STANDARDIZED FIELD SAMPLING METHOD FOR MONITORING THE DISTRIBUTION AND RELATIVE ABUNDANCE OF THE STONECAT (NOTURUS FLAVUS) MISSOURI POPULATION IN CANADA

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ABSTRACT

Macnaughton, C.J., Watkinson, D.A., and Enders, E.C. 2020. Standardized field sampling method for monitoring the distribution and relative abundance of the Stonecat (*Noturus flavus*) Missouri population in Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3355: ix + 38 p.

Stonecat is common in many areas of Canada, but it is extremely rare within Alberta and Saskatchewan, where it is the only catfish species native to Alberta and listed as *Threatened*. To provide Science Advice to future status and population assessments of Stonecat, this report aims to provide a consistent sampling method and survey design to inform on changes in the distribution and relative abundance of Stonecat populations in the Missouri watershed in Alberta and Saskatchewan. This report details (1) the sampling gear, (2) recommended sampling effort and timing, and (3) sampling sites for Stonecat occurrence and abundance. This standardized sampling protocol is intended to improve the monitoring of the species, the assessment of population trends, and consequently allow for a long-term monitoring of the species in the Missouri watershed in Alberta and Saskatchewan.

RÉSUMÉ

Macnaughton, C.J., Watkinson, D.A., and Enders, E.C. 2020. Standardized field sampling method for monitoring the distribution and relative abundance of the Stonecat (*Noturus flavus*) Missouri population in Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3355: ix + 38 p.

La barbotte des rivières est répandue au travers le Canada, mais elle demeure très rare dans les eaux douces du bassin versant de la rivière Missouri en Alberta et au Saskatchewan. Elle demeure la seule espèce endémique de l'Alberta et est ainsi classifiée comme étant menacée. Dans le cadre d'établir des cibles quantitatives pour la barbotte des rivières en vue d'assurer sa protection et son rétablissement, ce rapport sert à définir un protocole et un design d'échantillonnage qui serviront à faire l'inventaire des populations de barbottes des rivières dans le bassin versant de la rivière Missouri en Alberta et Saskatchewan. Ce rapport vise à décrire (1) l'engin de pêche recommandé, (2) l'effort et le moment de l'année idéal pour l'échantillonnage, et (3) la localisation des sites d'échantillonnage qui se retrouvent dans l'ensemble de l'aire de répartition de l'espèce, ainsi qu'à l'extérieur de cette zone pour faire le suivi de l'abondance à long-terme. Ce rapport contribue directement à la conservation de l'espèce en mettant en œuvre un plan de surveillance dans les cours d'eau canadiennes pour assurer la viabilité à long-terme de la barbotte des rivières.

ACKNOWLEDGEMENTS

Fisheries and Oceans Canada (DFO) wishes to acknowledge the contributions of those who collected field samples and provided fisheries data for the technical report: A. Batty, M. Lowdon, S. Kjartanson, D. Boguski, E. Macdonald, J. Eastman, A. Wruth. The Alberta Fish and Wildlife Management Information System (FWMIS) was used in this report.

1.0 INTRODUCTION

Various field sampling methods for quantifying the occupancy and relative abundance of small-bodied freshwater fishes in wadeable streams are currently in use. However, different field methods (e.g., beach seining vs. electrofishing) often yield different information on the species composition and effort, leading to complementary and/or incomplete data records for any given species. Inconsistent sampling effort and survey designs may, therefore, preclude pooling data from different sources for obtaining reliable estimates (e.g., distribution and relative abundance) of target species. Biases associated with these methods have led to the development of species-specific sampling protocols for many fish species (e.g., Macnaughton et al. 2019 a, b, c, d).

Stonecat (*Noturus flavus* Rafinesque 1818) is a tan to grey-coloured catfish that is found in Canada, in freshwater systems from Quebec to Alberta. Although this species is common in many areas in Canada, it is extremely rare within Alberta and Saskatchewan, where it is the only catfish species native to Alberta and in the Missouri watershed in Saskatchewan. Stonecat are distributed in the Milk River below the confluence with the North Milk River and the lower section North Milk River in Alberta, as well as the Frenchman River and Rock Creek in Saskatchewan. The Committee on the Status of Endangered Wildlife in Canada has not provided a national status designation of this species (COSEWIC status as of January 1, 2004). However, the species exhibits a restricted distribution in the Milk River in Alberta and has been considered an indicator species of water quality due to its vulnerability to siltation (i.e., embeddedness of substrates) and pollution (Ohio Department of Natural Resources 2002).

A multi-species approach to protect and maintain self-sustaining populations found in the Milk River and St. Mary River drainage basins in Alberta was established for the Western Silvery Minnow (*Hybognathus argyritis*) and the Rocky Mountain Sculpin (*Cottus sp.*) (Fisheries and Oceans Canada 2018). Like other *Species At Risk Act*-listed species with similar distributions in the Milk River, Stonecat may also be susceptible to similar anthropogenic threats including changes to flows and climate variability (e.g., drought) (Alberta Sustainable Resource Development 2004). As such, the Stonecat population in Alberta is designated as *Threatened* in Alberta, Canada. Status assessment of the Missouri population of Stonecat by COSEWIC may occur in the future.

To provide Science Advice to future status and population assessments of Stonecat, this report aims to provide a consistent sampling method and survey design to provide a baseline and inform on changes in the distribution and relative abundance of Stonecat populations in Alberta and Saskatchewan. Properly designed sampling programs should include knowledge of the biology of the species and the deployment of the appropriate gear under the direction of experienced personnel. This report specifically details which sampling gear to use, how much effort is required, where to sample Stonecat populations, and where range extension sampling should be planned as part of a long-term monitoring for the species in the Missouri watershed in Alberta and Saskatchewan.

Using existing field sampling data records for the species, this technical report provides knowledge on baseline occurrence and relative abundance of Stonecat throughout the Milk River and French River systems in Alberta and Saskatchewan. The use of this standardized sampling protocol that includes the frequency of sampling events over time, as well as baseline data required to establish Stonecat population trends and distribution targets for recovery, will build the basis for a better-informed future management of the species.

2.0 STONECAT

2.1 MORPHOLOGY

Stonecat morphology reflects its benthic oriented lifestyle. Stonecat are tan to gray-coloured dorsally and yellowish to white-coloured ventrally. The adipose fin extends to the anterior dorsal edge of the caudal fin (Stewart and Watkinson 2004). It is separate from the caudal fin by a notch. Pectoral fins lack posterior serrae and the caudal fin has a pale margin outlining it. The number of anal fin rays, pectoral fin rays, pelvic fin rays, and caudal fin rays range from 15 to 18, from nine to 11, from eight to ten, and 55 to 67, respectively. Stonecat have a premaxillary band of teeth located on the roof of their mouth, which is absent in other species of madtoms *Noturus* spp. (Trautman 1981; Etnier and Starnes 1993). Stonecat is distinguished from all other catfish by the subterminal mouth, the posterior extension of the tooth patch on each side of the upper jaw, a broad and flattened head, a pale saddle dorsal marking at the rear of the dorsal fin, a pale yellow streak along the upper and lower margins of the caudal fin, and the square or slightly rounded posterior margin of the caudal fin (Stewart and Watkinson 2004). Like other members of the catfish family, Stonecat has barbels and dermal taste buds located on the epidermis of the fish. Both barbels and dermal taste buds are used for locating food and perceiving the surrounding environment.

This relatively small catfish rarely exceeds 203 mm in total length (Scott and Crossman 1973), with the longest reported specimen in Alberta from the Milk River measuring 269 mm (R.L. & L. 2002). The species is seldom longer than 150 mm in Manitoba (Stewart and Watkinson 2004). In South Dakota, young-of-the-year reached 79 mm and 99 to 137 mm in the third and fourth years of life (average length = 114 mm; Etnier and Starnes 1993).

Figure 1. Stonecat (*Noturus flavus*) (photo courtesy of D. Watkinson).

2.2 Biology

Life Cycle and Reproduction

Stonecat females are generally larger than males and reach sexual maturity on average at three years of age (Etnier and Starnes 1993; Hammerson 2005). Stonecat form monogamous pairs for breeding and breed once a year, generally from April to July. In Canada, the peak spawning period appears to begin in June or July (Scott and Crossman 1973), when water temperatures reach 23–25 °C depending on the watershed, but in Illinois, females attained peak spawning condition when temperatures ranged from 27–29 °C (Walsh and Burr 1985). Like other catfish, males excavate or clean a nest located under flat stones and tend to it after spawning (Stewart and Watkinson 2004). Females will deposit a jelly like cluster of eggs (between 100–500 eggs) on the underside of flat stones and similar structures (i.e., nests) and males guard nests until the young hatch. Fecundity appears to differ between stream and lake populations from 973 eggs per female in Lake Erie (range of 767–1205 eggs; Langois 1954) to 189–570 eggs in a stream in Illinois (Walsh and Burr 1985). Fecundity is positively correlated with body size, which explains the larger number of eggs per female in lake vs. stream environments. Males are thought to be the nest guarders, but it is believed that females also take part in guarding the young (Etnier and Starnes 1993; Hammerson 2005). At hatching, larvae range from 6.7–7.5 mm in total length and will generally school closely together for protection (Walsh and Burr 1985).

Maturity and Age Structure

The lifespan of Stonecat in Illinois was only five to six years of age, with a maximum reported age of seven years (Etnier and Starnes 1993). Age of maturity is approximately three years of age (three to four years).

Feeding and Behaviour

Juvenile and adult Stonecat exhibit nocturnal behaviour and spend their days under rocks and woody structures, where it is dark. They come out at night to feed in the shallow waters (Hammerson 2005). Due to the sedentary nature of the species, it is thought that they have small home ranges. The species is primarily invertivore, feeding on larvae of mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), amphipod crustaceans (*Gammarus sp.*), and midges (Chironomidae). Adults will feed mainly on mayfly larvae and crayfish but will also eat small darters and minnows (Etnier and Starnes 1993; Hammerson 2005). Known predators include the Channel Catfish (*Ictalurus punctatus*) and Smallmouth Bass (*Micropterus dolomieu*).

Stonecat serve as indicator species of water quality, as they are not present in highly polluted and/ or silted substrates (Ohio Department of Natural Resources 2002). However, Stonecat may be found in silty water, but prefer substrates that are coarse with cover (Stewart and Watkinson 2004).

