COSEWIC
Assessment and Status Report

on the

Gibson's Big Sand Tiger Beetle
Cicindela formosa gibsoni

in Canada

THREATENED
2012

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

COSEWIC status reports are working documents used in assigning the status of wildlife species suspected of being at risk. This report may be cited as follows:

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COSEWIC
Assessment Summary

Assessment Summary – November 2012

Common name
Gibson's Big Sand Tiger Beetle

Scientific name
Cicindela formosa gibsoni

Status
Threatened

Reason for designation
This very restricted subspecies, with most of its populations 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.

Occurrence
Alberta, Saskatchewan

Status history
Designated Threatened in November 2012.

COSEWIC
Executive Summary

Gibson's Big Sand Tiger Beetle
Cicindela formosa gibsoni

Wildlife Species Description and Significance

Gibson's Big Sand Tiger Beetle, *Cicindela formosa gibsoni*, is one of five subspecies of *Cicindela formosa*. It has long, narrow legs and antennae, large mandibles, and is one of the largest tiger beetles in North America. Adult Gibson's Big Sand Tiger Beetles can be distinguished from other subspecies of *C. formosa* by the expanded pale maculations covering over 60% of the elytra (hardened front wings) and bluish-green colour underneath. Like other species of *Cicindela*, the larvae are grub-like with an armoured head capsule and large mandibles.

Nearly all of the Gibson's Big Sand Tiger Beetle's range is found in Canada and they are emblematic of imperilled sand dune flora and fauna. *Cicindela formosa* and its subspecies are significant models for ecological and evolutionary studies.

Distribution

The global distribution of the Gibson's Big Sand Tiger Beetle is centred on southwestern Saskatchewan with two small disjunct populations in Colorado and Montana. Its Canadian distribution is associated with large dune complexes particularly the Great Sand Hills, Pike Lake and Dundurn sand hills near Saskatoon, and the Elbow Sand Hills near Douglas Provincial Park. The western edge of its range is in the Empress Sand Hills along the Alberta/Saskatchewan border.

Habitat

Preferred adult and larval habitat is sparsely vegetated, dry, sandy areas of blowouts, sand hills, and the margins of larger sand dunes. This open sandy habitat has declined due to dune stabilization over the past several decades and further declines are projected.

Biology

Like other tiger beetles, the Gibson's Big Sand Tiger Beetle undergoes complete metamorphosis with an egg, larval, pupal, and adult stage. In Canada, their life span is three years, with two years spent in the larval stage. Gibson's Big Sand Tiger Beetles are predators in both the adult and larval stages. Adults are active during the day hunting small arthropods. Larvae reside in a vertical tunnel with a small pit-like opening at its mouth. They are active during the day and night and ambush ants and other small arthropods that fall into their tunnel.

Population Sizes and Trends

Population size is unknown but may be declining due to declining habitat. Gibson's Big Sand Tiger Beetle has been recorded from 20-25 sites in Saskatchewan and adjacent Alberta, but population estimates are not available for most sites.

Threats and Limiting Factors

The main threat to Gibson's Big Sand Tiger Beetle in Canada is the loss of suitable habitat due to continued stabilization of dunes by vegetation. The sand dunes with which it is associated in Canada are derived from glacial deposits, which have been stabilizing with vegetation during the last 200 years or so. Less than 1% of the dunes within the Canadian range of Gibson's Big Sand Tiger Beetle are currently bare sand.

Protection, Status, and Ranks

COSEWIC assessed the Gibson’s Big Sand Tiger Beetle as Threatened in November 2012. Currently, the Gibson's Big Sand Tiger Beetle is not protected by any endangered species legislation in Canada or the United States. The subspecies is ranked by NatureServe as critically imperiled globally (G5T1), in Canada (N1), and in Colorado (S1). The species *C. formosa* is listed as critically imperiled (S1) in Alberta and secure (S5) in Saskatchewan, Montana, and Colorado. Some of its Canadian habitat is in protected areas, but dune stabilization presents a continuing threat to populations even within parks and reserves.

TECHNICAL SUMMARY

Cicindela formosa gibsoni
Gibson's Big Sand Tiger Beetle — Cicindèle à grandes taches de Gibson
Range of occurrence in Canada: Saskatchewan, Alberta

Demographic Information

Generation time	3 yrs
Is there an inferred continuing decline in number of mature individuals?	Probably, based on declining habitat.
Estimated percent of continuing decline in total number of mature individuals within 5 years	Unknown
Suspected percent reduction in total number of mature individuals over the last 10 years.	Unknown
Suspected percent reduction in total number of mature individuals over the next 10 years.	Unknown
Suspected percent reduction in total number of mature individuals over any 10 period, over a time period including both the past and the future.	Unknown
Are the causes of the decline clearly reversible and understood and ceased? *Not ceased.*	No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence	30,500 km²
Index of area of occupancy (IAO) *330 is a projection based on a maximum estimate of potential sites.*	104 – 330 km²
Is the total population severely fragmented? It is likely that more than half of the individuals are in small and isolated subpopulations, because habitat occurs that way. Because habitat is declining at all sites, the occurrence patches have been and are being increasingly fragmented, and fragmentation is expected to continue with loss of subpopulations. Any eliminated subpopulations would have a low probability of recolonization even if habitat was re-established based on dispersal information.	Yes
Number of locations∗ Although there is one unifying threat of dune stabilization, this is moving at different rates in different sites and regions and will tend to eliminate small sites before larger ones. As a result it might be considered appropriate to divide the locations based on their being subject to variations in threat level. At present 20-25 sites have been recorded and a maximum of 73 are suspected. These correspond to four general regions, each of which may experience a slightly different rate of dune stabilization. A limited number of additional sites not yet discovered are likely to be within these 4 general regions. Allowing for variation in size of open sand areas in these regions, it may be appropriate to admit 2 locations for each general region, leading to 8 locations. Some of these locations made of smaller populations may disappear within 10 years (an arbitrary limit for "rapidly" on p. 40 of IUCN guidelines).	1-8
Is there a projected continuing decline in extent of occurrence?	Yes
Is there an inferred continuing decline in index of area of occupancy?	Yes

∗ See Definitions and Abbreviations on COSEWIC website and IUCN 2010 for more information on this term.

Is there a projected continuing decline in number of populations? The population is comprised of subpopulations, some of which are expected to decline but it is unlikely that all subpopulations will be lost over the next decade.	Yes
Is there a projected continuing decline in number of locations*?	Yes
Is there an observed continuing decline in [area, extent and/or quality] of habitat? *All three*	Yes
Are there extreme fluctuations in number of populations?	No
Are there extreme fluctuations in number of locations∗?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each population)

Population	N Mature Individuals
subpopulation sizes unknown	Unknown
Total	

Quantitative Analysis

Probability of extinction in the wild is at least [20% within 20 years or 5 generations, or 10% within 100 years].	No

Threats (actual or imminent, to populations or habitats)

The single important threat is loss of open sand due to increasing vegetation cover (dune stabilization). This is mostly due to climatic changes, but other factors may be involved such as the loss of historic ecological processes such as erosion due to bison activity and fire. Atmospheric changes such as increased nitrogen deposition and increased atmospheric carbon may also play a role.

Rescue Effect (immigration from outside Canada)

Status of outside population(s)? Apparently stable	
Is immigration known or possible?	Very unlikely
Would immigrants be adapted to survive in Canada?	Probably not
Is there sufficient habitat for immigrants in Canada?	Yes
Is rescue from outside populations likely?	Very unlikely

Status History

COSEWIC: Designated Threatened in November 2012.

Status and Reasons for Designation

Status: Threatened	**Alpha-numeric code:** E
Reasons for designation: This very restricted subspecies, with most of its populations 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.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Although something is known about the rates of decline of open sand, it has been less than 30% over a 10-year period and the extent to which declines may be offset by human activity in this case is unclear.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. The IAO is 104 km^2 (less than 500km^2) and decline is anticipated, but the data to support severely fragmented are lacking and the number of locations is unclear.
Criterion C: Not applicable. No accurate information on population numbers.
Criterion D: Not applicable because no information on population size. Almost meets D2 Threatened because there are less than 5 locations based on the single significant threat but this threat is expected to operate over a period of a few decades, not within a very short time period.
Criterion E (Quantitative Analysis): Meets E Threatened using rate of decline of sand dunes in the prairies, the probability of extinction within 100 years is 10%.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2012)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment Canada / Environnement Canada
Canadian Wildlife Service / Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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Gibson's Big Sand Tiger Beetle
Cicindela formosa gibsoni

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Kingdom: Animalia - Animal, animals, animaux

Phylum: Arthropoda - arthropodes, arthropods, Artrópode

Subphylum: Hexapoda - hexapods

Class: Insecta - hexapoda, insectes, insects, inseto

Subclass: Pterygota - insects ailés, winged insects

Infraclass: Neoptera - modern, wing-folding insects

Order: Coleoptera Linnaeus, 1758 - beetles, besouro, coléoptères

Suborder: Adephaga Schellenberg, 1806

Family: Carabidae Latreille, 1802 - carabes, ground beetles

Subfamily: Cicindelinae Latreille, 1802 - tiger beetles

Genus: *Cicindela* Linnaeus, 1758

Species: *Cicindela formosa* Say, 1817 - Big Sand Tiger Beetle

Subspecies: Cicindela f. gibsoni Brown, 1940 – Gibson's Big Sand Tiger Beetle

Cicindela formosa gibsoni Brown 1940, the Gibson's Big Sand Tiger Beetle, is a member of the Order Coleoptera (beetles), Family Carabidae (ground beetles), and subfamily Cicindelinae (tiger beetles). Tiger beetles were formerly considered a separate family, Cicindelidae, but recent classifications (e.g., Bousquet and Larochelle 1993; ITIS 2010) treat them as members of the ground beetle family (Carabidae). *C. formosa* has also been referred to as Beautiful Tiger Beetle (e.g., Acorn 2001) and la *cicindèle à grandes taches* in French (Dubuc 2010).

Gibson's Big Sand Tiger Beetle is recognized as a valid subspecies by the most recent and comprehensive authorities (Freitag 1999; Pearson *et al*. 2006). It is one of five recognized subspecies of *Cicindela formosa* Say, 1817 (Freitag 1999, Figure 1, 2, 3). This species is one of the most variable North American species of *Cicindela* with respect to colour and extent of maculation (Gaumer 1977). The nominate subspecies, *C. f. formosa* Say 1917, is generally found west of the Missouri-Mississippi River (Figure 4) and *C .f. generosa* Dejean 1831 is found further east of the Mississippi River. *Cicindela f. pigmentosignata* Horn, W., 1930 and *C. f. rutilovirescens* Rumpp, 1986 are restricted to the southern United States. Rumpp (1986) proposed that *C. formosa* radiated in central North America, adapting to barren sand conditions in what is now the Great Plains. It then dispersed along sand hills and major river systems and diverged into *C. f. generosa* east of the Mississippi and other subspecies along the periphery of its original range.

C. f. gibsoni *C. f. rutilovirescens* *C. f. pigmentosignata* *C. f. formosa* *C. f. generosa*

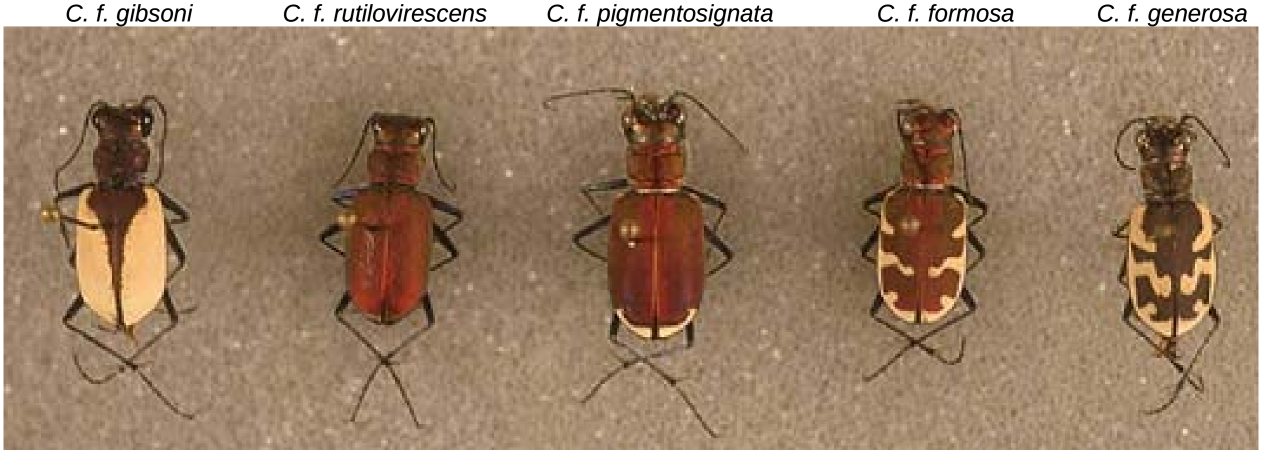

Figure 1. Specimens of the five subspecies of *Cicindela formosa* (T. Schulz photo).

