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Habitat Selection, Dispersal and Detectability of Cobblestone Tiger Beetles (Cicindela marginipennis Dejean) along the Genesee River, New York

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Habitat Selection, Dispersal and Detectability of Cobblestone Tiger Beetles (*Cicindela marginipennis* Dejean) along the Genesee River, New York

A Thesis

Presented to the Faculty of the Department of Environmental Science and Biology

of the State University of New York College at Brockport

in Fulfillment for the

Degree of Master of Science

Rhonda M. Hudgins

May 2010

Department of Environmental Science and Biology

Thesis Defense and Seminar by

Rhonda Hubgini

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Major Advisor	✓	
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BIOGRAPHICAL SKETCH

I graduated from the University of Northern Colorado, Greeley, CO with a Bachelor of Arts degree in American History and Mexican-American Studies in 1974 and then spent the next several years working with computers - computer operator, computer programmer, systems business analyst. When this career ended in 2006, I was a senior software project manager. Embarking on a career change, I attended Finger Lakes Community College, Canandaigua, NY and received an Associate of Applied Science degree in Natural Resources Conservation. I began classes at SUNY College at Brockport, in 2008, to acquire a Master of Science degree in Environmental Science and Biology.

Dedicated to my husband Thomas N. Martin and son Thomas N. Martin II (TJ).

ABSTRACT

The objectives of my two year study were to (1) understand the dispersal dynamics of the adult cobblestone tiger beetles (*Cicindela marginipennis*); (2) identify environmental variables associated with suitable habitat; (3) model habitat selection; (4) describe important features of their natural history; and (5) determine their detectability in the riparian habitat along the Genesee River, NY. Data on cobblestone tiger beetle habitat selection and populations established a baseline for monitoring environmental change and population status of this species of management concern in riverine and riparian habitats in western New York.

Cobblestone tiger beetles dispersed distances that far exceeded the maximum distance between surveyed cobble bars, and they sometimes moved between cobble bars. Cobblestone tiger beetles were more likely to occur in habitat patches with greater interior area and elevational relief. Occupied cobble bars also had few boulders and shrubs. I found cobblestone tiger beetles throughout occupied cobble bars and not restricted to the upstream end of cobble islands or sandy beaches as cited in most cobblestone tiger beetle literature.

My surveys examined two levels of detection probability – individual-level (the probability of detecting an individual cobblestone tiger beetle in a population on a single cobble bar) and site-level (the probability of detecting a single cobblestone tiger beetle on an occupied cobble bar). My results for individual-level detectability show that there was a lower probability of seeing an individual cobblestone tiger beetle than detecting the co-occurring and more common bronzed tiger beetle (*C. repanda*). The best-fit model for cobblestone tiger beetles had no covariates. Although cobblestone tiger beetle detection probabilities were the same for both models (no covariate and with ground temperature), the results for site-level detectability showed similar detection probabilities for cobblestone tiger beetles in 2008 and 2009, even though the number of sites surveyed and the number of visits per cobble bar differed between years. In addition, an evaluation of a smaller subset of cobble bars surveyed during both years and with the same level of effort showed that the site-level detectability and occupancy continued to be consistent with the individual year results.

Based on results from my study, I recommend (1) continuing occupancy surveys with at least three visits to each cobble bar as long as the site-level detection probability is greater than 0.5, in order to detect cobblestone tiger beetles on at least 90% of occupied cobble bars; (2) conducting occupancy surveys when cobblestone tiger beetles are the most active – in mid-July and mid-August; (3) conducting surveys between 10:00 and 17:00 on warm sunny days when ambient and ground temperature are at their highest, preferably when ambient temperatures are above 18.8 C; and (4) conducting surveys at three- to five-year intervals depending on the study objective – shorter times for better understanding of metapopulation dynamics or longer intervals for simply determining continued occupancy.

Keywords: cobblestone tiger beetle, *Cicindela marginipennis*, detection probability, dispersal, mark-recapture, occupancy, distance transect, habitat, monitoring.

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General Introduction

There are many reasons to protect the diverse array of invertebrates. They fill innumerable ecological niches, are a source of food for other organisms, and help maintain ecosystem-level processes such as decomposition, pollination, energy flows and trophic organization (McCollough, 1997). Invertebrates also can act as indicators of healthy environments. For example, tiger beetles (*Cicindela* spp.) can help track environmental changes within riparian systems. Tiger beetles are models to help us understand, manage and conserve biodiversity and ecosystems (Rodriguez *et al*., 1998; Pearson 2006).

Tiger beetles occur in a broad range of habitats, including exposed soils near stream and pond edges, seashores, dunes and open patches in grasslands. Whereas adults are very mobile, larvae of most tiger beetle species are sand / soil dwelling and sedentary. In addition, riparian tiger beetle habitats are prone to seasonal flooding. These periodic floods help to preserve heterogeneity within riparian systems by disturbing successional patterns and by removing vegetation. Tiger beetles in these areas have life cycles adapted to seasonal flooding. However, human changes to streams and rivers (channelization, damming, agricultural use) designed to reduce the impact of flooding on human activities have had negative effects on fish, amphibians, odonates and freshwater mussels (Naiman and Decamps, 1997; SaintOurs, 2002; Bailey *et al.*, 2004; Brust *et al.*, 2005; Bates *et al.*, 2007).

Many tiger beetle species are sensitive to habitat changes and several species of riparian tiger beetle have declined in abundance and distribution because of anthropogenic changes to their habitats. These include *Cicindela columbica* Hatch, *C. dorsalis dorsalis* Say, *C. gabbii* Horn, *C. puritana* Horn and several subspecies of *C. hirticollis* (Brust *et al.*, 2005; Cornelisse and Hafernik, 2009). In New York State, eight species of tiger beetles, including the cobblestone tiger beetle (*Cicindela marginipennis* Dejean), have been identified as "Species of Greatest Conservation Need" (New York State Department of Environmental Conservation, 2006) because they are scarce, found only in small localized areas, and threatened by anthropogenic activities (Graves and Brzoska, 1991; Novak, 2006).

Monitoring the status of species of conservation concern is important. However, it is difficult to show trends in survey data for the same reasons that these species are categorized as rare – they have small populations, are found in narrow geographical ranges, or occupy specialized habitats (Primack, 2006). Detection probabilities also vary over time due to behavior patterns and changing environmental conditions (Bailey *et al.*, 2004). Imperfect detection can be an important problem, as not all individuals are likely to be recorded within sample units (Field *et al.*, 2005).

This thesis is presented in two parts. In Chapter 1, I report results of a two-year study on cobblestone tiger beetle dispersal, suitable habitat and natural history. In Chapter 2, I report the results of two detectability studies and make monitoring recommendations for the management of cobblestone tiger beetles and their habitat.

Chapter 1 – Habitat Selection and Dispersal of Cobblestone Tiger Beetles (*Cicindela marginipennis* Dejean) along the Genesee River, New York.

Introduction

Anthropogenic changes to natural waterways resulting in altered flow patterns and pollution can lead to loss of riverine invertebrates (Allan, 1995; SaintOurs, 2002; Bates *et al.*, 2007). Lotic inhabitants face continuing threats from land development and agricultural practices that include changes to water temperature, pesticide concentration, nutrient regimes, storm water discharge and flow due to impoundments and irrigation practices (Allan, 1995; SaintOurs, 2002; Bates *et al.*, 2007). The loss of biodiversity and changes to riverine ecosystems in New York are major management concerns (Pfankuch, 1975; Novak, 2006).

Tiger beetles (*Cicindela* spp.) are useful organisms for tracking environmental changes within riverine and riparian systems. They act as models for understanding, managing and conserving biodiversity and ecosystems (Rodriguez *et al.*, 1998; Pearson, 2006), as they possess all or most of the seven criteria required for bioindicator species (Pearson and Cassola, 1992). Ideally, indicator species should (1) be in a well known and stable taxon, with species easily and reliably defined; (2) have well understood biology and life histories; (3) be easily observed in the field by observers with differing levels of experience; (4) occur across a wide geographical range in a broad number of habitats; (5) be narrow habitat specialists and sensitive to habitat changes; (6) have distributional patterns observed in other taxa; and (7) have potential economic importance that can be used to influence scientists and politicians to dedicate resources to relevant studies. Studies on speciation, extinction and ecology of tiger beetles have shown their usefulness as bioindicators in understanding complex habitats and environments (Pearson, 2006). Understanding the life history and habitat associations of indicator species are important in developing effective management strategies (McCollough 1997). One potential indicator species in New York State is the cobblestone tiger beetle (*Cicindela marginipennis* Dejean), a rare species adapted to natural river disturbances that maintain its required habitat, cobble bars.

Within the order Coleoptera, tiger beetles (Cicindelidae) are a distinct group. Close to 2600 species of tiger beetles have been identified worldwide; they are similar in shape, proportion and behavior, and differ mostly in size and coloration (Pearson and Cassola, 2005). Tiger beetles are found in a wide variety of habitats, excluding Antarctica, the high Arctic, Tasmania and isolated areas such as the Hawaiian Islands and Maldives. In the United States, 111 species of tiger beetles occur, 40% of which are habitat specialists (Pearson and Cassola, 1992). Eight species of tiger beetles, including the cobblestone tiger beetle, have been identified as "Species of Greatest Conservation Need" in New York State's Comprehensive Wildlife Conservation Strategy (New York State Department of Environmental Conservation, 2006) because they are scarce and found only in small localized areas, and threats to their populations have been identified (Graves and Brzoska, 1991; Novak, 2006).

In New York state, cobblestone tiger beetles are found in two watersheds and are possibly extirpated from a third watershed (NatureServe, 2009). There are few studies on cobblestone tiger beetles in New York and as a result, the specific habitat requirements and dispersal biology of this species are poorly understood.

The objectives of my study were to (1) understand the dispersal dynamics of the adult cobblestone tiger beetles; (2) identify environmental variables associated with suitable habitat; (3) model habitat selection; and (4) describe important features of their natural history. Data on cobblestone tiger beetle habitat selection established a baseline for monitoring environmental change and population status of this species of management concern in riverine and riparian habitats in western New York.

METHODS

STUDY SPECIES

Cobblestone tiger beetles are rapacious predators that live on cobble bars (Appendix 1). They are a dull olive color and are 11-14 mm in length with a white band around the outside edge of the elytra, which have no other white maculations. They are metallic blue-green underneath the elytra and have a red-orange abdomen (Graves and Brzoska, 1991; Leonard and Bell, 1999; Pearson *et al.*, 2006). Although adults are very mobile, larval stages for most tiger beetle species are sand/soil dwelling and sedentary (Nothnagle, 1995; Hoback *et al.*, 2000). Riparian tiger beetle habitats are prone to seasonal flooding (Pyzikiewicz, 2005). These floods help to preserve heterogeneity within riparian systems by disturbing successional patterns and by removing vegetation. Tiger beetles using these areas have life cycles adapted to seasonal flooding (Pyzikiewicz, 2005).

The cobblestone tiger beetle occurs in New York along the Genesee River in the Lake Ontario watershed and Cattaraugus Creek in the Lake Erie watershed (NatureServe, 2009); the population of cobblestone tiger beetles on the Delaware River in southeastern New York is considered extirpated (New York Natural Heritage Program, 2010). Cobblestone tiger beetles are classified as a "critically imperiled" species in Alabama, New Jersey, New York, Pennsylvania and Vermont because of their small numbers and vulnerable habitat. They are a protected species in New Hampshire (Pyzikiewicz, 2005). They are assumed to be extirpated in Mississippi (NatureServe, 2009), but they were detected for the first time in Maine in 2009 (Ward and Mays, 2010). The International Union for Conservation of Nature (IUCN) lists cobblestone tiger beetles as "near threatened" (Gimenez Dixon, 1996).

STUDY AREA

The Genesee River (Fig. 1-1) originates in Ulysses Township, Potter County, PA at an elevation of 683 m. It flows north for 241 km into Lake Ontario at Rochester, NY. South of Letchworth State Park, about halfway along its length, the river is a 2^{nd}- to 3^{rd}-order stream that meanders through a rural and agricultural landscape past a few towns and villages. The river's flow is fast in spring, with annual spring flooding. Mean peak water-flow measurement for 2000 - 2007 at Portageville, NY, within the target area, was 43 m^3/s (U.S. Geological Survey, 2010). The river is generally wide and shallow as it winds back and forth across a floodplain approximately 1.6 km wide. North of Portageville, NY, the Genesee River enters Letchworth State Park. There are three major falls at the south end of the park and the Mt. Morris Dam, a flood control dam completed in 1954, at the north end of the park. The gorge cut by the river has rock walls rising up to 170 m from the river.