Dispersal and Migration

In Alberta, Stonecat is present in the Fresno Reservoir, upstream of the Fresno Dam, in the lower portion of the North Milk River as well as the mid-sections of the Milk River mainstem (The Milk River Fish Species at Risk Recovery Team 2014). Natural recolonization of the lower Milk River is possible from upstream and downstream sources, though re-establishment in the lower Milk River from these sources may take a while due to the small size of the source population and the large distance upstream from the reservoir (85 km) (Alberta Sustainable Resource Development 2004). Stonecats have not been identified as a migratory species to date, but virtually no information on stonecat movement or seasonal migrations is available. A single study on the Grand River, Ontario using a fishway to monitor upstream fish movement observed many Stonecat moving upstream throughout the month of June, when water temperatures ranged from approximately 16 to 21°C and turbidity was relatively low (Bunt et al. 2001). The species has a propensity for range expansion, capable of moving into new upstream environments over relatively short periods of time or several generations (McCulloch and Stewart 1998). In the Milk River, Stonecat likely use different areas opportunistically, depending on water discharge and season (Alberta Sustainable Resource Development 2004).

2.3 Known Distribution

The North American distribution of Stonecat extends from the St. Lawrence-Great Lakes, Hudson Bay (Red River), and Mississippi River basins from Quebec to Alberta and south to northern Alabama, northern Mississippi, Arkansas, northeastern Oklahoma, and Colorado; Hudson River watershed and New York (Page and Burr 1991; McCulloch and Stewart 1998). Its Canadian range is limited to the southernmost watersheds of Quebec, Ontario, Manitoba, Saskatchewan, and Alberta.

Although the species is common in many areas south of the Canadian prairies, it is extremely rare in Alberta and Saskatchewan, present in the lower sections of the North Milk River, Milk River below the North Milk River confluence, Frenchman River below the Eastend Reservoir, and Rock Creek in Missouri National Freshwater Biogeographic Zone (NFBZ).

<u>Missouri Population listed *Threatened* by the Province of Alberta</u>

The species was designated as *Undetermined* in Alberta according to the *General Status of Alberta Wild Species 2000* (Alberta Sustainable Resource Development 2004), but has been upgraded to *Threatened* in 2007 and a provincial Recovery Plan has been developed by the Milk River Fish Species Recovery Team (Alberta Stonecat Recovery Plan 2013–2023; Fisheries and Oceans Canada 2018). The Committee on the Status of Endangered Wildlife in Canada has not provided a national status designation of this species.

It is very difficult to determine whether changes in the distribution and abundance of Stonecat have occurred over time in the Missouri NFBZ as there is a lack of directed sampling for the species. Since the first documented account of the species in the 1960s, the collection of Stonecat in the Milk River has remained low and the distribution does not appear to have changed over time (Alberta Sustainable Resource Development 2004).

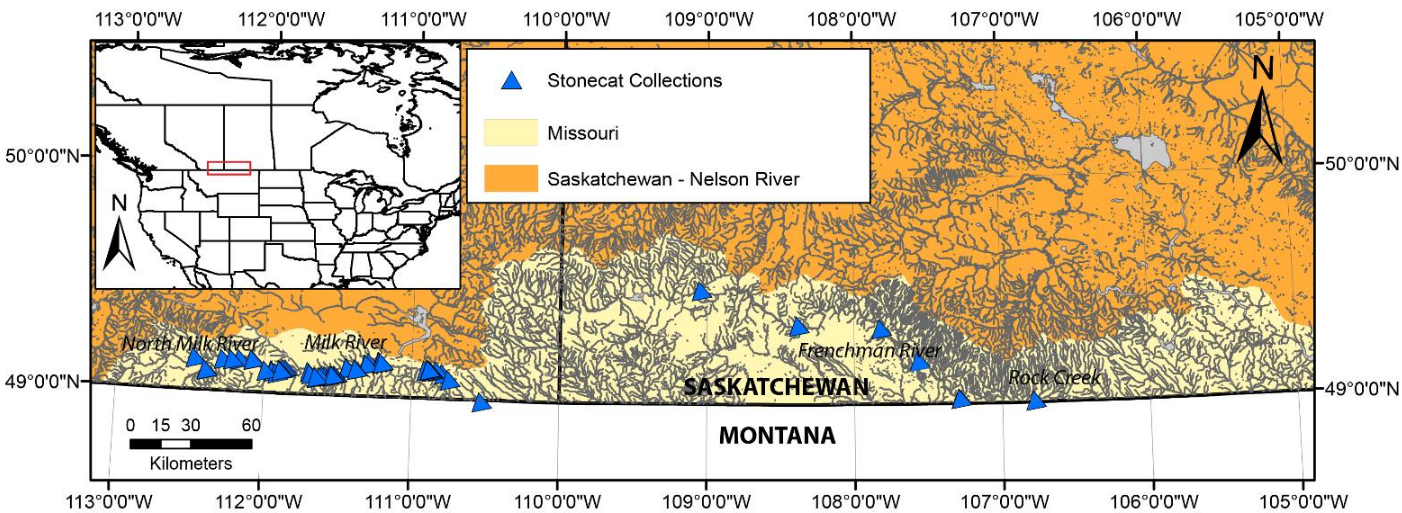

Figure 2. Occurrence of Stonecat in Milk River, southern Alberta and the Frenchman River watershed in Saskatchewan (FWMIS 2019; SKDC 2019).

2.4 Habitat

<u>Habitat Features</u>

The stonecat occurs in a variety of riverine habitats ranging from mid-sized to large streams, as well as wave-exposed rocky areas of large lakes. Stonecat have usually been documented in deep boulder pools or over rocky bottoms of cobble and boulder in riffle and rapid sections of rivers, but sand and gravel bar use in lakes has also been noted (Scott and Crossman 1973). Stonecats remain hidden under cobble and boulder substrates during the day and forage on the bottom at night. Its distribution in the Milk River, as well as the Red River in Manitoba, suggests that this species is likely tolerant of a wide range of turbidity levels (Stewart and Watkinson 2004). However, its distribution in these rivers strongly suggests that it is limited by water temperature. A study conducted in Maryland found that Stonecat were absent in first to third-order streams, where temperatures < 22°C and that abundance steadily increased downstream (Kline and Morgan 2000).

A habitat analysis for stonecats in the Milk River indicated that the species generally uses run and flat habitat types, generally defined by moderate depths and unbroken surface, with low to moderate water velocities (0.0-0.29 maximum velocities) and low silt depth (0.0-0.10 m) (R.L. & L. 2002). Stonecat appear to be intolerant of both fast currents in high-gradient systems (Trautman 1981). In the Red River in Manitoba and the Milk River in Alberta, they are present in low-gradient and silty habitats (Scott and Crossman 1973). It occurs in depths from 10 m deep of the Red River to 30–50 cm deep along the shorelines and tributaries (Stewart and Watkinson 2004). Substrates were mixed ranging from small to large rocky material, with mean substrate size represented by larger cobble and boulders (0.21-0.57 m in diameter; R.L & L. 2002).

Figure 3. Pictures of the Milk River (top left) and North Milk River, Alberta (top right), Frenchman River, Saskatchewan (bottom left), and Rock Creek, Saskatchewan (bottom right) (photos courtesy of D.A. Watkinson).

Habitat Trends and Threats

The greatest changes to habitat for Stonecat at the USA-Canada scale have been associated with irrigation. There is very little irrigation in Alberta from the Milk River proper, but the use of the Milk River as a canal has altered Stonecat habitats. Water in the Milk and St. Mary rivers are intensively managed for irrigation use both in Canada and the United States. As such, they are subject to provisions in the Boundary Waters Treaty of 1909 (the Treaty) between Canada and the United States, which is administered by a binational organization called the International Joint Commission (IJC) (https://ijc.org/en/aosmmr). The IJC has appointed members by both Canadian and American governments and the Treaty itself provides the principles and mechanisms to resolve disputes concerning shared water.

The context of the apportionment is best considered temporally regarding the irrigation season (April 1 to October 15 annually) and the non-irrigation season (October 16 to March 31). The water sharing agreement between Canada and the United States in the Milk and St Mary rivers has been to divert water from the St. Mary River (~ 18.4 $m^3 \cdot s^{-1}$) into the North Milk River, starting April 1. The natural winter flow in the Milk River is generally very low at this time of year (< 1 $m^3 \cdot s^{-1}$), thus, the increase in water flow is significant, rising up to ≥ 15 $m^3 \cdot s^{-1}$ in a relatively short period of time. This higher water flow continues in the Milk River until September or October, when water flow is reduced to natural or close to natural conditions, as the end of the irrigation season approaches. Both rivers have low winter flows, however, water flow in the Milk River watershed in the winter is natural, whereas it is managed in the St. Mary River via storage facilities in Montana (Sherburne Reservoir and St. Mary Lake)

The St. Mary Diversion moves water into the Milk River for withdrawal and irrigation purposes, which consequently impacts multiple species' habitats by altering the river's flow regime and morphology. Based on a study of two locations in the lower Milk River, the increase in discharge during the augmentation period was estimated to reduce suitable habitat from 40.2% and 28.3% of wetted area to 9.5% and 3.9% wetted area, respectively (Neufeld 2016). A prior study by Golder Associates (2010) estimated suitable habitat to be 30–40% wetted area in the lower Milk River and 40–50% near the town of Milk River from April to October. Both studies emphasized a reduction in suitable habitat for multiple species (i.e., Western Silvery Minnow, Rocky Mountain Sculpin, and Stonecat) during periods of flow augmentation. As a result, it is possible that suitable habitat was more abundant before 1917, prior to implementation of the diversion (COSEWIC 2017). However, a greater number of sample locations, where habitats are stratified and resampled, is needed to support these conclusions.

Despite these changes to habitat suitability, the St. Mary Diversion may be important in improving habitat availability and overwintering survival of several species in the Milk River, including Stonecat. During ice-over months, natural water levels decline substantially, leaving mostly standing or low-flow pools as refugia for overwintering fish. This, exacerbated by increased drought frequency, could greatly limit the winter survival and contribute to the range contraction of several species in Alberta (Mainstream Aquatics 2005; Hoagstrom et al. 2006; COSEWIC, 2017). Stonecat status in the Milk River is unclear because the combination of severe drought conditions and the operation of the St Mary Canal have left the lower Milk River, above and below the international border, with near complete drought conditions, except for a series of isolated pools during the fall and winter of 2001-2002, many of which were not deep enough to support overwintering fish (RL&L 2002a; Alberta Sustainable Resource Development 2004). Ongoing issuance of temporary water diversion licences in Canada during flow augmentation have contributed to an already severe drought. Should drought events become prolonged, they have the potential to extirpate these species, with no source of natural downstream recolonization due to the Fresno Dam (COSEWIC 2017). As a result, the St. Mary Diversion and resulting flow augmentation could be crucial in maintaining sufficient water levels and flow for the survival of these species in the Milk River (McLean and Beckstead 1980; COSEWIC 2017). Furthermore, global climate warming and drying may exacerbate these negative impacts on habitat quantity and quality.