Gaumer (1977) considered Canadian *C .f. gibsoni* to be distinct from Colorado Gibson's Big Sand Tiger Beetle populations, which he termed *C. f. yampa*, due to distinct differences in the number of setae (hairs) and colouration on the larval head capsule. Although this split has not been widely accepted, it has some merit because the Canadian and Montana populations are separated by more than 600 km (see *Global Range*) and are on different sides of the Continental Divide, which makes a common evolutionary origin less likely. Pearson *et al.* (2006) state that several additional forms are likely to be distinguished with further studies. Planned mtDNA work on *C. formosa* may help resolve relationships amongst and validity of the various subspecies (Spomer pers. comm. 2010).

Dahl (1942) rejected subspecific status for *C .f. gibsoni*, and instead considered it a very pale form of *C. f. manitoba*, through which it was connected by a series of intergrades with increasingly extensive white markings. *C. f. manitoba* Leng 1902 has been used to describe *C. formosa* with expanded pale markings from Manitoba and adjacent states (e.g., Wallis 1961; Boyd and Associates1982) but Gaumer (1977) found no significant differentiation, and it is now generally considered a form of *C. f. generosa* (e.g., Freitag 1999; Pearson *et al.* 2006). Populations of *C. formosa* from Montana, also with expanded pale markings, were described as *C. f. fletcheri* Criddle 1925, but are currently considered *C. f. formosa* (Horn 1935; Wallis 1961*)*. Acorn (2004) believes some Alberta forms to be distinct and worthy of subspecific status, perhaps a resurrected *C. f. fletcheri*. Acorn (pers. comm.) also considers occasional very pale *C. formosa* at Empress Sand Hills to be *C. f. fletcheri*, particularly because the ground colour is red, rather than the purple that is more typical of *C. f. gibsoni*. The "*Manitoba*" and "*fletcheri*" forms of *C. formosa* often have more expanded pale markings on the elytra than is typical for their respective subspecies *formosa,* and occasionally have some specimens that approach *C. f. gibsoni*. However, they usually do not have the very extensive pale marking typical of *C. f. gibsoni* and have different ventral colouration (see Morphological Description).

In summary, despite some local variations, *C. f. gibsoni* is well defined and accepted by experts, although the Colorado and Montana populations require more study.

Morphological Description

The Gibson's Big Sand Tiger Beetle has large bulging eyes and a head at least as wide as the pronotum (thorax) (Figure 1). Threadlike antennae are inserted at the base of large, sickle-shaped, toothed mandibles. Legs are long and slender. The Big Sand Tiger Beetle is one of the largest *Cicindela* in North America, ranging from 14-21 mm in length (Pearson *et al.* 2006), with specimens from Alberta reported as 15-17 mm (Acorn 2001).

The Gibson's Big Sand Tiger Beetle typically has dark red to purplish elytra (hardened front wings which cover their back when not in flight) with more well-developed pale markings than other *C. formosa* subspecies (Figure 2). In comparison, *C. f. formosa* has bright coppery red elytra and *C. f. generosa* has a brown elytra. The ivory maculations in the Gibson's Big Sand Tiger Beetle often coalesce, leaving only a broad dark wedge along the mid-line. Gaumer (1977) considered *C. formosa* with greater than 60% white maculation to be *C. f. gibsoni* or *C. f. yampa*. Populations of *C. f. formosa* in Alberta and the Manitoba race of *C. f. generosa* typically have white markings covering approximately 50% of the elytra, slightly more than the 30-40% that is usual for both subspecies in the main portion of their ranges farther south (Acorn 2001). However, the Gibson's Big Sand Tiger Beetle is metallic blue-green or bluish violet underneath on the proepisterna compared to metallic purple below in *C. f. formosa* and dark green with some coppery reflections in *C. f. generosa* (Pearson *et al.* 2006). In addition, *C. f. gibsoni* has elytral punctures the same colour as the ground colour, unlike in *C. f. generosa* (Gaumer 1977).

Figure 2. Gibson’s Big Sand Tiger Beetle from Douglas Provincial Park, Saskatchewan (Brian Ratcliff photo).

The Gibson's Big Sand Tiger Beetle is similar to the co-occurring, but slightly smaller and less bulky, Blowout Tiger Beetle (*C. lengi versuta*). In addition, the Blowout Tiger Beetle typically has longer humeral lunules, a longer labrum (in relation to body length), and less extensive pale markings, particularly along the marginal line.

Larvae of *C. formosa* have been described by Shelford (1908) and Hamilton (1925). Tiger beetles have white, grub-like larvae up to 2.5 cm long with a membranous integument. They have a large, darkened, armoured head capsule with six eyes on top and large mandibles underneath (Figure 3). There is a prominent hump with hooks on the larva's lower back to help it maintain its position in the vertical larval burrow. The size, shape, location, and number of hooks, sclerites, and setae can be used to distinguish larval *C. formosa* from other species (Leonard and Bell 1999). The 3rd instar larvae of Gibson's Big Sand Tiger Beetles can usually be separated from other subspecies of *C. formosa* within its range by a non-contrasting brownish pronotum and differences in primary pronotal setae (Gaumer 1977).

Figure 3. Head of larval Big Sand Tiger Beetle (*Cicindela formosa*) at mouth of burrow (Ted MacRae photo).

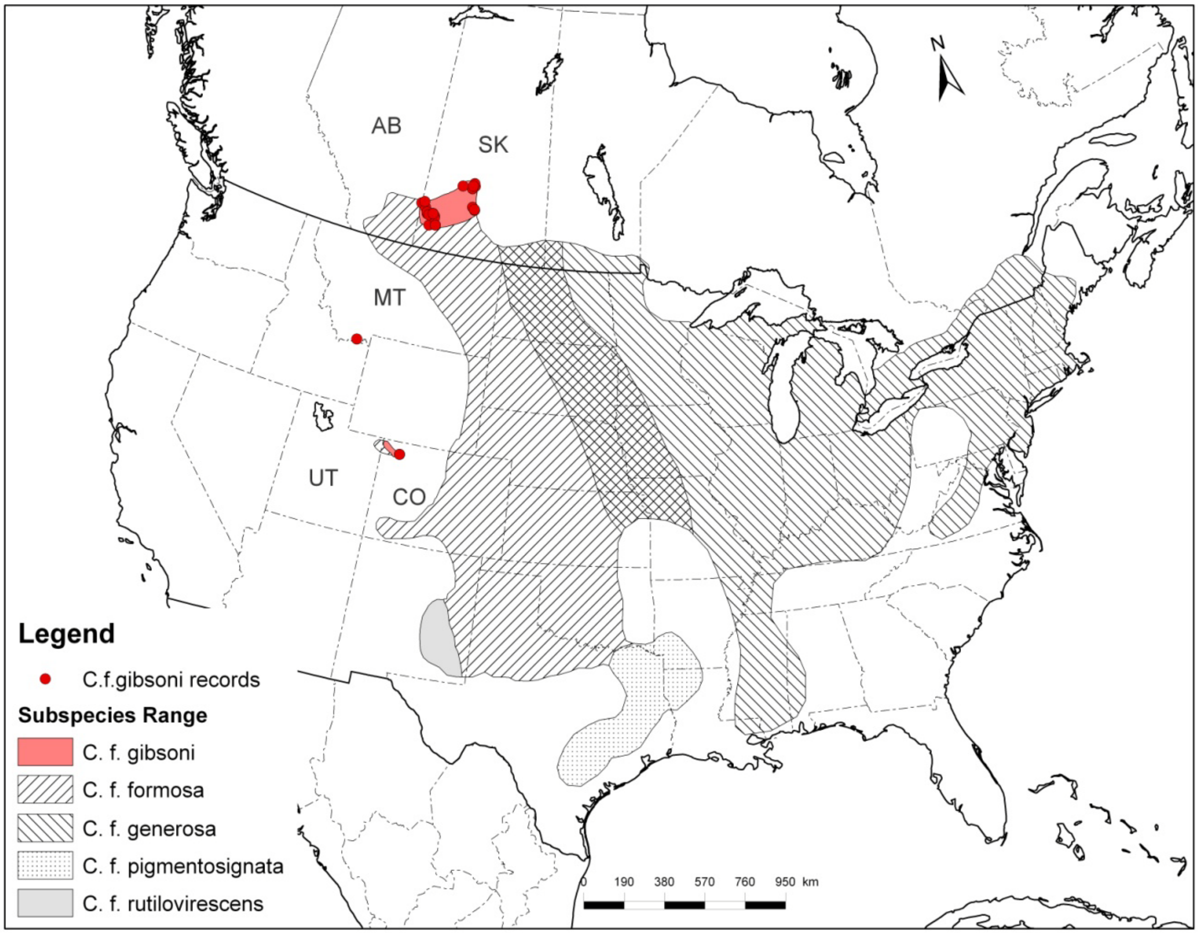

Figure 4. Global range of Gibson's Big Sand Tiger Beetle (based on Wallis 1961; Gaumer 1977; Hilchie 1985; Kippenham 1994; Leonard and Bell 1999; Pearson *et al.* 1997, 2005; Marshall 2000; Hoback and Riggins 2001; Hendricks and Lesica 2007; Lawton 2008; B. Knisley pers. comm. 2010).

Population Spatial Structure and Variability

There have been no genetic studies on subspecies of *Cicindela formosa*, including Gibson's Big Sand Tiger Beetle, although mtDNA studies have examined relationships among species of North American *Cicindela* (Volger and Welsh 1997; Vogler *et al.* 2005).

There is considerable phenotypic variation within populations of Gibson's Big Sand Tiger Beetle, particularly the degree of pale maculation which can cover from 60% to 95% of the elytra. Wallis (1961) found that the frequency of Gibson's Big Sand Tiger Beetles of various phenotypes (i.e., extent of pale markings) was similar for the Great Sand Hills, Elbow, and Pike Lake, although the latter population had slightly higher proportion of very pale specimens. He surmised that all three populations were about equally different from other subspecies of *C. f. formosa*.

Despite the intervening 1100 km, there is little morphological differentiation between adults from Saskatchewan and Colorado populations (Pearson *et al.* 2006). Based on larval characters, Gaumer (1977) considered Saskatchewan populations distinct from those found in Colorado (which he termed *C. f. yampa*). If the expanded pale maculation of adult Gibson's Big Sand Tiger Beetle evolved independently at these sites as an adaptation to the dune environment, then the designation as a single subspecies may not be appropriate (Pearson *et al.* 2006).

A population of highly variable *C. formosa* in southwestern Montana (Hendricks and Lesica 2007) has some individuals with very expanded pale maculation typical of Gibson's Big Sand Tiger Beetle (Spomer pers. comm. 2010). However, most specimens appear to be intermediate between *C. f. gibsoni* and *C. f. formosa* (or its Manitoba form) (Hendricks and Lesica 2007). The ventral colouration is also diverse, ranging from metallic green to blue and even purple (Winton 2010). Other populations in western Montana (subspecies unknown) have also been recently discovered (Winton pers. comm. 2010). Although initially published as Gibson's Big Sand Tiger Beetle, the subspecific status of these populations is unclear (Winton pers. comm. 2010).

