PROPOSED

Species at Risk Act
Recovery Strategy Series

Recovery Strategy for the Gibson's Big Sand Tiger Beetle (*Cicindela formosa gibsoni*) in Canada

Gibson's Big Sand Tiger Beetle

2022

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For copies of the recovery strategy, or for additional information on species at risk, including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Reports, residence descriptions, action plans, and other related recovery documents, please visit the Species at Risk (SAR) Public Registry[1].

Cover illustration: Gibson's Big Sand Tiger Beetle on a sandy road near Dundurn, SK © Kiara Calladine

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[1] www.canada.ca/en/environment-climate-change/services/species-risk-public-registry.html

Preface

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996)[2] agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada. Under the *Species at Risk Act* (S.C. 2002, c.29) (SARA), the federal competent ministers are responsible for the preparation of recovery strategies for listed Extirpated, Endangered, and Threatened species and are required to report on progress within five years after the publication of the final document on the SAR Public Registry.

The Minister of Environment and Climate Change Canada is the competent minister under SARA for the Gibson's Big Sand Tiger Beetle and has prepared this recovery strategy, as per section 37 of SARA. To the extent possible, it has been prepared in cooperation with the Province of Saskatchewan as per section 39(1) of SARA.

Success in the recovery of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions set out in this strategy and will not be achieved by Environment and Climate Change Canada, or any other jurisdiction alone. All Canadians are invited to join in supporting and implementing this strategy for the benefit of the Gibson's Big Sand Tiger Beetle and Canadian society as a whole.

This recovery strategy will be followed by one or more action plans that will provide information on recovery measures to be taken by Environment and Climate Change Canada and other jurisdictions and/or organizations involved in the conservation of the species. Implementation of this strategy is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

The recovery strategy sets the strategic direction to arrest or reverse the decline of the species, including identification of critical habitat to the extent possible. It provides all Canadians with information to help take action on species conservation. When critical habitat is identified, either in a recovery strategy or an action plan, SARA requires that critical habitat then be protected.

In the case of critical habitat identified for terrestrial species including migratory birds SARA requires that critical habitat identified in a federally protected area[3] be described in the *Canada Gazette* within 90 days after the recovery strategy or action plan that identified the critical habitat is included in the public registry. A prohibition against destruction of critical habitat under ss. 58(1) will apply 90 days after the description of the critical habitat is published in the *Canada Gazette*.

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[2] www.canada.ca/en/environment-climate-change/services/species-risk-act-accord-funding.html#2

[3] These federally protected areas are: a national park of Canada named and described in Schedule 1 to the *Canada National Parks Act*, The Rouge National Park established by the *Rouge National Urban Park Act*, a marine protected area under the *Oceans Act*, a migratory bird sanctuary under the *Migratory Birds Convention Act, 1994* or a national wildlife area under the *Canada Wildlife Act* see ss. 58(2) of SARA.

For critical habitat located on other federal lands, the competent minister must either make a statement on existing legal protection or make an order so that the prohibition against destruction of critical habitat applies.

For any part of critical habitat located on non-federal lands, if the competent minister forms the opinion that any portion of critical habitat is not protected by provisions in or measures under SARA or other Acts of Parliament, or the laws of the province or territory, SARA requires that the Minister recommend that the Governor in Council make an order to prohibit destruction of critical habitat. The discretion to protect critical habitat on non-federal lands that is not otherwise protected rests with the Governor in Council.

Acknowledgments

This recovery strategy was prepared by Sarah Lee (ECCC, CWS) and Aaron Bell (Troutreach SK, Saskatchewan Wildlife Federation) with contributions from Lea Craig-Moore and Candace Neufeld (ECCC, CWS). Valuable reviews were provided by Kiara Calladine (Troutreach SK, SK Wildlife Federation), Candace Neufeld, Yeen Ten Hwang, and Medea Curteanu (ECCC, CWS). The Saskatchewan and Alberta Conservation Data Centres provided updated element occurrence information. Valuable input was provided from individuals with Saskatchewan Ministry of Parks, Culture and Sport, and Meewasin Valley Authority Conservation Agency. Acknowledgement and thanks is given to all other parties that provided advice and input used to help inform the development of this recovery strategy including various Indigenous organizations and individuals, landowners, citizens and stakeholders who provided input and/or participated in consultations. The co-operation of all the landowners, lessees and land managers who granted access to their land to do surveys and who continue to provide habitat for species at risk is greatly appreciated.

Executive Summary

Gibson's Big Sand Tiger Beetle (*Cicindela formosa gibsoni* Brown) is a large, brightly-coloured tiger beetle whose distribution is restricted to active dune fields across southern Saskatchewan and southeastern Alberta in Canada, and possibly south into the central United States. In Canada, as of 2021, there were eleven extant populations within seven locations in Saskatchewan and one extant population within one location in Alberta; with a further four historically unconfirmed locations in Saskatchewan. Globally, the subspecies *gibsoni* is considered critically imperiled and Gibson's Big Sand Tiger Beetle was listed as Threatened under the *Species at Risk Act* in 2018.

Gibson's Big Sand Tiger Beetle is associated with sparsely vegetated sandy habitats such as parabolic dunes, blowouts, sand ridges, and intervening sandy trails. Primary habitat occurs in areas with sparse vegetation (approximately 35-50% cover) in the highly dynamic edge habitat that exists between early to mid successional stages and along the partially stabilized edges of parabolic dunes, blowouts, or sand ridges. Beyond this intermediate-level of vegetation cover, abundances decline sharply in both open active sand with no vegetation and areas that are completely vegetated. Less is known about the specific habitat requirements of larvae.

The primary threat to Gibson's Big Sand Tiger Beetle is loss of habitat quantity and quality due to the progressive stabilization of active sand dunes across its range; land-use changes resulting in alteration of natural disturbance regimes (fire suppression, changes to grazing) and climate have contributed to dune stabilization and loss of suitable habitat. If habitat quality and quantity continue to decline, known populations may also decline given the distribution of the species' is limited to the spatial distribution of sparsely vegetated sandy habitat. Other threats include invasive non-native alien species, climate change and severe weather, oil and gas drilling, and mining and quarrying.

Recovery of Gibson's Big Sand Tiger Beetle is determined to be biologically and technically feasible. The population and distribution objective is to improve the stability of extant populations of Gibson's Big Sand Tiger Beetle in Canada by providing for the natural expansion of the species' distribution. Recovery planning will be carried out through four broad strategies: inventory and monitoring, habitat management and stewardship, education and outreach, and research.

Critical habitat is fully identified in this recovery strategy for all extant populations in Canada and is considered sufficient to meet the population and distribution objectives. The area within which critical habitat is found is delineated by a 500 m critical function zone extending from the outer boundary of occupied primary suitable habitat or occurrences and a 2 km dispersal zone extending from the outer boundary of the critical function zone. Critical habitat is all natural landforms, soil, and vegetation (minus specific exclusions) within the critical function zone and all suitable habitat, as defined by where it meets the biophysical attributes, within the dispersal zone.

An action plan will be posted on the Species at Risk Public Registry within five years of the finalization of this recovery strategy.

Recovery Feasibility Summary

Based on the following four criteria that Environment and Climate Change Canada uses to establish recovery feasibility, recovery of Gibson's Big Sand Tiger Beetle has been deemed technically and biologically feasible.

1. Individuals of the wildlife species that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.

Yes. As of 2021, there are twelve extant Gibson's Big Sand Tiger Beetle populations within seven locations (active dune fields) in Canada. Population estimates are only available for one population within the Elbow Sand Hills where the adult population was estimated to be as high as 1474 individuals in 2017. Although the size and condition of some dune fields have significantly changed over the past several decades, Gibson's Big Sand Tiger Beetle has been detected at several of these locations for over 60 years. Once threats have been mitigated or controlled, individuals are likely to continue to reproduce and persist at these locations. Furthermore, it is possible that the species occurs at other active dune fields that have not yet been surveyed.

2. Sufficient suitable habitat is available to support the species or could be made available through habitat management or restoration.

Yes. Sufficient suitable habitat is presently available, although remaining habitat is fragmented and progressively declining due to stabilization of active sand dunes across the species' range. Adult Gibson's Big Sand Tiger Beetle require sandy soils with approximately 35-50% vegetation cover. Information regarding the specific habitat requirements during the larval life stages is limited. Two of the seven locations (Pike Lake Sand Hills and portions of the Dundurn Sand Hills) are considered to have less than optimal habitat as sand dunes have become almost completely stabilized. Management techniques for destabilizing sand dunes (grazing, controlled burns, herbicides, hand pulling, etc.) are currently available and have been used to improve habitat for other threatened tiger beetles in the United States. Four out of twelve populations (Dundurn Sand Hills, Elbow Sand Hills, Pike Lake Sand Hills) occur within Provincial Parks or other conserved lands (Nature Conservancy of Canada, Meewasin Valley Authority Conservation Agency) where there is capacity to implement habitat management techniques.

3. The primary threats to the species or its habitat (including threats outside Canada) can be avoided or mitigated.

Yes. The main threats to Gibson's Big Sand Tiger Beetle are those contributing to loss of habitat quality and quantity by increasing dune stabilization. The rate of sand dune stabilization varies across the species' range depending on the magnitude of threats at each location that contribute to dune stabilization. The main threats that promote dune stabilization include an alteration to, or suppression of, natural grazing and fire regimes, invasive alien plant species, and a prolonged wet climatic period. These threats can be reduced or mitigated primarily by implementing other forms of controlled disturbance, site-specific management, and implementation of best management practices at locations within Provincial Parks or other conserved lands where capacity exists. For populations within private or leased lands, stewardship and education can be used to promote best management practices.

4. Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable timeframe.

Yes. The main recovery technique will be management for improving habitat conditions at known occupied locations. Sand dune stabilization can be mitigated through stewardship using the development of best management practices to provide an appropriate level of site disturbance to maintain open sand conditions, while preventing the invasion of invasive plants. Best management practices on a site-specific level are currently unavailable, but are anticipated to be developed within a reasonable time frame. Further loss or degradation of habitat at extant populations can be mitigated through conservation easements/agreements; and municipal/provincial planning mechanisms or stewardship agreements with landholders that aim at implementation of site-specific best management practices.

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1. COSEWIC* Species Assessment Information

Date of Assessment: November 2012

Common Name: Gibson's Big Sand Tiger Beetle

Scientific Name: *Cicindela formosa gibsoni*

COSEWIC Status: Threatened

Reason for Designation:
This very restricted subspecies, with most of its population in Canada, requires open sand dune areas. This habitat is declining throughout the Prairies as a result of a dune stabilization trend. Loss of historical ecological processes such as bison-induced erosion, fire, and activities of native people, as well as possible accelerators such as increase in atmospheric CO_2, nitrogen deposition, and invasive alien plant species, may also be important factors in open sand reduction. There are believed to be fewer than 73 sites and a 10% possibility of extinction within 100 years based on rates of decline of open sand dunes.

Canadian Occurrence:
Alberta, Saskatchewan

COSEWIC Status History:
Designated Threatened in November 2012

* COSEWIC (Committee on the Status of Endangered Wildlife in Canada)

2. Species Status Information

Gibson's Big Sand Tiger Beetle (*Cicindela formosa gibsoni* Brown) is designated as Threatened on Schedule 1 of the federal *Species at Risk Act* (SARA). It is considered to be critically imperiled throughout its range (NatureServe 2021a) (Table 1). Gibson's Big Sand Tiger Beetle is not currently afforded further protections under Provincial legislation however, four out of twelve populations occur within Provincial Parks or other conserved lands (Pike Lake Provincial Park, Douglas Provincial Park, Cranberry Flats Nature Preserve, Nature Conservancy Canada property). The percentage of the global population located in Canada is estimated to be at least 94% (COSEWIC 2012) but, recent genetic analysis suggests this subspecies may be endemic to Canada (French et al. 2021, A. Bell pers. comm. 2021).

Table 1. NatureServe[1] conservation status for Gibson's Big Sand Tiger Beetle (NatureServe 2020).

	Global (G) Rank[a]	National (N) Rank[a]	Subnational (S) Rank[a]
Cicindela formosa gibsoni	G5T3	Canada (N3)	Saskatchewan (S3), Alberta (S1)
		United States (N1)	North Dakota[b] (SNR), Colorado[c] (S1), Montana[d] (SNR), Utah[e] (SNR), Wyoming[f]

[a] *The NatureServe conservation status of a species is designated by a number from 1 to 5, preceded by a letter reflecting the appropriate geographic scale of the assessment (G = Global, N = National, and S = Subnational). The numbers have the following meaning: 1 = critically imperiled, 2 = imperiled, 3 = vulnerable, 4 = apparently secure, and 5 = secure, while the letters indicate T= intraspecific taxon, NR = not ranked.*

[b] *Although Freitag (1999) and NatureServe (2021a) list the species in North Dakota, COSEWIC (2012) considers this record erroneous (Beauzay pers. comm. 2010), and it is not reported from North Dakota by Gaumer (1977) or Bousquet and Larochelle (1993).*

[c] *Northwest Colorado populations are now considered to be C.f. gaumeri on the basis of genetics (French et al. 2021).*

[d] *The degree of genetic similarity between Montana and Canadian populations of C.f. gibsoni is still uncertain (French et al. 2021) therefore, subspecies designation (based on genetics) is unknown at this time.*

[e] *Populations in Utah were not included in the genetic analysis by French et al. 2021 therefore, subspecies designation (based on genetics) is unknown at this time.*

[f] *The species has been recently recorded in Wyoming (M. Brust pers. comm. in Bell et al. 2019) although it is not yet listed by NatureServe (2021a) and is now considered to be genetically distinct from Canadian populations of C.f. gibsoni (French et al. 2021).*

3. Species Information

3.1 Species Description

Gibson's Big Sand Tiger Beetle is a member of Order Coleoptera, Family Carabidae (ground beetles) and subfamily Cicindelinae (tiger beetles). Gibson's Big Sand Tiger Beetle (*Cicindela formosa gibsoni*) is one of five subspecies of *Cicindela formosa* (Figure 1 in COSEWIC 2012).

Gibson's Big Sand Tiger Beetle is one of the largest tiger beetles in North America at 14-21 mm in length (Pearson et al. 2015) and is distinguished from other *C. formosa* subspecies by the extensive white maculations (a pattern of markings) that cover between 60-95% of the elytra (hardened wing covers) (Figure 1) (COSEWIC 2012). This morphological variation is expressed as

Figure 1. Adult Gibson's Big Sand Tiger Beetle showing variations in the white maculations on the elytra. © Robert Foster (left photo); Candace Neufeld (right photo)

a gradient of maculation, leading to some separation between what is referred to as *C. f. fletcheri*, although, there is no genetic distinctiveness between what looks like *C. f. fletcheri* and *C. f. gibsoni* (French et al. 2021). Although colouration patterns are variable, adults have a dark reddish-purple wedge down the middle that can extend to the tips of the elytra in a narrow band. The underside of the beetle is metallic blue-green or bluish-violet and its head is at least as wide as the pronotoum (thorax). As with other *Cincindela* species, Gibson's Big Sand Tiger Beetle has large bulbous eyes, a relatively stalky body, large sickle-shaped mandibles, and long slender legs (Pearson et al. 2015). Like many other beetle species, males can be distinguished from females by their expanded protarsomeres (fore-legs) with adhesive setae (a structure resembling a hair or bristle) underneath.

The life cycle of Gibson's Big Sand Tiger Beetle is three years from egg to adult (Shelford 1908, Gaumer 1977). Adult females lay eggs in individual holes 3-5 mm below the sand surface in early spring (Shelford 1908). The eggs hatch into 1st instar larvae, construct a vertical chamber, and then molt to 2nd and 3rd instar larvae by late summer of the first year. The 3rd instar larvae overwinter, then emerge in the spring and pupate in midsummer of the second year (Shelford 1908). Some immature adults emerge briefly in late summer and then overwinter as adults, while most overwinter in their pupal cavities, emerging as reproductive adults in the spring of their third year (Shelford 1908).

Larvae of Gibson's Big Sand Tiger Beetle have a dark brown, armored head capsule with six eyes and large mandibles (Figure 2). Larvae capture prey by positioning their head capsule flush with the surrounding substrate and ambushing prey that venture near the burrow, pulling them into their larval chamber. In contrast to the vertical chamber typical of other *Cicindela* species, the larvae of Gibson's Big Sand Tiger Beetle maintain a small pit-like depression at the opening of their burrow. This feature is unique among North American tiger beetles and is thought to aid in the capture of prey and in preventing the burrow from filling with sand (Gaumer 1977). The distinct characteristics of the larval burrow, especially the small pit-like depression at its opening, make it possible to document the presence of Gibson's Big Sand Tiger Beetle in areas even when conditions are unsuitable for adult or larval activity (A. Bell pers. obs.).