Large cobble bars are deposited at bends in the river and as islands. These areas are scoured by spring flooding and their locations may shift from year to year. The cobble bars typically consist of boulders, cobbles, pebbles and sand; they have wide areas with and without vegetation (Novak, 2006). Soil types adjacent to the river include alluvial deposits, loam, silt loam, gravelly silt loam, loamy-skeletal (variety of components), gravelly loam, silty clay loam, fine sandy loam and bedrock (USDA - Natural Resources Conservation Service, 2009; Appendix 2). The Genesee River carries high, naturally occurring, silt and sediment load as the soils throughout the upper Genesee River valley are highly erodible, and there are areas in the drainage with steep stream banks.

Extensive agricultural use (the primary non-point source of pollution) and land development contribute to silt and sediment loading. Point sources of pollution are inadequately maintained or failing on-site septic systems, salt storage and salt application for deicing (Bureau of Watershed Assessment and Research-Division of Water, 2003). Channelization for flood control and irrigation within some of the Genesee River tributaries and the lack of riparian vegetation add to water quality degradation (Bureau of Watershed Assessment and Research-Division of Water, 2003).

Portions of the Genesee River from Belfast, NY to Letchworth State Park, Castile, NY were surveyed for cobblestone tiger beetles by the New York Natural Heritage Program (NYNHP) between 2000 and 2002 as part of a biodiversity inventory of Letchworth State Park and subsequent, rare animal surveys south of the park (New York Natural Heritage Program, 2010). Seventeen cobble bars occupied by tiger beetles were identified during these surveys (Appendix 3).

DISPERSAL STUDY

During the summer of 2008, I used two series of cobble bars for the dispersal study. One set of three cobble bars was located east of Portageville, NY (Fig. 1-1). The largest cobble bar (P1) was the old riverbed which remained dry throughout the summer and was located on the west side of the Genesee River. The second cobble bar (P0) was on the east bank and approximately 171 m upstream, just below a cornfield. The third cobble bar (P2) was approximately 80 m downstream from P1 on the eastern side of the river; however, this cobble bar was inaccessible most of the summer due to high water.

The second series of three cobble bars was located farther south near the Rushford Reservoir outlet, Caneadea, NY (Fig. 1-1). The largest cobble bar (R2) was on the east side of the river and until 2002 had been an active cobble mine. The next cobble bar (R1) was located on the west side of the river approximately 95 m from State Route 19 and 46 m upstream from R2. The third cobble bar (R0) in this series was 164 m upstream from R1 on the east side of the river. Mixtures of trees, shrubs and forbs covered the inland side of all cobble bars. During the 2009 field season, the dispersal study was done only on the cobble bars near the Rushford Reservoir outlet (R0, R1 and R2), with an additional marking site (C1) located 34 m upstream from R0. C1 was located at the mouth of Crawford Creek where it enters the Genesee River.

According to Gordon (1939), the flight period for cobblestone tiger beetles in New York begins in late June and continues through early August. In 2008, I sighted the first cobblestone tiger beetle on 2 July, and mark – recapture (dispersal study) work began on 5 July, with 20 marking periods occurring between 5 July and 13 August. In 2009, the first sighting occurred on 23 June and mark - recapture work began on 29 June with 17 marking periods between 29 June and 13 August. Cobblestone tiger beetles were captured with a 38-cm diameter flexible net and occasionally by hand. Ovipositing females were not captured. I spent approximately 4 h per cobble bar visit in both 2008 ($\bar{x}$= 4.4) and 2009 ($\bar{x}$=3.9) and walked each cobble bar from access point to each end in a serpentine pattern until cobblestone tiger beetles were sighted or the cobble bar had been completely searched. I marked captured beetles with a unique number written on their elytra using Sharpie® oil-based extra-fine-point pens. Sex and ground temperatures were taken at each capture point. Elevation and x-y coordinates were obtained using a Garmin eTrex Legend® or Venture®

global positioning unit. Ambient and ground temperatures were taken using a Physitemp BAT-12 Microprobe Thermometer or a Radio Shack Indoor/Outdoor Thermometer with Hygrometer (Model: 63-1032).

Distance between cobble bars (nearest_cb), cobble bar area (area), perimeter-to-area ratio (perim/area) and cobblestone tiger beetle dispersal distances between initial marking point and recapture point were determined using ArcGIS 9.3 software (Bates *et al.*, 2006).

HABITAT SURVEYS

I conducted a systematic survey of ground cover on 40 cobble bars in 2009. I estimated ground cover (gravel, rocks and vegetation) percentages within 1 m^2 sample plots randomly placed along 100 m transect lines located at approximately 50 m intervals. Placement of the transect lines depended on the size and shape of the cobble bar. Vegetation was identified by type (i.e., forbs, grasses, shrubs) and substrate was identified by categories: (1) boulders (> 25 cm), (2) cobbles (6 – 25 cm), (3) pebbles (0.4 – 6 cm) and (4) small grains (< 0.4 cm). Ground cover was measured between mid-July and mid-August. I used Braun-Blanquet coverage classes for substrate and vegetation cover: (1) 0-5%, (2) 6-25%, (3) 26-50%, (4) 51-75% and (5) 76-100% (Elzinga *et al.* 1998).

To determine the number of plots required to sample vegetation and substrate adequately, I selected a mid-sized cobble bar from among the ones visited in 2008 for presampling. During the presample I placed 1-m^2 random sample plots along random transects; ground cover data were analyzed using a sequential sampling graph, with running mean and standard deviation. I determined the representative number of sample plots from the point where the curves began to smooth out (Elzinga *et al.*, 1998). I then used a ratio of plots 0.006 plots/100 m^2 of cobbles to determine the number of sample plots on each cobble bar (range: 4-90).

Habitat models were based on the presence or absence of cobblestone tiger beetles as determined by a minimum of three visits per site. Cobble bars visited were located between Oramel and Fillmore, NY, and within Letchworth State Park, Castile, NY (Fig. 1-1). This area was selected because cobblestone tiger beetles had been detected on some of the cobble bars in surveys done by the NYNHP between 2000 and 2002 (New York Natural Heritage Program, 2010). I divided the Oramel – Fillmore section of the Genesee River into three smaller sections (Oramel – Caneadea, Caneadea – Houghton and Houghton – Fillmore) based on river access points and the amount of time required for travel between the cobble bars. Each section contained at least nine accessible cobble bars. The stretches of cobble bars within Letchworth State Park were between Lee's Landing and St. Helena river access points. I made visits to cobble bars by kayak between 5 July and 7 September. I began each trip at approximately 10:00 and completed it by 17:00. I surveyed 40 cobble bars for cobblestone tiger beetles and noted the presence of other tiger beetle species (*C. ancocisconensis* and *C. repanda*). If a cobblestone tiger beetle was sighted, or when the entire cobble bar had been searched, I moved on to the next cobble bar.

MODEL SELECTION OF HABITAT CHARACTERISTICS

I used model selection techniques to evaluate the relationship between ground cover variables and the presence or absence of cobblestone tiger beetles. I converted substrate and vegetation variables from Braun-Blanquet coverage classes to median percent values for each class. To reduce multicollinearity, I used Pearson's correlation test to evaluate correlations between habitat variables and Principal Component Analysis (PCA) to combine boulders, cobbles, pebbles, small grains, forbs, grasses and shrubs into three components with eigenvalues ≥ 1.0. Analyzing ground cover variables by type (substrate and vegetation) explained less than 44% of the variation within the data. However, three components accounted for 70% of the total variance in the data set. I interpreted the components by examining the loadings of the original variables (Table 1-1) (SPSS, 2008). Cobble bars with many boulders and forbs and few pebbles scored high on the first axis (I), cobble bars with many small grains and few cobbles scored high on the second axis (II), and cobble bars scoring high on the third axis (III) contained few shrubs and some grasses. I used a t-test for equality of means to determine significant differences in variables between cobble bars with and without cobblestone tiger beetles. I used chi-square tests to test for differences in the sex ratio of captured beetles. If necessary, variables were transformed using z-scores in order to meet normal distribution requirements.

I used binary logistic regression to model the effects of predictor variables on cobble bar occupancy. The response variable for the logistic regression models was presence or absence of cobblestone tiger beetles on a cobble bar. Main effect covariates included PCA components (I, II and III), perimeter-to-area ratio (perim/area), difference between minimum and maximum elevations (diff_elev), area, and nearest cobble bar (nearest_cb). I created a series of models and compared them using a process described by Gjerdrum *et al.* (2005). Akaike's Information Criterion, corrected for small sample sizes (AIC_c), was used to determine the fitness of each model (Burnham and Anderson, 2002) and then the models were ranked according to ΔAIC_c. I also calculated AIC_c weights for each model, which assisted in assessing the evidence favoring a model (Burnham and Anderson 2002). At each step in my selection process, I evaluated the results for the most parsimonious model by sequentially removing the predictor variable with the highest P-value > 0.05. I built nine models *a priori* based on my understanding of tiger beetle biology and riverine ecosystems. The most complex model included all predictors, plus five two-way interactions (diff_elev*perim/area, diff_elev*area, PCA I *PCA III, PCA II*PCA III and PCA I *PCA II), two three-way interactions (area*diff_ elev*perim/area and PCA I*PCA II*PCA III), and one four-way interaction (PCA I*PCA II*PCA III*perim/area). I considered models with ΔAIC_c values < 2.0 to be most meaningful (Burnham and Anderson, 2002). I set α = 0.05 and summary statistics are reported as mean ± 1 SE unless otherwise noted.

RESULTS

DISPERSAL (MARK – RECAPTURE)

In 2008 and 2009, I marked 259 cobblestone tiger beetles. I marked a greater proportion of females than males (df=1, χ^2=5.1, P=0.02) over the two summers (Table 1-2). In 2008, there was no significant difference in proportion of males (N=53) to females (N=59) marked (χ^2=0.32, df=1, P=0.57), whereas there was a significantly larger proportion of females (N=86) than males (N=56) marked in 2009 (χ^2=6.34, df=1, P=0.01). Five beetles of undetermined sex were not used in this analysis.

Over the two years, I recaptured 21 of the 259 marked beetles. In 2008, eight individual cobblestone tiger beetles were recaptured (Table 1-3). One male was recaptured 322 m from his original capture point. The other recaptures ranged in distances from 0 – 123 m. In 2009, 13 individual cobblestone tiger beetles were recaptured. One male was recaptured three times over 21 d at distances ranging from 6 – 68 m from his original marking site. One beetle was observed to move between cobble bars in 2008, whereas four did so in 2009. Means for recapture distances did not differ significantly between years or sex (year: t=0.59, df=21, P=0.56; sex: t=0.76, df=21, P=0.46), nor did time between captures (year: t=1.00, df=21, P=0.33; sex: t=0.77, df=21, P=0.45) (Table 1-4). Recaptured cobblestone tiger beetles occasionally traveled distances greater than the maximum distance between adjacent cobble bars in the study area (beetles: $\bar{x}$=133 m, range 0-481 m; nearest_cb: $\bar{x}$=53 m, range 11-203 m).

Between 2000 and 2002, cobblestone tiger beetles were found on 17 cobble bars examined during the NYNHP survey on the Genesee River from Belfast through Letchworth State Park, New York (New York Natural Heritage Program, 2010). In 2008 and 2009, I found cobblestone tiger beetles on six of the 14 NYNHP cobble bars; three of their cobble bars were inaccessible in 2008 and 2009. Within Letchworth State Park, I surveyed five of the seven NYNHP cobble bars with cobblestone tiger beetles. Of these five, only one (LL6) still had cobblestone tiger beetles present in 2008 and 2009. Although cobblestone tiger beetles were not found on the majority of the NYNHP cobble bars in 2008 and 2009, I did find them on 17 other cobble bars. In 2009, I also found three occupied cobble bars where cobblestone tiger beetles had not previously been detected in 2008.