Within the Saskatchewan portion of the distribution in the Missouri NFBZ flows have been severely modified in the Frenchman River to allow for irrigation by the dam built on Cypress Lake (1937), and the creation of Eastend Reservoir (1939), Huff Lake (late 1930s), and Newton Lake (1937). The flows in the Frenchman River are often 0 $m^3 \cdot s^{-1}$ in the late summer and winter (Environment and Climate Change Canada 2019). Rock Creek is not modified and is a typical prairie intermittent stream with a highly variable hydrograph, where 37 monthly mean flows of 0 $m^3 \cdot s^{-1}$ occurred between 1979–2009 (COSEWIC 2012). There are currently no native or exotic piscivores known from the Canadian portions of Rock Creek.

2.5 Population Size and CPUE Trends in Canada

Population Trends in Alberta

It is very difficult to determine whether changes in the distribution and abundance of Stonecat have occurred over time as very little collection records exist and limited directed sampling has been conducted. Museum records indicated that Stonecat was first documented in the Milk River in 1962 (Nursall and Lewin 1964) and since that time, a limited number of surveys in 1966, 1967, 1973, 1974, 1979, 1986, 1992, 1997 and between 2000 and 2002 have recorded low numbers of Stonecat (Alberta Sustainable Resource Development 2004). Surveys conducted in October 2002 captured a single individual in the lower portion of the North Milk River, thus, extending the known range in the Milk River system. No population estimates are available for the Stonecat in the Milk River; however, the population is considered low in abundance and stable based on comparisons of relative abundance over time (Alberta Sustainable Resource Development 2004; The Milk River Fish Species at Risk Recovery Team 2014). Limited distribution and low abundance in Alberta make this species extremely vulnerable to ecological perturbations that affect habitat availability in the Milk River.

For samples collected using similar methods and presence only records, average CPUE and abundance across sites in the Milk River ranged from 0.014–1.84 fish·min^{-1} and 1–51 fish, respectively (Table 1). While most historical catch rates in Alberta are very low (average across sites and years = 0.27 fish·min^{-1}), as many as 51 fish (CPUE = 1.7 fish·min^{-1}) were captured in 2004 in a single site (Mainstream Aquatics Ltd.). Distance and time of each survey effort for these sites were inconsistently recorded, thus, CPUE was measured as the number of fish collected by minute of electroshocking (see Appendix 3 for all Stonecat data collected in Alberta and Saskatchewan). The potential for the population to dramatically fluctuate among years and the rarity of Stonecat in the system emphasize the need for a standardized monitoring protocol.

Table 1. Average (range) electrofishing survey effort, Stonecat CPUE and abundance surveyed in the Milk River.

Waterbody	Mean Effort in time (range in minutes)	Mean Site CPUE (range fish·min^{-1})	Mean Site Abundance (range fish)
Milk River	22.45 (4.1–71.6)	0.27 (0.014–1.84)	4.83 (1–51)

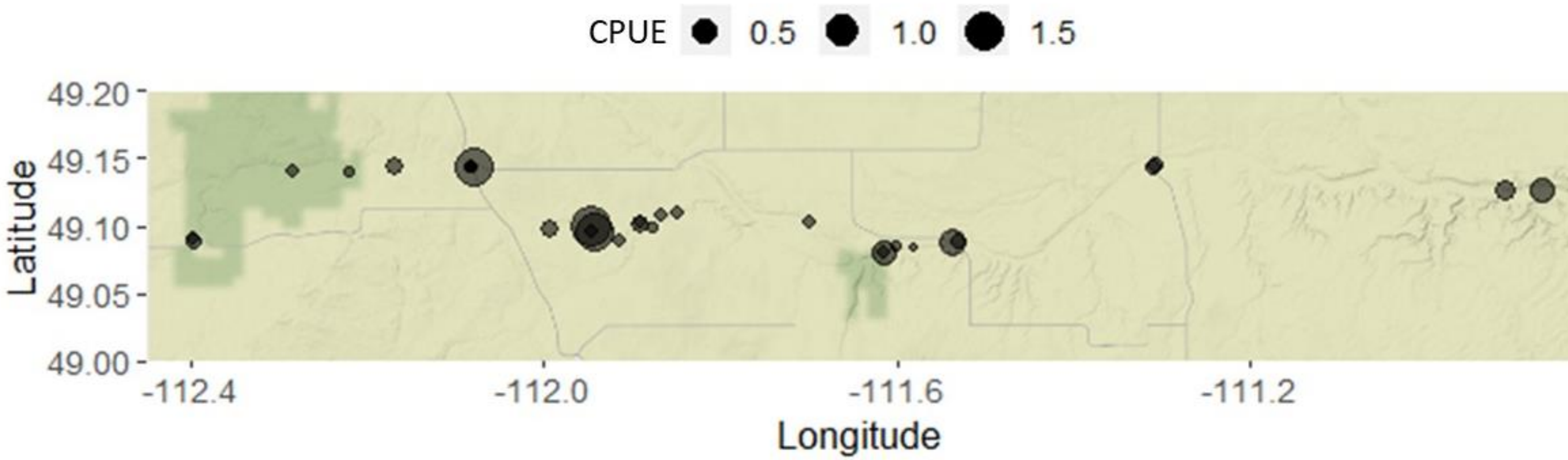

Figure 4. CPUE (fish min^{-1}) of Stonecat electrofishing surveys in the Milk River and North Milk River from years 1979–2014 (see Appendix 3 for raw data). Points indicate presence only data. Large points represent the largest Stonecat catches <1.5 fish·min^{-1}.

Population Trends in Saskatchewan

For the six sites surveyed in the Frenchman River and Rock Creek, a total of seven Stonecat were fished in 2006 and 2007 collectively (Appendix 3).

Table 2. Range site abundance by year of Stonecat electrofishing surveys in the Frenchman River and Rock Creek, Saskatchewan. Effort in time and distance not indicated.

Waterbody	Year	Range Site Abundance (# fish)	Comments
Frenchman River	2006	2–4	DFO survey; 2 sites
Rock Creek	1970*	2	Site location was 23 km S and 26 km E of Val Marie in Grasslands National Park
	2007	1	DFO survey

3.0 SAMPLING PROTOCOL

3.1 SAMPLING DESIGN

Seining and backpack electrofishing are considered the most efficient, readily available sampling gears in wadeable and non-wadeable habitats, however, seining may not be the most effective sampling method in habitats where debris, boulders or other obstacles are present (Mandrak and Bouvier 2014). To obtain consistent fish survey data and ensure that monitoring is effective, a standard sampling protocol using backpack electrofishing is recommended to monitor the distribution and abundance of Stonecat in Alberta (Milk River) and Saskatchewan (Frenchman River and Rock Creek).

The quality of the data collected via electrofishing may be variable depending on the skill level of the operator. Ample practice prior to conducting surveys is advisable, but the skill level of the electrofishing operator should be indicated with each survey. The sampling protocol for Stonecat described here uses elements of the existing fish surveying protocol for first-time surveys of small streams in Alberta (Fish and Wildlife Alberta 2008). This protocol applies to wadeable streams (<1 m in water depth) in Alberta and Saskatchewan, where the distribution of Stonecat is currently being monitored.

Access Points

Access points at which Stonecat are known to occur are found in the North Milk, Milk, and Frenchman river, as well as Rock Creek (red triangles; Figures 5 and 6). All of these access points are recommended for monitoring population trends over time and proposed range extension locations (blue squares; Figures 5 and 6) will provide information on whether the species' distribution is expanding or contracting (Appendix 1 for the full list of the six access points and associated coordinates in the Milk River, Frenchman River, and Rock Creek).

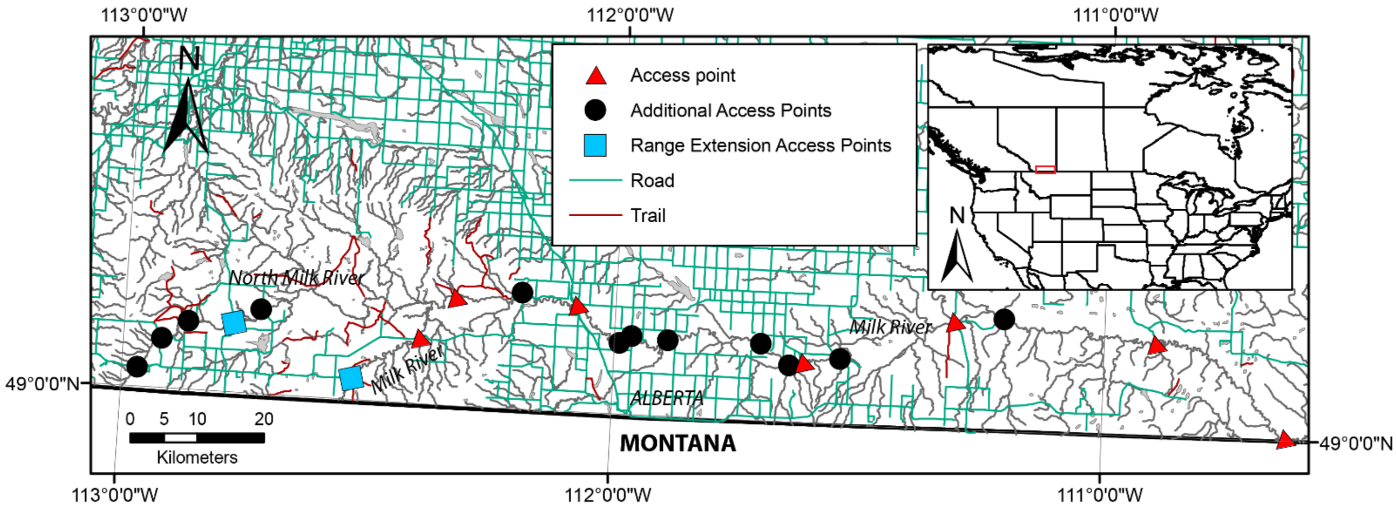

Figure 5. Map of the seven access points in the Milk River (red triangles) and 12 additional access points (black circles) and two range extension points (blue squares) in the Milk and North Milk rivers in Alberta.