According to Pearson *et al.* (2006), Gibson's Big Sand Tiger Beetle intergrades narrowly with *C. f. formosa* around its Saskatchewan range. At the Empress Dunes on the Alberta/Saskatchewan border, a few specimens with greatly expanded (>90%) pale markings typical of *C. f. gibsoni* have been collected (Lawton pers. comm. 2010), but most are *C. f. formosa* with more expanded light elytral markings than is typical of *C. f. formosa*. They may be intergrades between *C. f. formosa* and *C. f. gibsoni* but Acorn (2004) considers them *C. f. fletcheri.* Wallis (1961) found that about 4% of the 105 specimens from three Canadian populations (Great Sand Hills, Elbow, and Pike Lake) were within the range of variation for maculation in *C. f. manitoba* (*C. f. generosa*), which suggests there may actually be some intergradation with other subspecies along the periphery of its Canadian range. In northeastern Colorado, it intergrades with an isolated population of *C. f. formosa* to the west along the Green River in northeastern Utah (Pearson *et al.* 2006).

Designatable Units

The Gibson's Big Sand Tiger Beetle warrants treatment as a Designatable Unit (DU) distinct from other subspecies of *Cicindela formosa* because it represents a named subspecies recognized by recent authors (Freitag 1999, Acorn 2004; Pearson *et al.* 2006, meets COSEWIC guideline1, Appendix 5) and is likely a discrete and evolutionarily significant taxon.

Although the Canadian populations are somewhat isolated from each other, there is no reason to treat them as separate DUs because they were likely historically connected to a greater degree and there is no evidence for genetic differentiation among them and there is no evidence for differences in ecology. All Canadian sites exist within the Prairies Ecozone (ESWG 1995).

Special Significance

Tiger beetles have long been the study of amateur and professional entomologists due to their attractiveness, diurnal habits, and diversity. Consequently, they have been important models for the study of ecology and evolution (Pearson and Vogler 2001).

The vast majority of the global range of Gibson's Big Sand Tiger Beetle is in Canada, and it would be a Canadian endemic if genetic analyses support Gaumer’s (1977) contention that U.S. populations represent a separate subspecies.

In addition, Gibson's Big Sand Tiger Beetle is representative of a suite of co-occurring imperilled dune-adapted flora and fauna such as Ord’s Kangaroo Rat (*Dipomys ordi*), Western Spiderwort (*Tradescantia occidentalis*), and the Dusky Dune Moth (*Copablepharon longipenne*) and another moth, the Gold-edged Gem (*Schinia avemensis*).

DISTRIBUTION

Global Range

The global distribution of Gibson's Big Sand Tiger Beetle is restricted to three disjunct areas along the western periphery of the range of *C. formosa* (Figure 4). The subspecies is found in: 1) southwestern Saskatchewan and adjacent Alberta, 2) in northwestern Colorado near Maybell in Moffat County, and 3) in southwestern Montana in Beaverhead County. Although Gibson's Big Sand Tiger Beetle is listed as present in North Dakota by Freitag (1999), this record appears erroneous (Beauzay pers. comm. 2010). Gibson's Big Sand Tiger Beetle is not reported in North Dakota in Gaumer (1977), Bousquet and Larochelle (1993), or elsewhere in the published literature and no supporting specimens could be found.

Approximately 94% of the global range for Gibson's Big Sand Tiger Beetle is found in Canada. In Colorado, they have mainly been collected near Maybell along the Yampa River (Lawton and Willis 1974), but also at several other sites up to 100 km farther west (Kippenhan 1994). The disjunct population in Beaverhead County, Montana was only recently discovered, and is restricted to the Centennial Sandhills, which encompass less than 40 km^2 (Hendricks and Lesica 2007; Winton 2010). The Centennial Sandhills are approximately 600 km south of the nearest population of Gibson's Big Sand Tiger Beetle in Canada.

The global maximum extent of occurrence based on a minimum convex polygon is approximately 340,000 km^2. However, the actual range is much smaller, approximately 43,000 km^2, if minimum convex polygons are delineated separately around each of the three metapopulations (Canada, Montana, Colorado) rather than encompassing them all together.

Canadian Range

Here *C. f. gibsoni* is geographically defined by sites with the very pale *gibsoni* form (and associated characteristics), although individuals with characteristcs of other subspecies may occur at these sites to a greater or lesser degree (to a greater degree at Empress Sand Hills where 90 % and a lesser degree elsewhere, < 4 %). Nominate *C. formosa* have been found around the periphery of the Great Sand Hills near Estuary SK (Gaumer 1977), Suffield National Wildlife Area, AB (Teucher pers. comm. 2010) and Hilda AB (Lawton pers. comm. 2010), with mixed populations having specimens referable to both *C. f. gibsoni* and other subspecies (*C. f. formosa* or *C. f. generosa*) found at Empress AB (Acorn, Spomer pers. comm. 2010) and Piapot SK (Lawton pers. comm. 2010).

The Canadian range of Gibson's Big Sand Tiger Beetle is southwestern Saskatchewan and adjacent Alberta (Figure 5). All Canadian populations are within the mixed and moist mixed grassland ecoregions of the central grassland ecoprovince and the prairie ecozone (ESWG 1995). Their Canadian range extends from dune fields on the Alberta provincial boundary near Empress, 260 km northeast to Pike Lake near Saskatoon, and southeast to Douglas Provincial Park on the eastern shores of Diefenbaker Lake within the Elbow Sand Hills. They have been recorded from approximately 20-25 sites (the locality descriptions are vague on some specimens). Most Canadian records for Gibson's Big Sand Tiger Beetle are associated with the dune complexes of the Great, Pike Lake, Dundurn, and Elbow sand hills. Gibson's Big Sand Tiger Beetle has also been collected at several sites between the Great and Burstall sand hills, and single sites near the Carmichael, Piapot, and Kinley Sand Hills. The only records for Alberta are of the occasional individual at the Empress Sand Hills (Spomer pers. comm. 2010) and an unconfirmed report on private land near the Middle Sand Hills (Teucher pers. comm. 2010).

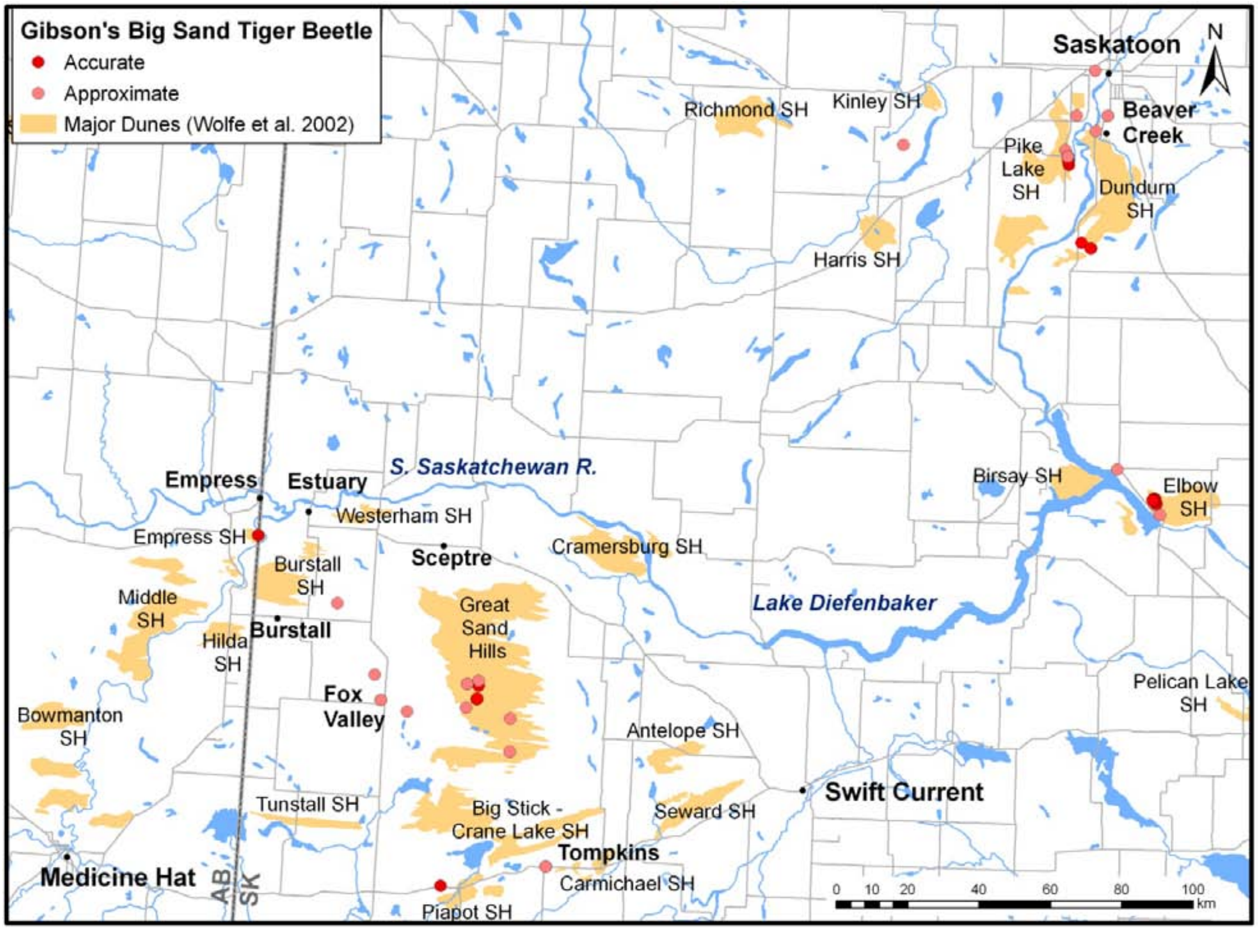

Figure 5. Known Canadian sites of Gibson's Big Sand Tiger Beetle in relation to sand hills (SH) identified by Wolfe (2010).

Within its Canadian range, Gibson's Big Sand Tiger Beetle has a patchy distribution, with the populations near Pike Lake and Douglas approximately 200 km from the nearest known location in the Great Sand Hills. Gibson's Big Sand Tiger Beetle has never been observed at dunes near Sceptre and Burstall, even though they are only about 20 km away from known populations.

Within the extent of occurrence, Wolfe (2010) mapped natural, open sand within dune fields in the prairies (Figure 6). Because Gibson's Big Sand Tiger Beetle is usually found in natural occurrences of open sand (see **Habitat**), and natural open sand is largely confined to dunefields that have been mapped, Wolfe's mapping provides an indication of potential habitat. He mapped approximately 200 sites (Figure 6) within the extent of occurrence and more than half of these are less than a km apart and may be considered as a single site. This leaves fewer than 100 sites. Some of these have already been surveyed and others are not likely to contain populations because only some of the potential habitat is occupied. As an example, despite repeated surveys under appropriate conditions, including fieldwork for this report, Gibson's Big Sand Tiger Beetles have not been confirmed from sites south of Sceptre in the Great Sand Hills or north of Burstall, even though they are less than 20 km from known populations and have apparently suitable habitat. Considering the likely number of sites with populations, there may be a maximum of 50 and there are a maximum of 23 (some of which have not been confirmed despite efforts) based on records (Table 1) resulting in a maximum of 73 sites. A similarly small number of sites could be reached another way. A rough estimate of the number of potential sites surveyed in the extent of occurrence is 40 which is 40% (of 100 sites) for which 20-25 sites exist so for the remaining 60 we expect 35. We then have a maximum of 58 sites.