HABITAT SELECTION

In 2009, I detected cobblestone tiger beetles on 23 of 40 surveyed cobble bars. Area, perimeter-to-area ratio, elevational difference and shrub cover differed significantly between occupied and unoccupied cobble bars (Table 1-5); occupied cobble bars had about twice the area and difference between minimum and maximum elevation, and higher shrub cover, than unoccupied cobble bars. Difference in percent boulder cover and distance to the nearest cobble bar also approached statistical significance, with occupied bars tending to have lower boulder cover and occurring nearer to other cobble bars. Shrub cover was significantly higher on occupied cobble bars, although cover for all vegetation types on surveyed bars was generally less than 10% (Table 1-5).

Seven predictor variables (area, diff_elev, perim/area, nearest_cb, and PCA components I, II and III) were used to develop habitat models for predicting cobblestone tiger beetle presence (Table 1-6). The model with perim/area alone had the strongest fit, with all other models having ΔAIC_c values ≥ 3.0. Cobblestone tiger beetles tended to occur on cobble bars with smaller perimeter-to-area ratio (i.e., cobble bars with more center area and less edge).

NATURAL HISTORY

I observed cobblestone tiger beetles in 2008 between 2 July and 7 September, and in 2009 between 23 June and 3 September (Fig. 1-2). I rarely encountered them before 10:00 or after 17:00, and then only on warm sunny days. Occasionally, one or two beetles were seen during light rain, but they soon disappeared when precipitation began to form puddles. Ambient air temperatures on dispersal study days ranged from 18.8 C to 32.7 C ($\bar{x}$=26.9 C), whereas ground temperatures ranged from 21.5 C to 46.4 C ($\bar{x}$=32.3 C). On hot days, beetles often were observed in areas of moist substrate near the river's edge. I also observed cobblestone tiger beetles to be the most active on warm sunny days between 10:00 and 17:00 with peak season in July and early August.

Cobblestone tiger beetles frequently were observed with the gregarious and more common bronzed tiger beetles (*C. repanda*) and the more elusive Appalachian tiger beetle (*C. ancocisconensis*). Bronzed tiger beetles occupied 37 cobble bars and Appalachian tiger beetles occupied 10 cobble bars in 2009. Cobblestone and bronzed tiger beetles were detected near the river's edge and in sandy patches scattered among cobbles, whereas Appalachian tiger beetles occurred closer to vegetation on the inland edge of cobble bars.

Cobble bars occupied by cobblestone tiger beetles were located along the river's edge and at bends in the river. One or two of these cobble bars were transitory islands that were isolated from the shoreline by storm events and high water levels. I did not observe cobblestone tiger beetles on cobble bars completely isolated from the shoreline. Occupied cobble bars were likely to have some area above high water levels. Areas of sand or other small grains were located downstream of the vegetation. Most of the occupied cobble bars were covered with loosely packed cobbles. These cobble bars had few boulders at the upstream end and sand / silt areas downstream. Other arthropods such as spiders, spider wasps and ants were always present on occupied cobble bars.

Discussion

The first objective of my study was to understand the dispersal dynamics of adult cobblestone tiger beetles. Cobblestone tiger beetles dispersed up to 481 m, which far exceeded the maximum distance between surveyed cobble bars, and they sometimes moved between cobble bars. *C. puritana* disperse up to 2.7 km (Omland, 2004), whereas *C. dorsalis dorsalis* were recaptured up to 24 km from their original marking site (Leonard and Bell, 1999). I did not observe cobblestone tiger beetles traveling to this extent, but they moved between cobble bars in both upstream and downstream directions. The ability to travel distances greater than recorded distances between cobble bars was a strong indicator of the beetles' ability to colonize other cobble bars. The observation of dispersing cobblestone tiger beetles moving up and downstream is consistent with the dispersal of aquatic insects in general (Smith *et al.* 2009). In 2009, I found an increase in the number of occupied cobble bars, which indicated possible colonization occurring since the initial 2000-2002 surveys and 2008 survey. Sightings of single cobblestone tiger beetles on some surveyed cobble bars may have been transitory beetles.

The flight period of cobblestone tiger beetles in western NY occurred from late June, with the emergence of adults, and continued through September, which was similar to flight period of cobblestone tiger beetles in West Virginia (Allen and Acciavatti, 2002). Gordon (1939) listed the flight period in New York from late June through the middle of August. Boyd (1978) gave 4 – 25 July as the peak period for cobblestone tiger beetles in New Jersey with occasional sightings as early as May. Surveying for adult cobblestone tiger beetles should coincide with their peak activity period.

Cobblestone tiger beetles were more likely to occur in habitat patches with greater interior area and elevational relief. Occupied cobble bars also had few boulders. I found cobblestone tiger beetles throughout occupied cobble bars and not restricted to the upstream end of cobble islands or sandy beaches in contrast to Boyd (1978), Dunn and Wilson (1979), and Leonard and Bell (1999). I observed cobblestone tiger beetles in areas of mixed-size cobbles and patchy vegetation, not just in areas of tightly packed cobbles; they also occurred close to the river's edge in areas of moist or wet sand and silt.

I found differences in the number of sites with detected cobblestone tiger beetles between the 2000-2002 NYNHP surveys and mine in 2008-2009. I did not find cobblestone tiger beetles on nine of the originally occupied NYNHP cobble bars, six of which were in Letchworth State Park. Whether these were true changes in occupancy or artifacts of sampling effort is uncertain; in 2008 and 2009 the detectability rate for cobblestone tiger beetles on occupied cobble bars was 0.68 (N=24) and 0.60 (N=45) respectively (*see* Chapter 2 - Results). However, there is good reason to believe that beetle patch occupancy has changed over the years. With summer high-water events and the Genesee River's natural load of silt and sediments, cobble bars change from boulder and cobble deposits to areas supporting increased vegetation growth, especially within Letchworth State Park. Mt. Morris dam, built for flood control in the 1950s, holds back high river flows to allow for a controlled release of water downstream. I found cobble bars with increased vegetation and fewer open areas were less suitable for cobblestone tiger beetles. Forbs, grasses and shrubs have overgrown the cobble bars at the northern end of the park. Three cobble bars where cobblestone tiger beetles had been detected previously were located between the dam and the St. Helena access point, where the gorge opens up and the river widens. These cobble bars had increased silt deposits and had become covered in vegetation. Research on *C. hirticollis* habitat along rivers in California (Knisley and Fenster, 2005) and *C. abdominalis* from the Virginia pine barrens (Knisley and Hill, 1992) described vegetation increases and the loss of open areas as possible reasons for the decline of these tiger beetles. Likewise, highly vegetated cobble bars facilitated by controlled flows appear to be unsuitable habitat for cobblestone tiger beetles.

Human disturbance could also be a cause of local extinctions of cobblestone tiger beetles. Disturbance to habitat by off-road vehicles and heavy foot traffic were reported as major factors in the decline of *C. dorsalis* on Northeastern beaches and of *C. oregona* along an Arizona stream (Knisley and Hill, 1992). The Genesee River within Letchworth State Park has become a favorite destination for river rafters and kayakers. The previously occupied cobble bar at Lee's Landing (LL2) has seen an increase in traffic as buses deposit river tour participants at this access point for river tours. Substrate compaction resulting from this increase in human traffic has possibly removed suitable areas for cobblestone tiger beetle larval burrows.

Cobblestone tiger beetles are ideal candidates to aid in monitoring overall riparian health along the upper Genesee River, and the use of bioindicator species can be helpful in reducing the amount of time and cost required for inventory (Carroll and Pearson, 1998). The beetles, although highly adapted to natural river disturbances such as seasonal flooding and ice scouring, appear to be sensitive to anthropomorphic changes that lead to increased vegetation and the reduction of open areas. Their sessile larvae have a narrower range of microhabitats, being restricted to their burrows, than adults have, and seem to tolerate fewer changes, especially in soil composition, soil moisture and temperatures (Rodriguez *et al.*, 1998).

In order to preserve cobblestone tiger beetles and riparian habitats along the upper Genesee River, habitats should be managed to reduce impacts from recreational activities (canoeing/ kayaking and off-road vehicles) and sand/gravel mining. Monitoring cobble bars for the presence of cobblestone tiger beetles should take place when they are most active - late mornings through mid-afternoons when ambient temperatures are the highest. Presence/absence surveys should continue on presently occupied cobble bars with further surveys made to evaluate cobblestone tiger beetle presence on feeder stream cobble bars and unsurveyed cobble bars and islands in the Genesee River. Future research should include identification of cobblestone tiger beetle larvae, which have not been described (Leonard and Bell, 1999) and the effect of anthropomorphic disturbance on their habitats.

TABLES AND FIGURES

TABLE 1-1. -- Ground cover factors and factor loading generated by Principal Component Analysis for cobblestone tiger beetles (*Cicindela marginipennis*) along the Genesee River, NY in 2009.

	I	II	III
Eigenvalue	2.6	1.3	1.0
Proportion of total variance explained	36.5	18.4	14.9
Cumulative variance explained	36.5	54.9	69.7
Variables			
Boulders	0.7	0.4	0.2
Cobbles	-0.5	-0.8	-0.1
Pebbles	-0.8	-0.2	0.1
Small Grains	-0.1	0.9	0.0
Shrubs	0.1	-0.1	-0.8
Forbs	0.8	-0.2	0.1
Grasses	0.2	0.0	0.6

Note: Only components with eigenvalues > 1.0 are shown.

TABLE 1-2. -- Mark – Recapture activity by sex for cobblestone tiger beetles (*Cicindela marginipennis*) along the Genesee River, NY for 2008 and 2009.

Year	Activity	Male	Female	Unknown	Total
2008	Marked	53	59	2	114
	Recaptured	6	2	-	8
2009	Marked	56	86	3	145
	Recaptured	5	11	-	16
TOTAL	Marked	109	145	5	259
	Recaptured	11	13	-	24

TABLE 1-3. -- 2008 and 2009 Recapture distances and time for individual cobblestone tiger beetles (*Cicindela marginipennis*).

Year	Sex	Location[1]	Distance (m)[2]	Time Between Marking and Recapture (d)
2008	F	P1	123	6
2008	F	R1	112	5
2008	M	P1	34	3
2008	M	P1	113	3
2008	M	R1 – R2	322	24
2008	M	P1	12	2
2008	M	P1	0	2
2008	M	R2	15	5
2009	F	R1	5	23
2009	F	R1	74	23
2009	F	R2 – R1	481	21
2009	M	R1	6	1
2009	M	R1	5	68
2009	M	R1	21	58
2009	M	R1	21	1
2009	F	R1	3	1
2009	F	R1	0	5
2009	F	R1	17	5
2009	F	R1	15	6
2009	F	R0 – R1	366	21
2009	M	R0 – R1	362	13
2009	F	R2	54	2
2009	F	R2 – R1	458	4

[1] – Cobble bar identifier. Two locations (R0 – R1) indicate movement between cobble bars from original capture point to recapture point.

[2] – Distance from original capture point.

TABLE 1-4. -- Cobblestone tiger beetle (*Cicindela marginipennis*) dispersal by distance and days and by year and sex.

									95% Confidence Interval for Mean	
Variable	**Year**	**Sex**	**N**	**Mean[1]**	**SE[1]**	**Minimum**	**Maximum**	**Range**	**Lower Bound**	**Upper Bound**
Distance (m)	2008	Female	2	117.8	5.3	112	123	11	107.3	128.3
		Male	6	82.6	50.6	0	321	321	-16.7	181.8
		Total	8	91.4	37.5	0	322	322	17.8	164.9
	2009	Female	10	147.3	63.9	0	481	481	22.1	272.5
		Male	5	103.0	65.8	6	362	356	-25.9	231.9
		Total	15	132.5	46.8	0	481	481	40.8	224.3
	Total	Female	12	142.4	52.8	0	481	481	38.8	245.9
		Male	11	91.8	38.7	0	362	362	16.0	167.7
		Total	23	118.2	32.9	0	481	481	53.7	182.7
Time between captures (d)	2008	Female	2	5.5	0.5	5	6	1	4.5	6.5
		Male	6	6.7	3.7	2	25	23	-0.6	13.9
		Total	8	6.4	2.7	2	25	23	1.1	11.7
	2009	Female	10	11.1	3.0	1	23	22	5.8	16.4
		Male	5	8.2	3.9	1	21	20	0.6	15.8
		Total	15	10.1	2.3	1	23	22	5.6	14.7
	Total	Female	12	10.2	2.6	1	23	22	5.1	15.2
		Male	11	7.4	2.6	1	25	24	2.4	12.4
		Total	23	8.8	1.8	1	25	24	5.3	12.3

[1] - Means and standard error (SE) for distances (m) between original marking point and recapture point and time (d) between initial capture and recapture by year and sex.