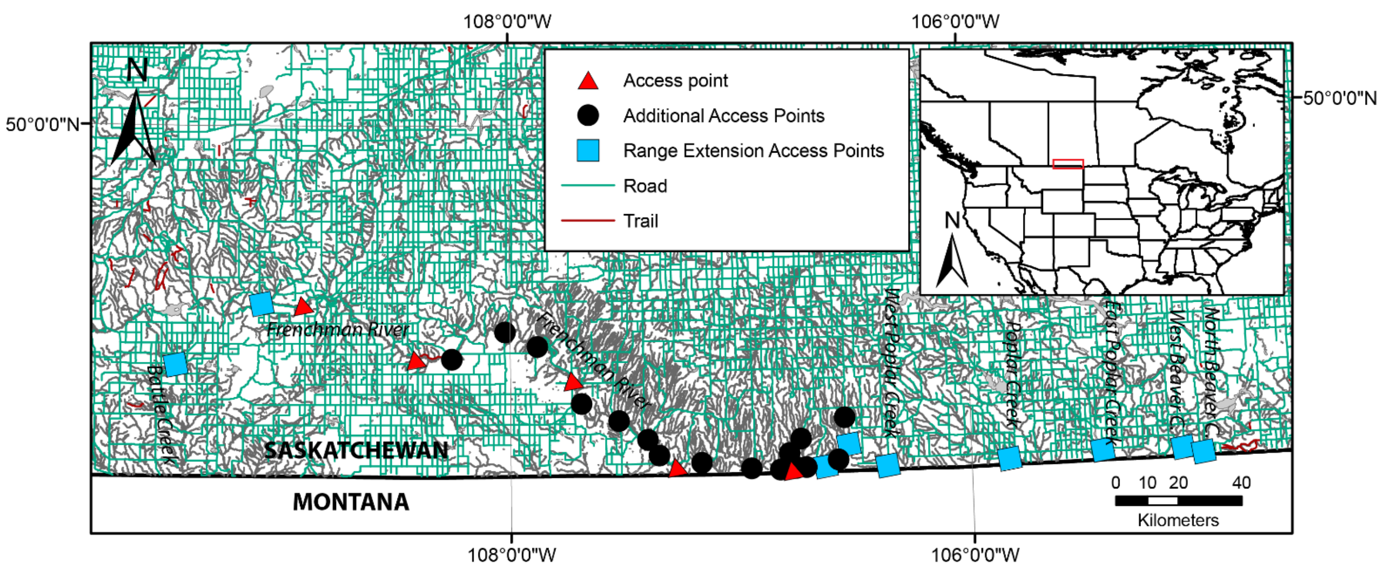

Figure 6. Map of the five access points (red triangles) 15 additional access points (black circles), and nine range extension points (blue squares) in the Frenchman River system in Saskatchewan.

Sites

A site represents the sampling unit (i.e., area) where surveying takes places. Sampling area for a given site in the North Milk River, Milk River, Frenchman River, and Rock Creek will be quite variable on account of fluctuating water flows and access to fish habitats (e.g., backwaters, river margins). Therefore, consistent sampling based on the length of a site and duration of the sampling effort must always be indicated.

For rivers, where the average wetted width is ≥ 5 m, a site represents an area of 300 m^2 or sampling unit of (e.g., 5 m wide by 60 m long or 2 m wide by 150 m long). In such cases, sites should be positioned alternating between either stream shore and if the depth allows for it, the middle (i.e., thalweg), according to the schematic (Figure 7). For narrower rivers and creeks < 5 m (e.g., Rock Creek), a site represents a 100 m long segment, making sure to sample both shores. Irrespective of the width of the river surveyed, sites should be evenly distributed among recommended access points along each river, maximizing the spatial extent of the surveying effort. Since there are seven access points for the Milk River and five access points for the Frenchman River and Rock Creek, respectively, it is recommended that four sites are established per access point, for a total of 20-28 sites, throughout the species' known distribution in Alberta and Saskatchewan.

Except for specialized habitats, sites should be randomly situated along the shores of each access point using a random number generator (1–100) that corresponds to the distance of the first most downstream site from the access point. In order to balance the spatial distribution of sampling sites with the effort of moving between these sites, we recommend that these sites are spaced out ~100 m apart from one another. To avoid disturbing fish during surveys, sampling should commence at the most downstream site at any given access point, moving upstream with each new site. Furthermore, habitat and environmental descriptors that specifically measure water quality (i.e., water turbidity and conductivity) should be obtained prior to entering the stream for sampling.

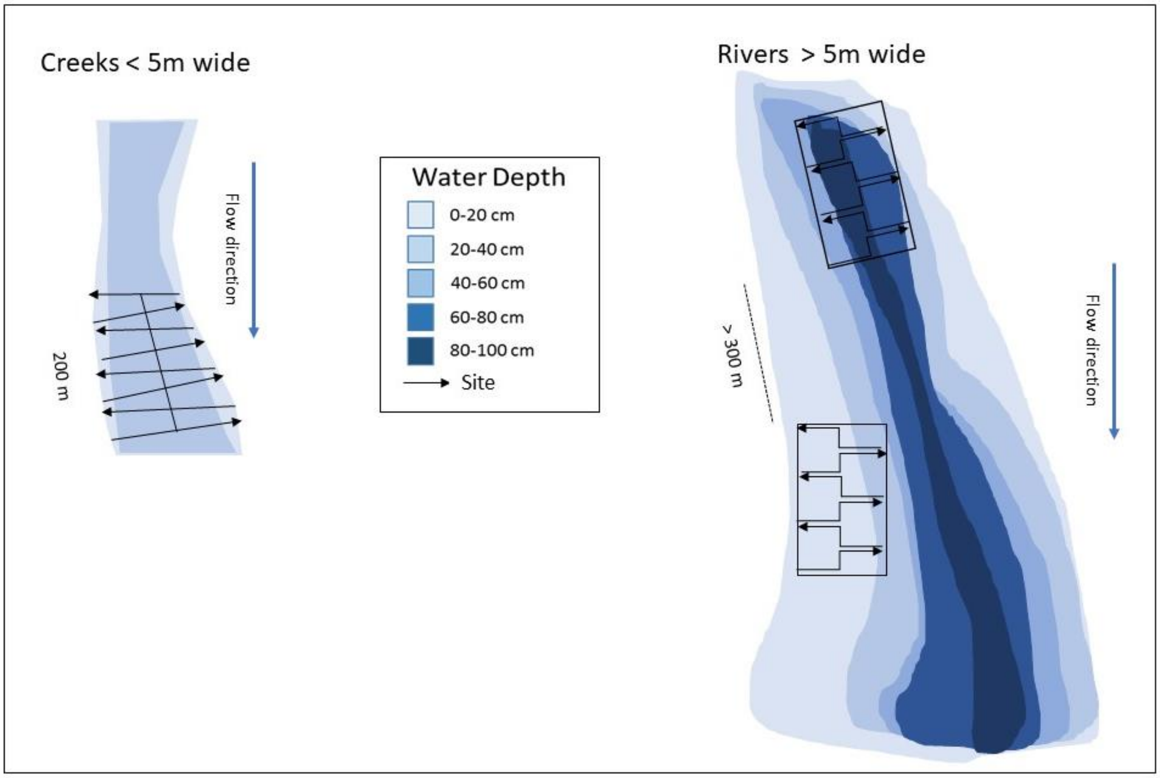

Figure 7. Schematic of electrofishing surveys for small creeks and larger rivers.

3.2 Timing of Sampling

It is important that sampling be timed to match the most appropriate conditions every year to reduce environmental variation. Individual sampling sites may be randomized while access points remain fixed among years. The sampling sites should therefore be georeferenced and photographed in the field to ensure that the same approximate locations are used repeatedly across years. The timing of sampling events should also be relatively consistent across years with the caveat that creeks should be sampled when they are flowing, rather than when much of the system is dry with isolated pools or stagnant.

Seasonality

Alberta

Survey feasibility in the Milk River watershed is contingent on seasonal water levels and water temperatures that allow fishing to consistently and predictably occur. Rather than aiming at calendar dates each year, surveys should occur within a range of targeted stream flows within a particular calendar period. Real-time hydrometric data for the systems are available from the Water Survey of Canada (https://wateroffice.ec.gc.ca/search/real_time_e.html) to inform on seasonal flow and water level variability (Table 3). The North Milk and Milk rivers downstream of the

North Milk River confluence have been severely impacted by changes in its seasonal flow regimes. Water diverted from the St. Mary River in Montana augments flows in the Alberta portion of the Milk River from late March or early April through late September or mid-October. As such, high flows from mid-September (Days 214–305 and 275-305; Figure 8) for the Milk River further reduces the window of time that Stonecat surveying can be conducted. To ensure that sampling is consistent among sites, it should occur during periods when augmentation is not occurring (i.e., low-flow) rather than during summer augmented flows.

Table 3. List of real-time hydrometric stations and recommended sampling time in the Milk River where Stonecat occur.