Figure 2. Third larval instar at the entrance to its larval burrow. Note the small pit-like depression in front of the burrow that is unique among North American tiger beetles. © Aaron Bell.

3.2 Species Population and Distribution

Gibson's Big Sand Tiger Beetle is native to North America where its known range extends across southern Saskatchewan and southeastern Alberta in Canada and possibly south into the central United States (Figure 3). Within this range, the species is confined to a few isolated locations of active dune fields (COSEWIC 2012, Bell et al. 2019).

In the United States, populations resembling Gibson's Big Sand Tiger Beetle (based on morphology alone) have been recorded in southwestern Montana in Beaverhead County, southern Wyoming in Carbon County, and northwestern Colorado in Moffat County extending into Utah (COSEWIC 2012, Bell et al. 2019, iNaturalist 2019). The northern-most location, found in the Centennial Sand Hills of Montana, is approximately 600 km south of the nearest Canadian location (COSEWIC 2012).

A recent genetic analysis of *C. formosa* found that populations of *C. f. gibsoni* in Canada are genetically distinct from morphologically similar populations in Colorado and Wyoming, but the degree of genetic similarity is still uncertain for Montana populations (French et al. 2021). These results also indicated that populations in Colorado belong to a new subspecies, *C. f. gaumeri* (French et al. 2021). Populations in Utah were not included in the genetic analysis by French et al. (2021) and therefore, subspecies designation (based on genetics) is unknown at this time. Based on genetics, it is plausible that Gibson's Big Sand Tiger Beetle may be endemic to Canada, although further analysis is required to confirm this.

Figure 3. Current range of Gibson's Big Sand Tiger Beetle in North America (adapted from COSEWIC 2012, updated based on French et al. 2021). Question marks indicate the population has not been genetically confirmed as *C. f. gibsoni*.

Canadian Distribution

The Canadian distribution of Gibson's Big Sand Tiger Beetle is restricted to the active dune fields of the Prairie Ecozone in southern Saskatchewan and southeastern Alberta (COSEWIC 2012, ESWG 2017). The current range encompasses seven extant[4]

[4] Extant means the location/population has been recently verified as still existing (recent refers to data that is less than or equal to 21 years old at the time of writing this recovery strategy), the horizontal positional accuracy of the data is considered reliable, and habitat still exists at the time of writing this recovery strategy.

locations[5] (Big Stick Sand Hills, Dundurn Sand Hills, Elbow Sand Hills, Great Sand Hills, Piapot Sand Hills, Pike Lake Sand Hills, Empress Sand Hills) (Figure 4). As of 2021, there are twelve known extant populations[6] within these seven locations in Canada (Table A1 in Appendix A). Additionally, there are a further four historic unconfirmed[7] locations in Canada (Burstall Sand Hills, Carmichael Sand Hills, Fox Valley, Kinley Sand Hills) (Figure 4, Appendix A) (COSEWIC 2012).

Empress Sand Hills: Two of the extant populations occur within the Empress Sand Hills, one in Alberta and one in Saskatchewan (Table A1 in Appendix A). Although several authors have referred to individuals in the Empress Sand Hills as a separate subspecies, *C. f. fletcheri* (Acorn 2004, Acorn 2011, Sheppard unpubl. data) based on morphological variation, recent genetic analysis showed that they are not genetically distinct from *C. f. gibsoni* (French et al. 2021), and are thus treated under the umbrella of Gibson's Big Sand Tiger Beetle.

Great, Big Stick, and Piapot Sand Hills: In the largest of the dune fields, the Great Sand Hills, two populations have been recorded in close proximity to the large active sand dunes east of Fox Valley and east of Liebenthal, and throughout the various road tracks and game trails in the area. Two populations have also been reported south of the Great Sand Hills, extending into the Big Stick and Piapot Sand Hills.

Elbow Sand Hills: In the Elbow Sand Hills, one population has been recorded in the active sand dunes within Douglas Provincial Park, although several historical records are reported further south-east of the dunes, closer to the Qu'Appelle valley (Wallis 1961, Willis and Stamatov 1971 in COSEWIC 2012).

Dundurn Sand Hills: Four populations in the Dundurn Sand Hills are mainly restricted to walking trails, stabilized dunes or edges of small blowouts, bladed fireguards, and a few places on the southern edge of the dune field although much of the Dundurn Sand Hills remains unsurveyed. Although several historical records are reported within the vicinity of Beaver Creek, surveys in 2018, 2019, and 2020 have not been able to confirm Gibson's Big Sand Tiger Beetle here (Environment and Climate Change Canada unpub. data).

Pike Lake Sand Hills: Although the Pike Lake Sand Hills are mostly stabilized, multiple records have been documented where sparse bits of exposed sand still exist, constituting one population.

Historic Unconfirmed Locations: Individuals have been recorded at four historically unconfirmed locations within Saskatchewan although these records pre-date the 1990s and their accuracy is considered approximate at best (COSEWIC 2012). With the exception of the Burstall Sand Hills, which was re-surveyed in 2010, the other three historically unconfirmed locations have not been re-surveyed since the mid-1980s.

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[5] Location means the geographical location and is defined as an active dune field as delineated in the Inventory of Active Sand Dunes and Blowouts in the Prairie Provinces by Stephen Wolfe, 2010 (Geological Survey of Canada).

[6] Population means a grouping of one or more Gibson's Big Sand Tiger Beetle occurrences and is equivalent to an element occurrence as defined by NatureServe (2021b).

[7] Historic unconfirmed means the location/population has not been recently verified as still existing (data is greater than 21 years old at the time of writing this recovery strategy), the horizontal positional accuracy of the data is considered approximate, and presence of Gibson's Big Sand Tiger Beetle at a location/population has not been confirmed with recent, accurate data.

It is possible that the full extent of this species' range is unknown considering there are several active dune fields within its' known range that have never been surveyed, and additional area remaining to be surveyed within dune fields known to support Gibson's Big Sand Tiger Beetle. Surveys of Cramersburg, Antelope, Seward, Burstall, and Birsay Sand Hills, for example, may uncover additional populations as these locations contain suitable habitat similar to other occupied dune fields.

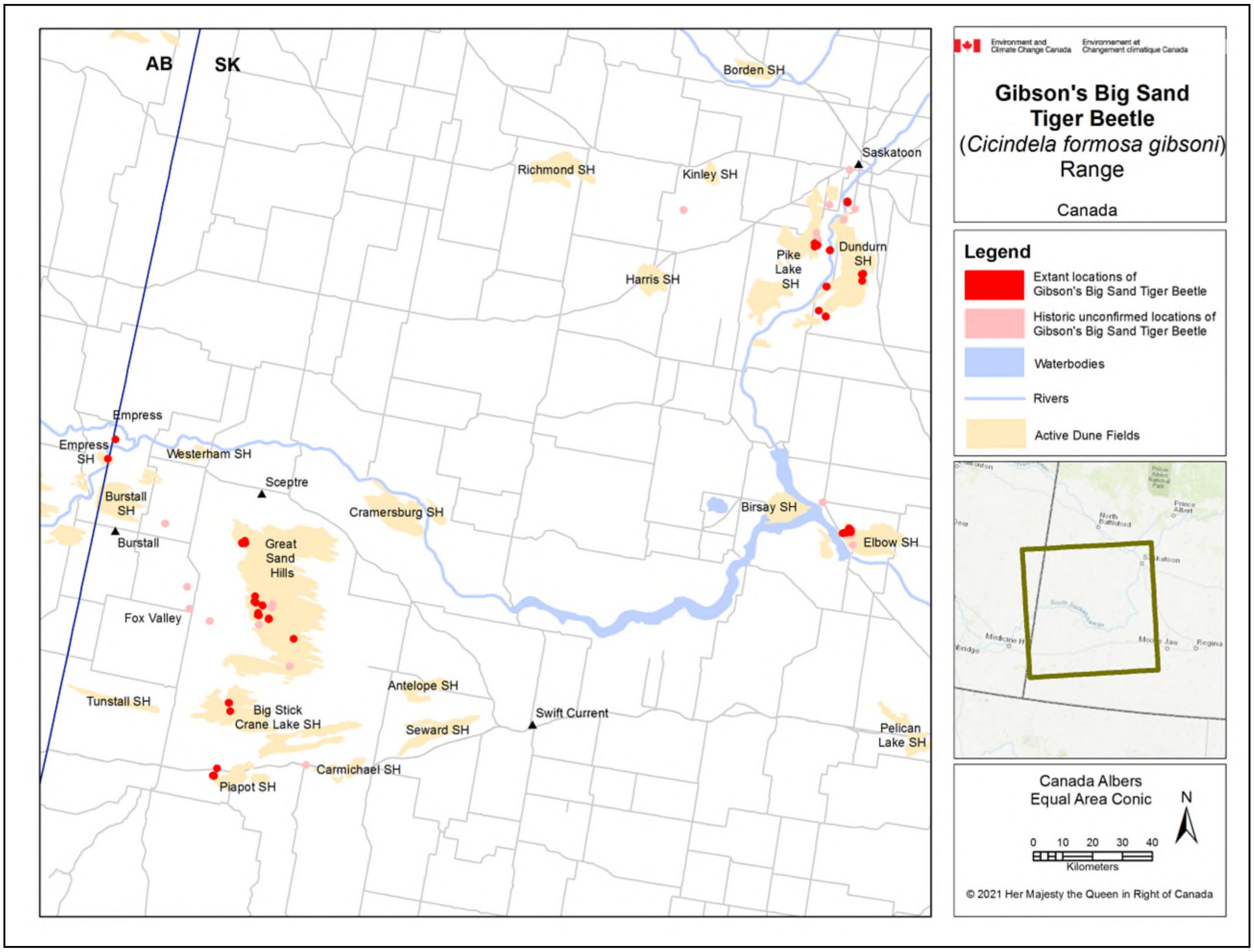

Figure 4. Current range of Gibson's Big Sand Tiger Beetle in Canada.

Canadian Population

Estimates of the number of Gibson's Big Sand Tiger Beetle in Canada are not currently known. Population estimates are only available for one population within the Elbow Sand Hills of Saskatchewan (Table A1 in Appendix A). During peak abundance (late May to early July), an average population size of 1313 individuals was estimated over the course of a three-year study, with low inter-annual variability (standard deviation: 118 individuals) (Bell et al. 2019). Estimated population size was lowest in 2016 (between 975 – 1237 individuals) and highest in 2017 (between 1350 – 1598 individuals), following periods of below-average and above-average rainfall, respectively (Bell et al. 2019). Sex ratio of captured adults was approximately equal (51.4%) (Bell et al. 2019). The number of adults varied substantially among inter-dunal swales (0 – 150 individuals/swale) with the highest density occurring in the north-western region of the dune complex, where a third of the population is concentrated in a small area of roughly 6 hectares (Bell et al. 2019). The methods used in Bell et al. (2019) are considered the most accurate way to obtain population estimates for Gibson's Big Sand Tiger Beetle (White et al. 1982, Gowan and Knisley 2014, Knisley et al. 2016, Knisley and Brzoska 2018) and it would be beneficial to use this method for obtaining consistent population estimates at other locations where data is currently unavailable.

3.3 Needs of the Gibson's Big Sand Tiger Beetle

General Habitat Requirements

Canadian populations of Gibson's Big Sand Tiger Beetle are associated with active dune fields consisting of glaciofluvial or glaciodeltaic sand deposits[8] that have been reworked into various forms of parabolic dunes, blowouts, and sand ridges (Table A2 in Appendix A) (Wolfe 2010, COSEWIC 2012). Parabolic dunes are u- or v- shaped, advancing downwind of the slipface, with partially stabilized and vegetated areas typically found on the wings, deflation depression, and back-slope, rather than the open sand of the head, crest, and slip face (Hugenholtz et al. 2010). Sand ridges are typically formed on the wings of a dune when the higher elevation portion remains unvegetated (Wolfe 2010). A blowout refers to a small bowl shaped area of wind-blown sand that is somewhat elongated in the direction of transporting winds (Wolfe 2010).

Active dune fields containing Gibson's Big Sand Tiger Beetle occur within a very specific climatic zone, characterized by mean annual temperatures between 2-6°C, 300-400 mm total annual precipitation, an annual P:PE ratio (precipitation : potential evapotranspiration) between 0.20 to 0.50 classed as semi-arid, annual precipitation deficits of -450 to -300 mm, and wind speeds that are above the threshold velocity for dry sand about 25-45% of the time (based on 1961-1990 climate normals) (Thorpe et al. 2001, Hugenholtz and Wolfe 2005, Wolfe 1997, Wolfe and Thorpe 2005). Climate exerts the overall influence on dune activity coupled with natural disturbance regimes of grazing and fire acting at a local scale to influence succession and dune mobility (Thorpe et al. 2001, Tsoar 2004, Hugenholtz and Wolfe 2005, Wolfe and Thorpe 2005, Wolfe et al. 2007, Hugenholtz et al. 2010). Thus, spatial and temporal shifts in suitable habitat will occur within a natural range of variation.

Primary suitable habitat for the Gibson's Big Sand Tiger Beetle occurs along the partially stabilized edges of parabolic dunes, blowouts, or sand ridges, and along the

[8] Sand that has been deposited from glacial meltwater in the form of a stream (glaciofluvial) or deposited as a glacial meltwater delta (glaciodeltaic).

periphery of larger dunes[9] in the highly dynamic edge habitat that exists between early to mid successional stages (approximately 35–50% vegetation cover) (Figures 12 and 13 in COSEWIC 2012) (Hooper 1969, Acorn 1991, Acorn 2011, Bell et al. 2019). Vegetation types within active dune fields vary locally based on temperature and moisture gradients (Thorpe et al. 2001, Wolfe and Thorpe 2005, Hugenholtz et al. 2010), but generally, associated vegetation includes Lanceleaf Scurfpea (*Psoralidium lanceolatum*), Veined Dock (*Rumex venosus*), Plains Silver Sagebrush (*Artemisia cana* ssp. *cana*), Creeping Juniper (*Juniperus horizontalis*), Brittle Prickly-Pear Cactus (*Opuntia fragilis*), and a variety of graminoids such as Long-leaved Reedgrass (*Calamovilfa longfolia* var. *longifolia*) and Blunt Sedge (*Carex obtusa*) (Acorn 1991, Thorpe and Godwin 1992, Wolfe 1997, Foster 2010, NatureServe 2021a).

Linear disturbances, such as game trails and hiking trails, provide secondary suitable habitat and also act as dispersal corridors where vegetation is disturbed enough to create a narrow band of bare sand within the more densely vegetated surrounding grassland (Figure 10 in COSEWIC 2012). Within the Elbow Sand Hills, Gibson's Big Sand Tiger Beetle was found along a hiking trail up to 2.5 km from the source population but in decreasing densities as distance from the source population increased (Bell 2017), suggesting the use of the trail as a dispersal corridor. In locations where the dunes are completely stabilized, Gibson's Big Sand Tiger Beetle is almost solely found within secondary suitable habitat along hiking and game trails (such as Pike Lake and Dundurn Sand Hills). The future viability of the species' at these locations is unknown but it has been observed within the Pike Lake Sand Hills since 1940 and within the Dundurn Sand Hills since 2011, suggesting secondary suitable habitat is important for species persistence in a landscape that naturally fluctuates between different states of succession and dune mobility.

Adult Habitat Preference and Activity

The distribution and abundance of adult tiger beetles in general is influenced by prey availability, quality of larval habitat, and temperature (Acorn 1988, Knisley and Hill 2001, Gowan and Knisley 2014, Knisley et al. 2017). For Gibson's Big Sand Tiger Beetle, temperature is hypothesized to be an important factor structuring local adult distribution and abundance (Acorn 1991, Bell et al. 2019). Gibson's Big Sand Tiger Beetle activity is strongly influenced by surface sand temperature, with normal adult activity typically occurring between 20 and 50 °C (Gaumer 1977, Bell et al. 2019). Like many other tiger beetle species, Gibson's Big Sand Tiger Beetle will burrow into the sand during periods of suboptimal temperature. Shuttling behavior, where beetles move between shaded and exposed microhabitats, can assist in the maintenance of optimal body temperature for foraging and daily activity when ambient temperatures are suboptimal (Dreisig 1980, 1984, 1985, Knisley and Schultz 1990, Hadley et al. 1992, Pearson et al. 2015); highest abundance of Gibson's was found in areas with a mix of sand and vegetation (about 35-50% cover) which is likely the most ideal combination of shaded versus exposed

[9] A sand dune is a "mound, hill or ridge of windblown sand, either bare or variously covered by vegetation, capable of movement from place to place through the development of a slip face, but always retaining its own characteristic shape for an extended period of time" (David 1977).

microhabitats for this species (Bell et al. 2019). Information on Gibson’s Big Sand Tiger Beetle home range and daily distribution (e.g., foraging distances, territory size) are unknown but thought to be limited by the distribution of sparsely vegetated sandy microhabitats that assist them in thermoregulation (A. Bell pers. comm. 2021).