TABLE 1-5. -- COBBLESTONE TIGER BEETLE (*CICINDELA MARGINIPENNIS*) HABITAT CHARACTERISTICS FOR OCCUPIED AND UNOCCUPIED COBBLE BARS ALONG GENESEE RIVER, NY, FOR 2009.
Bold indicates significant P-values ($\alpha = 0.05$).

	All Cobble Bars		**Beetles Present**		**Beetles Absent**		**T-test for Equality of Means**		
Predictor Variable	**Mean[1]**	**SE[1]**	**Mean**	**SE**	**Mean**	**SE**	***t***	**df**	**P**
Area (m^2)	10585	1423	13572	2038	6543	1451	2.62	38	**0.01**
Perimeter to Area Ratio	0.09	0.01	0.06	0.00	0.12	0.02	3.51	18	**0.00**
Elev. Difference (m)	21.7	2.96	28.0	4.43	13.0	2.36	2.99	32	**0.01**
Nearest Cobble Bar (m)	54	6.54	44	7.02	68	11.51	1.91	38	0.06
Boulders (%)	5.5	1.14	3.7	0.30	8.0	2.56	1.69	16	0.11
Cobbles (%)	67.5	2.86	69.3	3.16	65.2	5.39	0.71	38	0.48
Pebbles (%)	34.2	2.35	35.6	2.52	32.4	4.40	0.67	38	0.51
Small Grains (%)	40.5	3.27	39.1	3.90	42.4	5.71	0.50	38	0.62
Forbs (%)	9.4	1.107	9.1	1.05	9.9	2.13	0.34	38	0.74
Grasses (%)	4.5	0.46	4.2	0.41	4.9	0.94	0.70	22	0.49
Shrubs (%)	3.7	0.26	4.1	0.38	3.1	0.30	2.21	38	**0.03**
PCA I[2]	0.00	0.16	-0.10	0.16	0.14	0.32	0.74	38	0.46
PCA II[2]	0.00	0.16	-0.09	0.17	0.13	0.29	0.68	38	0.50
PCA III[2]	0.00	0.16	-0.28	0.18	0.38	0.25	2.14	38	**0.04**

[1] - Habitat predictor variables with mean and standard error (SE) for total (N=40), present (N=23) and absent (N=17) with T-test results for differences between Present and Absence means.

[2] – PCA I - Boulders/Pebbles/Forbs, PCA II - Cobbles/Small grains and PCA III - Shrubs/grasses.

TABLE 1-6. -- HABITAT MODELS FOR COBBLESTONE TIGER BEETLES (*CICINDELA MARGINIPENNIS*) FOR 2009 WITH AICC CORRECTED FOR SMALL SAMPLE SIZES. Models ranked relative to best-fit model, based on ascending ΔAIC_c values.

Model Variables	**Model Summary -2 Log Likelihood**	**AIC_c**	**ΔAIC_c**	**AICc sum of likelihood**	**AIC_c weight**
A,1	37.1	44.4	0.0	1.0	0.8
A,1,2	37.2	48.0	3.6	0.2	0.1
A,1,2,3	36.8	51.1	6.8	0.0	0.0
A,1,2,3,4,5,6,7	26.2	54.5	10.1	0.0	0.0
A,1,2,3,4,5,6,7,8	25.1	57.4	13.0	0.0	0.0
A,1,2,3,4,5,6,7,8,9,10	32.9	63.1	18.7	0.0	0.0
A,Main Effects (1,2,3,4,8,9,11)+	23.5	65.0	20.6	0.0	0.0
A,1,2,3,4,5,6,7,8,9,10,11,12,13,14	20.4	84.0	39.6	0.0	0.0
A,1,2,3,4,5,6,7,8,9,10,1112,13,14,15	20.4	91.1	46.8	0.0	0.0

+ Main effects model uses the covariate and factor main effects but no interaction effects.

Model variables are as follows:

A-Intercept, 1-Perim/area, 2-PCA I, 3-Area, 4-Diff_elev,

5-Diff_elev * Perim/area, 6-Area * Diff_elev, 7-Area * Diff_elev * Perim/area,

8-Nearest_cb, 9-PCA III, 10-PCA I * PCA III, 11-PCA II,

12-PCA I * PCA II, 13-PCA I * PCA II * PCA III,

14-Perim/area * PCA I * PCA II * PCA III, 15-PCA II * PCA I

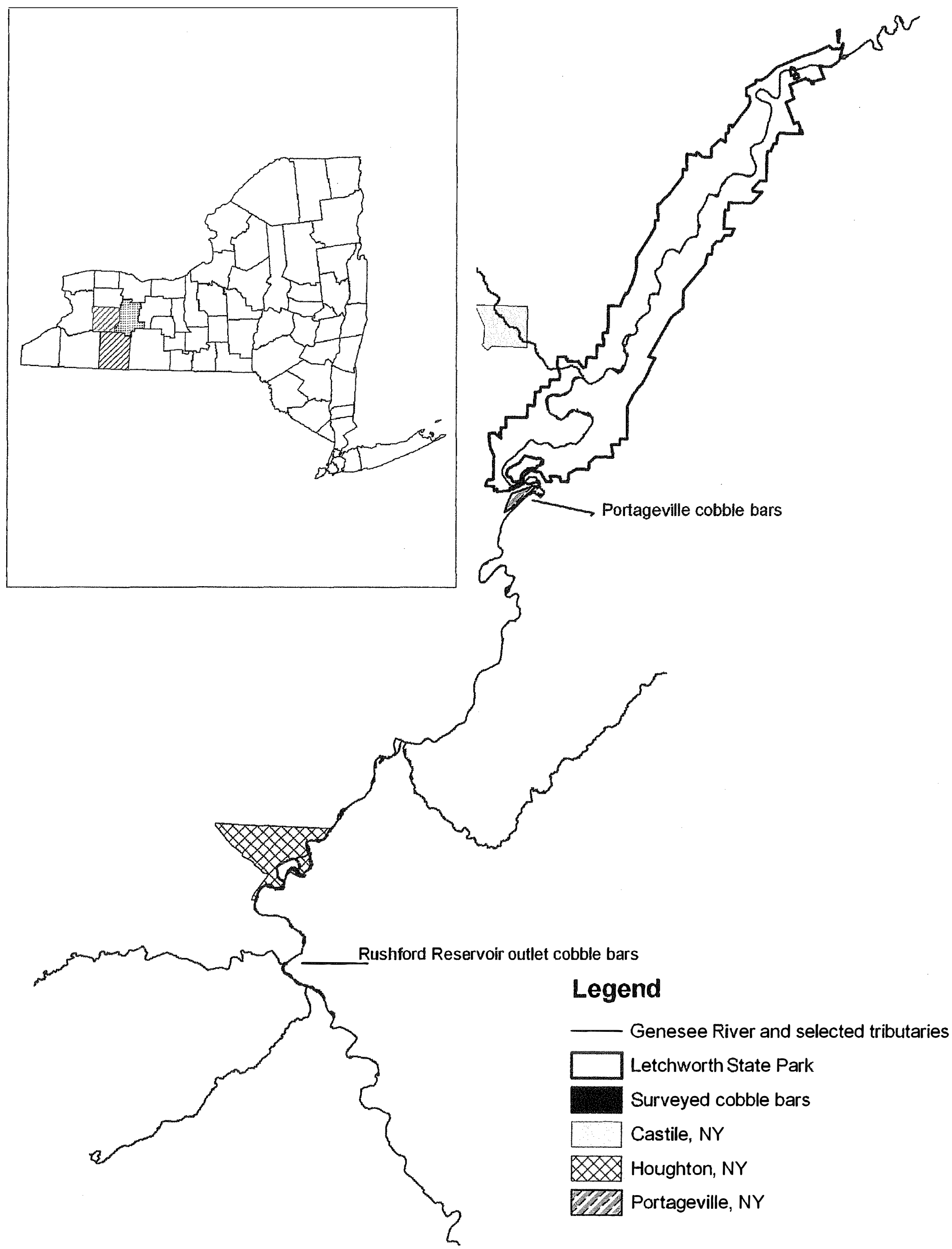

FIGURE 1-1. -- Study area on Genesee River, New York for 2008 and 2009.

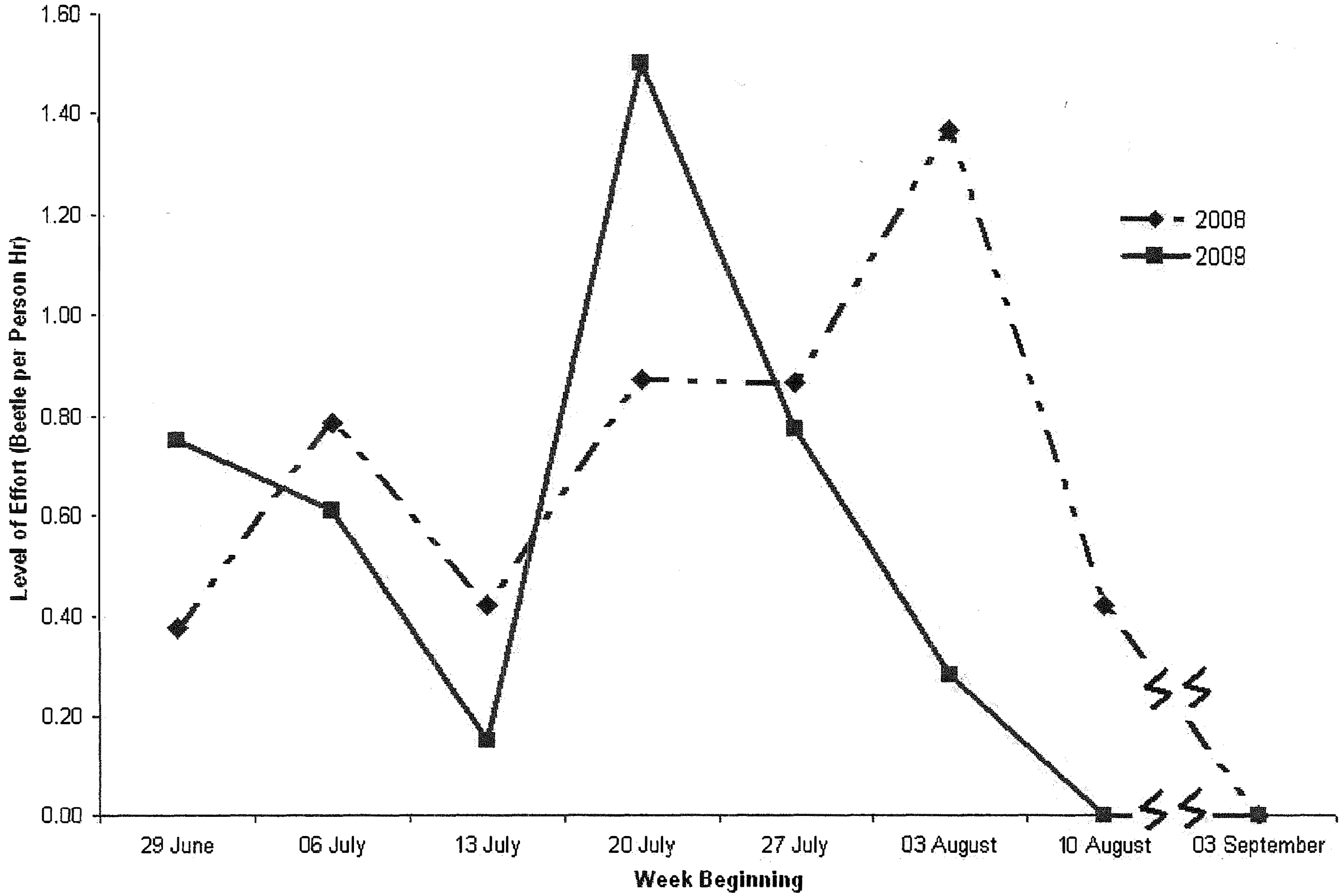

FIGURE 1-2. -- Cobblestone tiger beetles captured per unit effort along the Genesee River, NY. In 2008, the first observation occurred on 2 July and the last on 8 September; in 2009 the first observation occurred on 23 June and the last on 3 September.