Waterbody	**Hydrometric station**	**Location of hydrometric station**	**Suggested Sampling time**	**Source**
Milk River	11AA031	Milk River at Eastern Crossing of International Boundary	October 2nd - November 1st	Water Survey of Canada
North Milk River	11AA001	North Milk River at Western Crossing of International Boundary	August 2nd - November 1st	Water Survey of Canada

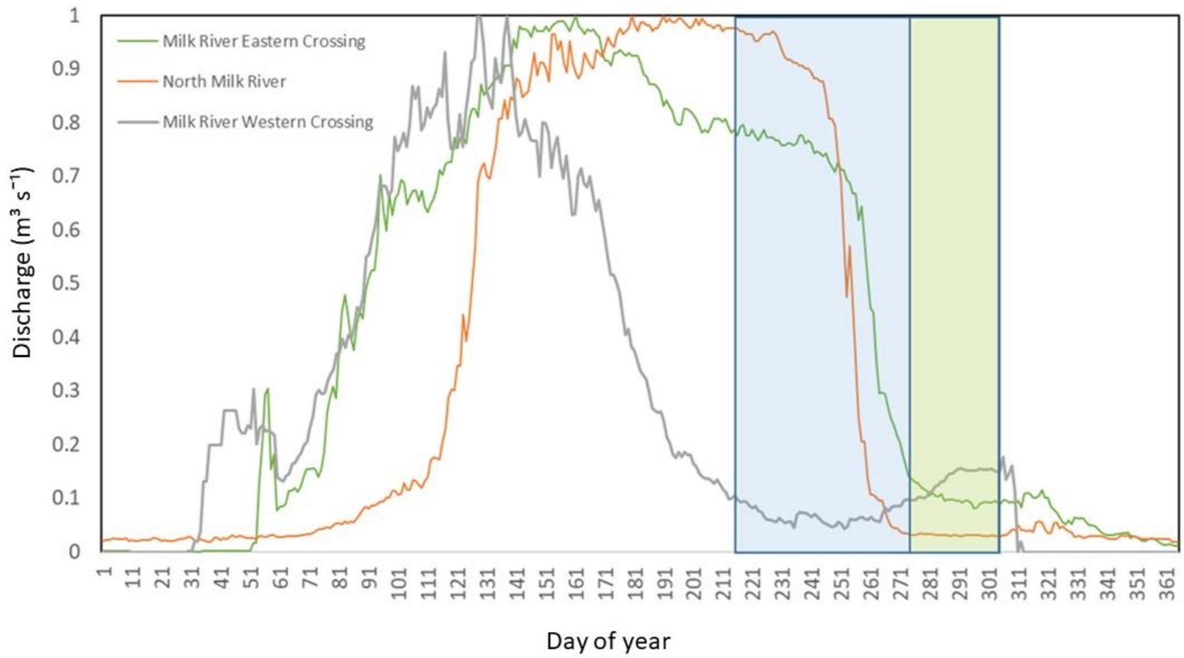

Figure 8. Hydrographs illustrating standardized median discharge ($m^3 s^{-1}$) over a year (Day 1 = January 1) for hydrometric data collected by Water Survey of Canada for Milk River Eastern crossing (green), North Milk River (orange), and Milk River Western crossing (grey). Windows of time for surveying Stonecat for all systems and the Milk River specifically depicted by the blue and green boxes at Days 214–305 and 275–305, respectively.

Saskatchewan

Rock Creek merges with Morgan Creek (the confluence ~ 1 km north of the Canada-USA border) and extends northward, in Grasslands National Park, Saskatchewan. Upstream portions of Morgan Creek are spring-fed whereas downstream portions of the creek are intermittently dry, leaving isolated pools where fish may be sampled. Upstream and downstream portions of Morgan Creek are quite variable, which make consistent sampling based on the length of a site in Morgan Creek nearly impossible.

Sampling feasibility in the Rock Creek watershed is contingent on seasonal water levels and water temperatures that allow sampling to consistently occur. Rather than aiming to sample particular calendar dates each year, annual studies should be conducted for targeted stream flows within a particular calendar period or under a similar flow stage. Real-time hydrometric data for the systems are available from the Water Survey of Canada and United States Geological Survey (USGS) to inform on seasonal flow and water level variability in the Frenchman River, Battle Creek, and Rock Creek (Sources: Water Survey of Canada 2019; USGS 2019; Table 4) and should be checked prior to field surveying. Rock Creek watershed becomes naturally intermittent in late-summer and winter, limiting the movement of fishes throughout the watershed. However, Stonecat should be able to immigrate and emigrate from the downstream portion of the watershed in Montana during most spring freshet conditions (April–May; Days 91–121; Figure 9). Rock Creek has a highly variable hydrograph, dipping to seasonal lows of 0 $m^3 \cdot s^{-1}$ from July 1st to mid-October. Upstream portions of Morgan Creek are spring-fed with greater flows than downstream portions of the creek. The lower Frenchman River has low flows (0 $m^3 \cdot s^{-1}$) for ~2 months of the year (End of August to mid-October) that may restrict survey area to isolated pools.

Table 4. List of real-time hydrometric stations and recommended sampling time in the Frenchman River and Rock Creek where Stonecat occur in Saskatchewan.

Waterbody	Hydrometric station	Location of hydrometric station	Suggested Sampling time	Source
Frenchman River	11AC041	At international boundary	July 19 to late-October	Water Survey of Canada
Battle Creek	11AB027	Battle Creek at Crossing of International Boundary	July 19 to late-October	Water Survey of Canada
Rock Creek	6169500	Below the confluence of Horse Creek (Montana)	June 30 to mid-October	USGS

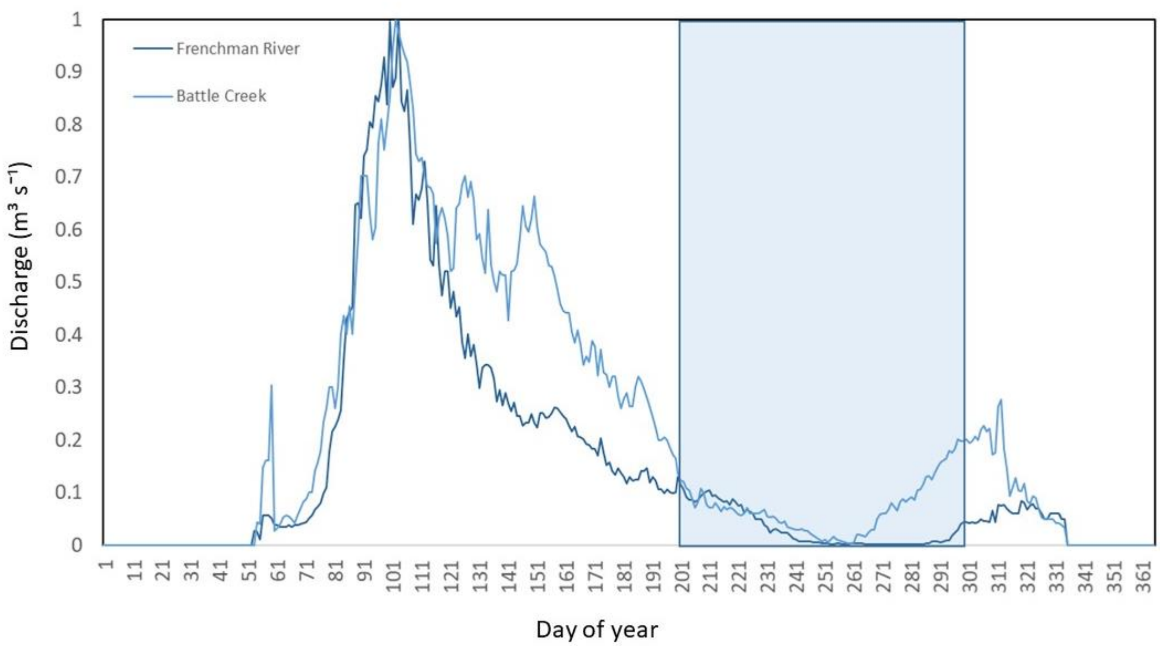

Figure 9. Hydrographs illustrating the standardized median discharge ($m^3\ s^{-1}$) over the days of a year (Day 1 = January 1). Data from1918–2015 for the Frenchman River (no data for winter months) and Battle Creek collected by Water Survey of Canada. Window of time for surveying Stonecat for both systems depicted by the blue box boxes from ~Day 200–300 (July 19–late-October).

Surveying Frequency

Baseline CPUE data is available for Milk River and to determine whether Stonecat populations are expanding or contracting, population trend assessments require more frequent surveying of the same sites and include range extension sampling. COSEWIC assessments determine the status of a species on a ten-year cycle, setting the timeline for when the information is required to update a species' status. To maximize the temporal extent of surveys and to provide a minimum of two estimates of the distribution and relative abundance of the species, sampling should be conducted twice in the ten-year cycle. Ideally, sites should be sampled once every five years, preferably not in consecutive years, once baseline data has informed the survey effort necessary to achieve reliable population trends. Two to three years of consecutive annual sampling should be sufficient to provide baseline data.

3.3 Sampling Gear and Method

A minimum crew size of three people is required, one to operate an LR-24 backpack electrofisher and two to net, each using a 33 cm wide by 38.10 cm long dipnet, with a 0.64 cm mesh (Smith-Root; Washington USA https://store.smith-root.com/dip-net-trapezoid-14in-mesh-p-112.html). The person with the backpack electrofisher is positioned between the netters, moving in an upstream zigzag fashion and sweeping the anode from left to right throughout the site. General electrofishing guidelines suggest 2–5 electrofishing $s \cdot m^{-2}$ (Mandrak and Bouvier 2014), which means that for sites of ~300 m^2, continuous electrofishing surveys should last from 600-1500 s, depending on habitat complexity and fish communities sampled. To accurately represent CPUE for Stonecat populations, surveys need to include survey area or distance, as well as time fished. As such, the approximate length and width of the electrofishing site must be recorded to calculate fish density and biomass, which can be compared across sites and between years. Once the electrofishing is finished, fish are placed in a bucket and immediately processed and released at the sampling site.

Many factors affect electrofishing success and the most important environmental factor is the conductivity of the water (i.e., its ability to conduct an electrical current due to the concentration of ions in the water). Other variables, including water temperature, depth, turbidity, and velocity will affect electrofishing efficiency either on their own or via each variable's influence on conductivity. To consistently survey Stonecat using an LR-24 backpack electrofishing unit (Smith-Root; Washington USA) across the species' distribution, the recommended range of settings for surveys are the same as for previous reports: 30 Hz, moderating the voltage between 100–400 V, with 15% pulse width in DC (Macnaughton et al. 2019 a, c). Alternatively, electrofishing settings have been set from 12%–20% duty cycle, a frequency of 70 Hz, and the voltage from 150–300 V for collecting madtoms in low conductivity habitats (Wagner et al. 2019).

At each sampling site, habitat data must be recorded to complement fish data and to quantify habitat usability. Water temperature trends (i.e., among and within streams) are thought to drive species' distribution via their cumulative impacts with water flow, dissolved oxygen concentration, and other habitat variables. Along with the habitat descriptors collected for each site, temperature loggers programmed for long-term monitoring of thermal trends at each access point should be considered to better understand population trends over time. Not included in the report is an approach for quantifying thermal trends in rivers, however, details on launching temperature loggers and their placement in streams may be found in Chu et al. (2009) and Mandrak and Bouvier (2014). Refer to Appendix 2 for the database templates.

