A practical investigation of the feasibility of conservation translocation for Northern Barrens Tiger Beetle (*Cicindela patruela*) in Ontario, Canada

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Introduction

Only 1.1% of insect species have been assessed by the IUCN; however, it is recognized that populations are declining, and immediate action is needed (Harvey *et al.* 2020). Of the 112 tiger beetle species assessed, 21% are Threatened (IUCN 2021). The loss of these mesopredator insect species could have cascading effects on ecosystems (Speight *et al.* 1999). As flagship species, tiger beetle conservation can help drive habitat restoration, provide benefits to co-occurring threatened species, and garner support of local communities for insect conservation (Knisley and Gwiazdowski 2021; ECCC 2021).

In eastern North America, the Northern Barrens Tiger Beetle (*Cicindela patruela*), is considered vulnerable due to continuing population losses and declines throughout its range (NatureServe 2011; Figure 1a). As ranges are predicted to shift north due to climate change, persistence of populations in Canada is increasingly important to reduce species' vulnerability to extinction; however, it is only known to occur in two remaining locations and is classified as Endangered (ECCC 2021; Farrell *et al.* 2011; COSEWIC 2009; Figure 1b). Due to extensive habitat loss since colonization, the extant populations are small and isolated making them susceptible to stochastic threats (ECCC 2021). Further, limited dispersal capabilities and specific habitat requirements of tiger beetles prevent colonization of new areas without human intervention (Gwiazdowski pers. comm.); thus, a conservation translocation is deemed necessary to ensure the security of the species within Canada (ECCC 2021).

There are several knowledge gaps that must be addressed before a translocation program can be implemented and be expected to be successful (Farrell *et al.* 2011; ECCC 2021). A detailed feasibility assessment is proposed to ensure adequate information to develop a robust translocation plan with compelling rationale for translocation, identification of success markers and exit strategies, as well as potential risks and mitigations. This proposal highlights the main considerations needed to plan a successful translocation project and next steps for research to test assumptions and improve feasibility of implementation.