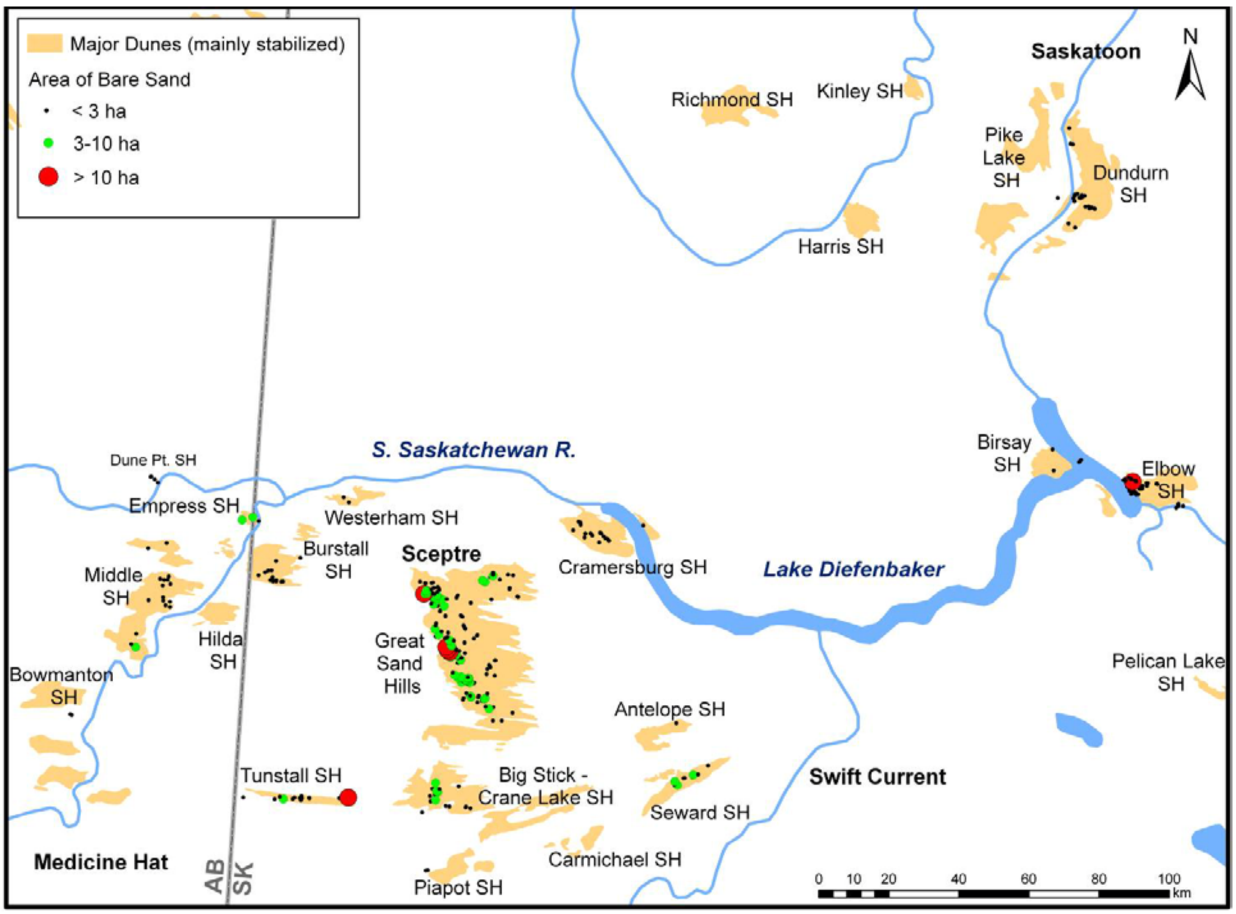

Figure 6. Areas of bare sand associated with major dunes (stabilized or otherwise) within the Canadian range of Gibson's Big Sand Tiger Beetle (adapted from Wolfe 2010). SH = Sandhills.

Table 1. Canadian records for Gibson's Big Sand Tiger Beetle.

Location	Date	Collector(s)	Source	# *C. f. gibsoni*
Great Sand Hills, W of Swift Current	27/05/1939	Brooks, A.R.	Smithsonian	1
Pike Lake	18/07/1940	Brooks, A.R.	Smithsonian	8
Pike Lake	07/06/1944	?	Royal Saskatchewan Museum	1
Pike Lake	13/06/1948	Vockeroth, J.R.	Smithsonian	7
Beaver Creek	06/09/1950	Brooks, A.R.	J.B. Wallis Museum of Entomology	1
Beaver Creek	22/06/1954	?	Montana Entomology Collection (MTEC)	?
Beavercreek, Saskatchewan	08/09/1954	Wallis	J.B. Wallis Museum of Entomology	1
Beaver R.	08/09/1954	B.R.?W.	Smithsonian	10
Elbow, SK	08/09/1954	?	Montana Entomology Collection (MTEC)	?
Tompkins	05/09/1967	Hooper, Ron	Royal Saskatchewan Museum	2
Tompkins	09/09/1967	Hooper, Ron	Royal Saskatchewan Museum	6
14 mi SE of Elbow, Qu'appelle Dam	07/06/1970	Stamatov, John	Willis and Stamatov 1971	3
15 mi e. Fox Valley	31/08/1970	Pearson, D.L & N.S.	Smithsonian	61
Douglas Prov. Park	07/06/1977	Hooper, Ron	Royal Saskatchewan Museum	7
Pike Lake Park	07/06/1977	Hooper, Ron	Royal Saskatchewan Museum	1
Tompkins	14/06/1977	Hooper, Ron	Royal Saskatchewan Museum	1
Douglas Prov. Park	17/08/1977	Lamont, S.M.	Royal Saskatchewan Museum	1
Fox Valley	22/06/1979	Hooper, Ron	Royal Saskatchewan Museum	1
Tp.16, Rge.22, W.3 Mer	17/05/1981	Carr, B. F. & J. L.	CNC	2
Douglas Prov. Park.	20/07/1985	Lawton, Todd	Lawton pers. comm.	?
Tp.35, Rge.6, W.3 Mer	20/07/1985	Carr, B. F. & J. L.	CNC	13
Tp.34, Rge.11, W.3 Mer	21/07/1985	Carr, B. F. & J. L.	CNC	7
Tp.20, Rge.27, W.3 Mer	18/04/1986	Carr, B. F. & J. L.	CNC	1
Tp.18, Rge.23, W.3 Mer	13/05/1986	Carr, B. F. & J. L.	CNC	7
Tp.18, Rge.26, W.3 Mer	13/05/1986	Carr, B. F. & J. L.	CNC	5
7.6 km west of Piapot, large dunes north of and visible from Hwy 1	18/05/1986	Lawton, Todd	Lawton pers. comm.	1
Douglas Prov. Park	21/05/1986	Lawton, Todd	J.B. Wallis Museum of Entomology	20
Tp.17, Rge.25, W.3 Mer	11/08/1986	Carr, B. F. & J. L.	CNC	4
Pike Lake area	06/05/1988	Lawton, Todd	Lawton pers. comm.	?
Douglas Prov. Park	22/06/1992	Hooper, Ron	Royal Saskatchewan Museum	1
Saskatoon	30/09/1992	Harris, L.	Royal Saskatchewan Museum	1
Elkink Rank (GSH)	01/07/2001		Spomer pers. comm.	0
N of Pike Lake PP, O'Malley Rd at Hwy 60	22/05/2005	Lawton, Todd	J.B. Wallis Museum of Entomology	3
Pike Lake area	22/05/2006	Lawton, Todd	Lawton pers. comm.	?
N of Pike Lake PP, O'Malley Rd at Hwy 60	26/06/2007	Lawton, Todd	J.B. Wallis Museum of Entomology	5
N of Pike Lake PP, O'Malley Rd at Hwy 60	10/05/2008	Lawton, Todd	J.B. Wallis Museum of Entomology	3
N of Pike Lake PP, O'Malley Rd at Hwy 60	18/05/2008	Lawton, Todd	J.B. Wallis Museum of Entomology	4
N of Pike Lake PP, O'Malley Rd at Hwy 60	25/05/2008	Lawton, Todd	J.B. Wallis Museum of Entomology	2
N of Pike Lake PP, O'Malley Rd at Hwy 60	29/05/2008	Lawton, Todd	J.B. Wallis Museum of Entomology	2
Empress Dunes, SK	20/05/2008	Lawton, Todd	Lawton pers. comm.	2
Pike Lake area	17/05/2009	Lawton, Todd	Lawton pers. comm.	?

Location	Date	Collector(s)	Source	# *C. f. gibsoni*
N of Pike Lake PP on Hwy 60, SK	12/06/2009	Lawton, Todd	J.B. Wallis Museum of Entomology	1
Douglas Lake P.P.	01/09/2010	Foster & Ratcliff	Foster 2010	14
Pike Lake P.P.	01/09/2010	Foster & Ratcliff	Foster 2010	12
Great Sand Hills, 25 km northeast of Fox Valley, SK	03/09/2010	Foster & Ratcliff	Foster 2010	?
Douglas Prov. Park	28-29/06/2012	SK Min. of Envt.	J. Pepper, pers. comm.	54
Dundurn Sand Hills (southern margin)	16-17/08/2012	SK Min. of Envt.	J. Pepper, pers. comm.	4
Great Sand Hills (25 km E of Fox Valley)	18/8/2012	SK Min. of Envt.	J. Pepper, pers. comm.	6+
Beaver Creek	?	Wallis?	Wallis 1961	?
Elbow (Qu'appelle Valley)	?	Wallis?	Wallis 1961	?
southeast of Elbow	?	Wallis?	Wallis 1961	?
point bar on South Saskatchewan River on provincial border, 11 km S of Empress	?	Acorn, J.	Acorn 1991	?
Fox Valley (Great Sand Hills)	?	Wallis?	Wallis 1961	?
Great Sand Hills, 25 km northeast of Fox Valley, SK	?	Acorn, J.	Acorn 1991	0
Pike Lake	?	Wallis?	Wallis 1961	0
Pike Lake	?	J.B.W.	Smithsonian	11
Pike Lake Park	?	Janzen, J.	Royal Saskatchewan Museum	2

Table 2. Area (ha) of bare sand patches of various size classes at Canadian dunes within the potential range of Gibson's Big Sand Tiger Beetle (C.f.g). Areas from Wolfe (2010)[1].

Prov	Dune Name	C.f.g.[3]	Blowout[2]						Dune						Total Bare Sand Area		Total Dune Area (ha)
			<0.3 ha		0.3 - 1.0 ha		1.0 -3.0 ha		1.0-3.0 ha		3.0 - 10 ha		>10 ha				
			#	ha	#	ha	#	ha	#	ha	#	ha	#	ha	#	ha	
AB	Dune Point SH	P			2	2	2.0	3							4	5.3	NA
AB	Middle SH	P	14	1.4	3	2			1	0.43					18	3.4	32,519
AB	Empress SH	C			1	1			1	1.9	1.0	5.2			3	7.8	1,716
AB	Bowmanton SH	P	2	0.1											2	0.1	24,844
SK	Big Stick–Crane Lake SH	P	6	0.8	6	3	2.0	4	3	4.12	1.0	6.0			18	17.6	35,847
SK	Birsay SH	P	2	0.3	2	1	1.0	1							5	2.2	9,668
SK	Burstall SH	P	1	0.1	6	4	8.0	20							15	23.6	15,364
SK	Cramersburg SH	P	4	1.0	13	7	2.0	4							19	11.7	18,965
SK	Dundurn SH	C	14	1.9	7	4	2.0	9							23	15.3	30,683
SK	Elbow SH	C	25	4.3	32	16	2.0	2					1	40	60	62.6	18,037
SK	Great Sand Hills SH	C	63	10.3	67	37	12.0	15	37	67.36	18	99.3	4	74.67	201	303.3	112,662
SK	Pelican Lake SH	P			1	0									1	0.3	7,247
SK	Piapot SH	C			1	1	1.0	2							2	3.1	7,384
SK	Pike Lake SH	C													0	0	29,125
SK	Seward SH	P	2	0.5	6	4	3.0	5	1	1.44	2	13.5			14	24.1	10,754
SK	Tunstall SH	P	9	1.1	6	3	1.0	1			1	9.6	1	19	18	34.1	5,827
SK	Westerham SH	P			1	0	1.0	1							2	1.7	3,950
	Grand Total		142	21.7	154	83	37.0	69	43	75.25	23	133.6	6	133.67	405	516.1	331,517

[1]some areas do not match Wolfe (2010) due to differences in naming of dune complexes (e.g., Bowmanton SH and Empress SH pooled with Middle SH in Wolfe 2010). [2] A blowout refers to a small, typically less than 1 hectare in size, area of wind blown sand, which is commonly bowl-shaped and somewhat elongated in the direction of transporting winds. An open dune is a larger, typically isolated, body of wind transported sand with a component of the sand body including a prominent slipface or slipfaces (Wolfe 2010).
[3] C.f.g.=*Cicindela formosa gibsoni* confirmed at or near the sand hill; P=potential.