Adults are active predators, ambushing and consuming a wide range of small insects and other invertebrates (Larochelle 1974a), particularly ants (Kippenhan 1990), but also acridid grasshoppers, lepidopteran larvae, coccinellid beetles, tent caterpillars (*Malacosoma*), and sphecid wasps (Acorn 1991, Bell 2017). Adults of Gibson’s Big Sand Tiger Beetle are poor flyers, flying in short bursts less than 25 meters at a time and prefer to run quickly on the sand, using a series of short bursts and pauses to locate and stalk prey (Bell 2017). Gibson’s Big Sand Tiger Beetle can be a significant predator of Ghost Tiger Beetles (*Cicindela lepida*) and Sandy Tiger Beetles (*Cicindela limbata*) (Acorn 1991).

Larval Habitat Requirements

Gibson’s Big Sand Tiger Beetle spends two thirds of its life cycle as a stationary larvae that is restricted to the vertical chambers where 1st instars dig their burrows. These areas have specific habitat requirements (i.e. soil moisture) that must be met during the entirety of the larval life cycle (Knisley 1987, Gowan and Knisley 2014, Knisley et al. 2018). Because adult tiger beetle abundances tend to peak following several years of high rainfall, fluctuations in the numbers of reproductive adults may depend on rainfall and associated larval survival in preceeding years (Knisley and Hill 2001, Gowan and Knisley 2014, Knisley et al. 2017, 2018, Bell et al. 2019). Rainfall influences soil moisture and the formation of cohesive sand that is necessary for larvae to dig and maintain burrows, which may result in larvae having higher survival and faster development times (Gowan and Knisley 2014, Knisley et al. 2017, 2018). During prolonged periods without rainfall, the larvae of many tiger beetle species plug the opening to their burrows. Shortly after rainfall events, Gibson’s Big Sand Tiger Beetle larvae re-open their burrow and construct the small pit-like depression at the burrow entrance (Figure 2).

Limiting Factors

Gibson’s Big Sand Tiger Beetle is relatively long-lived for an insect, spending two of its three-year life cycle in a stationary larval chamber. Numerous studies have shown that tiger beetle larvae are the limiting life stage and that larvae are highly sensitive to microhabitat and timing of rainfall (Gowan and Knisley 2014, Knisley et al. 2018). However, the microhabitat preference of larval Gibson’s Big Sand Tiger Beetle and their role in population dynamics are not well understood (Bell et al. 2019).

The bee fly, *Anthrax georgicus* (Diptera: Bombyliidae), is a specialist parasitoid of tiger beetle larvae, occurring in high enough densities to have decreased some tiger beetle populations (Bram and Knisley 1982). Bombylid flies (c.f. *Anthrax*) were observed at the Pike Lake and Elbow Sand Hills during 2010 but impacts on the Gibson's Big Sand

Tiger Beetle population are unknown. Tiger beetle larvae are also parasitized by *Methocha* (Hymenoptera: Tiphiidae) and *Tetrastichus* (Hymenoptera: Eulophidae) (Criddle 1919, Knisley and Schultz 1997), but it is unknown if they co-occur with populations of Gibson's Big Sand Tiger Beetle in Canada. At this time, it is unknown if parasitism is limiting population numbers or if these interspecific interactions are occurring in their natural state or have been exacerbated by other human impacts.

Robber flies (Diptera: Asilidae), birds, and a variety of mammals have been observed opportunistically preying upon tiger beetles (Criddle 1910, Lavigne 1972, Larochelle 1974b, 1975a, b). Larvae of robber flies may also prey on the eggs, larvae and pupae of other insects in the soil (Cannings 2010). The effects of predation on Canadian populations of Gibson’s Big Sand Tiger Beetle are currently unknown but likely not significantly limiting to overall population numbers (A. Bell pers. obs.).

Active dune fields are not evenly distributed across the Canadian range of the Gibson’s Big Sand Tiger Beetle (Figure 4). This results in multiple isolated locations separated by several hundreds of kilometers of unsuitable habitat. However, the degree of immigration/emigration between dune fields is unknown. Fragmentation of primary suitable habitat within dune fields can occur as exposed sand exists in a patchy distribution within the fully vegetated grassland matrix and an extensive area of unsuitable soil or dense vegetation probably acts as an effective barrier to dispersal by *C. formosa* (COSEWIC 2012). Studies on the dispersal capability of tiger beetles show that some species travel only short distances (up to 481 m in *C. marginipennis*, Hudgins et al. 2011) whereas others can travel much farther (2.7 km in *C. puritana*, Omland 2004, and 24 km in *C. dorsalis dorsalis*, Knisley and Schultz 1997). The dispersal capability and colonization potential of Gibson’s Big Sand Tiger Beetle is not well documented. One study within the Elbow Sand Hills, observed individuals along a sandy linear disturbance (hiking trail) up to 2.5 km from the source population (density of individuals decreased with increasing distance from the source population suggesting the use of the habitat as a dispersal corridor) (Bell 2017). This suggests that the dispersal capability and extent of occurrence of Gibson’s Big Sand Tiger Beetle within a dune field is limited to the spatial distribution of exposed sand.

4. Threats

4.1 Threat Assessment

The Gibson's Big Sand Tiger Beetle threat assessment is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system. Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (global, national, or subnational). Limiting factors are not considered during this assessment process. For purposes of threat assessment, only present and future threats are considered. Historical threats, indirect or cumulative effects of the threats, or any other relevant information that would help understand the nature of the threats are presented in the Description of Threats section.

Table 2. Threat calculator assessment.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
2	Agriculture & aquaculture	Low	Restricted	Slight	High	
2.3	Livestock farming & ranching	Low	Restricted	Slight	High	
3	Energy production & mining	Low	Small	Serious	Moderate	
3.1	Oil & gas drilling	Negligible	Negligible	Slight	Moderate	
3.2	Mining & quarrying	Low	Small	Serious	Moderate	
4	Transportation & service corridors	Low	Small	Slight	Moderate	
4.1	Roads & railroads	Low	Small	Slight	Moderate	
5	Biological resource use	Negligible	Negligible	Negligible	High	
5.1	Hunting & collecting terrestrial animals	Negligible	Negligible	Negligible	High	
6	Human intrusions & disturbance	Negligible	Small	Negligible	High	
6.1	Recreational activities	Negligible	Small	Negligible	High	
7	Natural system modifications	Medium	Pervasive	Moderate	High	
7.1	Fire & fire suppression	Medium	Pervasive	Moderate	High	

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
8	Invasive & other problematic species & genes	Low	Pervasive	Slight	High	
8.1	Invasive non-native/alien species	Low	Pervasive	Slight	High	
11	Climate change & severe weather	Medium - Low	Pervasive	Moderate - Slight	High - Low	Severity rating adjusted to account for cumulative effects, likely additive in nature, between the level two threats
11.1	Habitat shifting & alteration	Low	Pervasive	Slight	High - Low	
11.2	Droughts	Medium - Low	Pervasive	Moderate - Slight	Moderate - Low	
11.3	Temperature extremes	Low	Pervasive	Slight	Moderate - Low	

[a] **Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment timeframe (e.g., timing is insignificant/negligible or low as threat is only considered to be in the past); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[b] **Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[c] **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit ≥ 0%).

[d] **Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

4.2 Description of Threats

Table A1 in Appendix A identifies the threats associated with each population.

Loss of habitat quantity and quality among the known populations of Gibson's Big Sand Tiger Beetle is the primary threat to the species recovery in Canada (COSEWIC 2012). Future degradation of habitat will be partially as a result of threats acting together or on their own, ultimately leading to dune stabilization or habitat succession (e.g. changes to the natural disturbance regime of grazing and fire, invasive alien plant species, climate). Direct habitat loss, fragmentation or degradation is also likely from threats such as invasive alien plant species, roads, oil/gas drilling and mining/quarrying. Threats are discussed in more detail below.

IUCN-CMP Threat 2. Agriculture & aquaculture (Low)

2.3 Livestock farming and ranching

Dunes in the southern Canadian prairies have been stabilizing since at least the early 1900s through a combination of climate and changes to the natural disturbance regime of grazing and fire (Epp and Townley-Smith 1980, Wallis and Wershler 1988, Wolfe et al. 2007). The absence of disturbance from grazing and/or fire, and increased precipitation throughout the 1900s, led to vegetation growth at the edges of open dunes. Natural succession by grasses and forbs, then shrubs, and eventually trees, stabilized and eventually covered sand dunes with vegetation (Hugenholtz et al. 2010), thereby reducing or eliminating suitable habitat for Gibson's Big Sand Tiger Beetle. Changes in disturbance regimes contributing to dune stabilization primarily include loss of Bison (*Bison bison)* grazing, a reduction in the frequency and extent of prairie fires, as well as a more homogenous pattern of cattle grazing (Frank et al. 1998, Brockway et al. 2002, Samson et al. 2004, Hugenholtz and Wolfe 2005). The timing, intensity, duration and diet selection of domestic and wild animals today in Gibson's Big Sand Tiger Beetle habitat differ from historical natural grazing regimes (Milchunas and Lauenroth 1993, Houston 1999, Knapp et al. 1999, Fuhlendorf and Engle 2001, Kohl et al. 2013). In addition, stocking rates, frequency, and duration of cattle grazing will differ among and within locations, causing variable levels of severity. Responsible grazing at appropriate intensity, frequency and duration, is necessary in a system that evolved under grazing pressure, and likely has a neutral or beneficial impact by preventing dune stabilization, maintaining vegetation structure, and maintaining range condition (Higgins et al. 1989, Milchunas et al. 1989, Milchunas et al. 1992, Samson and Knopf 1994, Biondini et al. 1998).

Under high and persistent stocking densities, cattle grazing can negatively affect tiger beetles, mainly by trampling of larvae and their burrows (Bauer 1991, Brown and MacRae 2003, Knisley and Arnold 2004, USFWS 2005, Knisley and Haines 2010, Knisley 2011). While cattle grazing is important for reducing vegetation cover and improving tiger beetle habitat, areas where larvae are present will be more sensitive to the disturbance. Cattle grazing has been reported within or near populations in the

Dundurn, Big Stick, Piapot, and Great Sand Hills. Damage from overgrazing and trampling of larval burrows under high stocking densities has been observed within portions of the populations in the Piapot and Great Sand Hills (A. Bell pers. obs.).

IUCN-CMP Threat 3. Energy production & mining (Low)

3.1 Oil & gas drilling

Natural gas activities include a number of processes such as exploration, drilling, completion, production and transportation, abandonment and reclamation. These activities have the potential to harm Gibson's Big Sand Tiger Beetle and its habitat, either directly (e.g. mortality of beetles during construction/drilling, deposition of sulphurous and nitrogenous compounds on soil in proximity to sour gas wells) or indirectly (e.g. increased linear disturbances from pipeline right-of-ways causing invasive species introduction and habitat fragmentation (see threat 8.1)). Gas plants, compressor stations, battery stations, pipeline/flowline right-of–ways and two-track vehicle trails (see threat 4.1) are common developments in natural gas fields, leading to cumulative effects and habitat changes on the landscape (Appendix B and Section 1.5 in Environment Canada 2012).

Oil and gas activity continues to increase in the sandhills despite the sensitive nature of the habitat to disturbance (COSEWIC 2012), adding to a cumulative effect on the landscape. As of October 2020, the average number of wells[10] per section of land ranged from 3 in the Piapot Sand Hills to 13 in the Big Stick Sand Hills and the average length of pipeline[11] per section of land ranged from 3.28 km in the Piapot Sand Hills to 4.24 km in the Big Stick Sand Hills (I.H.S. 2020). Five Gibson's Big Sand Tiger Beetle populations occur within a natural gas field running throughout the Empress, Great, Big Stick, and Piapot Sand Hills (Saskatchewan Mining and Petroleum GeoAtlas 2020). Three of these populations are also in areas that hold helium potential, and with the global helium shortage, development of helium wells may become prevalent, particularly due to recent successful test wells in south-western Saskatchewan and an increased interest in this resource in recent years (Yurkowski 2016, Saskatchewan Mining and Petroleum GeoAtlas 2020).

3.2 Mining & quarrying

Mining of dunes for sand used in hydro-fractured gas wells, concrete, golf courses, sandblasting, and road construction is a potential, localized threat (COSEWIC 2012). Removal of the soil substrate not only kills Gibson's Big Sand Tiger Beetles directly, but also permanently removes all, or portions of, the habitat; this can have substantial implications for the future survival of the populations at those locations. This type of disturbance to the habitat can also lead to introduction and/or invasion by invasive plant species (see threat 8.1). Extraction of sand from the Dundurn Sand Hills for use in highway improvement is likely to occur in the near future and the sand has also been

[10] Information Handling Services data analysis for "wells" included both surface holes and boreholes.
[11] Information Handling Services data analysis for "pipelines" included both pipelines and flowlines.

investigated for use in fracking. Sand extraction within portions of the Piapot, Bigstick, Great, and Empress Sand Hills may be a threat in the future.

The Empress and Piapot Sand Hills have been explored for coal resources although it had low potential and no coal dispositions currently occur in the area (Saskatchewan Mining and Petroleum GeoAtlas 2020). The northern Great Sand Hills has been explored for potash potential and one population within the Dundurn Sand Hills is immediately adjacent to an area with active potash dispositions and may be at risk of potash development in the future (Saskatchewan Mining and Petroleum GeoAtlas 2020). Saskatchewan is the largest producer of potash in the world and although demand and pricing have been variable over the past decade, production is expected to rebound into the 2020's (Industry West 2020). Surface mining methods would result in the permanent removal of habitat and the direct mortality of Gibson's Big Sand Tiger Beetles.

IUCN-CMP Threat 4. Transportation & service corridors (Low)

4.1 Roads & railroads

Portions of two populations within the Empress and Pike Lake Sand Hills occupy the margins and ditches adjacent to sandy gravel roads. Direct mortality of beetles and habitat degradation may be caused by road construction and maintenance activities such as ditch widening or deepening, trenching, utility line installments, drainage projects, straightening or improving the road, grading, and haying or mowing in the ditches. Five Gibson's Big Sand Tiger Beetle populations occur within a natural gas field running throughout the Empress, Great, Big Stick, and Piapot Sand Hills (Saskatchewan Mining and Petroleum GeoAtlas 2020) and two-track vehicle trails are common developments that are expected to increase in the area as natural gas development progresses (see threat 3.1). While naturally vegetated sandy vehicle trails may provide dispersal corridors, direct mortality of beetles will also result from vehicle traffic. Increased linear disturbances from oil/gas access roads also contribute to the introduction and spread of invasive plant species throughout Gibson's Big Sand Tiger Beetle habitat (see threat 8.1).

IUCN-CMP Threat 5. Biological resource use (Negligible)

5.1 Hunting and collecting terrestrial animals

Gibson's Big Sand Tiger Beetle is a large charismatic species that collectors may find attractive; however, four out of twelve populations occur within protected areas (Provincial Parks and other conserved lands). Provincial permits are required for academic/research and species detection surveys in Saskatchewan which would include conditions in the permit related to collections. Although illegal collection is possible, there is no indication that collection of specimens is limiting population numbers at this time.

IUCN-CMP Threat 6. Human intrusions & disturbance (Negligible)

6.1 Recreational activities

Gibson's Big Sand Tiger Beetle occurs within numerous recreational areas including the Great Sand Hills, Pike Lake Provincial Park, Douglas Provincial Park, and Cranberry Flats Nature Preserve. Disturbance caused by foot and bike traffic in these areas may help destabilize dunes thereby keeping open sand habitat available through the removal of vegetation, and the displacement and exposure of sand to wind. The trade-off is that areas where larvae are present will be sensitive to trampling which can kill larvae and destroy burrows. The negative effects of off-highway vehicles (OHVs) on tiger beetles have been extensively documented in other sand dune systems (Knisley et al. 2017) and the use of OHVs (ATV's and motorized bikes) is known to occur within the Dundurn Sand Hills (COSEWIC 2012). The introduction, establishment, and spread of invasive plant species is also known to be associated with human intrusions and disturbances (see threat 8.1). The effects of recreational activities within privately owned lands is unknown.