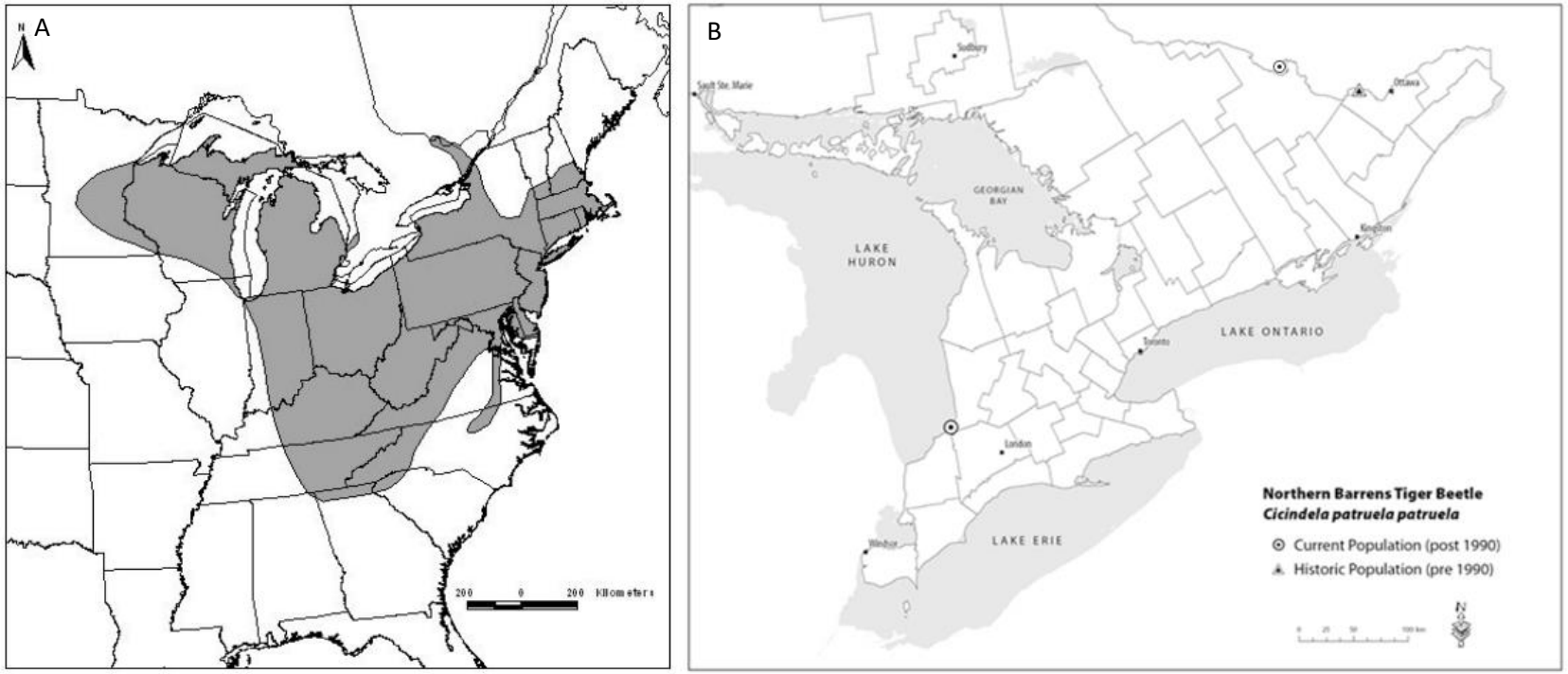


Figure 1. (A) Global range of Northern Barrens Tiger Beetle (*Cicindela patruela;* COSEWIC 2009). (B) Current and historical distribution of *Cicindela patruela* in Canada showing two known extant populations (Pinery Provincial Park, Ontario, and Ile Aux Allumettes, Quebec) and one known extirpated population (Constance Bay, Ontario; modified from Farrell *et al.* 2011).

Background

Ecology

Cicindela patruela is a predatory ground-dwelling beetle with a two-year life cycle: mating occurs in late spring followed by adult die-off while larvae develop in burrows for one year before emerging as adults in the fall (non-reproductive) or spring after hibernation (COSEWIC 2009; Figure 2). Adults occupy bare, sandy patches in open pine-oak savannah maintained through natural disturbance regimes (e.g., fire) while larval burrows are found in more shaded and compact patches of sandy soil (COSEWIC 2009). Adults (active predators) and larvae (ambush predators) feed on small invertebrates, especially ants, however their diet composition is mostly unknown (COSEWIC 2009). Adults are predated by robber flies and various generalist vertebrates while larvae may be parasitized by specialist bee flies, *Anthrax georgicus* (COSEWIC 2009). Effects of disease are unknown and competition with other tiger beetle species is thought to be minimal due to niche partitioning (COSEWIC 2009).

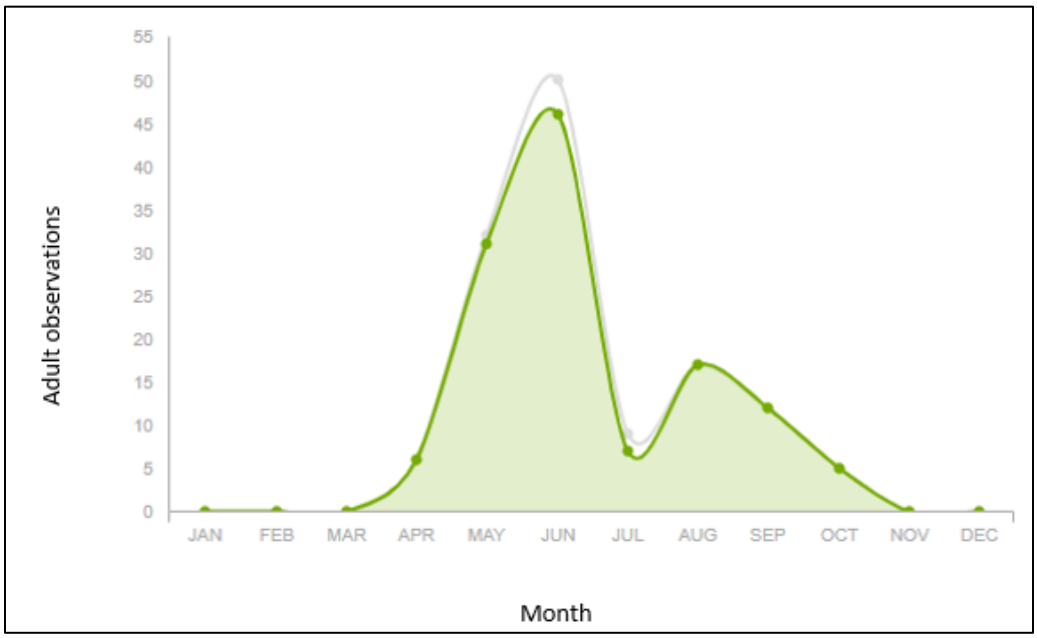


Figure 2. Seasonal activity patterns of adult Northern Barrens Tiger Beetles throughout their range (iNaturalist 2022)