The maximum extent of occurrence (EO) in Canada based on the known range of the subspecies encompasses approximately 30,500 km^2 using a minimum convex polygon (Figure 7). The biological area of occupancy is a very small proportion of this due to the highly fragmented distribution of dunes in its Canadian range. The maximum index of area of occupancy (IAO) encompasses 104 km^2 using a 2 km x 2 km grid and 32 km^2 using a 1 km x 1 km grid (Figures 8 and 9). A maximum of 73 sites would result in an index of area of occupancy of approximately 330 km^2.

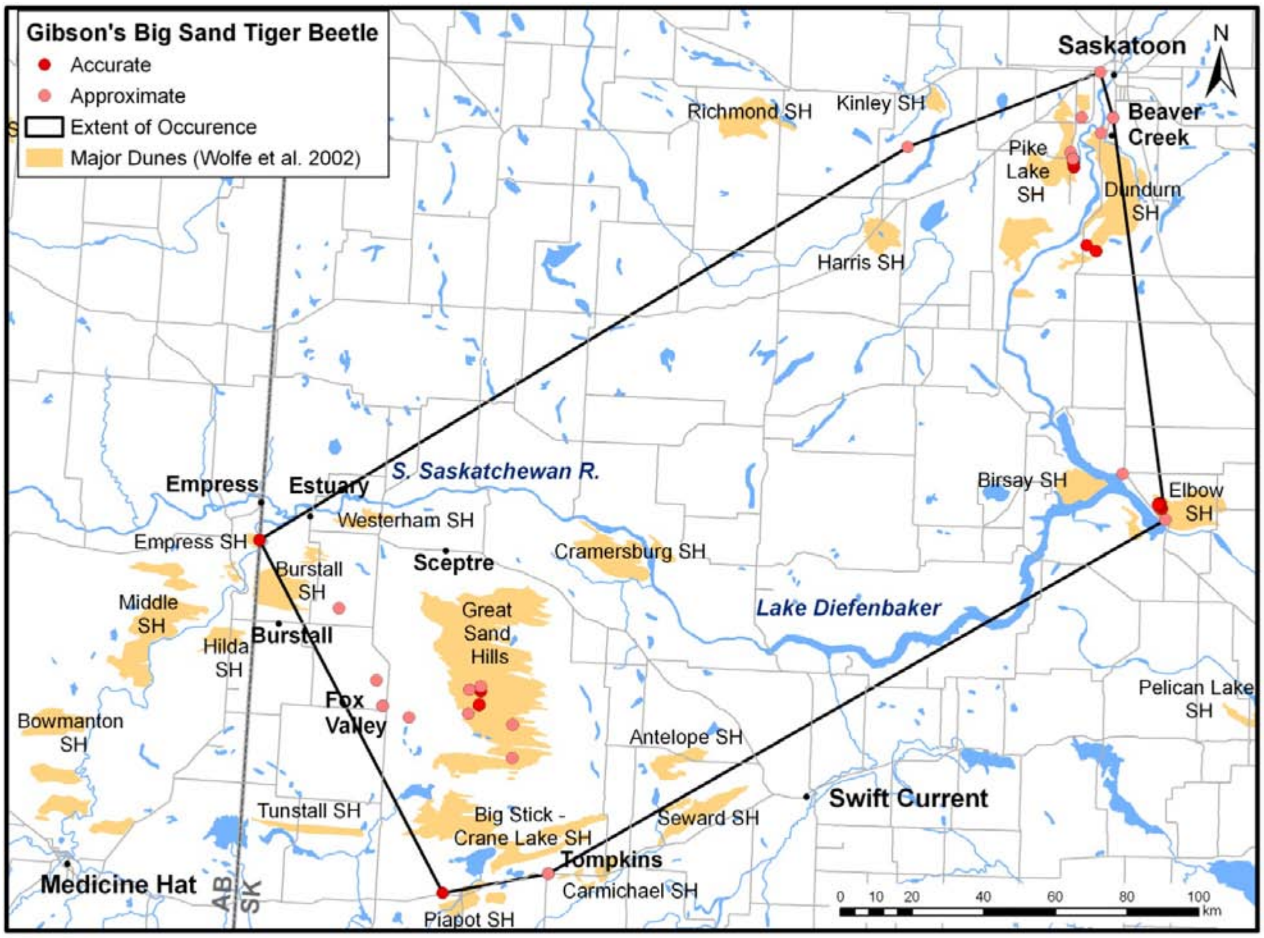

Figure 7. Canadian extent of occurrence for Gibson's Big Sand Tiger Beetle.

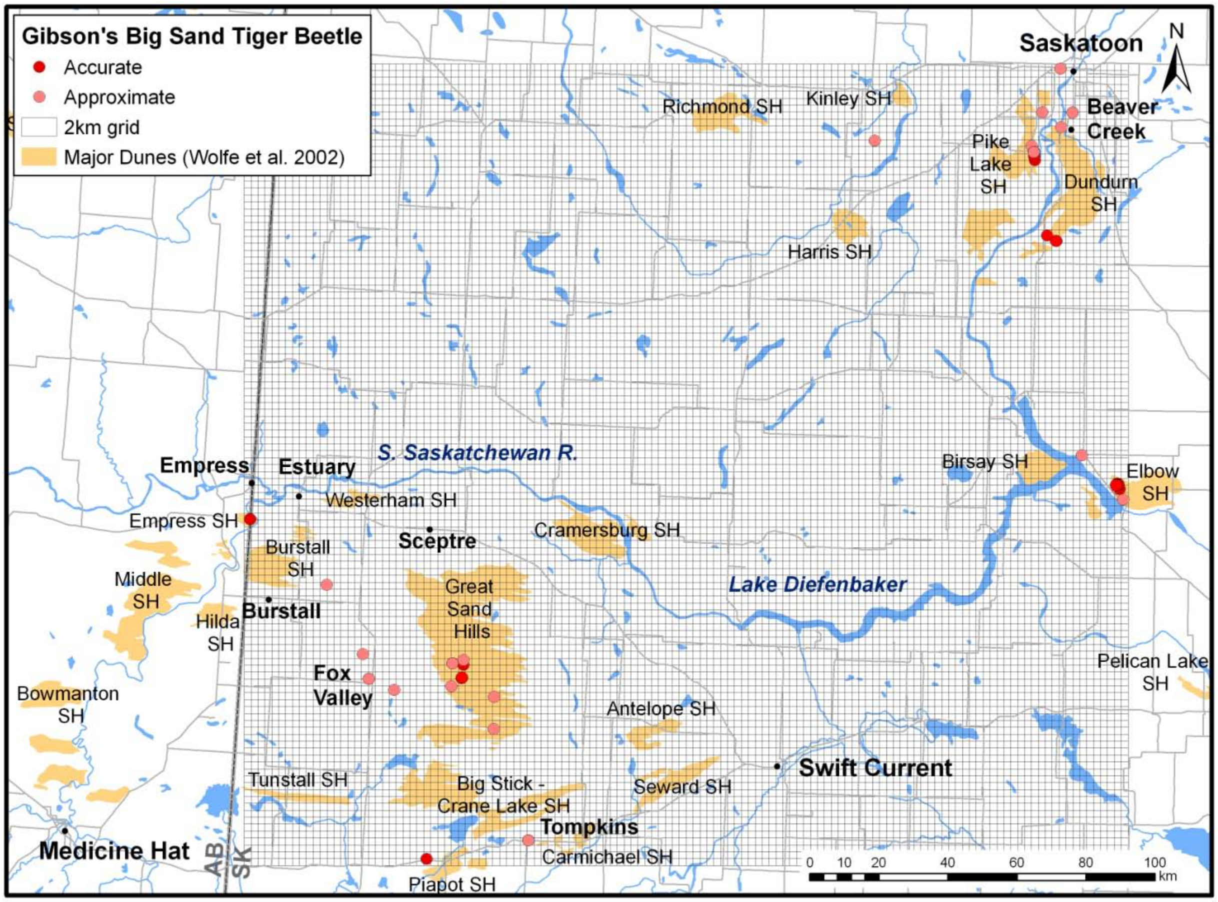

Figure 8. Index of area of occupancy for Gibson's Big Sand Tiger Beetle in Canada using a 2 km x 2 km grid. All red (accurate) or pink (approximate) dots were included in an approximate calculation. The grid shows 2 km X 2 km squares.

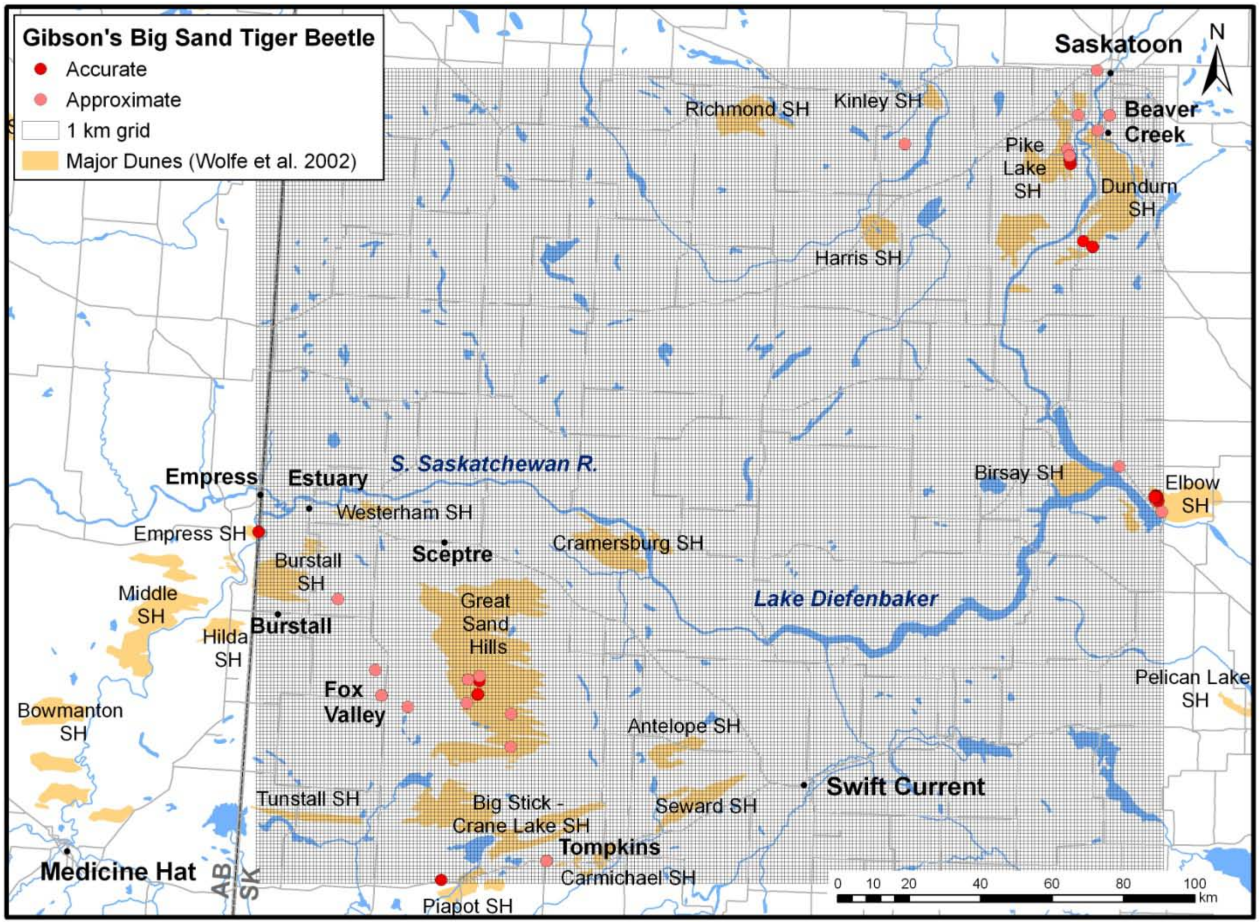

Figure 9. Index of area of occupancy for Gibson's Big Sand Tiger Beetle in Canada using a 1 km x 1 km grid. All red (accurate) or pink (approximate) dots were included in an approximate calculation. The grid shows 1 km x 1 km squares.