IUCN-CMP Threat 7. Natural system modifications (Medium)

7.1 Fire & fire suppression

As discussed in threat 2.3, habitat for the Gibson's Big Sand Tiger Beetle would have evolved under a natural disturbance regime of grazing, fire, and drought, acting independently or together to maintain the open, early to mid successional dune habitat required by the Gibson's Big Sand Tiger Beetle (Daubenmire 1968, White 1979, Collins 1987, Lesica and Cooper 1999). The function of fire within a prairie landscape is to maintain habitat structure and composition through recycling nutrients, maintaining fire adapted plant communities, and resetting successional pathways (Longpre and Tremblay 2017). Fire plays an important role in resetting successional pathways and maintaining dune mobility within sand dune dominated landscapes as it can increase wind erosion by removing the vegetative barrier that prevents sand from being exposed to wind (Whicker et al. 2002, Vermeire et al. 2005). A combination of fire and grazing likely destabilizes sand dunes and disrupts vegetative succession more effectively than either disturbance independently (Wallis 1988, Lesica and Cooper 1999).

Changes in land use practices since European settlement in the late 1800s have resulted in reduction in the frequency and extent of prairie fires (Higgins et al. 1989). Fire suppression, in combination with changes to grazing regimes and climate, has resulted in a decline in habitat quality and quantity as sand dunes continue to stabilize across the range of Gibson's Big Sand Tiger Beetle (Table A2 in Appendix A; see threat 2.3). Currently, fire does not occur at historical fire intervals within the range of Gibson's Big Sand Tiger Beetle in Canada. There have been no recorded wildfires near populations of Gibson's Big Sand Tiger Beetle since at least 1985 (Saskatchewan Ministry of Environment 2020) with the exception of several recent wildfires (2017, 2018, 2019) near one population within the Cranberry Flats Nature Preserve (R. Grilz pers. comm.). The last known wildfires within the Elbow and Pike Lake Sand Hills occurred around 1918 and 1972, respectively, and a portion of the Dundurn Sand Hills was last burned in the 1970s (Longpre and Tremblay 2017, Saskatchewan Ministry of Parks, Culture and Sport 2019, R. Dudrange pers. comm.). There have been no recorded wildfires within the Empress Sand Hills since at least 1931. Only four out of twelve populations occur within areas that use controlled burning as part of an ecosystem-based management plan (Pike Lake Provincial Park, Douglas Provincial Park, Cranberry Flats, Nature Conservancy Canada Property).

While natural disturbance is required to maintain habitat conditions required by this species, the level of tolerance of Gibson's Big Sand Tiger Beetle to fire in terms of frequency, intensity, and timing is unknown. Davis (1998) found that the abundance of tiger beetles increased following a spring prescribed burn in a grassland ecosystem. Ants (the main invertebrate species on which the Gibson's Big Sand Tiger Beetle feeds) living in sand dunes were found to be relatively resilient to fire, exhibiting only a temporary decline following a fire event (Glasier et al. 2015). McCravy and Baxa (2011) found that robber fly (an opportunistic predator of Gibson's Big Sand Tiger Beetle) abundance, diversity, and activity was affected by fire within a prairie landscape although the effects tended to be short-lived. However, no specific research has been done regarding the effects of fire and resulting interspecific interactions with Gibson's Big Sand Tiger Beetle.

IUCN-CMP Threat 8. Invasive & other problematic species & genes (Low)

8.1 Invasive non-native/alien species

Invasive non-native plant species, such as Baby's Breath (*Gypsophila paniculata)*, Russian Thistle (*Salsola kali*), and Leafy Spurge (*Euphorbia esula),* as well as escaped introduced forage species such as Crested Wheat Grass (*Agropyron cristatum),* Smooth Brome *(Bromus inermis*), Kentucky Blue Grass (*Poa pratensis*), and Sweet Clover (*Melilotus spp.),* have been documented within the Dundurn, Elbow, Pike Lake, Great, and Empress Sand Hills. Invasive non-native plant species in these areas are commonly associated with anthropogenic disturbances such as roads/trails, oil/gas sites, recreational disturbances or utility line right-of-ways and studies have found that the spread of invasive species can reach from 150 m to 1 km from the source (Appendix B in Environment Canada 2012). Sweet Clover has become one of the most widespread invasive non-native species in the northern Great Plains, due initially to deliberate planting in roadside edges, forage crops, and other reclaimed areas (Lesica and DeLuca 2000). In the past, reclamation purposefully used invasive non-native plant species, commonly Crested Wheat Grass, due to their ability to establish quickly on a site and for reasons of seed availability, ease of cultivation and use as forage (Sinton 2001). Leafy spurge is quite pervasive within the Dundurn and Elbow Sand Hills, and occurs within over half of the dune fields occupied by Gibson's Big Sand Tiger Beetle. Non-native plant species have not been assessed at the Bigstick or Piapot Sand Hills.

Some invasive non-native plant species may be relatively unpalatable to livestock and wildlife, or have different fuel properties, resulting in altered grazing and fire regimes

(Brooks et al. 2004). As a result, an influx of these invasive non-native plants could accelerate the stabilization of sand dunes and represent a threat to Gibson's Big Sand Tiger Beetle habitat. Some invasive non-native species like the legume Sweet Clover (*Melilotus* spp.) can elevate soil nitrogen through biological fixation and facilitate invasions by other species in a habitat that would otherwise be nutrient limited (Jordan et al. 2008, Van Riper and Larson 2009). Others, such as the invasive Eurasian species Leafy Spurge, have an extensive root system that can stabilize sand dunes, forming dense stands and spreading quickly, which can affect distribution and abundance of other plant species occupying the habitat (Selleck et al. 1962, Belcher and Wilson 1989, Butler and Cogan 2004). Invasive species in general have the potential to displace native species, reduce plant community richness and diversity, reduce seed bank composition and diversity, alter soil resource composition, and alter the storage and movement of nutrients throughout a prairie ecosystem (Gordon 1998, Wilson 1989, Wilson and Belcher 1989, Reader et al. 1994, Christian and Wilson 1999, Bakker and Wilson 2001, Henderson 2005, Henderson and Naeth 2005).

IUCN-CMP Threat 11. Climate change & severe weather (Medium – Low)

Due to the spatial and temporal overlap between threats 11.1, 11.2, and 11.3, and that these threats may act on their own or together[12] ultimately leading to a cumulative effect that is likely additive in nature, there is a range of uncertainty as to the overall severity of threat 11. For example, the combined impact of drought and increased temperature extremes on larval survival and the mating behavior of adult beetles (respectively) likely has a greater overall severity than each threat taken independently. Therefore, the severity rating has been adjusted to account for these level two threats acting independently and/or additively within the spatial and temporal scope of threat 11.

11.1 Habitat shifting and alteration

Sand dunes exist as a spatially and temporally shifting habitat between different stages of succession and dune mobility, making them particularly sensitive to climate change (Thorpe et al. 2001). The long-term availability of suitable habitat for Gibson's Big Sand Tiger Beetle will be dependent on factors affecting succession and dune mobility; at a local scale, changes in disturbance regimes (see threat 2.3 for grazing and 7.1 for fire) and at the landscape level, climate change (Thorpe et al. 2001, Tsoar 2004, Hugenholtz and Wolfe 2005, Wolfe et al. 2007, Hugenholtz et al. 2010, Acorn 2011).

The most recent period of dune activation on the Canadian prairies was related to a prolonged drought during the late 1700s at which time it was estimated that 10-20% of the Great Sand Hills region was bare sand (Wolfe et al. 2001). Since then, the long-term trend has been towards dune stabilization driven mainly by an increase in precipitation during the last century, and decreased wind speed and erosion resulting from continual vegetation succession on dunes (Wallis 1988, Wolfe et al. 1995, Wolfe et al. 2001, Hugenholtz and Wolfe 2005, Hugenholtz et al. 2010). Between 1938 to 1996,

[12] For example, a climate change scenario where there are changes in both temperature and precipitation creating a habitat that is both hotter (threat 11.3) and drier (threat 11.2).

stabilization rates within dune fields containing Gibson's Big Sand Tiger Beetle varied both spatially and temporally, with estimates as low as 0.4 ha/year in the Elbow Sand Hills to as high as 7.6 ha/year in the Great Sand Hills (Hugenholtz and Wolfe 2005). As of 1997, all dune fields have been classified as inactive with only a few within the Palliser Triangle classed as having actively moving sand along the crests of the dunes (Wolfe 1997). Recent estimates (2002-2010), show that <0.10% of the area remains as bare sand within the Big Stick, Dundurn, Piapot, and Pike Lake Sand Hills; and <0.50% of the area remains as bare sand within the Elbow, Great, and Empress Sand Hills (Table A2 in Appendix A) (Wolfe 2010).

However, increased aridity, decreased moisture availability, and drought are considered likely climate change scenarios for the Canadian Prairies (Thorpe et al. 2001, Wolfe and Thorpe 2005, Allen et al. 2018, Hoegh-Guldberg et al. 2018). As a result, it is predicted that vegetation will shift towards more open grassland with an increase in the proportion of warm-season (C4) species and less woody vegetation cover, increasing the potential for dune activation (Thorpe et al. 2001, Wolfe and Thorpe 2005). Areas such as the Great Sand Hills, which presently have active dune crests, are predicted to persist in this state, while areas such as the Dundurn Sand Hills, which are presently inactive, are predicted to move to an active state (active crests) (Thorpe et al. 2001). It is unlikely that future climate change scenarios would cause a shift in dune morphology (from the current parabolic state back to fully active barchanoid dunes), as even the driest predicted areas only exceeded the threshold for activating dune crests and sufficiently increased wind stress would be needed to destroy vegetation on already stabilized dunes (Wolfe 1997, Thorpe et al. 2001, Tsoar 2004). Therefore, it is likely that sparsely vegetated sandy habitats that support Gibson's Big Sand Tiger Beetle could persist under future climatic conditions if the current stabilizing trend is reversed.

11.2 Droughts

Drought is considered a likely climate change scenario for the Canadian Prairies due to the strong soil-moisture-temperature coupling (Hoegh-Guldberg et al. 2018, Thorpe et al. 2001). Predictions show increases in consecutive dry days, declines in summer precipitation, lower surface moisture availability, and an increase in aridity (Thorpe et al. 2001, Wolfe and Thorpe 2005, Hoegh-Guldberg et al. 2018).

Soil moisture, a key larval habitat requirement, is important during the breeding season and certain developmental stages (A. Bell pers. comm.). There is a strong link between rainfall and tiger beetle larval survival as rainfall influences soil moisture and the formation of cohesive sand that is necessary for larvae to dig and maintain burrows (Knisley and Hill 2001, Gowan and Knisley 2014, Knisley et al. 2017, 2018). Long-term studies of population trends in *C. albissima* have shown that adult abundances peak following several years of high rainfall, suggesting that fluctuations in the numbers of reproductive adults may depend on rainfall and associated larval survival in preceeding years (Knisley and Hill 2001, Gowan and Knisley 2014). Similarly, population size for Gibson's Big Sand Tiger Beetle in the Elbow Sand Hills was lowest in 2016 and highest in 2017, following years of below-average and above-average spring rainfall, respectively (Bell et al. 2019). A recent population decline in *C. albissima* indicates that even a drought of only two years is enough to reduce a population of more than 3000 individuals to less than 200 (A. Bell pers. comm.). Potential impacts of multi-year droughts on the population size of Gibson's Big Sand Tiger Beetle and the longevity of the effects warrants further study.

11.3 Temperature extremes

Gibson's Big Sand Tiger Beetle occur in extreme thermal environments where surface sand temperatures can easily reach more than 55 °C. As such, they have a variety of behavioural (e.g. stilting, seeking shade, see Pearson et al. 2015) and physical (e.g. longer slender legs, patches of setae, extensive white maculations on the elytra) adaptations that assist in thermoregulation and in the maintenance of high body temperatures that are optimal for foraging (Dreisig 1980, 1985). When sand surface temperatures are too hot (> 50 °C), adult beetles stop foraging and mating behaviour and burrow into the sand to escape the heat. Similarly, larvae avoid prolonged exposure to heat by plugging the entrance to their larval chamber. Although adults and larvae typically re-emerge once conditions are suitable, prolonged periods of extreme heat without precipitation can lead to reductions in adult and larval activity (A. Bell pers. obs.). Extended periods of inactivity, for example, could lead to fewer foraging opportunities and food shortage. Studies of food limitation in tiger beetles show that at low feeding levels females produce fewer offspring, larvae take longer to develop, and their pupal and adult stages are significantly smaller than those raised at high food levels (Pearson and Knisley 1985).

Under a global warming scenario of 1.5°C, the intensity and frequency of extreme heat days is expected to increase throughout Canadian continental interiors. It is predicted that higher intensity heat extremes will occur during the summer months and the number of extreme heat days will increase. Less is known about changes to the duration of extreme heat days (Wolfe and Thorpe 2005, Hoegh-Guldberg et al. 2018).

5. Population and Distribution Objectives

The population and distribution objective is to improve the stability of extant populations[13] of Gibson's Big Sand Tiger Beetle in Canada by providing for the natural expansion of the species' distribution.

For Gibson's Big Sand Tiger Beetle, two out of the three years in the life cycle are spent as larvae buried in the soil. The number of mature individuals fluctuates depending on factors which influence larval survival in preceeding years (mainly precipitation) (Knisley and Hill 2001, Gowan and Knisley 2014). These fluctuations in abundance are not necessarily indicators of threats to survival but they greatly complicate the determination

[13] All extant populations that are defined within this recovery strategy and any newly discovered or re-discovered populations. Occurrences or populations that are considered historical unconfirmed are excluded from these objectives until such time as they are re-discovered.

of trends or the ability to set specific quantitative population objectives. In addition, the majority of populations have not been enumerated, or have been revisited only once; therefore data on population sizes, magnitude of fluctuations, range of natural variability, etc. is lacking. Therefore, the population and distribution objectives are general targets.

Dune stabilization resulting in a loss of habitat quality and quantity is the primary threat to Gibson's Big Sand Tiger Beetle recovery in Canada and the distribution of the species' is limited to the spatial distribution of sparsely vegetated sandy habitat. If habitat quality and quantity continue to decline, known populations may also decline as a result. Therefore, the population and distribution objectives have been set in the context of reversing or preventing further declines in quality and quantity of habitat in order to improve stability, and if possible, provide habitat for the natural expansion of the species' distribution over the long term.

6. Broad Strategies and General Approaches to Meet Objectives

6.1 Actions Already Completed or Currently Underway

Inventory and Monitoring

Troutreach Saskatchewan (Saskatchewan Wildlife Federation) studied the population dynamics and distribution of Gibson's Big Sand Tiger Beetle in the Elbow Sand Hills, Douglas Provincial Park from 2016-2018 (Bell et al. 2019). This is the most comprehensive study of the species in Canada.

Habitat Management and Stewardship

The Government of Saskatchewan (2007) published the Great Sand Hills Environmental Study to assess the impact of human activities on the ecological integrity or sustainability of the sand hills ecosystem.

Range management and invasive non-native plant species control measures have been developed and implemented within Pike Lake Provincial Park, Douglas Provincial Park, Cranberry Flats Nature Preserve, and Nature Conservancy Canada lands. This includes the use of prescribed burning and/or grazing to maintain range condition and control invasive non-native species. Douglas Provincial Park also monitors the emergence of Leafy Spurge and sprays to eliminate the invasive non-native species when needed (J. Perry pers. comm. in Environment Canada 2014).

Education and Outreach

The Government of Saskatchewan created the Dune Nature Centre and set up signage along hiking trails within Douglas Provincial Park to educate visitors on sand dune ecosystems and tiger beetles.