Current and historical threats

Historical conversion and fragmentation of habitat due to agricultural and urban development has resulted in small populations susceptible to stochastic threats (ECCC 2021). Ongoing habitat degradation occurs through vegetative succession due to fire suppression as well as recreational activities (e.g., high-use trails) and forestry practices (Figure 3).

Figure 3. Simplified situation analysis for Northern Barrens Tiger Beetle (*Cicindela patruela*) showing direct threats (pink), contributing factors (orange), and biophysical factors (brown) that impact the population in Canada (compiled from ECCC 2021 and COSEWIC 2009 following the Conservation Standards Approach https://conservationstandards.org/wp-content/uploads/sites/3/2020/10/CMP-Open-Standards-for-the-Practice-of-Conservation-v4.0.pdf). Dashed lines indicate unknown impacts.

Overall goal

"…increase, to the extent possible, the number of local populations and the current area of occupancy of the species in Canada." (ECCC 2021)

Specific objectives

- Produce a clear, well considered framework for a conservation translocation protocol that can be used to develop a robust plan
- Establish conservation status and source viability of Ontario population
- Identify candidate release habitat and restoration needs

Methods

The following main elements for effective conservation translocations should be addressed through a combination of literature review and site assessments: current population status, candidate release sites, translocation strategy, and post-release monitoring.

Current population status

The state of the conservation target needs to be considered for several reasons (Stanley Price 1989; IUCN/SSC 2013; Nielson 1988):

- To identify and address key threats and drivers
- To determine if population is a viable source for translocation
- To establish a baseline to measure project success

Monitoring of the *C. patruela* population in Ontario has occurred sporadically over the past several decades (COSEWIC 2009; ECCC 2021); however, there is no recent, accurate estimate of population abundance (MacKenzie and Harris, pers. comm.). Annual monitoring surveys of the Pinery Provincial Park population should be implemented to determine status and assess whether removing individuals for translocation and/or captive breeding is viable. Several survey methods are feasible for tiger beetles (Table 1). The removal method, which accounts for imperfect detectability, is recommended for a balance between accurate assessment of abundance and required effort (Knisley pers. comm.). Methods and analysis described in Gowan and Knisley (2014) may be employed with appropriate modifications for species differences (e.g., habitat, seasonality, thermoregulatory behaviour, dispersal distances). Additional information may be collected simultaneously (Table 2). As *C. patruela* can easily be mistaken with *C. sexguttata,* training will be needed for surveyors (Figure 4). Similar data on population status should be obtained from provincial authorities in Quebec.

Table 1. Survey techniques for tiger beetle population monitoring.

Method	Uses	Limitations	Examples
Visual encounter surveys/distance sampling/timed index counts	• Presence/absence • Index of abundance	• Known to only sample 20-50% of population • Underestimates animals present	Schlesinger and Novak 2011; COSEWIC 2009; Knisley *et al.* 2016; Arnold and Knisley 2018; Smith *et al.* 2021
Capture-mark-recapture	• Abundance • Survival rates • Dispersal distances	• High level of effort • Low recapture rates can inflate population estimates • Risks to animals from handling	Wybron *et al.* 2021; Arnold and Knisley 2018; Hudgins *et al.* 2011
Removal surveys (non-lethal)	• Abundance	• Risks to animals from handling	Gowan and Knisley 2014
Occupancy modelling (grid system)	• Presence/absence • Population trends • Extinction/colonization probabilities • Detection probability	• Need to combine with other methods to estimate abundance	Wybron *et al.* 2021

Table 2. Suggested additional data that may be collected in conjunction with population surveys for adult Northern Barren Tiger Beetles (*Cicindela patruela*).

