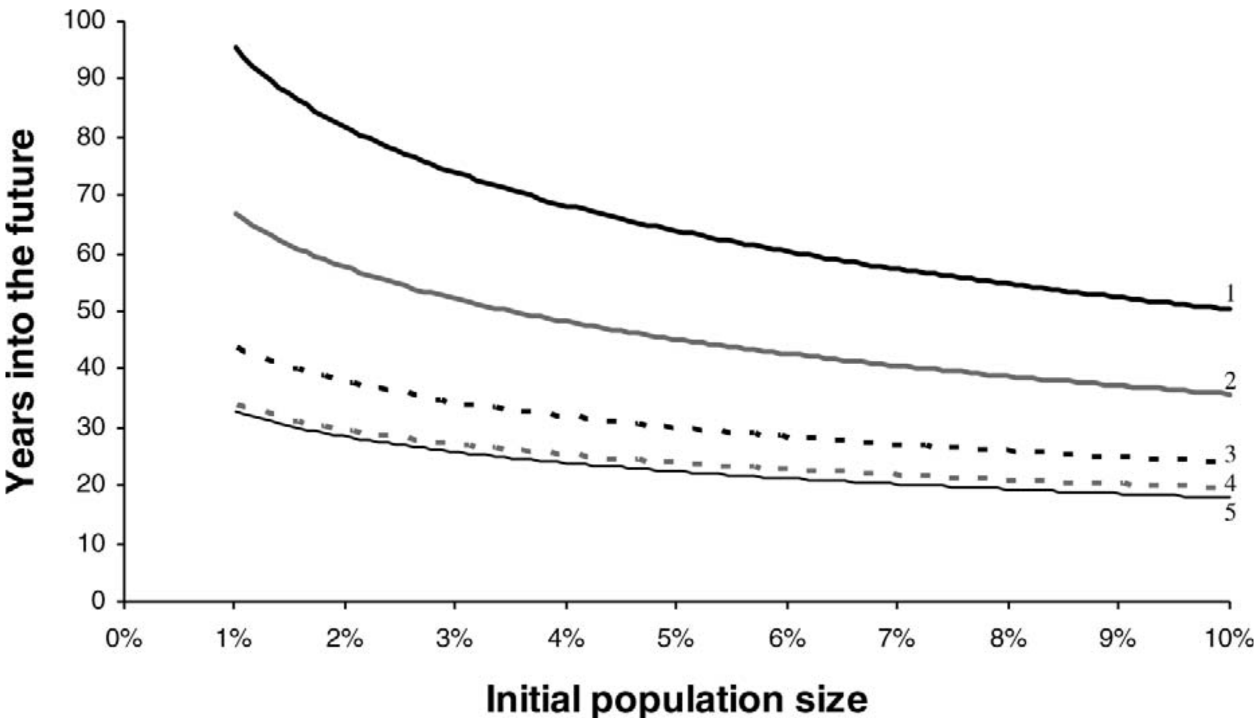

Figure 3. Stochastic projections of times to recovery for Lake Sturgeon based on initial population size (i.e., percentage of MVP) under five different recovery scenarios. Strategy 1 (solid black line) was the maximization of the survival rates of early adults, strategy 2 (solid grey line) added a 10% 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, as cited in Cleator et al. 2010).

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 was based on the best available information and Precautionary Framework (see Cleator et al. 2010 for explanation); 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	Saskatchewan River: The Forks – François-Finley GS	Cautious	Stable or Increasing	High	Moderate
5	Saskatchewan River: François-Finley GS – E.B. Campbell GS	Cautious	Unknown	Low	Low
6	Saskatchewan River: 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	Saskatchewan River: The Forks – François-Finley GS	Saskatchewan River: François-Finley GS – E.B. Campbell GS	Saskatchewan River: 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, as cited in Cleator et al. 2010). 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 drift 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.

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ISSN 1919-5079 (Print)
ISSN 1919-5087 (Online)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO. 2010. Recovery potential assessment of Lake Sturgeon: Saskatchewan River populations (Designatable Unit 2). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/049.