6.2 Strategic Direction for Recovery

Table 3. Recovery Planning Table

Threat or Limitation	Priority[a]	Broad Strategy to Recovery	General Description of Research and Management Approaches
All threats; Knowledge gaps	Medium-High	Inventory and monitoring	• Develop and implement a long-term standardized monitoring program throughout the species' Canadian range to ensure known populations are maintained, reliable population information is obtained, and threats are mitigated. • Conduct surveys for the species in suitable habitat at undocumented locations and historic unconfirmed locations to increase knowledge of the species' range in Canada. • Coordinate Gibson's Big Sand Tiger Beetle monitoring programs with those for other dune specialist species in the Canadian Prairies.
All threats except 5.1, 11.2, and 11.3	High	Habitat Management and Stewardship	• Determine and implement best management practices to achieve conservation of suitable habitat, activate dunes and reduce or eliminate threats. • Collaborate with land owners, land managers, government agencies and other relevant parties to promote, coordinate and implement habitat management and conservation efforts to activate dunes. • Integrate dune activation stewardship practises with those for other dune specialist species in the Canadian Prairies.
2.3, 5.1, 6.1, 8.1	Low	Education and Outreach	• Develop and deliver a communication/outreach strategy targeting landowners and land managers whose properties contain Gibson's Big Sand Tiger Beetle to raise awareness of the species and its habitat needs and threats. • Encourage landowners and the public to report sightings of Gibson's Big Sand Tiger Beetle.
All threats; Knowledge gaps; Limiting factors; Activities likely to destroy critical habitat (ALTD)	Medium-High	Research	• Fill in key knowledge gaps on the microhabitat requirements of all life stages, and the role of primary and secondary suitable habitat in dispersal, colonization, population viability and long-term persistence. • Investigate impacts of ALTD, limiting factors, human-related threats, climate change, and habitat management techniques. • Address knowledge gaps related to species' home range, site fidelity, territory size, daily foraging distances, etc. that aid in the further refinement of critical habitat identification. • Complete genetic analysis on populations in Montana and Utah; as well as those in eastern Saskatchewan, Manitoba, and extending south of the Canadian border to fill in knowledge gaps on subspecies taxonomic classifications.

[a] *"Priority" reflects the degree to which the broad strategy contributes directly to the recovery of the species or is an essential precursor to an approach that contributes to the recovery of the species.*

6.3 Narrative to Support the Recovery Planning Table

Inventory and Monitoring

Standardized survey and monitoring protocols should be implemented across the species' Canadian range in order to determine whether the population and distribution objectives are being achieved, to establish an estimate for the size of the Canadian population, and to assess the stability/trends in the Canadian population. The methodology used by Gowan and Knisley (2014) for *C. albissima* has been successfully adapted for Gibson's Big Sand Tiger Beetle (Bell et al. 2019) and should be used to meet these objectives. Regular systematic monitoring over several consecutive years at known populations is highly recommended. Surveying previously undocumented locations or historic unconfirmed locations would be of secondary importance. The dataset created by Wolfe (2010) identifying all active sand dunes and blowouts within the Canadian Prairie Provinces should be used to facilitate the planning of further surveys. These surveys should be conducted in concert with other studies focusing on threatened sand dune species in Canada.

Habitat Management and Stewardship

Habitat management and stewardship are high priorities in the recovery of Gibson's Big Sand Tiger Beetle. Adaptive management strategies that use disturbance (e.g. controlled burning, grazing, control of invasive non-native species through direct herbicide application and/or biological control agents) should be developed to reduce threats and maintain and promote suitable habitat for this species. Factors leading to dune stabilization and habitat succession are the greatest threats to Gibson's Big Sand Tiger Beetle (COSEWIC 2012), and the population and distribution objectives have been set in this context. Collaboration among individuals, organizations and government departments that own, lease, use, or manage land where Gibson's Big Sand Tiger Beetle occurs will be essential to its recovery.

Historically, the stabilization of active dunes was thought to be good conservation practice and land managers attempted to stabilize dunes by extinguishing fires, actively reseeding, altering grazing patterns, and placing objects, such as tires or bales, on blowouts (David 1977, Wallis and Wershler 1988). Protection of active sand dune habitat has only recently been recognized as an important conservation measure. Using disturbance to reduce encroaching vegetation would benefit Gibson's Big Sand Tiger Beetle and improve habitat. Numerous methods have proved successful in preventing complete stabilization for other tiger beetle species, including grazing (with appropriate timing, intensity, and frequency), controlled burns (Knisley 2005, Mawdsley 2007), use of herbicide on invasive non-native plant species (Knisley 2009, Bouffard et al. 2009), and even hand pulling of vegetation (Omland 2004). Implementing appropriate biological control agents, such as the use of flea beetles (*Aphthona* sp.) on leafy spurge, requires assessment of invasive plant species' composition and distribution. Similar methods have also been implemented for improving habitat for other threatened sand dune insects in Canada (e.g., the Gold-edged Gem, *Schinia avemensis*, see

Environment Canada 2014) and could be adapted for Gibson's Big Sand Tiger Beetle. Habitat management and dune activation stewardship practices should be integrated with other sand dune specialist species that co-occur with Gibson's Big Sand Tiger Beetle (Appendix C). As a general rule, management actions that incorporate or mimic natural disturbance regimes (e.g., fire and grazing) are natural components of prairie ecosystems and are not likely to negatively impact the persistence of other native species particularly if the timing, intensity and frequency mimic natural processes (Samson and Knopf 1994).

Education and Outreach

Gibson's Big Sand Tiger Beetle is an excellent candidate for outreach and educational opportunities owing to its large size and brilliant colouration. Featuring Gibson's Big Sand Tiger Beetle and other threatened dune insects on signs and information pamphlets where the species is found would increase awareness among the public.

Eight out of twelve populations occur within private or public lands that are not designated as a Provincial Park or other conserved land, therefore, engagement with landowners and land managers and encouraging conservation through stewardship are essential to the recovery of Gibson's Big Sand Tiger Beetle. Habitat requirements of Gibson's Big Sand Tiger Beetle on private and public lands should be incorporated during land use planning at all levels (local, municipal, regional, provincial) to ensure that land management practices benefitting the species can be implemented where it occurs. Development and implementation of adaptive site-specific best management practices for the species and its habitat to reduce or mitigate threats is required for successful conservation and may be possible to implement through stewardship agreements. Several environmental non-government organizations have already developed multi-species best management plans which may encompass areas occupied by Gibson's Big Sand Tiger Beetle, making collaboration of future efforts important.

Research

Effective recovery and management of Gibson's Big Sand Tiger Beetle will depend on scientific research into the ecology and microhabitat requirements of the species. Research into the role of primary and secondary suitable habitat in dispersal, colonization, and long-term persistence can help answer questions on population viability. Information on the impacts of limiting factors, human-related threats, and climate change on Gibson's Big Sand Tiger Beetle ecology and habitat needs is relevant to recovery and long-term population and distribution objectives. Investigation into appropriate management techniques are needed to assist in developing appropriate disturbance applications that improve habitat conditions while minimizing mortality. Addressing specific knowledge gaps related to habitat use and dispersal (e.g., home range size, territory size, site fidelity, foraging distance) are considered a priority for further refining critical habitat. Research into the effects of insecticides on prey or pollinator species can further the understanding of activities likely to result in the destruction of critical habitat. When possible, collaborative research with recovery teams working on other sand dune specialists would be both practical and appropriate.

Genetic analysis completed by French et al. (2021) provides evidence that Gibson's Big Sand Tiger Beetle may be endemic to Canada. Further genetic analysis between Canadian and United States populations is considered a high priority for determining the global range of this species. In light of the recent discovery by French et al. (2021) that two morphologically different subspecies (*C. f. fletcheri* and *C. f. gibsoni*) were not genetically distinct from each other, this brings into question the taxonomic classifications of other *C. formosa* subspecies. Genetic analysis on *C. formosa* subspecies in eastern Saskatchewan and Manitoba is considered a high priority for clarifying subspecies designations.

7. Critical Habitat

7.1 Identification of the Species' Critical Habitat

Critical habitat is defined in SARA (Subsection 2(1)) as *"the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species".* Section 41 (1)(c) of SARA requires that recovery strategies include an identification of the species' critical habitat, to the extent possible, as well as examples of activities that are likely to result in its destruction.

Critical habitat for Gibson's Big Sand Tiger Beetle is fully identified in this recovery strategy, to the extent possible, for all known extant populations, based on best available information, and is considered sufficient to meet the population and distribution objectives at this time. Additional critical habitat may be identified, or existing critical habitat may be amended, if new or additional information supports the inclusion or refinement of areas beyond those currently identified (e.g., new locations become colonized, expansion of existing area occurs, historical populations are re-discovered, new information becomes available about habitat requirements).

Biophysical attributes of suitable habitat for Gibson's Big Sand Tiger Beetle include the dynamic edge between active[14] and fully stabilized[15] sand on various forms of parabolic dunes, blowouts, and sand ridges (primary suitable habitat) as well as patches of exposed sand caused by linear disturbances (e.g., game trails, hiking trails) that have removed vegetation in the otherwise fully vegetated surrounding grassland (secondary suitable habitat / dispersal corridors). It is characterized by a mixture of exposed sand, vegetation in early to mid successional stages (35-50% vegetation cover; see section 3.3 for associated plant species) that provides a range of thermal conditions suitable for

[14] A surface devoid of vegetation where the soil particles are entrained or actively moved by the wind.
[15] A surface devoid of bare soil where the soil particles are anchored by vegetation and are not actively moved by the wind.

activity (surface sand temperature between 20 and 50 °C), and loose soil that permits construction of larval chambers for juveniles. The edge habitat is difficult to characterize as it is constantly shifting in space and time due to the nature of sand dune migration and different types of landscape-scale disturbances (e.g. grazing, fire, climatic cycles) that may act in combination and/or with varying frequencies to result in observed states of dune succession.

Considering the landscape-scale processes required to maintain the biophysical attributes of suitable habitat, and that suitable habitat is not static in place or time, critical habitat is recognized as the area that is necessary to maintain suitable habitat conditions. The area within which critical habitat is found (Appendix B) is delineated by a 500 m critical function zone extending from the outer boundary of occupied primary suitable habitat or occurrences and a 2 km dispersal zone extending from the outer boundary of the critical function zone. Critical habitat is all natural landforms, soil, and vegetation (minus specific exclusions[16]) within the critical function zone, and all suitable habitat, as defined by where it meets the biophysical attributes, within the dispersal zone.

Although the home range and territory size is unknown for Gibson's Big Sand Tiger Beetle, the distribution of the species' within a dune is related to the spatial distribution of sparsely vegetated sandy habitat that provides optimal thermoregulation (A. Bell pers. comm. 2021). Therefore, occupied primary suitable habitat was delineated[17] to represent an occurrence's home range. Where occurrences[18] occupy primary suitable habitat, a critical function zone extends 500 m from the outer boundary of the occupied primary suitable habitat. Where occurrences occupy secondary suitable habitat, a critical function zone extends 500 m from the occurrence point[19]. The 500 m critical function zone is based on the minimum dispersal distance documented for tiger beetles and is an estimate of the minimum area needed to provide habitat that is necessary for the survival of the species. Dispersal distances documented for tiger beetle species ranges from 481 m (Hudgins et al. 2011) to 24 km (Knisley and Schultz 1997). One study in the Elbow Sand Hills observed individuals of Gibson's Big Sand Tiger Beetle along a sandy linear disturbance up to 2.5 km from the source population (Bell 2017).

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[16] Surface water bodies, wetlands, pre-existing cultivated lands, and pre-existing anthropogenic disturbances that permanently cover the soil (such as, but not limited to, paved roads, well-pads, houses) are exempt from consideration as critical habitat.

[17] Primary suitable habitat was delineated ex-situ using the best available satellite imagery (WorldView 03/04 imagery from 2017/2018 at 0.31 m spatial resolution and WorldView 02 imagery from 2014/2015/2016 at 0.5 m spatial resolution (1:1000 map scale)) following concepts of object-based segmentation (Jobin et al. 2008) and was visually identified using colour and texture.

[18] Information on Gibson's Big Sand Tiger Beetle known to Environment and Climate Change Canada as of July 2021 was used in the identification of critical habitat where the data[a] met the accuracy requirements (occurrences[b] less than or equal to 21 years old (within 7 generations) at the time of writing this recovery strategy and with a horizontal positional accuracy within 25m).

[a] Occurrence data is binary (presence/absence) as information on population size and trends is not available at this time. Refer to Table A1 in Appendix A for inference on viability.

[b] An occurrence is a grouping of one or more Gibson's Big Sand Tiger Beetle individuals.

[19] Due to the linear nature of secondary suitable habitat, it was not possible to delineate a spatially explicit occupied area.

Thus, 2.5 km is a conservative estimate for the potential dispersal distance of Gibson's Big Sand Tiger Beetle and the additional 2 km dispersal zone surrounding the 500 m critical function zone is an estimate of the minimum area needed to provide habitat that is necessary for the recovery of the species.

Critical habitat for Gibson's Big Sand Tiger Beetle is identified within 7 active dune fields and encompasses an area of 43202.8 hectares (432.02 km²) (1636.4 hectares in Alberta and 41566.4 hectares in Saskatchewan) (Appendix B). This occupies or overlaps into approximately 883 quarter sections of land in the Dominion Land Survey (35 in Alberta and 848 in Saskatchewan). All jurisdictions and landowners who are controlling surface access to this area, or who are currently leasing and using parts of this area, may be provided upon request with geo-referenced spatial data or large-format maps delineating the boundaries of critical habitat displayed in Appendix B.

7.2 Activities Likely to Result in the Destruction of Critical Habitat

Destruction is determined on a case-by-case basis. Destruction would result if part of the critical habitat were degraded, either permanently or temporarily, such that it would not serve its function when needed by the species. Destruction may result from a single or multiple activities at one point in time or from the cumulative effects of one or more activities over time (Government of Canada 2009). Activities described in Table 4 outline examples of activities likely to cause destruction of critical habitat for Gibson's Big Sand Tiger Beetle; however, destructive activities are not limited to those listed.

Table 4. Activities Likely to Result in the Destruction of Critical Habitat

Description of Activity	Description of Effect	Details of Effect
Compression, Covering, Inversion/excavation/extraction of soil (e.g., creation or expansion of permanent/temporary structures, repeated motorized traffic, concentrated livestock activity, spreading of solid waste materials, roadbed construction, new or expanded cultivation, sand and gravel extraction pits, dugouts, pipeline installation, stripping of soil for well pads)	Compression can damage soil structure and porosity, may directly destroy larval burrows, and change habitat conditions such that larval burrows and activity are no longer viable at the site. Covering the soil prevents solar radiation and water infiltration needed for germination and survival of plants necessary to maintain mid successional habitat (35-50% vegetation cover), and directly prevents individuals from accessing the substrate within which to create larval burrows and access prey. Soil inversion, excavation, or extraction can alter soil porosity, and thus temperature and moisture regimes, such that vegetation communities change to those dominated by competitive invasive species. This also results in the direct loss of the substrate that the species' relies on for survival and would constitute a direct removal of critical habitat and residences (larval burrows).	This activity must occur within the bounds of critical habitat to cause its destruction, can be a direct or cumulative effect, and is applicable at all times.

Description of Activity	Description of Effect	Details of Effect
Alteration to hydrological regimes (e.g., temporary or permanent inundation from construction of impoundments downslope or downstream, and accidental or intentional releases of water upslope and upstream; groundwater depletion)	As Gibson's Big Sand Tiger Beetle is adapted to semi-arid conditions, flooding or inundation by substances like water or hydrocarbons, even for a short period of time, can be sufficient to alter habitat enough to be unsuitable for survival and re-establishment. For example, road construction can interrupt or alter overland water flow, altering habitat conditions and threatening the long-term survival of the species at that location.	This activity can occur within and outside the bounds of critical habitat to cause its destruction, can be a direct or cumulative effect, and is applicable at all times.
Indiscriminate application of fertilizers or pesticides (e.g., non-selective spraying of broad-leaf herbicide and insecticide, arbitrary additions of fertilizers to soil)	Non-selective broad-leaf herbicide and fertilizer effects that can destroy critical habitat include altering soil water and nutrient availability such that species composition in the surrounding plant community can change. These changes, in addition to the altered interspecific competition that results from them, could render the habitat unsuitable. Single or repeated use of broad-spectrum insecticides can deplete prey (refer to Section 3.3) and pollinator species, such that the function of critical habitat may be negatively impacted.	This activity can occur within and outside the bounds of critical habitat to cause its destruction (e.g. chemical drift, groundwater or overland flow of contaminated water), can be a direct or cumulative effect, and is applicable at all times.
Deliberate introduction or promotion of invasive alien plant species (e.g., intentional dumping or spreading of feed bales containing viable seed of invasive alien species, seeding invasive alien species, use of uncleaned motorized vehicles contaminated with invasive species material)	Once established, invasive alien plant species can alter soil resource availability and directly compete with native vegetation, leading to a change in community composition and increased stabilization of sandy habitats. Critical habitat may be destroyed by invasive alien species (refer to Section 4.2), as well as by other prohibited or noxious prohibited weeds. It may also be destroyed by the following species that are not restricted by any legislation due to their economic value: Smooth or Awnless Brome (Bromus inermis), Crested Wheatgrass, Yellow Sweet Clover (Melilotus officinalis), White Sweet Clover (Melilotus alba). This form of destruction is often a cumulative effect resulting from the first four examples of critical habitat destruction.	This activity can occur within or adjacent to the bounds of critical habitat to cause its destruction, can be a direct or a cumulative effect, and is applicable at all times.
Deliberate actions to stabilize sand dunes (e.g., revegetating, use of flax bales or tires, straw crimping, drift fencing, or landscape fabric)	These activities can artificially promote vegetation cover, change plant community structure and diversity, stabilize dunes or hasten vegetative succession on dunes, thereby contributing to the loss of critical habitat.	This activity must occur within the bounds of critical habitat to cause its destruction, can be a direct or a cumulative effect, and is applicable at all times. This activity is only intended to apply to culpable activities.