Data	Factor	Methods
Prey composition	Available prey	Pitfall traps
	Consumed prey	Opportunistic observations
Behaviour	Activity patterns, interspecies interactions, mating	Opportunistic observations
	Breeding rates	Larval burrow belt transects
Microhabitat requirements	Larval habitat: soil temperature and humidity, canopy cover	Measure at observed larval burrows
	Adult habitat: temperature and canopy cover	Measure at capture location during surveys *note limitations under Risks on p. 15

A

Cicindela patruela
Northern Barrrens Tiger Beetle
Pinery Provincial Park
Spring to late summer

B

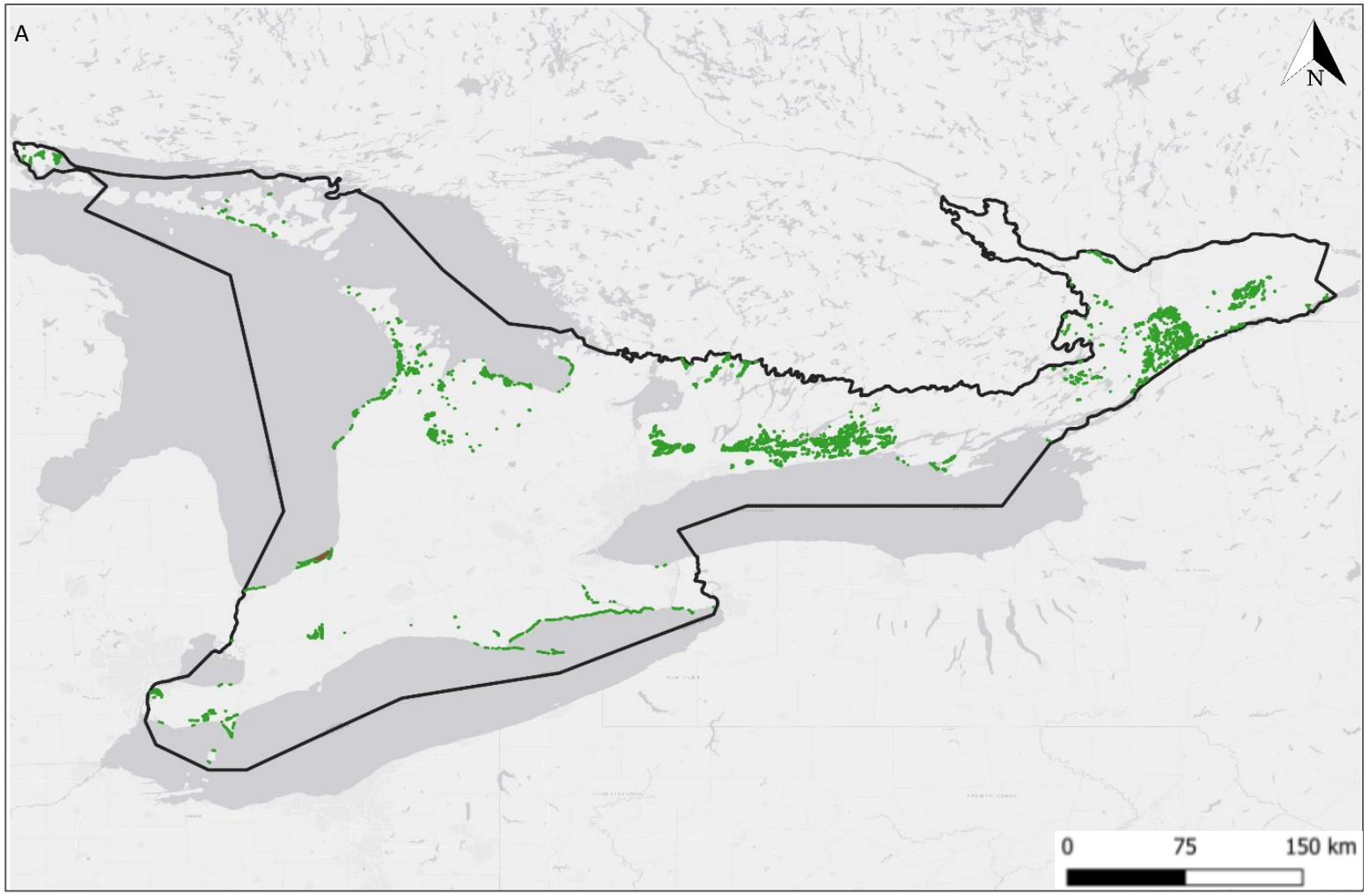
Cicindela sexguttata
Six-spotted Tiger Beetle
Open woodlands
Spring; uncommon in fall

Figure 4. (A) Endangered Northern Barrens Tiger Beetle (*Cicindela patruela*) compared with (B) similar common Six-spotted Tiger Beetle (*C. sexguttata*; from Conboy 2016).