Randomizing Quadrats within Sites and Collecting Habitat Data

To capture the variability within a site, there are inherent biases to sampling what one perceives as similar or what one perceives as different. For each site, it is recommended to overlay an imaginary grid over the site, dividing the site into 2 m sections longitudinally and the width of the creek/ river into thirds. This results in 150 potential sampling quadrats that may be measured within a 100 m long site. To select the placement of the five quadrats where water velocity, depth, substrate complexity, and plant cover are measured, randomly select five numbers from a number generator or a table of numbers. The habitat data collected from the five quadrats are then entered on the database template shown below (Appendix 2). Habitat data must be collected from each sampled stretch of creek/river regardless of whether Stonecat are captured.

Environmental/Habitat Descriptors

1. Waterbody name – List the name of the river surveyed (e.g., Milk River).
2. Waterbody ID – List a unique number assigned to water bodies in Alberta (e.g., 2136) (Fish and Wildlife Management Information System (FWMIS)).
3. Date of surveying – Use the format (dd/mm/yyyy). Do not abbreviate.
4. Crew – List the names of crew members so that appropriate persons may be contacted to verify data.
5. Latitude and longitude coordinates – Units should be in decimal degrees (WGS84). Provide geographic reference locations of each sample site.
6. Site location notes – Give concise description of the geographic location of the reach or site surveyed using map and site observations (e.g., 10 m upstream from confluence with tributary X).
7. Site number – Give a unique number to the cross section/site surveyed.
8. Water temperature – Measure the water temperature (ºC) where the water column is thoroughly mixed using an appropriately calibrated thermometer. Temperature influences the distribution of biota and the catchability of certain species. Avoid taking measurements in stream margins, outflows from tributaries or stagnant pools (unless the site is located in these habitats). Record the time of day (24 h).
9. Conductivity – Measure the conductivity, the capacity of transmitting electricity, within the site using a portable conductivity meter ($\mu S \cdot cm^{-1}$, standardized to 25 ºC). Conductivity influences catchability and may provide the means to stratify data.
10. Turbidity – Measure the turbidity within the site using a portable turbidity meter (NTU) and Secchi disk (cm). Turbidity influences catchability and may provide the means to stratify data.
11. Wetted and rooted width of the cross section – If possible, measure the channel wetted and rooted widths (m) using a tape measure at the downstream (DS) and upstream (US) locations of the river reach surveyed. Wetted width corresponds to the width of the channel at the surface of the water at the time of survey. Wetted width influences seining effort and efficiency, affecting catchability and CPUE. Rooted or bank-full width corresponds to the channel width at the base of permanently rooted vegetation. For braided channels, the measurement should include any islands not covered by permanent vegetation.
12. Maximum depth – Measure the depth of the water at the deepest point between the wetted banks using a meter stick.
13. Water depth – Measure the depth of the water (m) in five quadrats within a site, making sure to obtain measurements from the center of selected quadrats.
14. Water velocity – Measure the water velocity of the water ($m \cdot s^{-1}$) in five quadrats within a site using a flow meter metre and wading rod (Marsh-McBirney Flo-Mate), making sure to obtain measurements from the center of the randomly selected quadrat.
15. Substrate complexity – Calculate the proportion of the substrate within each quadrat (visual or if need be tactile assessment) that are: bedrock, boulder, cobble, large gravel, small

gravel, sand, silt, and clay (modified Wentworth scale). Repeat substrate complexity estimates at three quadrats within a site.

16. Plant cover – Calculate the proportion of plant cover within each quadrat (visual assessment), at the three quadrats within a site.
17. Site characterization – Characterize the site surveyed based on the pool/riffle/run/ backwater categories observed to provide a broad idea of productivity and a mechanism for stratifying data.
18. Photo number – Take a picture and record the number of the photograph taken during the stream survey.
19. Photo description – Briefly describe the picture taken for later reference. Indicate whether you are facing upstream (US) or downstream (DS).
20. Comments – Briefly describe any details relating to surveying, location, and sources of error (e.g., outflow from tributary) or change (e.g., seepage or barrier).

Backpack electrofishing descriptors

21. Time electrofished – Record the time (s) the electrofisher is in use and reset to zero at the start of each survey (quadrat). Electrofishing seconds corresponds to the sampling effort of each survey. This should be standardized for each site (600–1,500 s).
22. Distance/area – Record the distance (m) or area (m^2) of each survey. Electrofishing distance translates to the sampling effort of each survey. This should be standardized for each site (100 m or 300 m^2).
23. Pulse width – Note the pulse width used to target the species. Should be standardized for each site (15% DC).
24. Frequency – Note the frequency used to target the species. Should be standardized for each site (30 Hz).
25. Voltage/ Power – Note the voltage (V) and power (W) used. Power should be standardized for each site and the voltage will vary based on the water conductivity (100–400 V).

Fishing descriptors

26. Capture method – Since the recommended capture method for Stonecat is electrofishing, write backpack electrofishing (LR24).
27. Sample Number – Sequentially number fish, an entry per fish sampled.
28. Species – Enter the name code for Stonecat sampled (i.e., STON).
29. Fork length/total length – Record the fork (tip of the snout to the natural fork of the tail) and total (tip of the snout to the end of the tail) lengths (mm) for each fish sampled. Ensure that fish are placed on a flat measuring board.
30. Injuries/ comments – Note body condition and injury observations (e.g., lesions or parasite burden).
31. Sample picture – Place the fish on a flat, non-reflective surface and take a photograph of the fish on its left side, next to a ruler. Identify the picture number- (STON-number-date-river).

32. Sample specimen – retain a voucher specimen at each access point, indicating the location, time and date where the specimen was taken.
33. Refer to specimen collections for archives and life history (Macnaughton et al. 2019a; Appendix 3).
34. Refer to eDNA sampling protocol (Macnaughton et al. 2019a; Appendix 4).

4.0 SUMMARY AND RECOMMENDATIONS FOR FUTURE SAMPLING INVESTIGATIONS

The basis of any effective monitoring program is reliable baseline data against which to monitor and compare future conditions. Generally, a couple of years of data should be collected to establish baseline trends for targeted species and monitoring should continue for several years with the same methods, sites, and timing of sampling (Lewis et al. 2013). Adopting monitoring programs that include integrated and consistent surveying protocols provide more efficient, comparable, and powerful assessments of population trends over time.

The appropriate method for a particular project, or combination of methods for fish sampling, will require consideration of the capture probability of the species/life stages of interest, as well as the physical conditions of the site (Lewis et al. 2013). Although this report describes a protocol for sampling a minimum area based on electrofishing, the timing of surveys will dictate whether surveys can take place. Specifically, changes to river habitats due to natural climate variability and/or augmented flows in the Milk River watershed will drive the fish distribution throughout the system. As such, the timing of surveys should consider annual flow conditions as well as inter-annual flow trends to ensure that surveys are conducted for similar flow stages.

Despite the recommendations provided here, studies will invariably be conducted in different years and using different methods (i.e., seining vs. backpack electrofishing) as they have been done since the 1970s. This will likely increase the variance in results and reduce the power of any future effort to make conclusions across individual monitoring studies. However, a comparison of surveying methodologies for assessing population trends may improve sampling protocols, once sufficient baseline data is collected. Understanding these method biases is particularly important when sampling *Noturus* spp., which are notoriously difficult to detect (Reid and Haxton 2017; Wagner et al. 2019) due to their reclusive nocturnal behaviour and cryptic colour patterns.

Recommendations from the current report directly inform on establishing baseline CPUE from comparable electrofishing methods and proposing a standardized sampling protocol that will assist with monitoring the extent and abundance of Stonecat populations in the Canadian Prairies. Stonecat are thought to be very rare in portions of the Milk River, according to surveys conducted from 1979–2014. By recommending that surveys be conducted ~ every five years, data from two survey events align with the COSEWIC assessment timeline (i.e., ten years) and allow for a better management of the species over time.

The greatest alterations to fish habitat in the Missouri River NFBZ are related to water diversions, reservoirs, and water removal for irrigation. Frequent droughts experienced in southern Alberta and Saskatchewan, further affect the availability of fish habitat. Not only do these alterations impact the availability of suitable habitat for multiple species including Stonecat, they reduce the window of time when surveys may be conducted. In the face of uncertain changes to suitable fish habitat and limited data to derive population trends for Stonecat, the need has never been more critical for more consistent sampling protocols, frequent assessments, and reporting of fish and fish habitat data collections. By increasing our understanding of how human activities affect Stonecat survival, potential threats to the species can be mitigated.

5.0 LITERATURE CITED

Alberta Sustainable Resource Development. 2004. Status of the stonecat (*Noturus flavus*) in Alberta. Alberta Sustainable Resource Development, Fish and Wildlife Division, and Alberta Conservation Association, Wildlife Status Report No. 52, Edmonton, AB. 22 pp.

Bunt C. M., B. T. van Poorten, and W. Wong. 2001. Denil fishway utilization patterns and passage of several warmwater species relative to seasonal, thermal and hydraulic dynamics. University of Waterloo, Department of Biology, Ecology of Freshwater Fish 10: 212–219.

Chu, C., N. Jones, A. Piggott, and J. Buttle. 2009. Evaluation of a simple method to classify the thermal characteristics of streams using a nomogram of daily maximum air and water temperature. North American Journal of Fisheries Management. 29: 1605–1619.

COSEWIC. 2012. COSEWIC assessment and status report on the Plains Minnow *Hybognathus placitus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 41 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

COSEWIC. 2017. COSEWIC assessment and status report on the Western Silvery Minnow *Hybognathus argyritis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 47 pp.

Etnier, S., W. Starnes. 1993. The Fishes of Tennessee. Knoxville: The University of Tennessee Press.

Environment and Climate Change Canada. 2019. Extracted from the Environment and Climate Change Canada Historical Hydrometric Data web site (https://wateroffice.ec.gc.ca/mainmenu/historical_data_index_e.html) on December 30, 2019.

Fisheries Management Standards Committee (FMSC) 2008. Standard for the initial sampling of small streams in Alberta. Small Streams Inventories. Fish and Wildlife Alberta. 04/21/2008.

Fisheries and Oceans Canada. 2018. Action Plan for the Milk River and St. Mary River Drainage Basins in Canada. Species at Risk Act Action Plan Series. Fisheries and Oceans Canada, Ottawa. iii + 24 pp.

Golder Associates. 2010. Milk River instream flow needs study. Submitted to: Milk River Watershed Council Canada. 147 pp.