CHAPTER 2 – DETECTABILITY AND MONITORING RARE SPECIES: A CASE STUDY OF THE COBBLESTONE TIGER BEETLE (*CICINDELA MARGINIPENNIS* DEJEAN)

INTRODUCTION

Many rare species occur in biological communities and may be important in maintaining stable, healthy and functional ecosystems (McCreadie and Adler, 2008). Knowledge of rare organisms and their associations with habitat structure is important to understanding population viability and persistence (Edwards *et al.*, 2004). Given that the goal of many conservation plans is to protect rare organisms, effective management needs to be built on an adaptive framework that recognizes the uncertainty of natural systems and uses new information to improve future actions (Thompson, 2004). New information comes from monitoring and it is usually done by collecting data on spatial distribution or trends in abundance or density.

However, interpreting monitoring data on distribution or population trends may be difficult unless detection probability is accounted for. Detection probability, the probability of correctly identifying the presence of an individual or species, may be affected by observers, environmental conditions, the time of day and time of year, size and coloring of the animal, and temporal and spatial distribution (Bailey *et al.*, 2004; Thompson, 2004; Bulluck *et al.*, 2006). Interpretation of detection probability also is affected by monitoring goals. The goal of detecting an organism at a study site (site-level detection) may have different implications than the goal of detecting an individual within a known population (individual-level). In both cases, imperfect detection can be an important problem, as not all individuals are likely to be recorded (Field *et al.*, 2005).

Monitoring for rare or elusive species may interact with issues of detectability further to complicate monitoring surveys. Rare species may be simply defined as having low abundance and/or restricted geographical distribution (Primack, 2006), whereas an elusive species, by one definition, has low detection probabilities (Thompson, 2004). In some instances, rarity may result from a lack of knowledge about a species and inadequate sampling (McDonald, 2004). For example, several well-known tiger beetles may be considered rare because of their low abundance and limited geographical distribution. In addition to being rare, little is known about cobblestone tiger beetles (*Cicindela marginipennis* Dejean).

Many tiger beetle species are sensitive to habitat changes and several species of riparian tiger beetles have declined in abundance and distribution because of anthropogenic changes in their habitats. These include *Cicindela columbica* Hatch, *C. dorsalis dorsalis* Say, *C. gabbii* Horn, *C. puritana* Horn and several subspecies of *C. hirticollis* (Brust *et al.*, 2005; Cornelisse and Hafernik, 2009). In New York State, eight species of tiger beetles, including the cobblestone tiger beetle, have been identified as "Species of Greatest Conservation Need" (New York State Department of Environmental Conservation, 2006) because they are scarce, found only in small, localized areas, and threats to their populations have been identified (Graves and Brzoska, 1991; Novak, 2006).

Tiger beetles occur in a broad range of habitats, including exposed soils near stream and pond edges, seashores, dunes and open patches in grasslands (Pearson *et al.*, 2006). Although adults are very mobile, larval stages for most tiger beetle species are sand / soil dwelling, and sedentary (Nothnagle, 1995; Hoback *et al.*, 2000). Riparian tiger beetle habitats are prone to seasonal flooding (Pyzikiewicz, 2005). These floods help to preserve heterogeneity within riparian systems by disturbing successional patterns and by removing vegetation. Tiger beetles using these areas have life cycles adapted to seasonal flooding (Pyzikiewicz, 2005). However, changes to streams and rivers (i.e., channelization, damming, agricultural use) designed to reduce the impact of flooding on human activities have had negative effects on tiger beetles and other organisms like fish, amphibians, odonates and freshwater mussels (Naiman and Decamps, 1997; SaintOurs, 2002; Bailey *et al.*, 2004; Brust *et al.*, 2005; Bates *et al.*, 2007).

While monitoring is recognized as important for understanding the long-term viability of tiger beetles (New York Natural Heritage Program, 2010), few studies have examined the potential for imperfect detectability to compromise estimates of occupancy and population size in these insects. The objective of my study was to determine the detectability and occupancy of cobblestone tiger beetles in riparian habitat along the Genesee River, NY and to develop guidelines for monitoring the beetles. I also considered behavioral issues related to monitoring rare and elusive species.

METHODS

STUDY SPECIES

Cobblestone tiger beetles are rapacious predators that live on cobble bars. They are a dull olive color and are approximately 11-14 mm in length with a white band around the outside edge of the elytra, which have no other white maculations. They are metallic blue-green underneath the elytra and have a red-orange abdomen (Graves and Brzoska, 1991; Leonard and Bell, 1999; Pearson *et al.*, 2006). Although adults are very mobile, larval stages for most tiger beetle species are sand/soil dwelling and sedentary (Nothnagle, 1995; Hoback *et al.*, 2000).

Cobblestone tiger beetles are endemic to North America and are found in isolated areas from New Brunswick, Canada south through Northeastern United States extending to Ohio and Indiana. Populations have also been found in South Carolina, Alabama and historically in Mississippi (NatureServe, 2009). Cobblestone tiger beetles are classified as a "critically imperiled" species in Alabama, New Jersey, New York, Pennsylvania and Vermont because of their small numbers and vulnerable habitat. They are on the endangered species list in New Hampshire (Pyzikiewicz, 2005) and are assumed to be extirpated in Mississippi (NatureServe, 2009). In New York, cobblestone tiger beetles occur along the Genesee River in the Lake Ontario watershed and in Cattaraugus Creek in the Lake Erie watershed (NatureServe, 2009). The populations of cobblestone tiger beetles on the Delaware River in southeastern New York and in the New York City vicinity are considered extirpated (New York Natural Heritage Program, 2010). The International Union for Conservation of Nature (IUCN) lists *C. marginipennis* as "near threatened" (Gimenez Dixon, 1996).

Cobblestone tiger beetles are restricted to riparian cobble bars and islands where their cryptic coloring makes them hard to detect among the cobbles and sparse vegetation (Dunn and Wilson, 1979; Graves and Brzoska, 1991). These isolated and unique habitats also influence cobblestone tiger beetle detectability because of their inaccessibility due to geographic location or high waters from seasonal storm events.

STUDY SITE

The Genesee River (Fig. 1-1) originates in Ulysses Township, Potter County, PA at an elevation of 683 m. It flows north for 241 km into Lake Ontario at Rochester, NY. South of Letchworth State Park, the river is a 2^{nd}- to 3^{rd}-order stream that meanders through a rural and agricultural landscape past a few towns and villages. The river's flow is fast in spring, with annual spring flooding. Mean peak water-flow measurement for 2000 - 2007 at Portageville, NY, within the study area, was 43 m^3/sec. The river is generally wide and shallow as it winds back and forth across a floodplain approximately 1.6 km wide.

North of Portageville, NY, the Genesee River enters Letchworth State Park. There are three major falls at the south end of the park and the Mt. Morris Dam, a flood control dam completed in 1954, is located at the north end of the park. The gorge cut by the river has rock walls rising up to 170 m from the river.

Large cobble bars are deposited at bends in the river and as islands. These areas are scoured by spring flooding and their locations may shift in time. The cobble bars typically consist of boulders, cobbles, pebbles and sand; they have wide areas with and without vegetation (Novak, 2006). Soil types adjacent to the river include alluvial deposits, loam, silt loam, gravelly silt loam, loamy-skeletal (variety of components), gravelly loam, silty clay loam, fine sandy loam and bedrock (USDA - Natural Resources Conservation Service, 2009). The Genesee River carries high, naturally occurring silt and sediment load as the soils throughout the upper Genesee River valley are highly erodible, and there are areas with steep stream banks. Extensive agricultural use (the primary non-point source of pollution) and land development contribute to silt and sediment loading. Point sources of pollution are inadequately maintained or failing on-site septic systems, salt storage and salt application for deicing (Bureau of Watershed Assessment and Research-Division of Water, 2003). Channelization for flood control and irrigation within some of the Genesee River tributaries and the lack of riparian vegetation add to water quality issues (Bureau of Watershed Assessment and Research-Division of Water, 2003).

The New York Natural Heritage Program (NYNHP) surveyed portions of the Genesee River from Belfast, NY to Letchworth State Park, Castile, NY for cobblestone tiger beetles between 2000 and 2002 as part of a biodiversity inventory of Letchworth State Park and subsequent follow-up rare animal surveys south of the park (New York Natural Heritage Program, 2010). There were seventeen occupied cobble bars identified during these surveys.

DETECTABILITY AND OCCUPANCY SURVEYS

In 2008 and 2009, I made repeated visits to a series of cobble bars along the Genesee River to determine patch occupancy and the probability of detecting cobblestone tiger beetles on an occupied cobble bar (site-level detectability). Also, in 2009 I conducted a series of transect surveys at a single cobble bar where cobblestone tiger beetles were common, in order to determine probability of detecting an individual tiger beetle in a local population (individual-level detectability).

Occupancy models are based upon repeated searches at each study site for the presence or absence of the study organism (Bailey and Adams, 2005). In 2008, I searched 24 cobble bars for cobblestone tiger beetles between 2 July and 7 September, while in 2009 I surveyed 45 cobble bars between 23 June and 7 September. Cobble bars visited were located between Oramel and Fillmore, NY, and within Letchworth State Park, Castile, NY (Fig. 1-1). This area was selected because cobblestone tiger beetles had been identified on some of the cobble bars in surveys done by the NYNHP between 2000 and 2002 (New York Natural Heritage Program, 2010). I divided the Oramel-Fillmore section of the Genesee River into three smaller sections (Oramel – Caneadea, Caneadea – Houghton and Houghton – Fillmore) based on river access points and the amount of time required for travel between the cobble bars. Each section contained at least nine accessible cobble bars. The stretches of cobble bars within Letchworth State Park were between the Lee's Landing and St. Helena river access points. I made visits to surveyed cobble bars by kayak. I began each trip at approximately 10:00 and completed it by 17:00. I walked each cobble bar until a cobblestone tiger beetle was sighted or until the entire cobble bar was surveyed without encountering a beetle; I then moved on to the next cobble bar. While searching for cobblestone tiger beetles, I also noted the presence of Appalachian tiger beetles (*C. ancocisconensis*) and bronzed tiger beetles (*C. repanda*).

Between 1 July and 19 August 2009, I used 100-m transects to study the individual-level detectability of cobblestone and bronzed tiger beetles (Appendix 4). The transects were located on the largest of the Portageville, NY cobble bars. I chose this cobble bar because beetles were common there, and it was large enough (36,548 m^2) to contain several transects. I determined transect locations by randomly choosing a point from 2008 mark-recapture points; if transects intersected, a new starting point was chosen. One transect ran parallel to the Genesee River, maintaining a 2 m distance from the water's edge throughout the summer. A second transect was placed farther inland near the interior edge of the cobble bar closer to the inland vegetation. The third transect was located along the old riverbed, whereas the fourth transect ran diagonally from the interior edge toward the river's edge near the southern end of the cobble bar. A co-worker and I walked the four transects two to three times per week; all observations were made on warm and sunny days between 10:00 and 16:00. Training for both observers consisted of two hours spent walking a test transect to identify *Cicindela* spp. in mid-June before cobblestone tiger beetle emergence. On sighting a tiger beetle, I placed a colored wire flag marked with species at the initial beetle location and another flag at the spotter's location. Close-focus binoculars were used as necessary to distinguish tiger beetle species. I measured the distance from the beetle's location to the observer's position along the transect using a tape, and took ground temperatures using a Physitemp BAT-12 Microprobe Thermometer or a Radio Shack Indoor/Outdoor Thermometer with Hygrometer (Model: 63-1032). Angles between the spotter's location on the transect's centerline to the beetle's location were determined with a compass rose.

HABITAT SURVEYS

I completed a systematic survey of ground cover on 40 cobble bars in 2009. Ground cover (gravel, rocks and vegetation) percentages were estimated within 1-m^2 sample plots randomly placed along 100 m transect lines located at approximately 50-m intervals. Placement of the transect lines was dependent on the size and shape of the cobble bar. Vegetation was classified as forbs, grasses, or shrubs, and substrate was classified as boulders (> 25 cm), cobbles (6 – 25 cm), pebbles (0.4 – 6 cm), or small grains (< 0.4 cm). Ground cover was measured between mid- July and mid- August. I estimated substrate and vegetation cover using Braun-Blanquet coverage classes: (1) 0-5%, (2) 6-25%, (3) 26-50%, (4) 51-75% and (5) 76-100% (Elzinga *et al.* 1998).