Candidate release sites

Translocation of animals cannot be considered unless suitable habitat is available and is likely to persist in the long-term requiring an analysis of potentially suitable areas to identify candidate release sites or required restoration efforts (Stanley Price 1989; IUCN/SSC 2013).

Habitat is a key factor for tiger beetle population growth – if suitable habitat is available, they will proliferate (Knisley pers. comm.). It is recommended that candidate release sites for *C. patruela* be identified through a habitat suitability model of soil and vegetation types and current land use (Figure 5; Knisley and Arnold 2013). Further, transects at selected sites should be surveyed to assess model validity and microhabitat presence (i.e., bare sandy patches; Table 2) or potentially identify unknown *C. patruela* populations. Habitat restoration, management, and protection plans should be developed with land managers, Indigenous communities, and other project partners to ensure long-term habitat suitability that balance needs of other species.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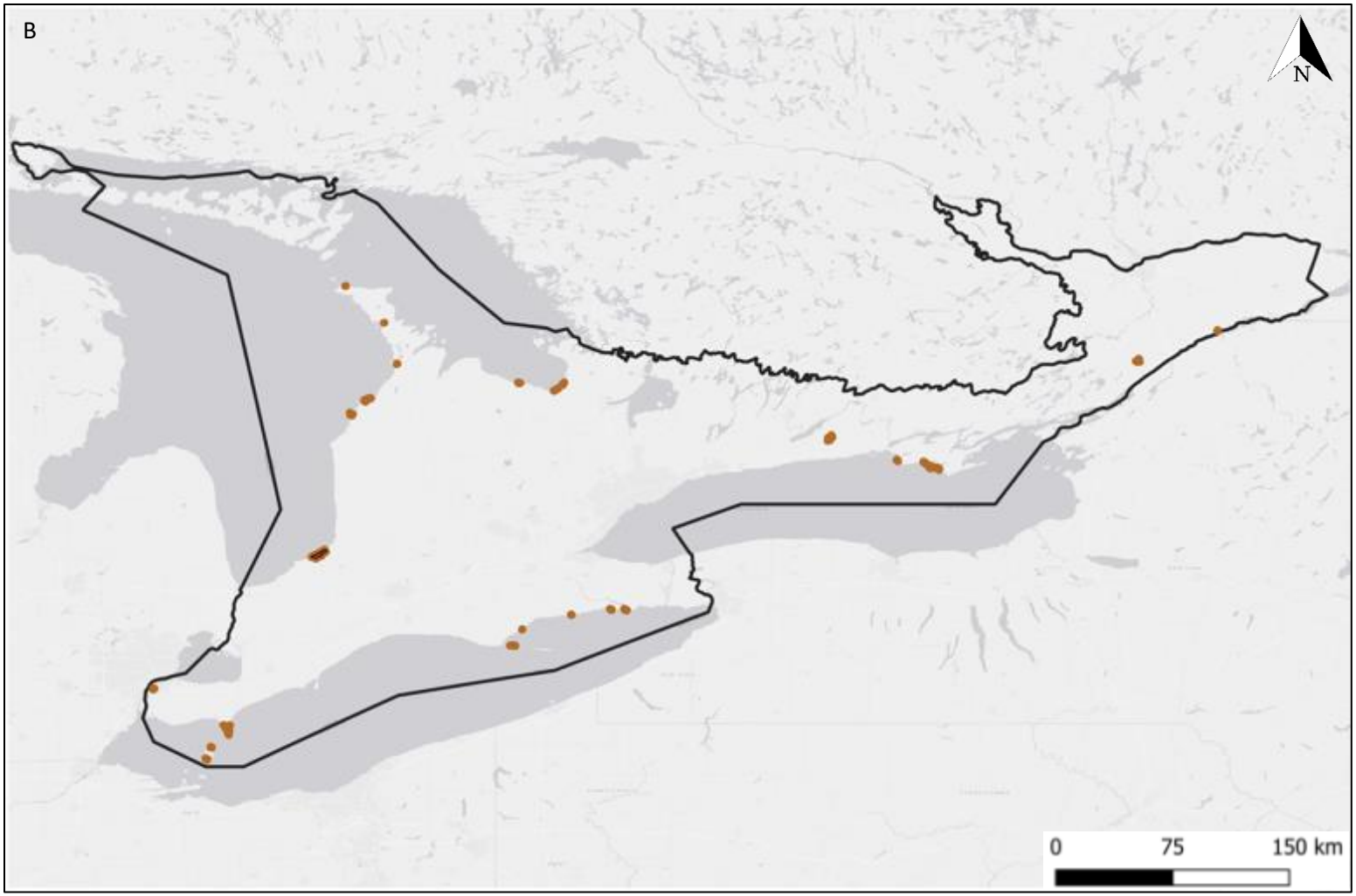