Although there is one unifying threat of dune stabilization, this is moving at different rates in different sites and regions and will tend to eliminate small sites before larger ones. Stabilization is proceeding more rapidly in some of the dunefields of the eastern part of the prairie region than in the west (Hugenholtz *et al*. 2010). As a result it might be considered appropriate to define the sites based on their being subject to variations in threat level. At present 20-25 sites are known and these correspond to four general regions, each of which may experience a slightly different rate of dune stabilization. A limited number of newly discovered sites are likely to be within these four general regions. Allowing for variation in size of open sand areas in these regions, it may be appropriate to assign 2 locations for each general region, leading to 8 locations. Some of these locations made of smaller populations may disappear within 10 years (an arbitrary limit for “rapidly” on p. 40 of IUCN guidelines).

Search Effort

The general search effort for tiger beetles, all of which occupy open sand (or clay) habitats like Gibson's Big Sand Tiger Beetle, is indicated up to 1961 in the maps produced by Wallis (1961) in his classic monograph. By this time tiger beetles had been collected throughout the prairie region at over 100 sites. With Wallis' work as a basis, more study of tiger beetles followed and enough new information had accumulated by 1969 for Hooper's review of the group in Saskatchewan. This was followed by Hilchie's (1989) work on the tiger beetles of Alberta, this in turn was followed by Acorn's well known and beautifully illustrated book (2001) on the same subject. In addition to the work by these authors and their publications, throughout the period from 1961 to the present, tiger beetles have been collected and photographed and the limited extent of occurrence of Gibson's Big Sand Tiger Beetle has not changed substantially over the period of 51 years. Tiger beetles have received a lot of attention in the Canadian prairies and are generally a very popular group of insects for which a field guide is available (Pearson *et al.* 2006). Given the level of attention to this group and the coverage in the prairie region it seems unlikely that the extent of occurrence (30,500 km^2) will change.

Most of the surveys for tiger beetles since the mid-20th century, notably by J. Acorn, A.R. Brooks, R. Dzenikew, R. Hooper, T. Lawton, and D. Pearson, have focused on the more accessible sites. At least some of these entomologists conducted targeted searches for Gibson's Big Sand Tiger Beetle (Catling pers. comm. 2012). Gaumer (1977) obtained specimens from 47 institutional collections and 15 private collections for *Cicindela formosa* which constituted all the collections holding significant material for the species at that time. Specimens were found for only four Canadian sites: Estuary (*C. f. formosa only*), Elbow, Pike Lake, and east of Fox Valley. Together with the Empress, Burstall and Middle sand hills, these appear to the most commonly surveyed sites. Targeted searches for Gibson's Big Sand Tiger Beetle in 2010 (Foster 2010) and 2012 (Pepper pers. comm. 2010) found three new sites in the Great Sands Hills and along the southern margin of the Dundurn Sand Hills.

For this report, 6 person-days of targeted visual surveys for Gibson's Big Sand Tiger Beetle were conducted September 1-3, 2010 in southwestern Saskatchewan and adjacent Alberta at historical and new locations (Foster 2010) resulting in confirmation of three historical sites and absence at 8 potential sites. In 2012 one new location was discovered on the southern margin of the Dundurn Sandhills and the species was absent at two sites considered likely and confirmed at two other locations that were already known (Pepper pers. comm. 2010). Less than one quarter of the historic sites have been recently confirmed.

HABITAT

Habitat Requirements

The larvae of *C. formosa formosa* are intolerant of hypoxic conditions caused by flooding (Brust and Hoback 2009) and larval burrows of Gibson's Big Sand Tiger Beetle are found in open areas of well-drained sandy soil with little vegetation (Gaumer 1977; Foster 2010) suggesting that they also require dry sites (Figures 10-15). Canadian populations are typically on fine to medium sands (Gaumer 1977) and typically associated with extensive sandy blowouts and dunes (Pearson *et al.* 2006).

Figure 10. Gibson's Big Sand Tiger Beetle habitat at Pike Lake Provincial Park, September 2010 (R. Foster photo).

Figure 11. Sandy hillside with abundant Gibson's Big Sand Tiger Beetles along road north of Pike Lake (T. Lawton photo).

Figure 12. Southwest margin of dunes at Douglas Provincial Park where numerous Gibson's Big Sand Tiger Beetle were observed, September 2010.

Figure 13. Margin of small dune in the Great Sand Hills east of Fox Valley rural district where numerous Gibson's Big Sand Tiger Beetle were observed on September 3, 2010.

Figure 14. GoogleEarth image of small active dune with confirmed Gibson's Big Sand Tiger Beetle habitat east of Fox Valley rural district . Arrow shows direction of photograph in Figure 13.

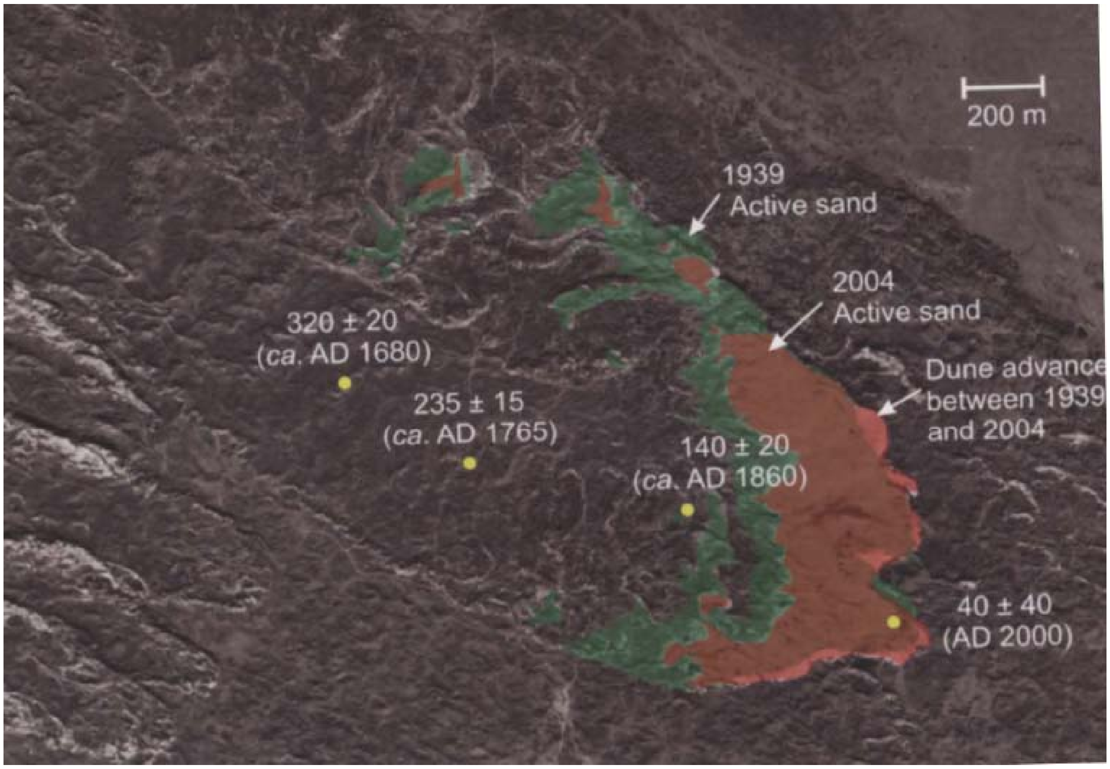

Figure 15. Areas of active sand in 1939 and 2004 at the active dune complex in the northwestern portion of the Elbow Sand Hills (Wolfe *et al*. 2007). Also shown are optical ages of surface and subsurface samples. Green and brown together represent active sand in 1939. Brown and pink represents active sand in 2004.

Canadian populations of the Gibson's Big Sand Tiger Beetle are mainly associated with large dune complexes such as the Great Sand Hills (SH), Pike Lake SH, Dundurn SH, and Elbow SH. These are typically glaciofluvial or glaciodeltaic sand deposits that have been reworked into dunes by wind at varying times throughout the Holocene (Wolfe 2010). Many apparently suitable small sand areas have no *C. formosa* populations (Wallis 1961), and Acorn (1992) suggested the subspecies evolved in large dune complexes such as the Great Sand Hills, which have more permanency than smaller dunes or blowouts. However, they are sometimes, but much less commonly, found along road tracks, ATV trails, cattle trails, oil/gas well pads, dugouts, cattle-disturbed areas around water wells sites and ranches, and sand pits, mostly in close association with large natural open sand dune areas (less than 0.5 km away), the single exception being Lawton’s (pers. comm. 2010) observations of Gibson's Big Sand Tiger Beetles along sandy roadside embankments near Pike Lake, which were still less than 2 km from a natural occurrence of open sand. Six roadside bank sites near to existing populations during the 2012 directed survey did not reveal any populations.

Gibson's Big Sand Tiger Beetle adults are usually not found out in the bare sand of the open dune like the Ghost Tiger Beetle (*C. lepida*) and the Sandy Tiger Beetle (*C. limbata*). Rather, they are most commonly found in areas with sparse vegetation on sand hills, blowouts, road cuts, and along the periphery of larger dunes (Hooper 1969; Acorn 1991). These partially stabilized and vegetated areas are typically found on the wings, deflation depression, and back-slope of parabolic dunes, rather than the open sand of the head, crest, and slip face. Typical associated vegetation includes Scurf Pea (*Psoralea lanceolata*), Veiny Dock (*Rumex venosus*), Silver Sagebrush (*Artemesia cana*), Creeping Juniper (*Juniperus horizontalis*), Prickly Pear Cactus (*Opuntia fragilis*), and a variety of graminoids such as Prairie Sandreed (*Calamovilfa longfolia*) and Obtuse Sedge (*Carex obstusa*) and others (Acorn 1991; Thorpe and Godwin 1992; Wolf 1997; Foster 2010).

In Colorado, Gibson's Big Sand Tiger Beetles have been collected from dry sandy roadside cuts in sand dunes with sparse to moderate vegetation and along the periphery of larger dunes (Willis and Stamatov 1971; Schmidt 2010). In Montana they are found on semi-stabilized parabolic dunes of the Centennial Sandhills (Hendricks and Lesica 2007). In the Centennial Sandhills, they are found on a wider variety of microhabitats, including dune and swale, than is typical elsewhere for Gibson's Big Sand Tiger Beetle (Winton 2010).

Habitat Trends

Where sandy areas become vegetated and stabilized, populations of *Cicindela formosa* tend to decline (Pearson *et al.* 2006). Trends in Gibson’s Big Sand Tiger Beetle habitat in Canada are likely linked to periods of dune activity and stability related to climate (Acorn 1992). Dunes in the southern Canadian prairies have had alternating periods of activity and stability throughout the last 10,000 years (Hugenholtz and Wolfe 2005). Dunes were more active during a severe drought in the late 1700s that was preceded by at least a century of below average precipitation (Wolfe *et al.* 2001). Following an active period of approximately 80 years, they have been slowly stabilizing despite periodic drought intervals (Wolfe *et al.* 2001). Barchan dunes nearly devoid of vegetation have been transformed to parabolic dunes whose form is controlled by vegetation (Wolfe and Hugenholtz 2009).

Less than 1% of the dune area in the Canadian prairies is currently active with bare sand (Wolfe 2010). Based on interpretation of air photos and satellite imagery, the area of active sand in the northwest portion of the Great Sand Hills has declined from approximately 210 ha to about 140 ha over the last 70 years (Wolfe 2010) and the area of open sand in the Empress dunes has declined from 48 ha in 1938 to 5 ha in 1984 (Acorn 1992). Pike Lake Sand Hills are now vegetated and inactive, with only a few blowouts in disturbed areas (Wolfe *et al.* 2002). Active sand at the Elbow Sand Hills has declined from 67 ha in 1939 to 31 ha in 2004 (Wolfe *et al.* 2007), likely reducing the zone of suitable habitat for Gibson's Big Sand Tiger Beetle along the sparsely vegetated periphery. At Pike Lake Provincial Park, Gibson's Big Sand Tiger Beetle were largely restricted to sandy footpaths through otherwise stabilized dunes (Foster 2010), and are apparently less abundant in the park than on sandy blowouts along nearby roads outside the park (Lawton pers. comm. 2010). The extent to which habitats created by human activity are utilized is unclear, but it appears to be generally much less than natural habitats, and even the anthropogenic open sandy habitats are often declining (Catling pers. comm. 2012). Possibly more relevant than general human disturbance is the effect of cattle which are present in most of the sandhills areas. Disturbance by trampling and grazing of cattle in one Fox Valley site may have been responsible for the persistence of Gibson's Big Sand Tiger Beetles on small blowouts that would be overgrown otherwise. A reduction in cattle ranching could accelerate dune stabilization and reduce habitat suitability for the beetle.