To determine the number of plots required to sample vegetation and substrate adequately, I selected a middle-sized (median) cobble bar from the ones visited in 2008 for presampling. During the presample I placed 1-m^2 random sample plots along random transects; ground cover data were analyzed using a sequential sampling graph, with running mean and standard deviation. At the point where the curves began to smooth out, I had a representative number of sample plots (Elzinga *et al.*, 1998). A ratio of plots 0.006 plots/100 m^2 of cobbles was used to determine the number of sample plots on each cobble bar.

STATISTICAL ANALYSIS

I used data from occupancy surveys in 2008 and 2009 to model site-level detectability on cobble bars using the software program PRESENCE (Hagler and Jackson, 2001; Bailey and Adams, 2005; Hines, 2006). The program PRESENCE calculates two basic statistics: (1) the probability that a site is occupied by the species (PSI), and (2) the probability of detecting the species if it is present at the site (p_j) (Mackenzie *et al.*, 2005). I ran models for each season (2008 and 2009), and for the 2008 and 2009 seasons combined (Donovan and Hines, 2007). The multi-season model included estimated probabilities that an occupied site would go extinct (extinction) and that an unoccupied site would be colonized (colonization). I also ran models for 2009 with site-specific covariates, which included percent of cover for boulders, cobbles, pebbles, small grains, shrubs, forbs and grasses. I converted ground cover variables from Braun-Blanquet coverage classes to median percent value for each class. To reduce multicollinearity, I used Pearson's correlation test to evaluate correlations between habitat variables. Principal Component Analysis (PCA) was used to combine boulders, cobbles, pebbles, small grains, forbs, grasses and shrubs into three components with eigenvalues greater than 1.0 (Table 2-1) (SPSS, 2008). The three components accounted for 70% of the total variance in the data set. I interpreted the components by examining the loadings of the original variables. Cobble bars with many boulders and forbs and few pebbles scored high on the first axis (I), cobble bars with many small grains and few cobbles scored high on the second axis (II) and cobble bars with few shrubs and some grasses scored high on the third axis (III).

I compared models for site-level detectability using a process described by Gjerdrum *et al.* (2005). Akaike's Information Criterion, corrected for small sample sizes (AIC_c), was used to determine the fitness of each model (Burnham and Anderson, 2002) and then the models were ranked according to ΔAIC_c. I also calculated AIC_c weights (w_i) for each model, which assisted in assessing the evidence favoring a model and I focused my analysis on models with ΔAIC_c values < 2.0 (Burnham and Anderson, 2002). The 2009 models included the same models used for 2008, and models with habitat variables that included perimeter-to-area ratio, area, PCA components (I, II and III), elevational differences and nearest cobble bar distance.

I calculated individual-level detection probability and population density of cobblestone and bronzed tiger beetles along permanent transects using the software package DISTANCE 5.0 (Thomas *et al.*, 2009). I applied the half-normalized/cosine model to the complete dataset with and without covariates (species, observer and ground temperature). AIC_c values were used to determine the fit of each model (Burnham and Anderson, 2002) and then the models were ranked according to ΔAIC_c values. I used a t-test of means to determine differences in means for species and for observer. Although sample sizes of cobblestone tiger beetles per observer were small (N=25 and 45), the total sample sizes for cobblestone and bronzed tiger beetles (N=149) were adequate for analysis with DISTANCE (Buckland *et al.*, 2001).

In order to assist managers in designing monitoring programs for cobblestone tiger beetle populations, I estimated the number of surveys needed to detect cobblestone tiger beetles on a targeted proportion of cobble bars where they actually occurred. To do this, I used data on site-level detection probabilities and the proportion of occupied cobble bars from my 2009 surveys, and the formula $\Sigma(dp_i n)$ where dp = the probability of detection, i =

the i^{th} survey and n = the number of cobble bars where cobblestone tiger beetles occur, but have not yet been detected at the start of the i^{th} survey.

RESULTS

OCCUPANCY SURVEY

The site-level detection probability for cobblestone tiger beetles (Table 2-2) in 2008 was 0.68 with 30% of the surveyed cobble bars occupied. The site-level detection probability for 2009 was 0.60, but 63% of the surveyed cobble bars were occupied. For 2008 and 2009 combined, site-level detectability was 0.67 with cobblestone tiger beetles occupying 51% of cobble bars surveyed in both years; 6.7% of the occupied sites in 2008 went extinct; and in 2009, 6.5% of the unoccupied sites were colonized (Table 2-2).

For both 2008 and 2009, the best-fit occupancy model was the predefined "1 group, constant p" model in the program PRESENCE, where all sites were detected with a single detection probability (Table 2-3). The implications of this model are important because the model suggests that detection probability did not change over the course of visits and was not affected by habitat variables.

Given a site-level detection probability of 0.60 and the fact that cobblestone tiger beetles were detected on 0.63 of the 45 cobble bars surveyed in 2009, and the formula $\Sigma(dp_i n)$ (*see* Chapter 2 - Methods), I estimate that two surveys would be needed to detect cobblestone tiger beetles on at least 0.80 of the cobble bars where they actually occurred (Table 2-4). Three and four visits, respectively, would be needed to detect cobblestone tiger beetles on at least 0.90 and 0.95 of the cobble bars where they actually occurred (Table 2-4).

TRANSECT SURVEYS

I observed cobblestone tiger beetles at significantly higher mean ground temperatures than bronzed tiger beetles (t=6.69, df=147, P=0.00) (Table 2-5). There was no difference between observers in mean distance or ground temperature at which beetles were sighted (Table 2-5). Ground temperatures from transect surveys ranged from 21.5 C to 48.8 C with a mean temperature of 32.2 C for transect surveys. Although not recorded for transect surveys, ambient temperatures collected at a nearby cobble bar ranged from 18.8 C to 30.4 C.

The best-fit individual-level detectability model for bronzed tiger beetles included ground temperature as a covariate, which may indicate that bronzed tiger beetles were sensitive to temperatures. The best-fit model for cobblestone tiger beetles had no covariates (Table 2-6). Although cobblestone tiger beetles were observed at significantly higher mean ground temperatures than bronzed tiger beetles, ground temperatures did not influence their detection probability. The individual-level detectability for bronzed tiger beetles was 0.82, whereas the detectability for cobblestone tiger beetles, was 0.50; there was little difference among models in detection probability for either bronzed or cobblestone tiger beetles. Program DISTANCE calculated an estimated density of 0.2 cobblestone tiger beetles per 100 m^2.

DISCUSSION

Monitoring is the repeated measurement of environmental parameters and is a key component of adaptive management (Nichols and Williams, 2006). Effective monitoring asks clear questions and produces high-quality data (Field *et al.*, 2005; Lovett *et al.*, 2007) critical to understanding organisms and habitats in need of conservation. When there is limited knowledge, monitoring produces estimates of the ecological status and environmental attributes of the study species and its habitat, which can be compared to model predictions. The comparison of monitoring data to models may help separate hypotheses about ecological variables to create and guide conservation plans (Nichols and Williams, 2006).

The objective of this study was to determine the detectability of cobblestone tiger beetles along the upper Genesee River, NY and to develop guidelines for monitoring the beetles. As monitoring estimates should include detection probabilities (Thompson, 2004), I examined two types of detectability. The first was site-level detectability: the probability of detecting a single cobblestone tiger beetle on an occupied cobble bar. This was calculated by the program PRESENCE and was similar to the "species detectability" described by de Solla et al. (2005); it took into account issues such as not detecting a cobblestone tiger beetle on a cobble bar when it is present. The second was individual-level detectability: the probability of detecting an individual cobblestone tiger beetle in a population on a single cobble bar. Individual-level detectability is concerned with population issues of abundance and density. This was determined by repeatedly walking transects on a single cobble bar, and was calculated by the program DISTANCE. Individual-level detectability was similar to "animal detectability" described by Beavers and Ramsey (1998).

Numerous factors may influence the detection of animals such as the abilities of the observer, size and coloring of the animal (Beavers and Ramsey, 1998), environmental conditions, time of day and time of year. By conducting surveys only during periods of good weather, the species peak active period and 10:00 – 17:00, I attempted to maximize detection probabilities. In terms of size, once spotted, cobblestone tiger beetles were easily identified, as their reddish abdomens were visible when in flight, and their long stilt legs gave an identifiable profile when resting or moving across the substrate. During surveys, the white maculation on the external edge of the elytra was their key identifying characteristic. Cobblestone tiger beetles were more difficult to detect when they were motionless in areas of mixed and loosely packed cobbles and pebbles, nevertheless; after two to three encounters, most observers readily identified the beetles.

Site occupancy is of interest to wildlife managers assessing the impacts of management actions and reliable inferences from occupancy surveys require repeated surveys of sample sites to overcome non-detection errors (Gu and Swihart, 2004; Bailey *et al.*, 2007). The results of my occupancy surveys showed a narrow range of site-level detection probabilities (0.60 – 0.68) for cobblestone tiger beetles in 2008 and 2009, although the number of sites surveyed and the number of visits per cobble bar varied between years. In addition, an evaluation of a smaller subset of cobble bars surveyed with the same level of effort during both years showed that site-level detectability and occupancy were within the range for single-year results. I also determined that three or four visits (Table 2-4) per site should detect cobblestone tiger beetles on over 90% of the cobble bars where they occurred. The results from the combined 2008-2009 survey also showed an estimated equilibrium in extinction and colonization of local populations on cobble bars. However, this statistical estimate of extinction and colonization may not show real metapopulation events, but may be the result of cobblestone tiger beetle life history; larvae may be present even when adults have not been detected and detected adults may be transitory given their possible dispersal distances (> 400 m) (*see* Chapter 1).

My results for individual-level detectability show that there was a lower probability of seeing an individual cobblestone tiger beetle than detecting the co-occurring and more common bronzed tiger beetle. The higher detectability for bronzed tiger beetles may be due to the gregarious behavior of the species and its tendency to occur on sand patches, where they were easier to spot. Cobblestone tiger beetles, with their cryptic coloring, were more difficult to spot among cobbles. The individual-level model for bronzed tiger beetle with ground temperature as a covariate had the best fit, whereas the best-fit model for cobblestone tiger beetles had no covariate. However, cobblestone tiger beetle detection probabilities were the same for both models (no covariate and with ground temperature). The homogeneity of detectability among individual-level detection probability models for cobblestone tiger beetles may be because I limited my surveys to warm sunny days when cobblestone tiger beetles were most active.

However, I did find a significant difference in the mean ground temperatures at which bronzed and cobblestone tiger beetles were observed, with cobblestone tiger beetles being occurring in areas with higher ground temperatures. The difference in ground temperature observations for cobblestone tiger beetles and bronzed tiger beetles might be accounted for by the substrate where they were observed and the radiation absorption or reflection rates of the sand, pebbles and cobbles. Bronzed tiger beetles were most often sighted on light sandy areas or in damp areas near the river's edge, where evaporation would lower temperatures, whereas cobblestone tiger beetles were often seen in cobbled areas with darker colored substrate, where there was less moisture for evaporation. Tiger beetle thermal ecology may also influence the differences in ground temperatures where they were observed. Bronzed tiger beetles are a spring/fall species, meaning they emerge in early spring to mate and are less frequently observed during the mid-summer months (Graves and Brzoska, 1991; Pearson and Vogler, 2001; Allen and Acciavatti, 2002). On the other hand, cobblestone tiger beetles emerge and are active during the summer months (Gordon, 1939; Nothnagle, 1995). The maximum ground temperature recorded (46.7 C) in my study for active cobblestone tiger beetles was higher than the maximum ground temperatures recorded for active northern dune tiger beetles (*C. hybrida*) in Denmark (Dreisig, 1981).

I analyzed detection probabilities for cobblestone tiger beetles from two types of surveys – individual-level (distance transects) and site-level (occupancy) – and arrived at different detection probabilities. I found a higher rate of detection at the site-level (0.60 – 0.68) than at the individual-level (0.50). Although in both types of surveys observers searched for individual cobblestone tiger beetles, the differences in detection probability may be related to the amount of area to be searched. With site-level detections, the observers were not limited to walking along a transect and instead may take full advantage of the beetle movements in response to the observer efforts to observe the beetle and the entire area/cobble bar may be searched until one cobblestone tiger beetle was detected. With individual-level detectability, as calculated by DISTANCE, there are more assumptions in observations: all study organisms on the line are detected, the study organism does not move and distance measurements are exact (Thomas *et al.*, 2009). Site-level detections would be best used in identifying a species spatial range, whereas if used for estimate of population abundance and density, non-detection may increase the possibility of errors (Gu and Swihart, 2004). Individual-level detections over a wide area can be expensive, but on a small scale an efficient method for determining local population abundance and density (Joseph *et al.*, 2006). It is important that these two distinct detection probabilities are not confused, but I have not seen this issue discussed previously.