Figure 5. (A) Preliminary habitat suitability model for Northern Barrens Tiger Beetle (*Cicindela patruela*) in the mixed-wood plains ecozone of southern Ontario based on macrohabitat conditions of extant population in Pinery Provincial Park (shown in red): soil A texture = sand, land cover class = open forest. (B) Potential habitat areas (as described in A) for Northern Barrens Tiger Beetle (*Cicindela patruela*) within provincial and federal parks in the mixed-wood plains ecozone of southern Ontario. Maps author's own; data from Ontario Soil Survey Complex (Ministry of Natural Resources 2019) and Global Land Cover 100m (Buchhorn *et al.* 2020).

Translocation strategy

The translocation strategy should include capture, transportation, captive breeding (if necessary) and release methods based on known methods for similar species appropriate to the target life stage as well as available resources and practicalities (Nielson 1988).

While adult translocation of tiger beetles is preferable in terms of time and resources (Table 3; Gwiazdowski pers. comm.), it is probable that based on results of the pre-translocation population surveys, the extant population is not sufficient to support adult (or larval) translocations and captive propagation may be needed (Mackenzie pers. comm.). WPC has expertise in captive rearing of endangered insects such as Taylor's checkerspot (*Euphydryas editha*) and there are several successful captive breeding and translocation projects for other tiger beetle species which are ecologically similar (Tables 3 and 4; Gwiazdowski 2021). It is recommended that a pilot study of captive breeding methods is conducted with the closely related common species, Six-spotted Tiger Beetle (*C. sexguttata*) before attempting with the endangered *C. patruela* to ensure methods are appropriate and improve likelihood of permit approval (e.g., BIAZA 2022; Palmer and Klatt 2014)

Although inbreeding concerns may be minimal in relation to tiger beetles given the strategy of colonizing dynamic habitat patches through a few individuals (Knisley pers. comm.), standard advice regarding the need to minimise genetic bottlenecks is acknowledged. It is generally recommended that the minimum number of founders required for a captive breeding population is 30 (1:1 sex ratio) to ensure that sufficient genetic diversity is captured (Goetz pers. comm., Palmer and Klatt). It is further recommended to have a high initial output (i.e., "go big"; Goetz pers. comm.). For example, WPC's Taylors Checkerspot captive breeding program aims to release 5000 larvae/year for 5 years (Gielens pers. comm.). Ideally released animals should come from genetically or geographically proximate sources to ensure climatic and phenological compatibility and reduce spread of disease (Knisley and Gwiazdowski 2021; IUCN/SSC 2013) therefore the Quebec population should also be considered as a potential source for introductions to sites in the Ottawa Valley.

Table 3. Review of tiger beetle (*Cicindela spp.*) conservation translocation methods

Species and location	Translocation method	Success of initial translocation/ population establishment	Main results/lessons learned
Cicindela formosa Marinette County, WI (Brust, 2002 as described in Knisley, Hill and Scherer 2005)	**Wild-wild adult translocations**	**+/+**	• Established a small population in a patch of sand dune • Adults likely did not disperse as the small sand dune was surrounded by unsuitable habitat
Cicindela dorsalis dorsalis Sandy Hook, NJ (Knisley, Hill and Scherer 2005)	**Wild-wild larval translocations** pilot translocations: <400 larvae/yr for 2 years primary: >475 larvae/yr for 3 years	**+/-**	• Larval translocation successful; highest emergence rate with late spring translocation of third instars • Adult translocations not successful due to high dispersal rates • Need to account for local adaptations of source population compared to release site conditions • Laboratory rearing of larvae from field-collected adults may be necessary because of the small number and size of existing populations
Cicindela dorsalis dorsalis Monomoy National Wildlife Refuge, MA (Gwiazdowski, pers. comm.)	**Wild-wild larval translocations**	**+/+**	• Translocation has been extremely successful with <150 larvae translocated over a 4-yr period from 2000 to 2003, resulting in a population estimate of over 10,000 adults • Suitable habitat present, therefore, beetles able to flourish • Larval translocation is cost and time intensive
Cicindela nevadica lincolniana Lincoln, NE (Jenkins and Clevenger 2015)	**Release of captive bred larvae**	**-/-**	• Wild adult population is still extremely low, even with ongoing release efforts • Need to address the timing/strategy of releases • Overwintering continues to be an area where more research is required