Hammerson, G. 2005. “NatureServe Explorer: An online encyclopedia of life.” (on-line). NatureServe Explorer. Accessed December 9th, 2019 at http://explorer.natureserve.org/servlet/NatureServe?searchName=Noturus%20flavus

Hoagstrom, C.W., A.C. DeWitte, N.J. Gosch, and C.R. Berry Jr. 2006. Perennial warmwater fish communities of the Cheyenne River drainage: a seasonal assessment. Proceedings of the South Dakota Academy of Science 85: 213–245.

Kline, M. J. and R. P. Morgan II. 2000. Current distribution, abundance and habitat preferences of the stonecat (*Noturus flavus*) in Maryland. Prepared for Paul Kazyak, Maryland Department of Natural Resources, Monitoring and Non-Tidal Division, Annapolis, Maryland. Available online: dnrweb.dnr.state.md.us/download/bays/ streams/ea-00-7_stonecat.pdf.

Langois, T. H. 1954. The western end of Lake Erie and its ecology. J.W. Edwards Bros. Inc., Ann Arbor, Michigan. 479 pp.

Lewis, F.J.A., A.J. Harwood, C. Zyla, K.D. Ganshorn, and T. Hatfield. 2013. Long term Aquatic Monitoring Protocols for New and Upgraded Hydroelectric Projects. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/166. ix + 88 p.

Macnaughton, C. J., T. Rudolfsen, D.A. Watkinson, and E.C. Enders 2019a. Standardized field sampling method for monitoring the occurrence and relative abundance of the Rocky Mountain Sculpin (*Cottus* sp.) in Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3313: x + 54 p.

Macnaughton, C. J., T. Rudolfsen, D.A. Watkinson, and E.C. Enders 2019b. Standardized field sampling method for monitoring the distribution and relative abundance of the Western Silvery Minnow (*Hybognathus argyritis*) population in Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3315: vii + 26 p.

Macnaughton, C. J., T. Rudolfsen, D.A. Watkinson, and E.C. Enders 2019c. Standardized field sampling method for monitoring the distribution and relative abundance of Plains Sucker (*Pantosteus jordani*) populations in Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3316: viii + 35 p.

Macnaughton, C. J., T. Rudolfsen, D.A. Watkinson, and E.C. Enders 2019d. Standardized field sampling method for monitoring the distribution and relative abundance of the Plains Minnow *(Hybognathus placitus)* population in Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3317: vii + 24 p.

Mainstream Aquatics Ltd. 2005. Milk River habitat photograph interpretation study. Provided to Fisheries and Oceans Canada. 6 pp.

Mandrak, N.E., and L.D. Bouvier. 2014. Standardized data collection methods in support of a classification protocol for the designation of watercourses as municipal drains. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/077. v + 27 p.

McCulloch, B. R. 1994. Dispersal of the stonecat (*Noturus flavus*) in Manitoba and its inertactions with resident fish species. M.Sc. Thesis, Department of Zoology, University of Manitoba, Winnipeg, Manitoba. 108 pp.

McCulloch, B. R. and K. W. Stewart. 1998. Range extension and new locality records for the stonecat, *Noturus flavus*, in Manitoba: evidence for a recent natural invasion. Canadian Field-Naturalist 112: 217–224.

McLean, D.G., and G.R. Beckstead. 1980. Long term effects of a river diversion on the regime of the Milk River. Alberta Research Council Contribution Series No. 1054. 21 pp.

Neufeld, K.R. 2016. Improving our ability to assess the impacts of hydrologic alteration on stream fishes: An interdisciplinary approach to assess the Threatened Western Silvery Minnow *Hybognathus argyritis* in Canada. M.Sc. thesis. University of Alberta, Edmonton, AB. 116 pp.

Nursall, J.R., and V. Lewin. 1964. The stonecat, *Noturus flavus*, newly recorded in Alberta. Canadian Field-Naturalist 78:128-129.

Ohio Department of Natural resources. 2002. Accessed from Animal Diversity Web. University of Michigan Museum of Zoology. “*Noturus flavus* Stonecat” (On-line) in December, 2019 at https://animaldiversity.org/accounts/Noturus_flavus/#28d4ca7944d1b3e1aa2b057ed21c5bd1.

Page, L., and B. Burr. 1991. A field guide to freshwater fishes of North America north of Mexico. Boston: Houghton Mifflin Company.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Reid, S.M., and Haxton, T.J. 2017. Backpack electrofishing effort and imperfect detection: Influence on riverine fish inventories and monitoring. Journal of Applied Ichthyology, 33(6), 1083–1091. https:// doi.org/10.1111/jai.13463.

R.L. & L. Environmental Services Ltd. 2002. Fish species at risk in the Milk and St. Mary Drainages. Prepared for Alberta Sustainable Resource Development. Alberta Species At Risk Report No. 45. 82 pp.

Scott, W.B., and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fish. Res. Bd Can. Bull. 184, Ottawa, ON.

Stewart, K.W. and Watkinson, D.A. 2004. The freshwater fishes of Manitoba. University of Manitoba Press, Winnipeg, MB. 140–141 pp.

The Milk River Fish Species at Risk Recovery Team. 2014. The Alberta Stonecat Recovery Plan 2013-2023. Alberta Environment and Sustainable Resource Development, Alberta Species at Risk Recovery Plan No. 33. Edmonton, AB. 34 pp.

Trautman, M.B. 1981. The fishes of Ohio. Revised Edition. Ohio State University Press, Columbus, Ohio. 782 pp.

United States Geological survey (USGS). 2019. National Streamflow Information Program. https://waterdata.usgs.gov/mt/nwis/uv?site_no=06169500.

Wagner M.D., Schumann D. A., and Smith B.J. 2019. Gear effectiveness and size selectivity for five cryptic madtom species (*Noturus spp.*). Journal of Applied Ichthyologist; 1–10. https://doi.org /10.1111/jai.13892.

Walsh, S. J. and B.M. Burr. 1985. The biology of stonecat, *Noturus flavus* (Siluriforms: Ictaluridae), in central Illinois and Missouri streams, and comparisons with Great Lakes populations and congeners. Ohio Journal of Science 85: 85–96.

Water Survey of Canada. 2016. Historical Hydrometric Data: Environment Canada, Government of Canada. www.wateroffice.ec.gc.ca/search/real_time_e.html.

Watkinson, D.A. Unpublished data from fisheries surveys in the Milk River of southern Alberta, 2005–2007. Research Biologist, Fisheries and Oceans Canada, Winnipeg, MB.

6.0 APPENDICES

APPENDIX 1. ACCESS POINTS FOR STONECAT SURVEYING SITES IN ALBERTA AND SASKATCHEWAN: PROVINCE, WATERBODY, LOCATION, SITE TYPE, LATITUDE AND LONGITUDE, AND NOTES.

Province	Waterbody	Location	Site Type	Latitude	Longitude	Notes
AB	North Milk River	HWY 501	Additional Access Point	49.02641	-112.96956	Roadside access
AB	North Milk River	Range Rd 225a	Additional Access Point	49.06737	-112.9224	Roadside access
AB	North Milk River	Range Rd 222b	Additional Access Point	49.09299	-112.87037	Ford Crossing, Nature Conservatory of Canada
AB	North Milk River	Range Rd 212a	Additional Access Point	49.11419	-112.72283	Roadside access
AB	Milk River	Township Rd 24a	Additional Access Point	49.15694	-112.19241	Roadside access
AB	Milk River	Township Rd 20	Additional Access Point	49.09605	-111.98948	Goldspring Park
AB	Milk River	Range Rd 154	Additional Access Point	49.10646	-111.96447	Near trout ponds
AB	Milk River	Range Rd 150a	Additional Access Point	49.10267	-111.8905	Roadside access
AB	Milk River	Township Rd 21a	Additional Access Point	49.10424	-111.6998	Roadside access
AB	Milk River	Township Rd 20	Additional Access Point	49.07709	-111.64036	Writing on Stone Picnic
AB	Milk River	Hwy 500	Additional Access Point	49.08851	-111.53676	Roadside access
AB	Milk River	Range Rd 95a	Additional Access Point	49.15118	-111.20523	Farm Access
SK	Frenchman River	Grasslands National Park, Near Breed and Little Breed creeks	Additional Access Point	49.15228	-107.52845	Roadside access

SK	Frenchman River	Grasslands National Park	Additional Access Point	49.05161	-107.35500	Roadside access
SK	Frenchman River	Grasslands National Park	Additional Access Point	49.09898	-107.40431	Roadside access
SK	Frenchman River	Downstream of Huff lake	Additional Access Point	49.36754	-107.88038	Roadside access
SK	Frenchman River	Road Crossing in Grasslands National Park	Additional Access Point	49.20365	-107.69005	Roadside access
SK	Frenchman River	Gravel Road	Additional Access Point	49.40981	-108.02137	Roadside access
SK	Frenchman River	Gravel Road	Additional Access Point	49.33316	-108.25387	Roadside access
SK	Bluff Creek	Private Land	Additional Access Point	49.02992	-107.17178	Trail crossing
SK	McEachem Creek	Private Land	Additional Access Point	49.00997	-106.95607	Trail crossing
SK	Horse Creek	Grasslands National Park	Additional Access Point	49.00300	-106.83077	Trail crossing near US border
SK	Horse Creek	Grasslands National Park	Additional Access Point	49.05093	-106.79129	Trail crossing
SK	Rock Creek	At the confluence with Wetherall Creek	Additional Access Point	49.00797	-106.76197	Foot Access ~1 km
SK	Wetherall Creek	At the confluence with Rock Creek	Additional Access Point	49.00959	-106.76133	Foot Access ~1 km
SK	Wetherall Creek	Grasslands National Park	Additional Access Point	49.09234	-106.73767	Trail crossing
SK	Rock Creek	Grasslands National Park	Additional Access Point	49.00897	-106.71734	Trail crossing
SK	Morgan Creek	South of trail in Grasslands National Park	Additional Access Point	49.02747	-106.57884	Foot Access
SK	Morgan Creek	Just north of Grasslands	Additional Access Point	49.14786	-106.54741	Trail crossing

APPENDIX 2. DATABASE TEMPLATE DEVELOPED FOR THE STANDARDIZED SAMPLING PROTOCOL OF STONECAT IN WADEABLE RIVERS IN ALBERTA AND SASKATCHEWAN.