Description of Activity	Description of Effect	Details of Effect
Spreading of wastes (e.g., spreading of materials such as manure, drilling mud, and septic fluids)	These have the potential to negatively alter soil resource availability, species compositions, and increase surrounding competitor plants -effectively destroying the critical habitat. These liquid or semi-liquid materials can infiltrate the surface in the short-term, but leave little long-term evidence at the surface that could point to the cause of negative changes observed thereafter.	This activity can occur within and outside the bounds of critical habitat to cause its destruction (e.g. drift, groundwater or overland flow of contaminated water), can be a direct or cumulative effect, and is applicable at all times.

8. Measuring Progress

The performance indicators presented below provide a way to define and measure progress toward achieving the population and distribution objectives. Every five years, success of recovery strategy implementation will be measured against the following performance indicators:

- The species' spatial distribution within each extant population defined within this recovery strategy and each newly discovered or re-discovered population remains stable

- Quality of critical habitat has been maintained at a level that supports Gibson's Big Sand Tiger Beetle populations

- Quantity of critical habitat has been maintained, at a minimum, as the amount defined in this recovery strategy

9. Statement on Action Plans

One or more action plans for Gibson's Big Sand Tiger Beetle will be posted on the Species at Risk Public Registry within 5 years of the completion of this recovery strategy.

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Appendix A: Summary of Gibson’s Big Sand Tiger Beetle Populations and Locations in Canada

Table A1. Summary of Gibson’s Big Sand Tiger Beetle populations in Canada.

Population [EO_ID][a]	First Observed	Last Observed	Last Survey Year	Population Estimate [year]	Status	Threats
SASKATCHEWAN						
Big Stick Sand Hills						
Big Stick [17399]	2008	2015	2015	Unknown	Extant	2.3, 3.1, 3.2, 4.1, 5.1, 7.1, 8.1, 11.1, 11.2, 11.3
Burstall Sand Hills						
Burstall [Unassigned]	1986	1986	2010	Unknown	Historic Unconfirmed[b]	Threats not assessed
Carmichael Sand Hills						
Tompkins [Unassigned]	1967	1977	1977	Unknown	Historic Unconfirmed[b]	Threats not assessed
Dundurn Sand Hills						
Dundurn [17401]	2018	2019	2019	Unknown	Extant	7.1 (capacity exists for implementing controlled burning in the future), 8.1, 11.1, 11.2, 11.3
South Dundurn [17402]	2011	2018	2018	Unknown	Extant	2.3, 3.2, 5.1, 6.1, 7.1, 8.1 (Crested Wheat Grass, Smooth Brome, Leafy Spurge, Baby's Breath), 11.1, 11.2, 11.3
Cranberry Flats [17403]	2017	2020	2020	Unknown	Extant	1.3, 6.1, 7.1 (actively managed with controlled burning), 8.1, 11.1, 11.2, 11.3
Riverbank East [21571]	2021	2021	2021	Unknown	Extant	5.1, 7.1, 8.1, 11.1, 11.2, 11.3
Beaver Creek [Unassigned]	1954	1954	2020	Unknown	Historic Unconfirmed[b]	Threats not assessed

Population [EO_ID][a]	First Observed	Last Observed	Last Survey Year	Population Estimate [year]	Status	Threats
Elbow Sand Hills						
Douglas PP [17314]	1954	2019	2019	1313 mature individuals [averaged from 2016 to 2018]	Extant	1.3, 6.1, 7.1 (actively managed with controlled burning), 8.1 (Crested Wheat Grass, Kentucky Blue Grass, Leafy Spurge, Baby's Breath), 11.1, 11.2, 11.3
Fox Valley						
Fox Valley [Unassigned]	1979	1986	1986	Unknown	Historic Unconfirmed[b]	Threats not assessed
Great Sand Hills						
Leibenthal [17405]	2014	2016	2016	Unknown	Extant	1.3, 2.3, 3.1, 3.2, 4.1, 5.1, 6.1, 7.1, 8.1 (Crested Wheat Grass, Kentucky Blue Grass, Smooth Brome), 11.1, 11.2, 11.3
East Fox Valley [17400]	1939	2018	2018	Unknown	Extant	2.3, 3.1, 3.2, 4.1, 5.1, 7.1, 8.1, 11.1, 11.2, 11.3
Kinley Sand Hills						
Kinley [Unassigned]	1985	1985	1985	Unknown	Historic Unconfirmed[b]	Threats not assessed
Piapot Sand Hills						
Piapot [17398]	1986	2018	2018	Unknown	Extant	2.3, 3.1, 3.2, 4.1, 5.1, 7.1, 8.1, 11.1, 11.2, 11.3
Pike Lake Sand Hills						
Pike Lake [17404]	1940	2018	2018	Unknown	Extant	1.3, 4.1, 6.1, 7.1 (actively managed with controlled burning), 8.1 (Smooth Brome), 11.1, 11.2, 11.3
Empress Sand Hills						
Empress Cemetery [18735]	2018	2018	2018	Unknown	Extant	3.2, 4.1, 5.1, 7.1, 8.1, 11.1, 11.2, 11.3

Population [EO_ID][a]	First Observed	Last Observed	Last Survey Year	Population Estimate [year]	Status	Threats
ALBERTA						
Empress Sand Hills						
Empress [27514]	~1984	2015	2015	Unknown	Extant	3.1, 3.2, 4.1, 5.1, 7.1, 8.1 (Crested Wheat Grass, Leafy Spurge, Russian Thistle), 11.1, 11.2, 11.3

[a] EO_ID refers to the element occurrence identification number, as assigned by the Saskatchewan Conservation Data Center (SK CDC) and Alberta Conservation Information Management System (ACIMS) to indicate a distinct element occurrence based on NatureServe's element occurrence delimitation guidance (NatureServe 2021b). For the purposes of this recovery strategy, an element occurrence is considered to be analogous to a population. Values in the table are those known to Environment and Climate Change Canada as of July 2021.

[b] Historic unconfirmed populations are not being considered as part of the population and distribution objectives nor are they considered as part of the threats assessment.

Table A2. Summary of Gibson's Big Sand Tiger Beetle locations in Canada.

Location / Active Dune Field	Morphology	Dune Field Total Area (ha)[a]	Recent Estimate of Bare Sand Area (ha) [Year][a]	Percentage of Area that remains as Bare Sand [Year][a]	Stabilization Rate (ha/year) [Time Interval][b]
SASKATCHEWAN					
Big Stick Sand Hills	parabolic dunes	21962	17.6 [2002]	0.08 [2002]	
Dundurn Sand Hills	blowout hollows, elongate sand ridges, windpits	28784	15.2 [2010]	0.05 [2010]	
Elbow Sand Hills	blowouts, closed parabolic dunes, ridge-sided dunes	15696	62.8 [2010]	0.4 [2010]	1.9 [1944-1970]; 0.4 [1970-1996]
Great Sand Hills	parabolic dunes (v- and u-shaped), blowouts, shield, border ridges	112363	303.3 [2010]	0.27 [2010]	7.2 in the NW and 1.4 in Wcentral [1946-1970]; 7.6 in the NW [1970-1979]; 1.3 in Wcentral [1970-1988]; 10.5 in the NW [1979-1991][c]
Piapot Sand Hills	elongate parabolic dunes, blowouts	5792	3.2 [2010]	0.06 [2010]	

Pike Lake Sand Hills	blowouts, elongate sand ridges, windpits	29125	0 [2010]	0 [2010]	
ALBERTA					
Empress Sand Hills	elongate dunes	1716	7.8 [2010]	0.45 [2010]	0.94 [1938-1984]

[a] Values from Wolfe 2010

[b] Values from Hugenholtz and Wolfe 2005, and Acorn 1992

[c] Value is the rate of dune activation

Appendix B: Critical Habitat for Gibson's Big Sand Tiger Beetle in Canada

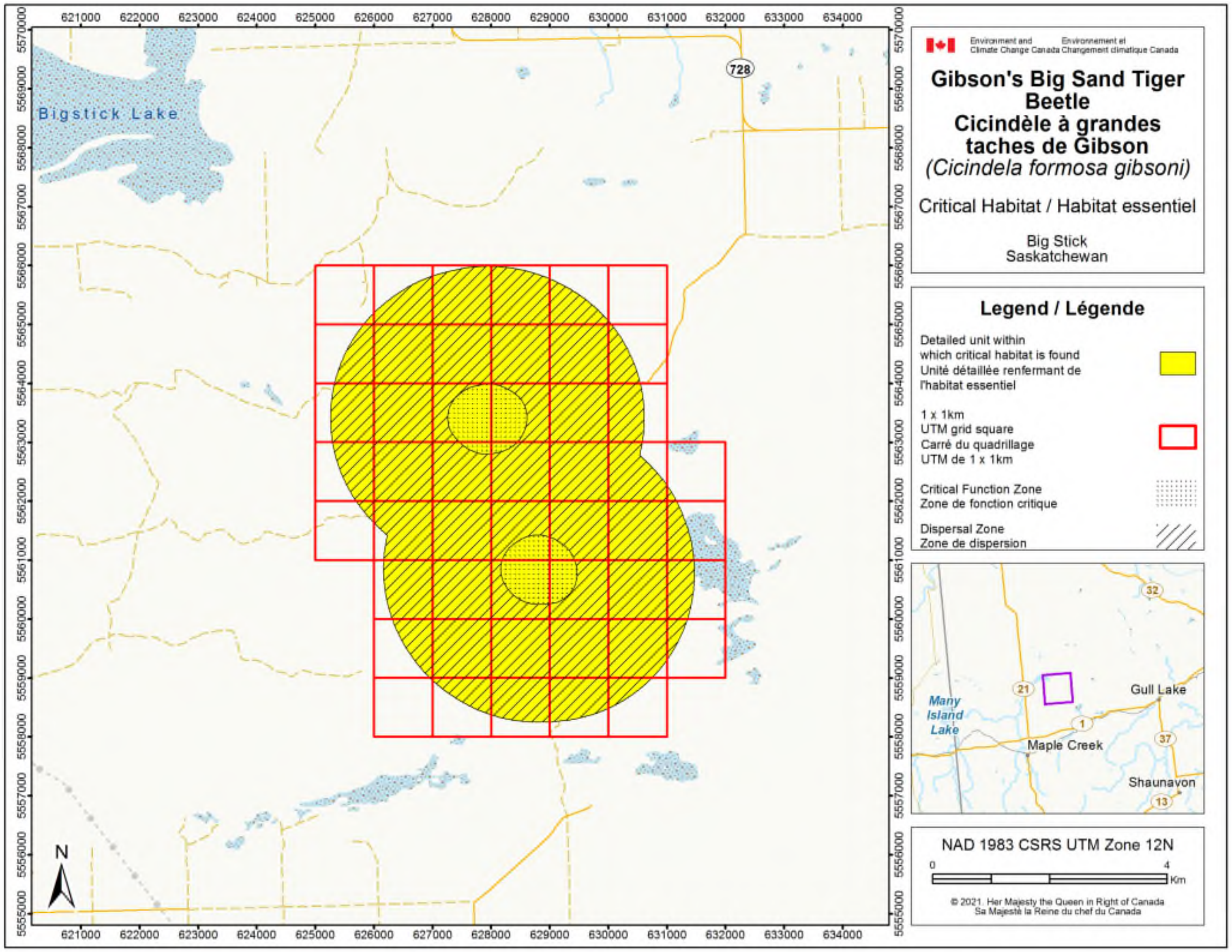

Figure B1. Critical habitat for Gibson's Big Sand Tiger Beetle (Big Stick [EO 17399] population as described in Table A1) is represented by the yellow shaded units, where the criteria set out in Section 7.1 are met. The 1 km x 1 km UTM grid overlay shown on this figure is a standardized national grid system that indicates the general geographic area containing critical habitat. Areas outside of the yellow shaded units do not contain critical habitat.

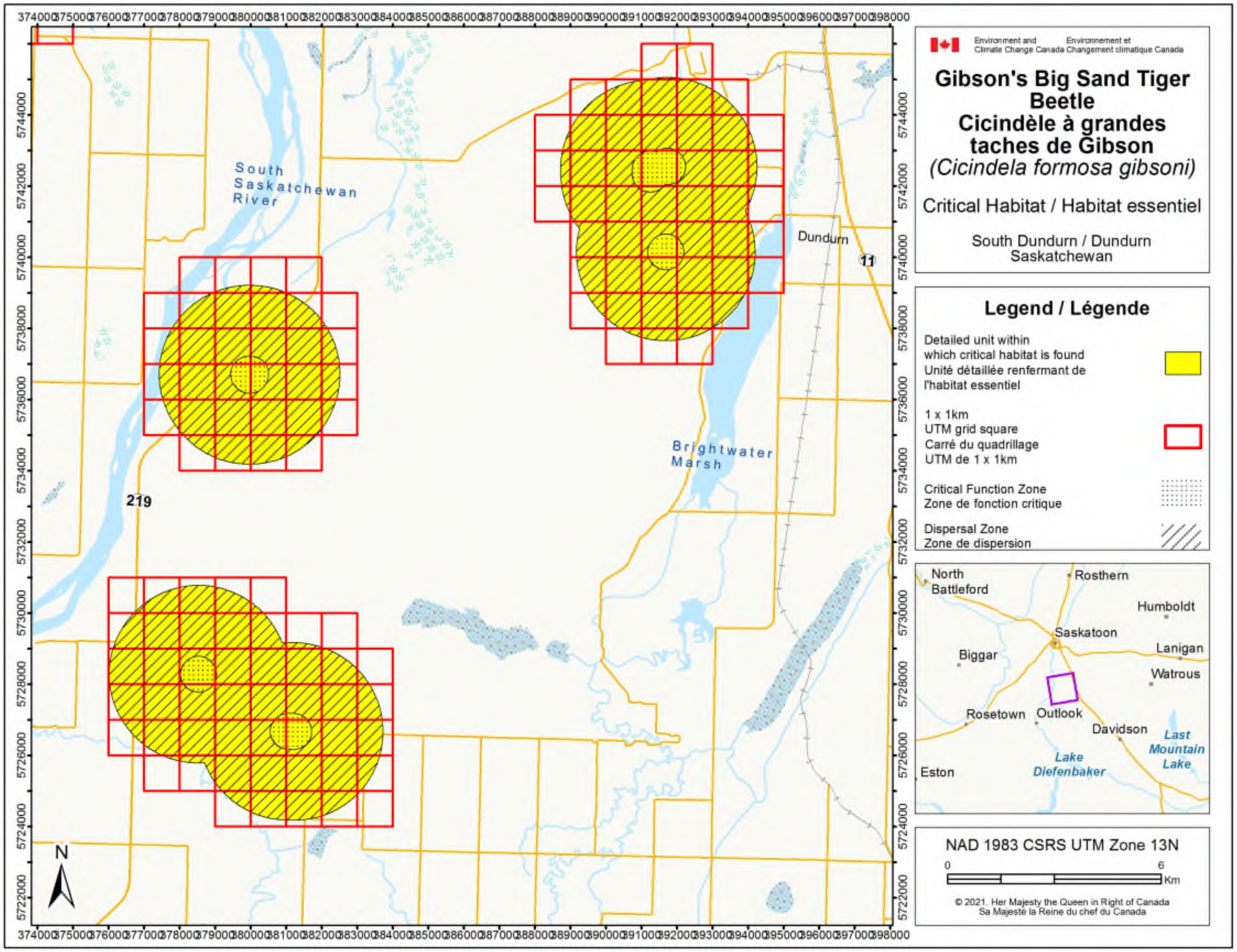

Figure B2. Critical habitat for Gibson's Big Sand Tiger Beetle (South Dundurn [EO 17402] and Dundurn [EO 17401] populations as described in Table A1) is represented by the yellow shaded units, where the criteria set out in Section 7.1 are met. The 1 km x 1 km UTM grid overlay shown on this figure is a standardized national grid system that indicates the general geographic area containing critical habitat. Areas outside of the yellow shaded units do not contain critical habitat.