Table 4. Review of tiger beetle (*Cicindela spp.*) captive breeding programs

Species and location	**Breeding success**	**Main results/lessons learned**
Ellipsoptera puritana Sunderland, MA (Gwiazdowski, 2018, as described in Knisley and Gwiazdowski 2021)	**+**	• Produced large numbers of larvae • Experimental release to supplement existing populations/test for using additional captive bred larvae for translocation to unoccupied sites with potential habitat
Cicindela (=*Ellipsoptera*) *nevadica lincolniana* Lincoln, NE (Palmer and Klatt 2014; Jenkins and Clevenger 2015)	**-/+**	• Long running captive rearing program since 2002 • Catch and release wild adults to establish initial captive breeding colony • Challenges to produce sustainable numbers in captivity required several years of modifications and experiments with surrogate species to improve methods
Cicindela spp. Northeastern North America (Gwiazdowski *et al.* 2011)	**+**	• General protocol • Rearing large numbers of larvae is feasible with endangered species • Tubes may hold the possibility for obtaining a larger yield of larvae, higher quality of data, and lower risk of spread of disease than rearing in communal bins
Cicindela campestris England (BIAZA 2022)	**+**	• Successful overwintering, metamorphosis, and emergence in trial with one breeding pair of common species as surrogate for endangered species

Post-Release Monitoring

Long-term monitoring of source and release populations is extremely important for assessing success and efficacy of translocation strategies and identification of issues or unknown threats (Williams *et al.* 2020). For example, Knisley had initial success at establishing a population of tiger beetles in New Jersey, but through post-release monitoring detected a subsequent decline in the reintroduced population. Wybron (2021) found that occupancy modelling can be used to accurately assess abundance trends in *C. patruela* populations and can be paired with population abundance survey methods (Table 1). In addition to establishing ongoing monitoring programs with project partners to determine if translocated populations are self-sustaining and breeding in the wild, there is potential to engage with amateur entomologists through iNaturalist to conduct annual occupancy surveys of designated sites (MacKenzie pers. comm.).

Outputs

- detailed framework for the translocation of *C. patruela*
- current population estimate for Ontario
- improved understanding of apparent microhabitat preferences
- identification of suitable habitat and/or restoration areas

Outcomes

- Short-term: decision to move forward with project including partner support/recovery team formation and improved feasibility
- Long-term: restoration of pine-oak savannah in Ontario benefiting other species-at-risk that rely on the same habitat

Resources

Project component	**Required resources**
Desktop assessment	Contract experienced entomologist
Population and habitat surveys	1 lead biologist, 2 field technicians (summer students), training
	Vehicle, fuel
	GPS receiver, maps/satellite images
	Combination aerial/sweep nets
	Insect collection vials, cooler
	Thermometers (soil and air), hygrometer
	Spherical crown densiometer

Timeline

	Year 1		Year 2				Year 3			
Task	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Literature review										
Identify and meet with potential recovery team partners/donors										
Preliminary site visits to map survey routes										
Develop habitat suitability model										
Surveyor training										
Survey extant population										
Survey candidate release sites										
Analyze abundance and distribution										
Analyze habitat use and refine habitat suitability model										
Report results and meet with recovery team										
Select potential sites and identify habitat management needs										
Model translocation options and produce feasibility assessment										

Risks

The habitat of remnant populations may be suboptimal due to habitat destruction, biasing habitat suitability assessments, and climate change impacts may affect future habitat suitability (e.g., changes in human recreational use, MacKenzie pers comm.), therefore further research may be needed to understand preferred habitat.

If captive breeding is deemed necessary due to low population numbers, timelines may need to be adjusted to incorporate rearing trials. There is also limited knowledge of *Cicindela* pathology (Gwiazdowski *et al.* 2011), so measures should be taken to reduce the risk of unknown disease transmission.

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