It is likely that more than half of the individuals in the total Canadian population of *C. f. gibsoni* are in small and isolated subpopulations, because habitat occurs that way. Because habitat is declining at all sites, the occurrence patches have been and are being increasingly fragmented with populations becoming smaller. Fragmentation is expected to continue with loss of subpopulations. Any eliminated subpopulations would have a low probability of recolonization, due to continuing decline of habitat. Even if habitat was re-established, or created elsewhere it may not be colonized due to dispersal limitations.

Dune activity is expected to continue to decline in the coming decades under the present climate and disturbance regimes (Wolfe 2010). Adding to the problem of stabilization is the recent and rapid increase in Leafy Spurge (*Euphorbia esula* L.) which may be leading to more rapid stabilization in some regions than would result from native species. However, if recent projections of climate warming and increased aridity hold true, there is the potential for increased dune activity particularly near the centre of the Palliser Triangle in the Great Sand Hills (Wolfe and Hugenholtz 2009) at some time in the future. Although regional reactivation of sand dunes may require several decades (Wolfe 1997; Wolfe *et al.* 2001), this would eventually result in an increasing amount of suitable habitat for Gibson's Big Sand Tiger Beetle if it had not already been extirpated in Canada. These dune fields are extremely sensitive to climatic variability and the potential for reactivation is high, even in the absence of a warming climate (Muhs and Holliday 1995).

Some calculations are possible and these help to establish the habitat trend: (1) Estimated area of open, active sand in 1938 = 210+48+67 = 325 ha; (2) Estimated area of open, active sand in 2005 = 140+5+31 = 176 ha. Based on these estimates, the annual loss of open, active sand is (325−176)=149 ha from 1938 to 2005, a period of 67 years. This represents a loss of 2.22 ha per year. If one assumes that this rate of decline of 2.22 ha per year has persisted since 2005 and will continue to do so in the future, and that there were 176 ha available in 2005, then there would have been 160.2 ha in 2012.

In reference to the application of Criterion E, in 20 years it is forecast that more than 100 ha of open, active sand habitat would be available (see figure on following page). Thus, it is not clear that one could reliably conclude that there is a 20% or greater probability of extinction within the longer of 20 years or 5 generations (15 years for this species) from 2012. This means that this application of Criterion E would not support a status assessment of Endangered.

At the estimated rate of loss of active, open sand habitat experienced from the late 1930s to 2005, it is forecast that there will be no open, active sand habitat in 2083 at 4 of 5 sand hills (71 years from 2012). Given the evident importance of this habitat to the persistence of this species, and that the generation time for this species is 3 years, it seems reasonable to conclude that the probability of extinction of this species within the next 100 years (i.e., 2112) is at least 10%. (See Appendix 1 for details of this analysis.)

BIOLOGY

Life Cycle and Reproduction

Like other beetles, Gibson's Big Sand Tiger Beetle undergoes complete metamorphosis with an egg, larva, pupa, and adult. *Cicindela formosa* has a two- or three-year life cycle depending on latitude and food availability (Pearson *et al.* 2006). *Cicindela f. generosa* populations in Manitoba (Criddle 1910) and Wisconsin (Brust 2002) take 3 years to complete their development, spending about 2 years as a larva and 1 year as an adult. Canadian populations of Gibson's Big Sand Tiger Beetle probably have 3-year life cycles as well (Acorn 2001).

In Canada, new adult Gibson's Big Sand Tiger Beetle begin to emerge in early August (Acorn 1991), feed for several weeks, and overwinter in burrows below the frost line. Adults re-emerge the following spring, feed, and mate (Hendricks and Lesica 2007). In Canada, peak spring numbers are usually in late May through early June (Lawton pers. comm. 2010), with May 6 the earliest specimen date. In Canada, small numbers of adult Gibson's Big Sand Tiger Beetle persist throughout the summer months (Acorn 1991), but farther south in its range, *C. formosa* is a spring-fall species, with few if any adults active in mid-summer (Pearson *et al.* 2006).

In the spring, each female lays approximately 50 eggs in individual holes 3-5 mm deep (Shelford 1908). Eggs hatch in early summer, and the first instar digs a deeper burrow, which is enlarged in successive instars (Pearson 1988). At the end of the first summer, the second or third instar larva closes its burrow and overwinters. It reopens the burrow the following spring, passes the summer, and overwinters a 2nd time as a 3rd instar. The following spring, it reopens its burrow, pupates during the summer in a sealed side chamber about 10 cm below ground surface, and emerges as an adult in late summer (Shelford 1908).

A small cup-like pit at the opening of *C. formosa* larval burrows apparently aids in capturing prey and preventing the main burrow from filling with sand, and is unique among North American *Cicindela* (Gaumer 1977). *Cicindela f. generosa* burrows in Aweme, Manitoba were 130-200 cm deep (Criddle 1910), with the great depth allowing the larvae to survive the winter below the frost line (Pearson *et al.* 2006). Larvae can move their burrows in response to disturbance but the distance is likely only a few metres at most. Annual movements for adults are probably restricted to a small area within the immediate area of stabilized dune.

Physiology and Adaptability

Although larvae are active night and day, adult Gibson's Big Sand Tiger Beetles are only active during the day (Gaumer 1977). Because of its larger body size relative to other *Cicindela*, it warms up more slowly and becomes active later in the morning than other tiger beetles (Schultz 1983). They begin to become active at an air temperature of approximately 18ºC, which can be as early as 8:00 a.m. in sunny patches where the soil surface has warmed to 20-24ºC (Gaumer 1977). Due to its pale colouration, the Gibson's Big Sand Tiger Beetle can be active longer than other *C. formosa* at high temperatures but basks longer in cool weather (Acorn 1992; Schultz and Hadly 1987). Willis and Stamatov (1971) observed that Gibson's Big Sand Tiger Beetle near Maybell, Colorado ceased to be active around noon when the air temperature hit 92ºF (33ºC). Depending on soil and air temperature, it may be active as late as 10:00 p.m. (Gaumer 1977).

Cicindela formosa is a relatively adaptable species that is widely distributed east of the Rocky Mountains in sandy habitats. *Cicindela formosa* is at the northern limit of its range in Canada; it has been suggested that overwintering mortality is a limiting factor in its distribution (Acorn 1988). Gibson's Big Sand Tiger Beetle populations are adaptable to dynamic dune systems and have spread to adjacent roadsides through sandy soil.

Dispersal

Adult tiger beetles seldom fly unless disturbed by a larger organism or predator, and when they do fly it is usually only a short distance, unless the wind carries them (Gaumer 1977). In comparison to other tiger beetle species, *C. formosa* is noted for making long, powerful escape flights (Larochelle and Larivière 2001; Pearson *et al.* 2006). An extensive area of unsuitable soil or dense vegetation probably acts as an effective barrier to dispersal by *C. formosa* (Gaumer 1977). The Gibson's Big Sand Tiger Beetle appears to be absent at dunes at Burstall and Sceptre despite the presence of confirmed populations less than 20 km away and potentially suitable intervening habitat. Acorn (1992, 2001) suggested that this pattern may indicate that the Gibson's Big Sand Tiger Beetle is not a strong disperser. However, Wallis (1961) postulated that it might reflect a subtle but unknown habitat preference (Wallis 1961).

Interspecific Interactions

The Gibson's Big Sand Tiger Beetle commonly occurs with the Festive Tiger Beetle (*C. scutellaris*) through most of their ranges (Pearson and Vogler 2001). In Canada, the Blowout Tiger Beetles also co-occur along the margins of dunes with the Ghost Tiger Beetle and Sandy Tiger Beetle common on the open dune (Gaumer 1977; Acorn 2001).

Gibson's Big Sand Tiger Beetle adults are active predators, ambushing and consuming a wide range of small insects and other invertebrates (LaRochelle 1974a), particularly ants (Kippenham 1990), but also acridid grasshoppers, lepidopteran larvae, coccinelid beetles, and sphecid wasps (Acorn 1991). Gibson's Big Sand Tiger Beetle can be a significant predator of Ghost and Sandy Tiger Beetles (Acorn 1991). Larval Gibson's Big Sand Tiger Beetles ambush ants and other small invertebrates that fall into the depression at the mouth of the larval burrow, but they reject noxious bugs (Criddle 1910).

Robber flies (Diptera: Asilidae) have commonly been observed preying upon tiger beetles, seizing the tiger beetle while in, and stabbing it at the base of the elytra (Lavigne 1972). Large asilids were observed in the Pike Lake and Elbow Sand Hills during 2010 fieldwork (Foster pers. obs.). A least a dozen species of mammals, herptiles, and numerous bird species feed opportunistically upon tiger beetles (Larochelle 1974b, 1975a,b). Criddle (1910) noted that badgers sometimes eat large numbers of adult *Cicindela* in Manitoba.

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 Sand Hills during 2010 fieldwork but impacts on Gibson's Big Sand Tiger Beetle populations 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 Canadian populations of Gibson's Big Sand Tiger Beetle.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Targeted visual searches for adult Gibson's Big Sand Tiger Beetles have been conducted in Canada, but effort has varied widely, is usually unreported, and efficacy is very dependent on weather conditions and phenology. Timed adult index counts are often used to derive an index of abundance for tiger beetles (Knisley and Schultz 1997), and were used to in 2010 fieldwork in Saskatchewan (Foster 2010). This index count method involves an estimate of number seen based on observer path and flight direction. It typically yields an estimate of about 20-50% of the individuals actually present in the population (Knisley and Schultz 1997).

No mark-recapture studies for adults or area-based larval surveys have been published. Acorn (1988) used a total of 50 pitfall traps with ethylene glycol to sample tiger beetles at five adjacent dunes south of Empress, Alberta (10 traps per dune, spaced every 5 m along each 50 m transect). On the basis of this study he estimated 2027 *C. formosa* (subspecies not discriminated, but primarily *C. f. formosa*) between June 2 and August 27, 1984.

Abundance

Hooper (1969) described Gibson's Big Sand Tiger Beetle as being “quite common” in the Great Sand Hills north of Tompkins, Saskatchewan on September 9, 1967. An estimated 50 Gibson's Big Sand Tiger Beetles were observed on a small (0.9 ha) blowout in the Great Sand Hills east of Fox Valley on September 3, 2010 (Foster 2010). This results in an estimate of 100 to 250 in the population.

Despite only 12 Gibson's Big Sand Tiger Beetle observed in September 2010 in Pike Lake Provincial Park (Foster 2010), they are still widespread, though patchy, on sandy blowouts along a few roads outside the park (Lawton pers. comm. 2010). No estimate can be made for the Elbow Sand Hills, however, because only a very small proportion of the suitable habitat within Douglas Provincial Park was surveyed. A total of 14 Gibson's Big Sand Tiger Beetles were observed in approximately 4 person-hours of survey on September 1, 2010 (Foster 2010). The status and size of other previously recorded populations that were not sampled in 2010 are unknown.

The population size for Gibson's Big Sand Tiger Beetle in Canada cannot be reliably estimated given existing data because: 1) there are only crude population estimates at recently surveyed sites, 2) no population estimates are available at all for many historic sites, 3) no surveys have been undertaken at a large number of sites where suitable habitat has been identified from remote imagery and 4) there are likely other, smaller sites with suitable habitat that have not yet been identified or surveyed.

Fluctuations and Trends

No information on population trends or fluctuations is available for Gibson's Big Sand Tiger Beetle. Schultz (1989) observed rapid declines in *C. f. generosa* as the result of succession. Populations of Gibson's Big Sand Tiger Beetles are likely to have declined over the past century in concert with the stabilization of dune complexes.

Rescue Effect

In the event of the extirpation of Canadian populations, recolonization is extremely unlikely because the nearest population is more than 600 km distant. Additionally there is some evidence that the species does not disperse significantly as a result of absence from sites near the existing sites.