MONITORING RECOMMENDATIONS

Monitoring by itself is not conservation. However, it should play an important role in determining the success of any adaptive management plan. Monitoring surveys can warn managers of changes to surveyed habitat long before the changes affect the other inhabitants of the surveyed areas, and the results of these small-scaled surveys may have ramifications for other areas (Bhargav *et al.*, 2009).

My study has established baseline values useful in developing a management plan and monitoring for cobblestone tiger beetles along the Genesee River in western New York. Based on the results from this study, I recommend: (1) continuing occupancy surveys with at least three visits to each cobble bar as long as the site-level detection probability is greater than 0.5 (MacKenzie, 2005; Mackenzie and Royle, 2005), in order to detect cobblestone tiger beetles on at least 90% of occupied cobble bars; (2) conducting occupancy surveys when cobblestone tiger beetles are the most active – in mid-July and mid-August (*see* Chapter 1); (3) conducting surveys between 10:00 and 17:00 on warm sunny days when ambient and ground temperature are at their highest, preferably when ambient temperatures are above 18.8 C; and (4) conducting surveys at three- to five-year intervals depending on the study objective – shorter times for better understanding of metapopulation dynamics or longer intervals for simply determining continued occupancy. Occupancy surveys should focus on cobble bars known to have supported cobblestone tiger beetles in the past (*see* Chapter 1), as well as other cobble bars with habitat characteristics favorable to cobblestone tiger beetles. These characteristics include relatively large cobble bars with greater interior area and elevational relief. Occupied cobble bars had few boulders and shrubs; cobblestone tiger beetles were detected in areas of mixed-size cobbles and patchy vegetation, not just in areas of tightly packed cobbles; they also occurred close to the river's edge in areas of moist or wet sand and silt. Cobblestone tiger beetles were detected throughout occupied cobble bars not just restricted to the upstream end of cobble islands or sandy beaches (*see* Chapter 1). Occupancy surveys should also be conducted after major flood events to evaluate the extent of the disturbance to occupied cobble bars and look for the formation of new cobble bars suitable for cobblestone tiger beetle occupancy. One last recommendation is to not suppress natural disturbances. Riparian tiger beetles are adapted to spring floods and ice scouring. Prevention of these and other naturally occurring events may reduce the open cobble bar areas occupied by cobblestone tiger beetles. Examples of threats that the suppression of naturally occurring disturbances include the wildfire suppression that prevents the creation of natural openings occupied by the pine barrens tiger beetle (*C. patruela*) (Schlesinger, 2010), and Furbish lousewort (*Pedicularis furbishiae*), which well adapted to natural riparian disturbances, but it is threatened by anthropogenic disturbances to its environment (U.S. Fish and Wildlife Service, 2005).

In conclusion, understanding individual-level and site-level detection probability is important in adaptive management and failure to account for detection probabilities may lead to biased or misleading estimates (Thompson, 2004). Changes in individual-level detections influence inferences about population abundance and density, whereas site-level detection influence conclusions about spatial distribution and metapopulation structure. In this study, the best-fit model for site-level detectability determined that detection probability was the same over time; in reality, however, detection probability may vary due to observers, weather conditions and time of day. Monitoring plans should be designed to reduce sources of variation in detection (Mackenzie and Royle, 2005). With design-related variations accounted for, changes in detection probabilities may give better insight to colonization and extinction of local populations.

TABLES AND FIGURES

TABLE 2-1. -- GROUND COVER FACTORS AND FACTOR LOADINGS GENERATED BY PRINCIPAL COMPONENT ANALYSIS FOR COBBLESTONE TIGER BEETLE (*CICINDELA MARGINIPENNIS*) HABITAT VARIABLES ALONG THE GENESEE RIVER, NY IN 2009.

	I	II	III
Eigenvalues	2.6	1.3	1.0
Proportion of total variance explained	36.5	18.4	14.9
Cumulative variance explained	36.5	54.9	69.7
Variable			
Boulders	0.7	0.4	0.2
Cobbles	-0.5	-0.8	-0.1
Pebbles	-0.8	-0.2	0.1
Small Grains	-0.1	0.9	0.0
Shrubs	0.1	-0.1	-0.8
Forbs	0.8	-0.2	0.1
Grasses	0.2	0.0	0.6

Note: Only components with eigenvalues > 1.0 are shown.

TABLE 2-2. -- SITE-LEVEL DETECTION PROBABILITIES (PROGRAM PRESENCE) OF COBBLESTONE TIGER BEETLES (*CICINDELA MARGINIPENNIS*) FOR 2008 AND 2009 ALONG THE GENESEE RIVER, NY.

Year	N[1]	Detection Probability (SE)	PSI[3] (SE)	Colonization (SE)	Extinction (SE)
2008	24	0.68 (0.06)	0.30 (0.11)	n/a	n/a
2009	45	0.60 (0.05)	0.63 (0.08)	n/a	n/a
2008-2009[2]	17	0.67 (0.04)	0.51 (0.12)	0.067 (0.10)	0.065 (0.10)

[1] – N is the number of cobble bars included in the analysis.
[2] – 2008-2009 cobble bars numbers were limited to cobble bars that were surveyed during both summers.
[3] – PSI is the probability that a site is occupied by the species.

TABLE 2-3. -- PROGRAM PRESENCE MODELS ESTIMATING SITE-LEVEL OCCUPANCY PROBABILITY OF COBBLESTONE TIGER BEETLES (*CICINDELA MARGINIPENNIS*) ALONG THE UPPER GENESEE RIVER, NEW YORK. **Bold indicates best-fit model. * - Over time model had detection probability calculated for each visit.**

Year	Model	K[1]	N[2]	-2*Log Likelihood	AIC_c	ΔAIC_c[3]	AIC_c W_i[4]	AIC_c Sum of Likelihood
2008	**p()**	2	24	98.2	**102.8**	**0.0**	1.0	1.0
	p(over time*)	22	24	69.7	1125.7	1022.9	0.0	0.0
2009	**p()**	2	45	225.8	**230.1**	**0.0**	1.0	1.0
	p(over time)	21	45	195.6	277.8	47.6	0.0	0.0
	p(perimeter to area)	3	45	303.3	309.9	79.7	0.0	0.0
	p(area, perimeter to area)	4	45	302.7	311.6	81.5	0.0	0.0
	p(PCA III)	3	45	309.2	315.8	85.6	0.0	0.0
	p(PCA II)	3	45	313.4	320.0	89.9	0.0	0.0
	p(PCA I)	3	45	313.5	320.0	89.9	0.0	0.0
	p(all covariates[5])	10	45	293.8	320.3	90.1	0.0	0.0
	p(area)	3	45	317.3	323.9	93.7	0.0	0.0
2008-2009	psi(),gamma(),p()[6]	3	17	203.5	**211.3**	**0.0**	0.7	1.0
	psi,gamma(),eps(),p()[7]	4	17	201.8	213.1	1.8	0.3	0.4
	psi(.),gam(.),eps=1-gam,p()[8]	3	17	212.3	220.1	8.8	0.0	0.0

[1] – K = number of parameters in model.
[2] – N = sample size.
[3] – ΔAIC_c = change in AIC_c values (from smallest value).
[4] – AIC_c W_i = model weight.
[5] – All covariates include area (m^2), perimeter to area ratio, elevational difference (m), nearest cobble bar (m) and PCA components (I, II, and III).
[6] – Model psi(),gamma(),p() is PRESENCE multi-season default model (initial occurrence, colonization and detection).
[7] - Model psi,gamma(),eps(),p() is PRESENCE multi-season default model (initial occurrence, colonization, extinction and detection).
[8] – Model psi(.),gam(.),eps=1-gam,p() is PRESENCE multi-season default model (initial occurrence, colonization, extinction as the reciprocal of colonization and detection).

TABLE 2-4. -- ESTIMATES OF THE NUMBER OF SURVEYS REQUIRED TO DETECT COBBLESTONE TIGER BEETLE (*CICINDELA MARGINIPENNIS*) ON A GIVEN PROPORTION OF THE COBBLE BARS WHERE THEY OCCUR, BASED ON 2009 DATA.
Bold indicates number visits to achieve finding cobblestone tiger beetles at the indicated goal.

N	PSI[1]	PSI of N[2]	Goal[3]	# of Cobble Bars at Goal	Site-level Detection Probability[4]	Visits to Cobble Bars: 1[5]	2	1 + 2	3	1+2+3	4	1+2+3+4	Predicted Proportion of Cobble Bars Occupied[6]
45	0.63	28.35	0.80	**22.7**	0.6	17.0	6.8	**23.8**					**0.84**
45	0.63	28.35	0.90	**25.5**	0.6	17.0	6.8	23.8	2.7	**26.5**			**0.93**
45	0.63	28.35	0.95	**26.9**	0.6	17.0	6.8	23.8	2.7	26.5	1.1	**27.6**	**0.97**

1 – PSI is the probability that cobblestone tiger beetles occupy a site.
2 – PSI of N is the number of cobble bars occupied relative to PSI (N * PSI).
3 – Goal is detecting cobblestone tiger beetles on proportion of cobble bars where they actually occur.
4 – Site-level detectability from program PRESENCE (Table 2).
5 – Visit is proportion of PSI of N times Goal.
6 – Predicted proportion of total occupied cobble bars where cobblestone tiger beetles were detected given the number of visits at determined number of visits (Visits to cobble bar / PSI of N).

TABLE 2-5 -- MEANS AND T-TEST RESULTS FOR DISTANCE (CM) AND GROUND TEMPERATURES (C) FOR TIGER BEETLE BY SPECIES (*CICINDELA MARGINIPENNIS* AND *C. REPANDA*) AND BY OBSERVER FROM TRANSECT SURVEYS AT PORTAGEVILLE, NY FROM 9 JULY – 22 AUGUST 2009. **Bold** = significant p-value < 0.05.

	Species				
	Cobblestone tiger beetles (*C. marginipennis*)(N=70)	Bronzed tiger beetles (*C. repanda*)(N=78)	*t*	df	P
Distance from Observer (cm)[1]	329.7 (15.4)	317.8 (11.9)	0.55	146	0.59
Tg at sighting (C)[2]	34.3 (0.5)	30.0 (0.5)	**6.69**	**147**	**0.00**
	Observer				
	cb (N=42)	rmh (N=107)			
Distance (cm)[3]	326.8 (20.6)	321.8 (10.6)	0.18	147	0.85
Tg (C)[2]	31.7 (0.7)	32.4 (0.5)	0.73	146	0.47

[1] – Mean distance (cm) is from observer to sighted tiger beetle.
[2] – Mean ground temperature (C) at beetle location.
[3] – Mean distance (cm) from observer to sighted tiger beetle for individual observer.
[4] – Mean ground temperature (C) observed for individual observer.

TABLE 2-6. -- Model for individual-level detectability for tiger beetles (program DISTANCE) at Portageville, NY in 2009. Tg = ground temperature, Obs = observer, Spp = species, **Bold** indicates best-fit models.

Data	Model	# Parameters (k)	AIC_c	ΔAIC_c	$AIC_c W_i$	-2* Log Likelihood	Detection Probability	# Observations	# Samples
Cicindela repanda	Obs[1]							78	56
	Tg (C)	2	**949.5**	0.0	1.00	945.3	**0.82**	77	56
	Obs-Tg (C)	3	952.0	2.4	0.28	945.7	0.82	77	56
	No covariate	1	961.6	12.2	0.00	959.5	0.85	78	56
C. marginipennis	**No Covariate**	1	**894.7**	**0.0**	1.00	892.5	**0.50**	70	56
	Obs	2	896.5	1.9	0.38	892.3	0.49	70	56
	Tg (C)	2	896.6	2.0	0.36	892.4	0.50	70	56
	Obs-Tg (C)	3	898.6	4.1	0.13	892.3	0.49	70	56

[1] – Model *C. repanda* with covariate (observer) failed to converge, no log-likelihood calculated and model ignored.