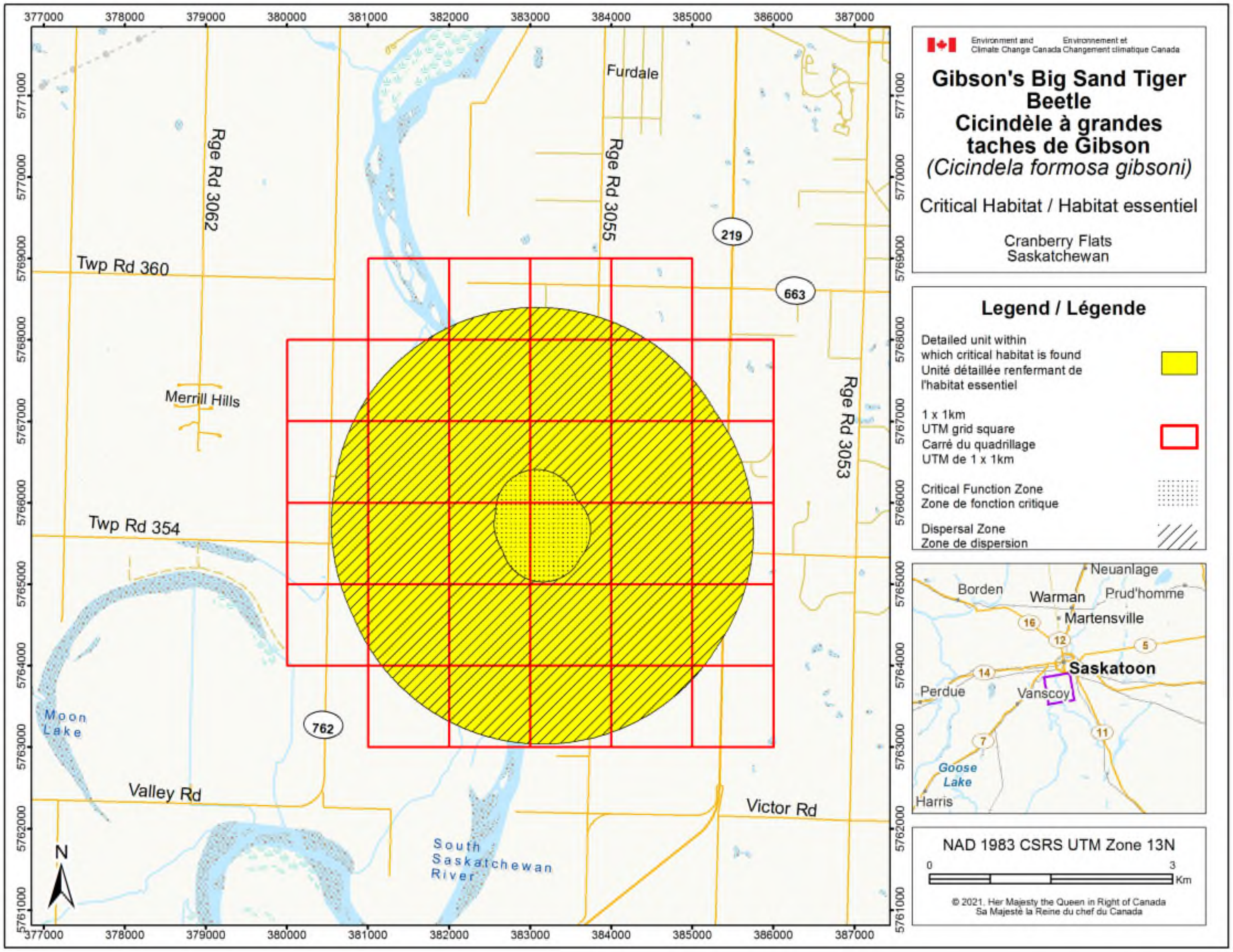

Figure B3. Critical habitat for Gibson's Big Sand Tiger Beetle (Cranberry Flats [EO 17403] population as described in Table A1) is represented by the yellow shaded units, where the criteria set out in Section 7.1 are met. The 1 km x 1 km UTM grid overlay shown on this figure is a standardized national grid system that indicates the general geographic area containing critical habitat. Areas outside of the yellow shaded units do not contain critical habitat.

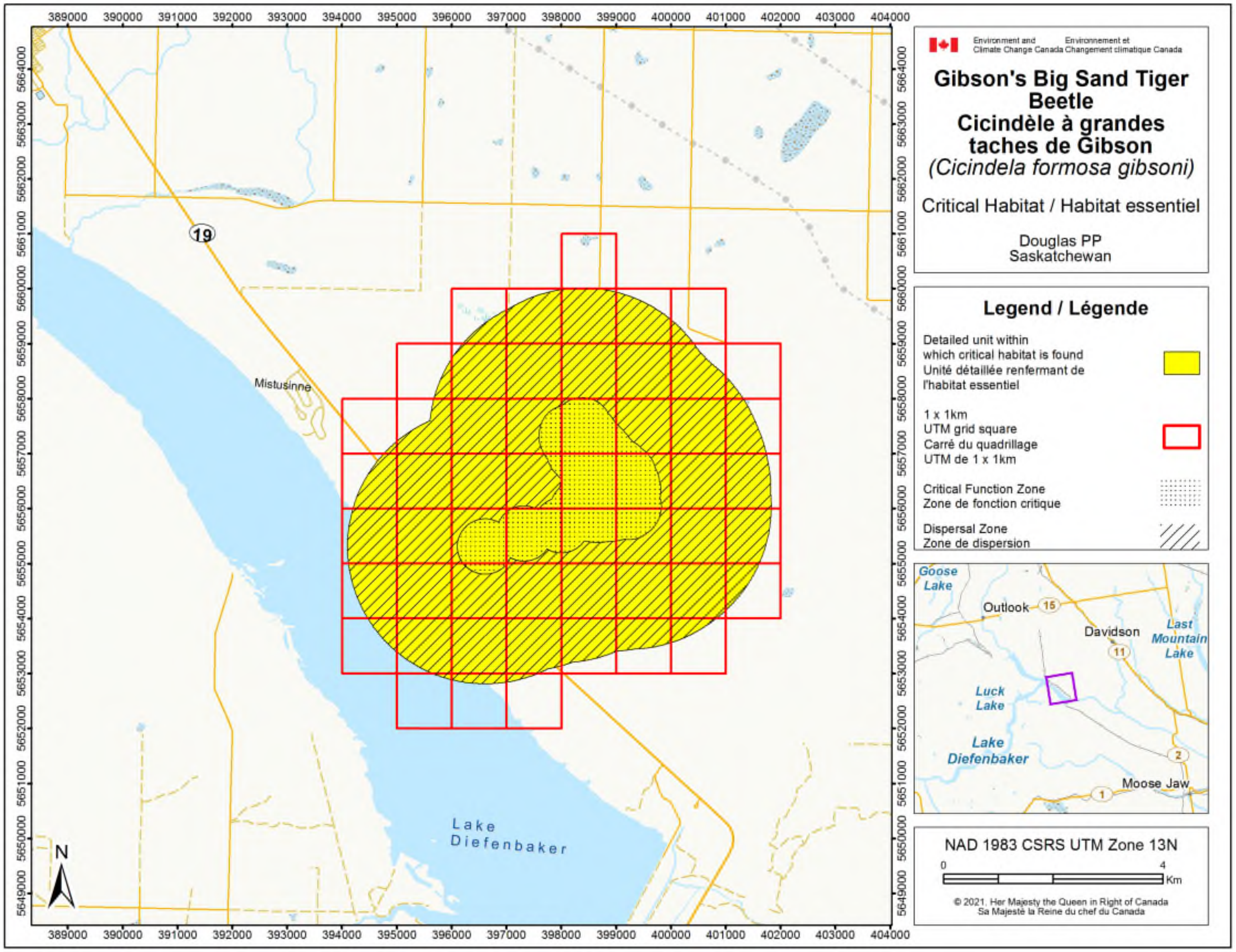

Figure B4. Critical habitat for Gibson's Big Sand Tiger Beetle (Douglas PP [EO 17314] population as described in Table A1) is represented by the yellow shaded units, where the criteria set out in Section 7.1 are met. The 1 km x 1 km UTM grid overlay shown on this figure is a standardized national grid system that indicates the general geographic area containing critical habitat. Areas outside of the yellow shaded units do not contain critical habitat.

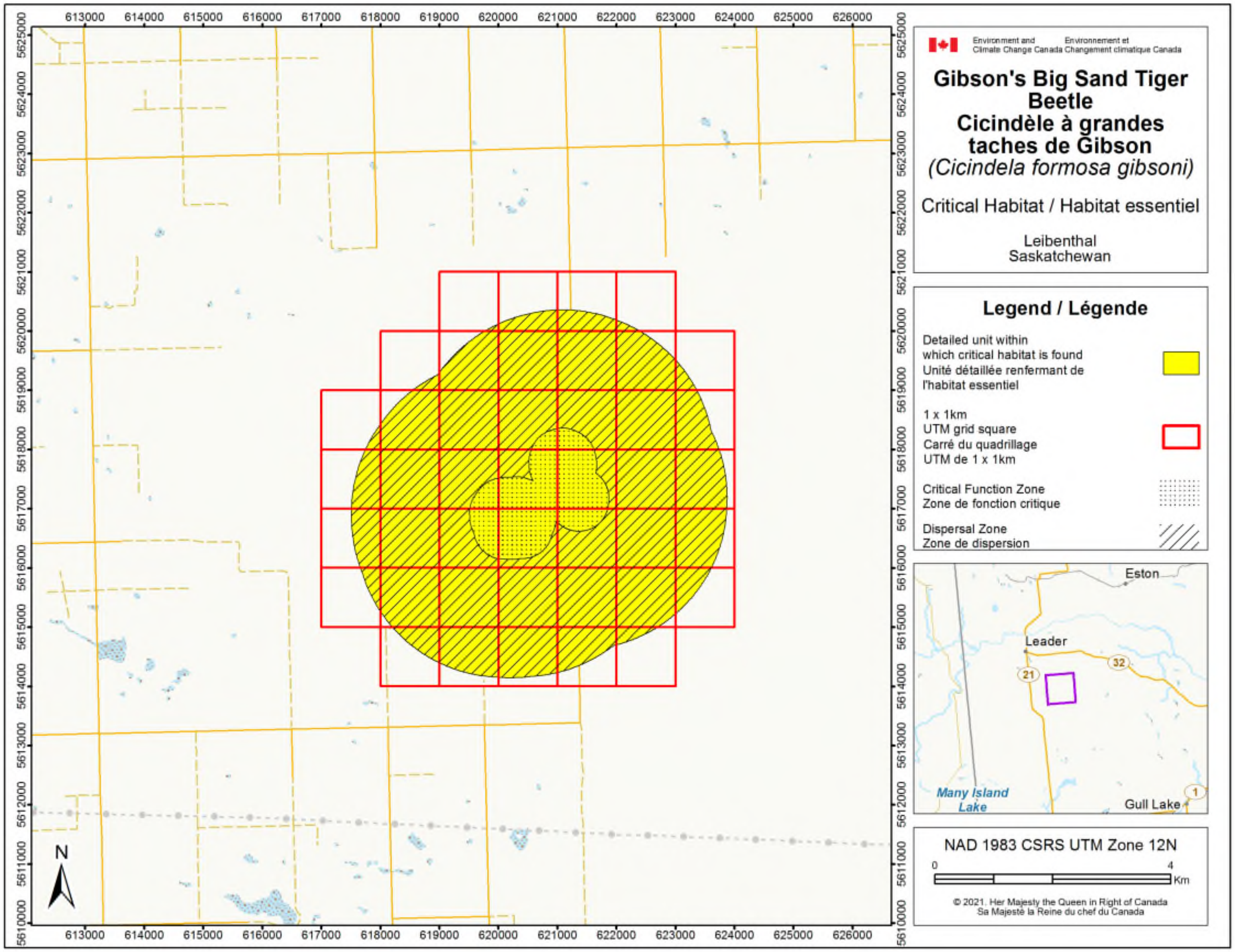

Figure B5. Critical habitat for Gibson's Big Sand Tiger Beetle (Leibenthal [EO 17405] population as described in Table A1) is represented by the yellow shaded units, where the criteria set out in Section 7.1 are met. The 1 km x 1 km UTM grid overlay shown on this figure is a standardized national grid system that indicates the general geographic area containing critical habitat. Areas outside of the yellow shaded units do not contain critical habitat.

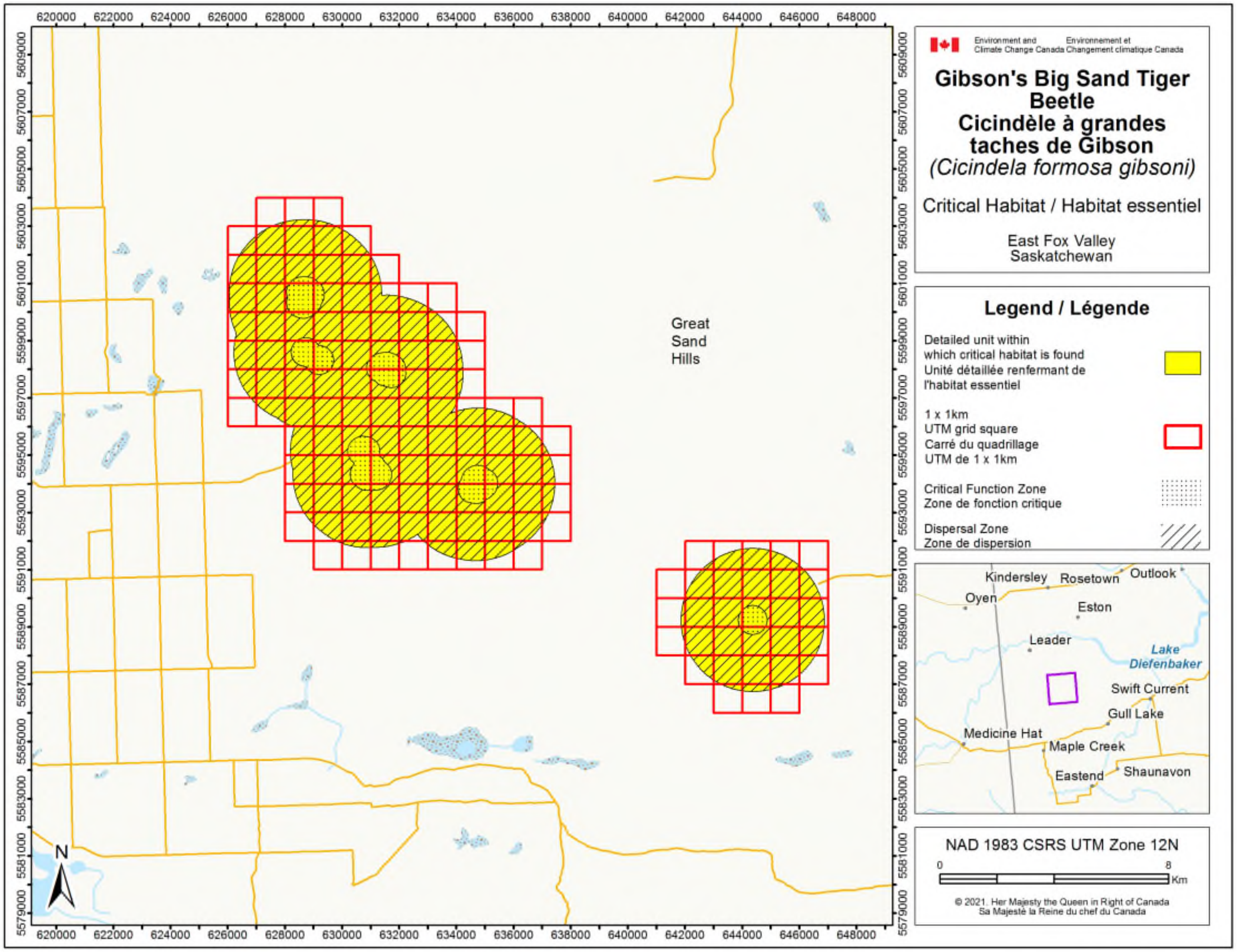

Figure B6. Critical habitat for Gibson's Big Sand Tiger Beetle (East Fox Valley [EO 17400] population as described in Table A1) is represented by the yellow shaded units, where the criteria set out in Section 7.1 are met. The 1 km x 1 km UTM grid overlay shown on this figure is a standardized national grid system that indicates the general geographic area containing critical habitat. Areas outside of the yellow shaded units do not contain critical habitat.