THREATS AND LIMITING FACTORS

The current distribution and abundance of Gibson's Big Sand Tiger Beetle is probably limited by the availability of sparsely vegetated sandy habitat, and loss of open sand is the primary threat. Most dunes within the Canadian range of Gibson's Big Sand Tiger Beetle have trended towards stabilization since the early 1900s, which is likely due to a complex variety of factors including changes in climate, air composition, irrigation, loss of bison, and lack of fire. Disturbance is insufficient to reactivate dunes under current climate conditions (Forman *et al.* 2001; Wolfe et al. 2007). Invasive species such as Leafy Spurge (*Euphorbia esula*) could accelerate stabilization of the dunes. This invasive alien plant was well established in the Canadian prairie region by 1979 and has a capacity to grow in dry sandy soils (Catling and Mitrow 2012). Large recent declines in open sand are projected to continue in the Canadian prairie region for several decades (Wolfe 1997, Wolfe *et al*. 2001).

Although individual larval burrows could be crushed by trampling, grazing may help maintain the sparsely vegetated habitat preferred by Gibson's Big Sand Tiger Beetle. Animal disturbance, especially in times of drought, has been implicated in the formation of dunes in the Great Sand Hills (Hullet *et al.* 1966) and localized overgrazing may have caused dune formation in some areas (Acorn 1992). Cattle operations are found within the Burstall, Elbow, Dundurn, Great, Bigstick, and Middle sand hills (Foster 2010; Wolfe 2010). Cattle are ranched at the confirmed site on private land in the Fox Valley rural district on the west side of the Great Sand Hills that was surveyed in 2010. This site had abundant Gibson's Big Sand Tiger Beetles. A reduction in cattle ranching could accelerate dune stabilization and reduce habitat suitability for the beetle.

The Great Sand Hills are under increasing pressure from oil and gas exploration (GSHAC 2007). However, disturbance such as roads and drill pads may improve habitat for Gibson's Big Sand Tiger Beetles, which prefer relatively open habitats. Mining of dunes for “frac sand” used in hydro-fractured gas wells or other industrial use (e.g. concrete, golf courses, sandblasting) is a potential, localized threat. Off-road recreational activity (ATV and motorized bikes) are used at Dundurn SH (Wolfe 2010), and likely elsewhere, but are not seen as a threat to populations.

Partly as a consequence of their relatively large size and metallic colouration, Tiger Beetles are popular with insect collectors. The number of sites for Gibson's Big Sand Tiger Beetles and occurrence of some in parks makes this less of a concern for this species than for some others in this group that are in a risk category. It is considered a very minor threat.

Although there is one unifying threat of dune stabilization, this is moving at different rates in different sites and regions and will tend to eliminate small sites before larger ones. This has been taken into account by considering a maximum of 8 locations (**see under Canadian Range**).

PROTECTION, STATUS, AND RANKS

Legal Protection and Status

COSEWIC assessed the Gibson’s Big Sand Tiger Beetle as Threatened in November 2012. Currently, the Gibson's Big Sand Tiger Beetle is not protected under the Canada’s *Species at Risk Act* or the *U.S. Endangered Species Act*. It is not listed by the IUCN Red Book or CITES. It is not protected by any provincial or state legislation other than restrictions associated with protected areas (e.g., research permits required for collecting in Saskatchewan parks and ecological reserves).

Non-Legal Status and Ranks

Gibson's Big Sand Tiger Beetle is ranked as critically imperiled globally (G5T1) (NatureServe 2010). It is also ranked as critically imperiled in Canada (N1), the United States (N1), and Colorado (S1). The Gibson's Big Sand Tiger Beetle is not ranked (SNR) in Saskatchewan, Alberta, or Montana, but the species *C. formosa* is listed as critically imperiled (S1) in Alberta and apparently secure (S5) in Saskatchewan, Montana, and Colorado.

Habitat Protection and Ownership

Many sand hills in the Prairie Provinces have been designated some level of conservation status (Wolfe 2010). Known populations of Gibson's Big Sand Tiger Beetle are found within Great Sand Hills Representative Area Ecological Reserve, Pike Lake Provincial Park, and Douglas Provincial Park representing portions of the Great Sand, Pike Lake, and Elbow sand hills respectively. The Elbow Sand Hills are co-managed by Douglas Provincial Park and the Elbow Pasture of Prairie Farm Rehabilitation Administration (Wolfe *et al.* 2007). Established in 1973, Douglas P.P. is a natural environment class park with an emphasis on conservation of natural ecosystems and biodiversity, with grazing used to maintain existing species diversity and habitats where necessary (Thorpe and Godwin 1992). The lands at or near Pike Lake Sand Hills and Dundurn Sand Hills are variously owned / managed by: Agriculture and Agri-Food Canada (PFRA: Dundurn 1 and 2 community pasture), National Defence (Canadian Forces Base Dundurn), Agriculture and Agri-Food Canada (PFRA: Montrose community pasture), First Nations Land: Whitecap I.R. 94.

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BIOGRAPHICAL SUMMARY OF REPORT WRITERS

Robert Foster is co-founder and principal of Northern Bioscience, an ecological consulting firm offering professional consulting services supporting ecosystem management, planning, and research. Dr. Foster has a D. Phil in Zoology from the University of Oxford (Zoology) for which he studied dung beetles in East Africa. He published on the population genetics of five species of Ontario tiger beetles while working as a biology undergraduate with Dr. Richard Freitag at Lakehead University. Rob has authored or coauthored COSEWIC status reports on the Crooked-stem Aster, Bogbean Buckmoth, Laura’s Clubtail, Rapids Clubtail, Northern Barrens Tiger Beetle, Bluehearts, and Drooping Trillium, as well as recovery plans for rare plants, lichens, and odonates.

Allan Harris is a biologist with over 20 years' experience in northern Ontario. He has a B.Sc. in Wildlife Biology from the University of Guelph and an M.Sc. in Biology from Lakehead University. After spending seven years as a biologist with Ontario Ministry of Natural Resources, he co-founded Northern Bioscience, an ecological consulting company based in Thunder Bay, Ontario. Al has authored or coauthored dozens of scientific papers, technical reports, and popular articles, including COSEWIC status reports for Crooked-stem Aster, Bogbean Buckmoth, Laura's Clubtail, Rapids Clubtail, Northern Barrens Tiger Beetle, and Drooping Trillium and Small-flowered Lipocarpha. Al also authored the Ontario provincial status report for woodland caribou, and has authored or coauthored national and provincial recovery strategies for vascular plants and birds.

COLLECTIONS EXAMINED

The following collections were searched for Gibson's Big Sand Tiger Beetle specimens: Canadian National Collection of Insects, Arachnids, and Nematode (S. Juneja), Royal Saskatchewan Museum (R. Poulin), North Dakota State University (P. Beauzay), J.B. Wallis Museum at the University of Manitoba (B. Sharanowski, G. Band) and Royal Alberta Museum (M. Buck). On-line searches of collections at the E.H. Strickland Entomological Museum and the Chicago Field Museum were also conducted by R. Foster.

R. Foster examined 97 specimens at the Smithsonian Museum of Natural History, Washington, DC including some examined by Gaumer (1977). Gaumer obtained specimens from 47 institutional collections and 15 private collections for *Cicindela formosa*, which constituted all the collections holding significant material for the species at that time.

Some voucher specimens from 2010 fieldwork (Foster 2010) for this report will be used for mtDNA analysis and the remaining will be deposited at the Royal Saskatchewan Museum.

Appendix 1. Support for an argument for applying Criterion E to the Threatened status assigned to Gibson's Big Sand Tiger Beetle (from Jeff Hutchings with support from Dave Fraser, Paul Catling, and Jennifer Heron gratefully acknowledged)

The status report includes the following information for the 5 sand hills on which the species has been accurately located (see Figure 5 of the report):

Sand Hill (SH)	Year	Area of open, active sand (ha)	Reference
Great SH (northwest portion)	1946	210	Wolfe (2010)
	2005	140	
Empress SH	1938	48	Acorn (1992)
	1984	5	
Pike Lake SH	2010	0	Wolfe *et al.* (2002)
Elbow SH	1939	67	Wolfe *et al.* (2007)
	2004	31	
Dundurn SH	2010	15.3[1]	Wolfe (2010)

Habitat Trend[2] (based on Great, Empress, and Elbow SH's)

Estimated area of open, active sand in 1938 = 210+48+67 = 325 ha
Estimated area of open, active sand in 2005 = 140+ 5+31 = 176 ha

Based on these estimates, the annual loss of open, active sand is (325 − 176)=149 ha from 1938 to 2005, a period of 67 years. This represents a loss of 2.22 ha per year.

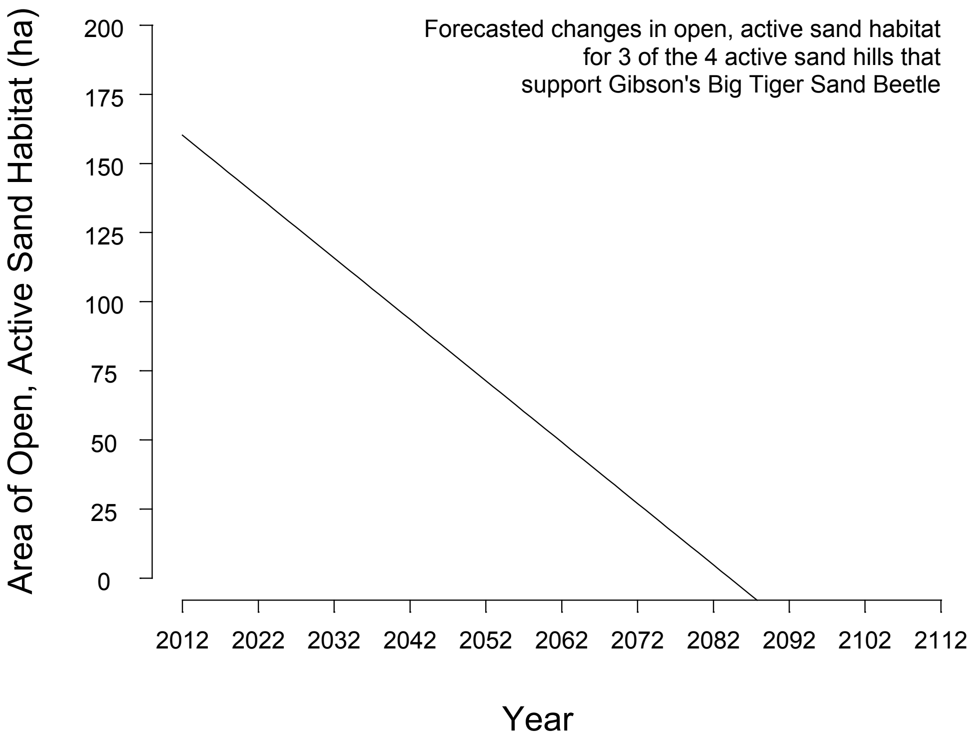
If one assumes that this rate of decline of 2.22 ha per year has persisted since 2005 and will continue to do so in the future, and that there were 176 ha available in 2005, then there would have been 160.2 ha in 2012.

In reference to the application of Criterion E, in 20 years it is forecast that more than 100 ha of open, active sand habitat would be available (see figure on following page). Thus, it is not clear that one could reliably conclude that there is a 20% or greater probability of extinction within the longer of 20 years or 5 generations (15 years for this species) from 2012. This means that this application of Criterion E would not support a status assessment of Endangered.

[1] The value for Dundurn SH is based on the total area of blowouts of 15.3 ha. Wolfe (2010) does not report open sand dune habitat on this sand hill.
[2] These estimates incorporate the assumptions that: (1) the area of open, active sand in 1938 for Great SH and Elbow SH was equal to that available in 1946 and 1939, respectively; and (2) the area of open, active sand in 2005 for Empress SH and Elbow SH was equal to that available in 1984 and 2004, respectively.

Key Point:

At the estimated rate of loss of active, open sand habitat experienced from the late 1930s to 2005, it is forecast that there will be no open, active sand habitat in 2083 at 4 of 5 sand hills (71 years from 2012). Given the evident importance of this habitat to the persistence of this species, and that the generation time for this species is 3 years, it seems reasonable to conclude that the probability of extinction of this species within the next 100 years (i.e., 2112) is at least 10%.



Note: If one includes the 15.3 ha for blowouts reported above for Dundurn SH to the 176 ha identified above for 2005, the year in which no active sand habitat is available is forecast to be the year 2100 (82 years from now).