Waterbody Body		Activity Date (day/month/year)	
Waterbody ID		Time of Day	
Access Point		Crew	

Start Latitude (decimal degrees)	Start Longitude (decimal degrees)	Site #	DS Wetted Width (m)	US Wetted Width (m)	Rooted Width (m)

Discharge (velocity/ depth) at US cross section	1	2	3

Water Temperature (°C)	Conductivity (µS/cm)	Secchi (cm)	Turbidity (NTU)	Max. Depth (m)

ELECTROFISHING

Time Fished (s):	Area (m^2) or Distance Fished (m):	Model Number	Pulse Width (ms)	Frequency (Hz)	Volts

QUADRAT	1	2	3	4	5
Water depth (m)					
Water velocity ($m \cdot s^{-1}$)					
Bedrock (>1024 mm)					
Boulder (256-1024 mm)					
Cobble (64-256 mm)					
Large Gravel (32-64 mm)					
Small Gravel (2-32 mm)					
Sand (0.062-2 mm)					
Silt (0.004-0.062 mm)					
Clay (<0.004 mm)					
Plant material					

Photo Number:	Description:

Experience of crew for fishing and identifying species (name/ experience):

Fish #	Species ID	Total Length (mm)	Picture	Specimen Collected (Y/N)	Comments

APPENDIX 3. STONECAT DATABASE FOR FISH SURVEYS CONDUCTED IN THE MISSOURI RIVER WATERSHED IN ALBERTA AND SASKATCHEWAN: PROVINCE, WATERBODY, LOCATION, DATE, LATITUDE AND LONGITUDE, STAKEHOLDERS (COLLECTORS), EQUIPMENT/ METHOD, EFFORT (TIME (S) AND DISTANCE (M), PASS, AND FISH COUNT.

Province	Waterbody	Location	Date	Latitude	Longitude	Stakeholders	Equipment/method	Effort (s)	Effort (m)	Pass (count)	Fish count
Alberta	Milk River	USA - 1	2006-05-28	48.99546	-110.53149	DFO	Seine 9.14 m/1.82 m/4.76 mm	NA	NA		1
Alberta	Milk River	HWY 501	2006-10-03	49.08958	-112.39791	DFO	Backpack model 12A	724	NA		1
Alberta	Milk River		2005-08-09	49.089571	-111.537274	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2007-12-19	49.14357	-112.082866	AMEC FOSTER WHEELER ENVIRONMENT & INFRASTRUCTURE	Electrofishing	3260	200		2
Alberta	Milk River		2014-07-09	49.141097	-112.284624	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	1387	2000	1	1
Alberta	Milk River		1986-08-27	49.08427	-111.58118	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	4296	4500		1
Alberta	North Milk River		2002-10-22	49.140634	-112.477805	P&E ENVIRONMENTAL CONSULTANTS LTD.	Electrofishing	678	65		1
Alberta	Milk River		2005-06-23	49.151455	-111.286504	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2004-11-01	49.14461	-112.081067	MAINSTREAM AQUATICS LTD.	Electrofishing	3398		1	1
Alberta	Milk River		1997-08-13	49.114064	-110.788748	FISHERIES MANAGEMENT	Sample Angling	39600		1	3
Alberta	Milk River		2005-08-04	49.151239	-111.206279	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				3

Alberta	Milk River		2005-07-29	49.125193	-111.43948	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				3
Alberta	Milk River		2005-11-17	49.145724	-111.307738	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	1121			2
Alberta	Milk River		1986-10-20	49.144662	-111.310129	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	684	100		1
Alberta	Milk River		2001-10-19	49.127586	-110.910706	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	246			1
Alberta	Milk River		2014-06-27	49.08493	-111.60088	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	1936	1000	1	1
Alberta	Milk River		2013-09-13	49.129959	-110.887515	UNIVERSITY OF ALBERTA	Seine;Trawl		8.4		0
Alberta	Milk River		2001-10-18	49.125383	-110.831145	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	633			4
Alberta	Milk River		2013-08-11	49.128939	-110.87752	UNIVERSITY OF ALBERTA	Seine;Trawl		13.1		1
Alberta	Milk River		1979-11-20	49.086527	-111.548405	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing		50		29
Alberta	Milk River		2013-09-13	49.129959	-110.887515	UNIVERSITY OF ALBERTA	Seine;Trawl		8.4		0
Alberta	Milk River		2000-10-22	49.087333	-111.536803	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	755	65		8
Alberta	Milk River		2005-08-03	49.131092	-110.88643	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				4
Alberta	Milk River		2009-07-21	49.089824	-112.397003	ROYAL ALBERTA MUSEUM	Electrofishing	2000			2
Alberta	Milk River		2009-07-22	49.102183	-111.698482	ROYAL ALBERTA MUSEUM	Electrofishing	1115			1
Alberta	Milk River		2007-12-11	49.143114	-112.083846	AMEC FOSTER WHEELER	Electrofishing	3780	150		2

						ENVIRONMENT & INFRASTRUCTURE					
Alberta	Milk River		2000-10-21	49.126204	-110.868033	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	883	150		7
Alberta	Milk River		2005-07-08	49.076768	-111.649666	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2013-08-24	49.130234	-110.883526	UNIVERSITY OF ALBERTA	Seine;Trawl		9.8		1
Alberta	Milk River		2014-06-24	49.1088	-111.849311	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	765	1000	1	1
Alberta	Milk River		2014-06-26	49.096519	-111.945567	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	1709	2000	1	2
Alberta	Milk River		2005-07-29	49.124994	-111.439657	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2014-06-24	49.107478	-111.866278	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	771	1000	1	1
Alberta	Milk River		2013-06-28	49.088542	-110.749225	UNIVERSITY OF ALBERTA	Seine;Trawl		20.7		1
Alberta	Milk River		2001-10-22	49.100131	-111.944962	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	586			18
Alberta	Milk River		2005-08-04	49.151535	-111.206842	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2005-07-26	49.089266	-111.536929	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				2
Alberta	Milk River		2005-07-13	49.089276	-111.536847	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2014-06-24	49.099321	-111.87789	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	2161	1000	1	1

Alberta	Milk River		2001-05-08	49.124198	-110.874507	PROVINCIAL MUSEUM OF ALBERTA	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2005-08-08	49.087691	-111.537227	ALBERTA CONSERVATION ASSOCIATION	Sample Angling	68400		1	1
Alberta	Milk River		2003-10-21	49.143463	-112.168421	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	428	200		1
Alberta	Milk River		2000-10-22	49.096438	-111.944578	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	483	81		12
Alberta	Milk River		2001-10-21	49.081052	-111.614715	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	1011			1
Alberta	Milk River		2005-08-09	49.087691	-111.537227	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		1992-04-30	49.15531	-111.219473	PROVINCIAL MUSEUM OF ALBERTA	Seine;Trawl				1
Alberta	Milk River		2004-11-04	49.14461	-112.081067	MAINSTREAM AQUATICS LTD.	Electrofishing	1800		1	51
Alberta	Milk River		2014-06-26	49.088467	-111.915556	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	1357	2000	1	1
Alberta	Milk River		2001-10-22	49.14351	-112.082959	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	792			1
Alberta	Milk River		2005-06-28	49.090567	-111.516137	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2005-08-03	49.1262	-110.88799	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2005-08-09	49.087581	-111.53754	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2013-09-13	49.129959	-110.887515	UNIVERSITY OF ALBERTA	Seine;Trawl		8.4		0

Alberta	Milk River		2000-10-20	49.080627	-111.61483	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	684	100		5
Alberta	Milk River		2013-10-10	49.158663	-111.21436	UNIVERSITY OF ALBERTA	Seine;Trawl		7		1
Alberta	Milk River		2013-09-13	49.129959	-110.887515	UNIVERSITY OF ALBERTA	Seine;Trawl		8.4		0
Alberta	Milk River		2005-08-10	49.142971	-111.311026	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2005-06-15	49.145257	-111.307228	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2005-08-03	49.126326	-110.888181	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				2
Alberta	Milk River		2005-08-16	49.131065	-110.886553	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				6
Alberta	Milk River		2005-06-28	49.090647	-111.516275	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2007-12-20	49.14357	-112.082866	AMEC FOSTER WHEELER ENVIRONMENT & INFRASTRUCTURE	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2013-08-23	49.153127	-111.206657	UNIVERSITY OF ALBERTA	Seine;Trawl		13.4		1
Alberta	Milk River		1986-10-19	49.088965	-111.531703	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	696	100		1
Alberta	Milk River		2005-08-24	49.120138	-111.378311	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2014-07-02	49.140818	-112.221836	ALBERTA CONSERVATION ASSOCIATION	Electrofishing	1951	2000	1	1
Alberta	Milk River		2009-07-22	49.092462	-111.68747	ROYAL ALBERTA MUSEUM	Electrofishing				1

Alberta	Milk River		2001-10-21	49.102629	-111.891002	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	773			1
Alberta	Milk River		2013-09-13	49.129959	-110.887515	UNIVERSITY OF ALBERTA	Seine; Trawl		8.4		1
Alberta	Milk River		2001-10-22	49.097835	-111.992331	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	944			3
Alberta	Milk River		2005-07-13	49.089266	-111.536929	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2000-10-20	49.100524	-111.891946	RL&L ENVIRONMENTAL SERVICES LTD.	Electrofishing	645	91		2
Alberta	Milk River		2005-08-24	49.120463	-111.380575	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Alberta	Milk River		2013-09-13	49.129959	-110.887515	UNIVERSITY OF ALBERTA	Seine; Trawl		8.4		0
Alberta	Milk River		2005-08-12	49.077416	-111.651112	ALBERTA CONSERVATION ASSOCIATION	Trap nets, Minnow Traps, Dip Nets				1
Saskatchewan	Rock Creek		2007-09-05	49.00300	-106.78065	DFO	Seine 9.14 m/1.82 m/4.76 mm	NA	NA	3	1
Saskatchewan	Rock Creek		2007-09-06	49.00435	-106.78077	DFO	Seine 9.14 m/1.82 m/4.76 mm	NA	NA	4	1
Saskatchewan	Frenchman River	French4	2006-09-27	49.02046	-107.28407	DFO	Seine 9.14 m/1.82 m/4.76 mm				4
Saskatchewan	Frenchman River		NA	49.511645	-108.806362	NA	NA				1
Saskatchewan	NA	23 km S and 26 km E of Val Marie. Grasslands National Park.	1970-07-15	49.050127	-107.361222	NA	NA				2