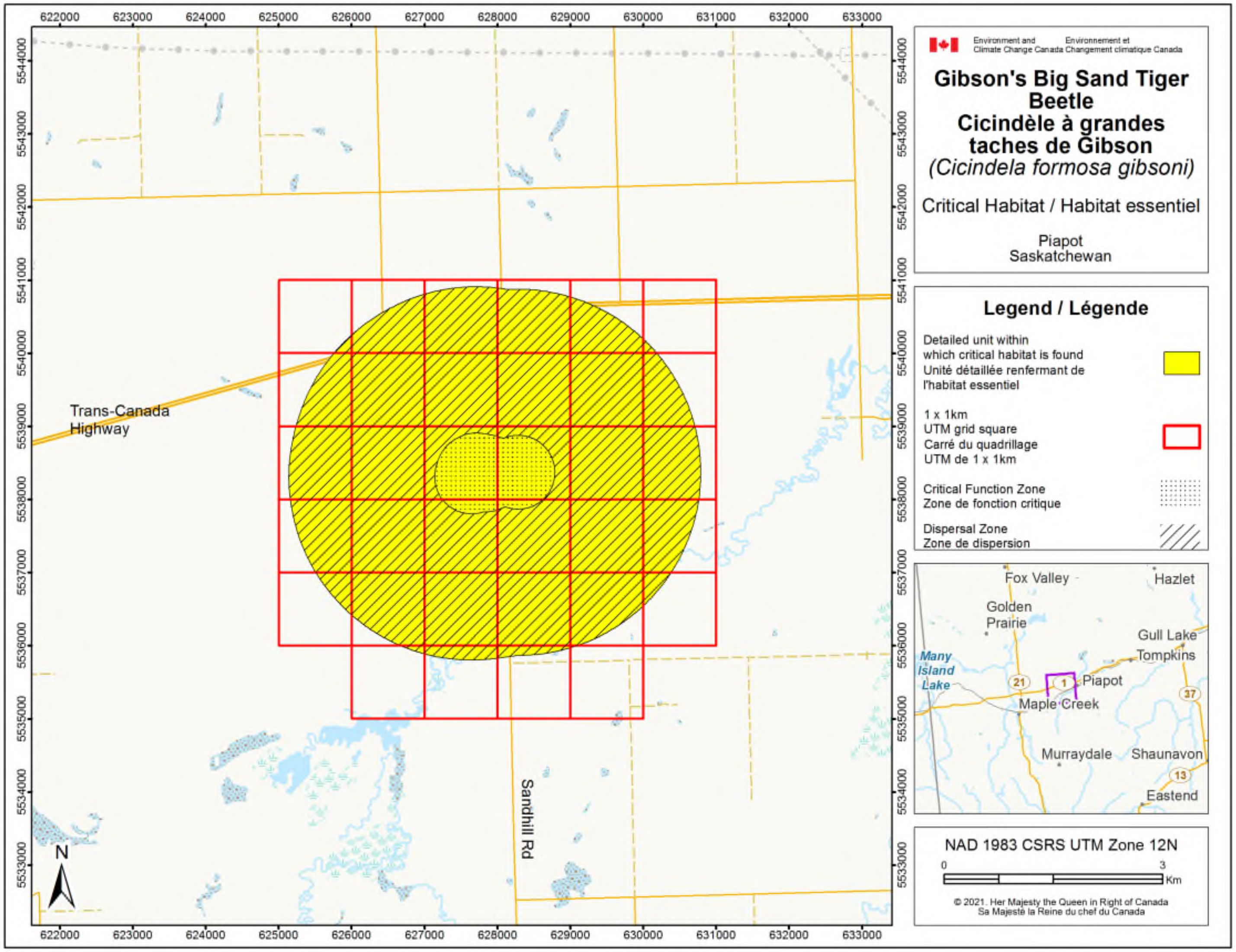

Figure B7. Critical habitat for Gibson's Big Sand Tiger Beetle (Piapot [EO 17398] population as described in Table A1) is represented by the yellow shaded units, where the criteria set out in Section 7.1 are met. The 1 km x 1 km UTM grid overlay shown on this figure is a standardized national grid system that indicates the general geographic area containing critical habitat. Areas outside of the yellow shaded units do not contain critical habitat.

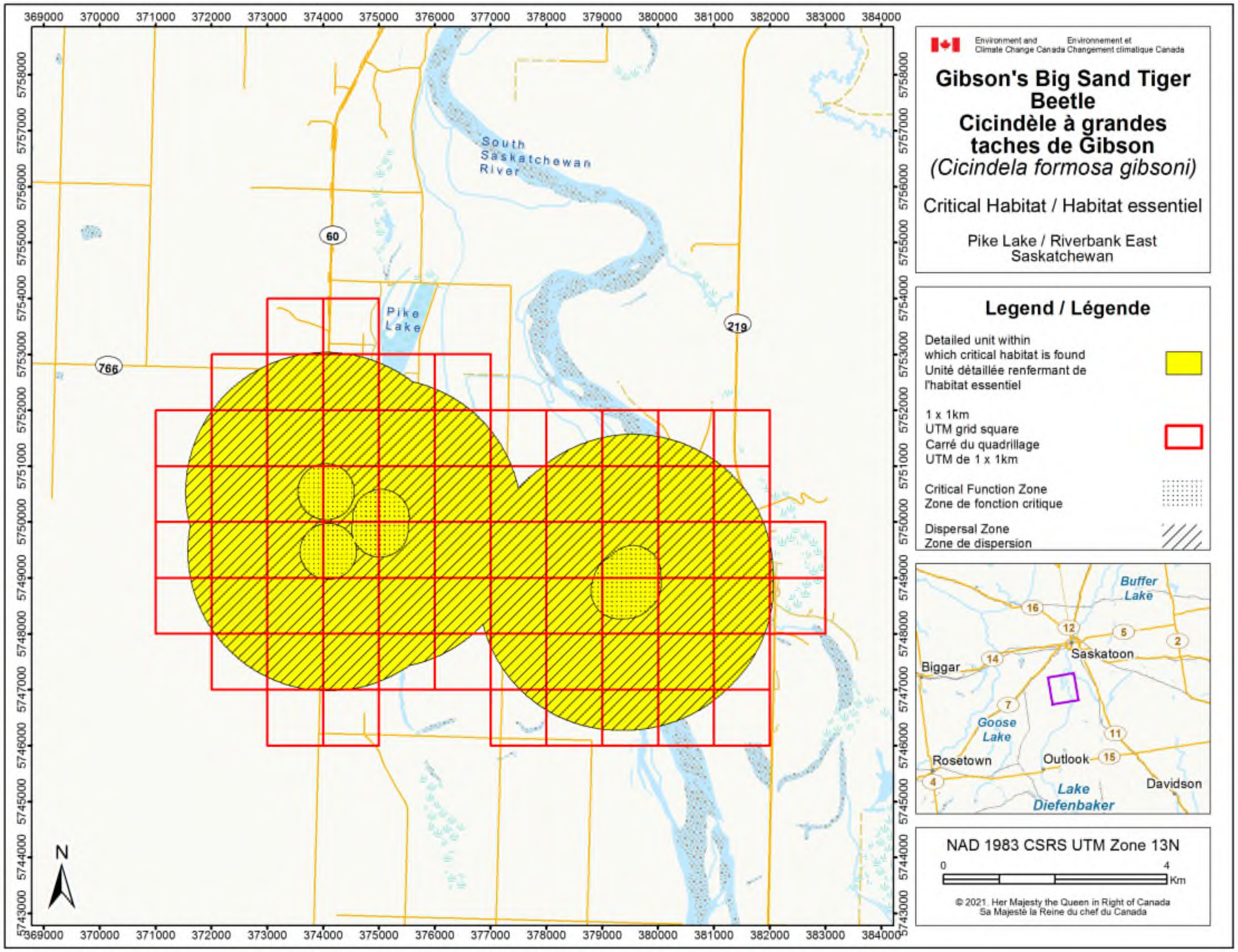

Figure B8. Critical habitat for Gibson's Big Sand Tiger Beetle (Pike Lake [EO 17404] and Riverbank East [EO 21571] populations as described in Table A1) is represented by the yellow shaded units, where the criteria set out in Section 7.1 are met. The 1 km x 1 km UTM grid overlay shown on this figure is a standardized national grid system that indicates the general geographic area containing critical habitat. Areas outside of the yellow shaded units do not contain critical habitat.

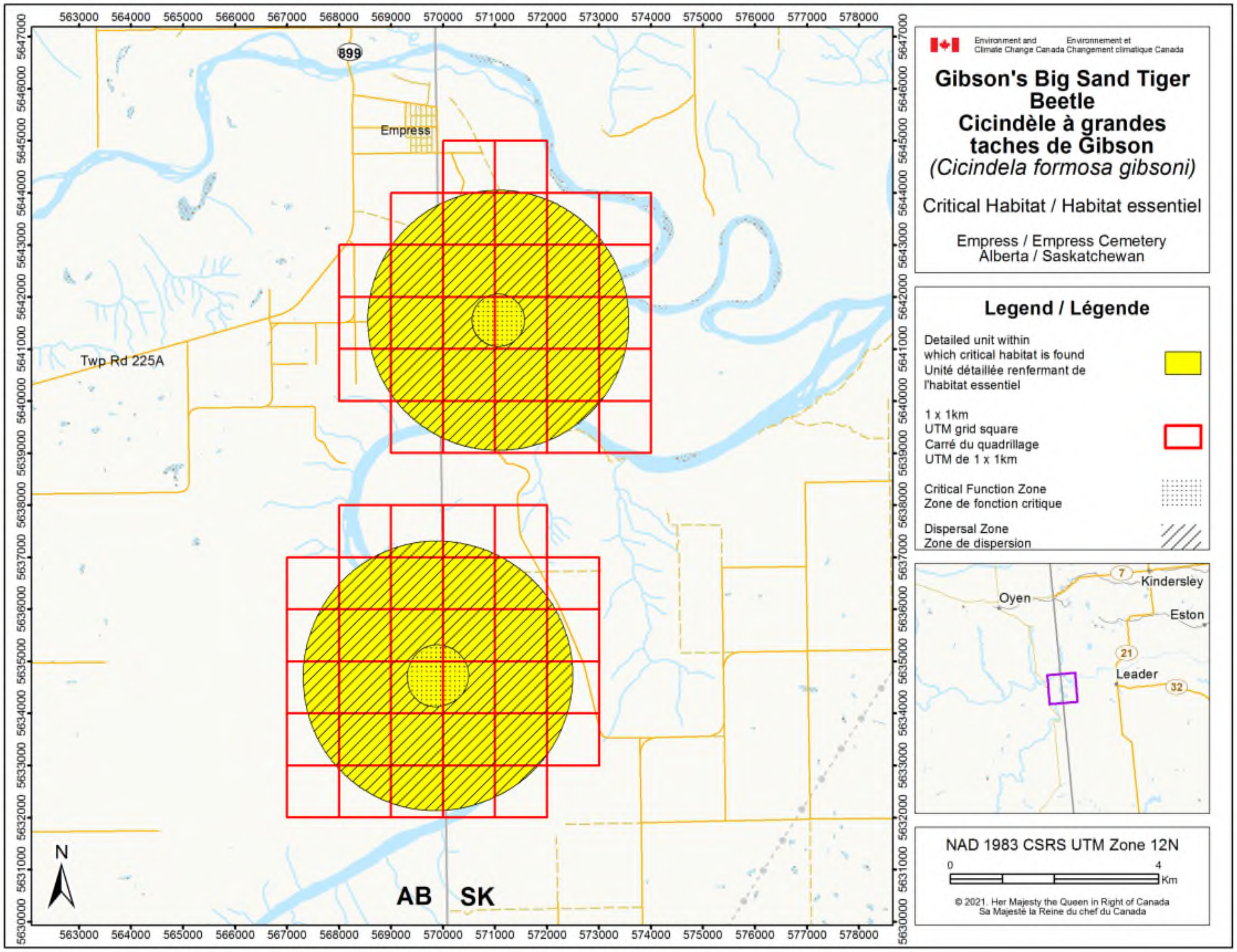

Figure B9. Critical habitat for Gibson's Big Sand Tiger Beetle (Empress [EO 27514] and Empress Cemetery [EO 18735] populations as described in Table A1) is represented by the yellow shaded units, where the criteria set out in Section 7.1 are met. The 1 km x 1 km UTM grid overlay shown on this figure is a standardized national grid system that indicates the general geographic area containing critical habitat. Areas outside of the yellow shaded units do not contain critical habitat.

Appendix C: Effects on the Environment and Other Species

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the *Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals*[20]. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making and to evaluate whether the outcomes of a recovery planning document could affect any component of the environment or any of the Federal Sustainable Development Strategy's[21] (FSDS) goals and targets.

Recovery planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that strategies may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the strategy itself, but are also summarized below in this statement.

A number of species rely on sand dunes for their survival, including other species at risk (Table C1) and provincially rare species that co-occur with Gibson's Big Sand Tiger Beetle. Most, if not all, of these species should benefit from recovery activities and management of threats intended to maintain dune ecosystems for the benefit of Gibson's Big Sand Tiger Beetle. The potential for the strategy to inadvertently lead to adverse effects on other species was considered. Some management activities, including prescribed burns and some forms of integrated weed management, have the potential to harm some species, at least in the short term. As a general rule, management actions that incorporate or mimic natural disturbance regimes (e.g., fire and grazing) are natural components of prairie ecosystems and are not likely to negatively impact the persistence of other native species particularly if the timing, intensity and frequency mimic natural processes (Samson and Knopf 1994). Recovery activities and beneficial management plans should strive to benefit as many species as possible and the ecological risks of any action must be considered before undertaking them in order to reduce possible negative effects. Efforts should be coordinated with other recovery teams and organizations working in the dune ecosystem to ensure the most efficient use of resources and to prevent duplication of effort and conflicts with research. The broad strategies described in this recovery strategy are expected to benefit the environment and not entail any significant adverse effects on other species at risk or biodiversity of sand dune ecosystems.

[20] www.canada.ca/en/environmental-assessment-agency/programs/strategic-environmental-assessment/cabinet-directive-environmental-assessment-policy-plan-program-proposals.html
[21] www.fsds-sfdd.ca/index.html#/en/goals/

Table C1. Species at risk that co-occur in similar habitats to Gibson's Big Sand Tiger Beetle.

Species Name	SARA Designation
Mammals	
Swift Fox (*Vulpes velox*)	Threatened
Ord's Kangaroo Rat (*Dipodomys ordii*)	Endangered
Birds	
Loggerhead Shrike (*Lanius ludovicianus*)	Threatened
Common Nighthawk (*Chordeiles minor*)	Threatened[a]
Sprague's Pipit (*Anthus spragueii*)	Threatened
Ferruginous Hawk (*Buteo regalis*)	Threatened[b]
Burrowing Owl (*Athene cunicularia*)	Endangered
Reptiles	
Bullsnake (*Pituophis catenifer sayi*)	Special Concern
Invertebrates	
Gold-edged Gem (*Schinia avemensis*)	Endangered
Dusky Dune Moth (*Copablepharon longipenne*)	Endangered
Pale Yellow Dune Moth (*Copablepharon grandis*)	Special Concern
Vascular Plants	
Small-flowered Sand-verbena (*Tripterocalyx micranthus*)	Endangered
Slender Mouse-ear-cress (*Halimolobos virgata*)	Threatened
Hairy Prairie-clover (*Dalea villosa var. villosa*)	Special Concern
Western Spiderwort (*Tradescantia occidentalis*)	Threatened
Smooth Goosefoot (*Chenopodium subglabrum*)	Threatened
Tiny Cryptantha (*Cryptantha minima*)	Threatened

[a] Designated as Special Concern by COSEWIC in 2018); under consideration for addition to Schedule 1 of the SARA

[b] Designated as Special Concern by COSEWIC in 2021); under consideration for addition to Schedule 1 of the SARA.