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APPENDICES

APPENDIX 1. -- NATURAL HISTORY

Count Dejean first described cobblestone tiger beetles in 1831 (Dunn and Wilson, 1979). They are a dull olive color and are approximately 11-14 mm in length with a white band around the outside edge of the elytra, which have no other white maculations. They are metallic blue-green underneath the elytra and have a red-orange abdomen (Graves and Brzoska, 1991; Leonard and Bell, 1999; Pearson *et al.*, 2006).

There is little published research on the dispersal patterns and habitat requirements of cobblestone tiger beetles. Consequently, it is difficult to understand the niche that cobblestone tiger beetles fill and if the species might serve as a useful bioindicator. The data that do exist do not give a clear view of population trends (Novak, 2006) or the behavior of cobblestone tiger beetles.

The life history of tiger beetles follows two patterns – spring/fall species and summer species. In spring/fall species, adults overwinter in their burrows and mate the following year, while summer species adults do not live past their first summer (Leonard and Bell, 1999; Brust *et al.,* 2005). Cobblestone tiger beetles are a summer species (Dunn and Wilson, 1979; Nothnagle, 1984, 1989). Cobblestone tiger beetle larvae go through three stages (instars) while remaining in the same burrow, enlarging it as they grow (Hoback *et al.*, 2000). It takes two years for complete development from larvae to pupae to adult (Nothnagle, 1989). Adults emerge from the pupal stage in the late spring and early summer, mate, deposit eggs and die before the next winter.

On the Connecticut River, adults are found primarily between July and September (Dunn and Wilson, 1979; Nothnagle, 1984, 1989). Their peak flight season is late June through July in New York (Gordon, 1939), though they are found in August in western New York (New York Natural Heritage Program, 2010). Newly emerged adults are identified by their soft flexible cuticle and coloration (Schultz, 1989). Females deposit fertilized individual eggs in open sandy areas between cobblestones in midsummer (Leonard and Bell, 1999).

There is very little information available on cobblestone tiger beetle larvae (Leonard and Bell, 1999). Tiger beetle larvae in general are very similar in appearance. They are white and grub-like. On their large heads, they have up to six small eyes on top and powerful mandibles underneath. A key feature of the larvae is the two pairs of large forward-facing hooks located on the back of the fifth abdominal segment (Graves and Brzoska, 1991; Pearson and Vogler, 2001).

Both adult and larval cobblestone tiger beetles are carnivorous. Larvae are ambush hunters. When a larva is positioned at the top of its burrow, the head and thorax are flush with the substrate and fill the burrow's entrance. It remains in the burrow until prey comes within reach. The larva then jumps backwards, grabs the victim with its mandibles and uses the hooks on its abdomen to keep it from being pulled from the burrow (Pearson and Vogler, 2001). Adults actively hunt by chasing their prey in short bursts with stops. Tiger beetles run faster than they can locate an object; the stops allow them to re-sight their prey (Pearson and Vogler, 2001).

The most specific information about cobblestone tiger beetles is from a study of *C. marginipennis* along the Connecticut River bordering Vermont and New Hampshire (Dunn and Wilson, 1979). These cobblestone tiger beetles were found on gravel river bars with tightly packed cobblestones and sparse vegetation and which were inundated during spring flooding. Boyd (1978) in New Jersey and Novak (1999) in New York also identified cobblestone tiger beetles on cobble bars along rivers. They have been found on the upstream ends of islands and along the river's edge among the rounded stones and small patches of sand. For example, a population of cobblestone tiger beetles in Zoar Valley, NY was found on four riverside cobble bars in a 2.4-km stretch of the Cattaraugus Creek. The occupied cobble bars were similar in appearance, with sand and cobble intermixed with little or no vegetation (Novak, 1999). In Letchworth State Park, cobblestone tiger beetles have been found on bars with mixes of cobble sizes and sand. Many of the inhabited cobble bars have up to 20% vegetative cover that is a mix of forbs and cottonwood (*Populus*) and willow seedlings (*Salix*) (D. Basset, Biologist, Letchworth State Park, NY, pers. comm.). Occupied cobblestone areas in Vermont were flat and showed signs of disturbance by winter ice scouring and inundation during spring floods (Nothnagle, 1984). The exact proportion of sand, cobble, and vegetation required by cobblestone tiger beetles has not been reported in published literature (Novak, 1999).

We do not know how far cobblestone tiger beetles disperse or the amount of time they take to move to other locations. In a mark and recapture study, puritan tiger beetles (*Cicindela puritana*) dispersed a maximum distance of 2.7 km between patches on the Connecticut River (Omland, 2004), while the northeastern beach tiger beetle (*C. dorsalis dorsalis*) dispersed up to 24 km from their original marking site (Leonard & Bell, 1999).

Riverine/riparian habitats are constantly changing as the result of heavy precipitation and annual spring flooding. Tiger beetles are well adapted to these natural events (Omland, 2004). *Cicindela* spp. can survive inundation in their burrows for up to a week (Brust *et al.* 2005). Longer periods of inundation along the Genesee River above the Mt. Morris Dam may have extirpated some of the local population of cobblestone tiger beetles (D. Basset, Biologist, Letchworth State Park, NY, pers. comm.). The main threats to these beetles are from human activities such as mining cobble bars, off-road vehicles, insecticides, and engineered changes to the natural hydrological flow that reduce flooding events (Graves and Brzoska, 1991; Leonard and Bell 1999; Novak, 2006). Cobblestone tiger beetles should be candidates for protection because of their fragile habitat and the threats from human activities (Graves and Brzoska, 1991; Leonard and Bell 1999; Novak, 2006)

APPENDIX 2. -- SOIL DESCRIPTIONS FROM THE GENESEE RIVER IN ALLEGANY, LIVINGSTON AND WYOMING COUNTIES, NEW YORK[1]

Information adapted from USDA - Natural Resources Conservation Service. 2009. Web Soil Survey. Available: Http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx. Accessed 25 October 2009.

River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
		Definition	Fluvaquents	Consists of alluvium with highly variable texture.	Fluvaquents— This soil is very deep and very poorly drained. Slopes range from 0 to 5 percent. The parent material consists of alluvium with highly variable texture. Depth to the top of a seasonal high water table is 0 inches. Annual flooding is frequent. Annual ponding is frequent. Shrink-swell potential is low. Available water capacity is moderate
		Definition	Udifluvents	Consists of alluvium with a wide range of texture.	This soil is very deep and moderately well drained. Slopes range from 0 to 8 percent. The parent material consists of alluvium with a wide range of texture. Depth to the top of a seasonal high water table ranges from 24 to 72 inches. Annual flooding is frequent
Belfast-Houghton, Fillmore-Houghton	Allegany	Alluvial	1A-Udifluvents and Fluvaquents, frequently flooded, 0 to 3 percent slopes	Udifluvents and Fluvaquents	Udifluvents and Fluvaquents

River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
Belfast-Houghton, Fillmore-Houghton	Allegany	Loam	3A-Tioga loam, occasionally flooded, 0 to 3 percent slopes	Consists of loamy alluvium.	This soil is very deep and well drained. The parent material consists of loamy alluvium. Depth to the top of a seasonal high water table ranges from 36 to 72 inches. Annual flooding is occasional. Shrink-swell potential is low. Available water capacity is high
Fillmore-Houghton, Belfast-Houghton	Allegany	Silt loam	8A-Middlebury silt loam, 0 to 3 percent slopes	Consists of loamy alluvium predominantly from areas of shale and sandstone with some lime-bearing material.	This soil is very deep and moderately well drained. The parent material consists of loamy alluvium predominantly from areas of shale and sandstone with some lime-bearing material. Depth to the top of a seasonal high water table ranges from 18 to 24 inches. Annual flooding is occasional. Shrink-swell potential is low. Available water capacity is high
Fillmore-Houghton	Allegany	Silt loam	9A Pawling silt loam, 0 to 3 percent slopes	Consists of loamy over sandy and gravelly alluvium.	This soil is very deep and moderately well drained. The parent material consists of loamy over sandy and gravelly alluvium. Depth to the top of a seasonal high water table ranges from 18 to 24 inches. Annual flooding is occasional. Shrink-swell potential is low. Available water capacity is moderate

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River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
Fillmore-Houghton	Allegany	Silt loam	19A Olean silt loam, 0 to 3 percent slopes	Consists of silty and clayey alluvium or eolian deposits over sandy and gravelly glaciofluvial or deltaic deposits.	This soil is very deep and moderately well drained. The parent material consists of silty and clayey alluvium or eolian deposits over sandy and gravelly glaciofluvial or deltaic deposits. Depth to the top of a seasonal high water table ranges from 18 to 24 inches. Shrink-swell potential is moderate. Available water capacity is high.
Belfast-Houghton, Fillmore-Houghton	Allegany	Silt loam	20A Unadilla silt loam, 0 to 3 percent slopes	Consists of glaciolacustrine deposits, eolian deposits, or old alluvium, comprised mainly of silt and very fine sand.	This soil is very deep and well drained. The parent material consists of glaciolacustrine deposits, eolian deposits, or old alluvium, comprised mainly of silt and very fine sand. Depth to the top of a seasonal high water table is greater than 60 inches. Shrink-swell potential is low. Available water capacity is high.
Fillmore-Houghton	Allegany	Silt loam	20B Unadilla silt loam, 3 to 8 percent slopes	Consists of glaciolacustrine deposits, eolian deposits, or old alluvium, comprised mainly of silt and very fine sand.	This soil is very deep and well drained. The parent material consists of glaciolacustrine deposits, eolian deposits, or old alluvium, comprised mainly of silt and very fine sand. Depth to the top of a seasonal high water table is greater than 60 inches. Shrink-swell potential is low. Available water capacity is high.

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River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
Fillmore-Houghton	Allegany	Silt loam	22A Allard silt loam, 0 to 3 percent slopes	Consists of silty eolian, glaciolacustrine, or old alluvial deposits over sandy and gravelly glaciofluvial deposits.	This soil is very deep and well drained. The parent material consists of silty eolian, glaciolacustrine, or old alluvial deposits over sandy and gravelly glaciofluvial deposits. Depth to the top of a seasonal high water table is greater than 60 inches. Shrink-swell potential is low. Available water capacity is moderate
Fillmore-Houghton	Allegany	Gravelly silt loam	25B Chenango gravelly silt loam, 3 to 8 percent slopes	Consists of gravelly loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits, derived mainly from sandstone, shale, and siltstone.	This soil is very deep and well drained. The parent material consists of gravelly loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits, derived mainly from sandstone, shale, and siltstone. Depth to the top of a seasonal high water table is greater than 60 inches. Shrink-swell potential is low. Available water capacity is moderate
Belfast-Houghton	Allegany	Silt loam	35A Rhinebeck silt loam, 0 to 3 percent slopes	Consists of clayey and silty glaciolacustrine deposits.	This soil is very deep and somewhat poorly drained. The parent material consists of clayey and silty glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from 6 to 18 inches. Shrink-swell potential is moderate. Available water capacity is high.
Fillmore-Houghton	Allegany	Silt loam	38A Niagara silt loam, 0 to 3 percent slopes	Consists of silty and clayey glaciolacustrine deposits.	This soil is very deep and somewhat poorly drained. The parent material consists of silty and clayey glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from

River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
					6 to 18 inches. Shrink-swell potential is low. Available water capacity is high.
Belfast-Houghton, Fillmore-Houghton	Allegany	Silt loam	38B Niagara silt loam, 3 to 8 percent slopes	Consists of silty and clayey glaciolacustrine deposits.	This soil is very deep and somewhat poorly drained. The parent material consists of silty and clayey glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from 6 to 18 inches. Shrink-swell potential is low. Available water capacity is high.
Belfast-Houghton	Allegany	Gravelly silt loam	81C Varysburg gravelly silt loam, 8 to 15 percent slopes	Consists of gravelly loamy glaciofluvial deposits over clayey glaciolacustrine deposits.	This soil is very deep and well drained. The parent material consists of gravelly loamy glaciofluvial deposits over clayey glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from 18 to 33 inches. Shrink-swell potential is moderate. Available water capacity is moderate
Belfast-Houghton	Allegany	Gravelly silt loam	81D Varysburg gravelly silt loam, 15 to 25 percent slopes	Consists of gravelly loamy glaciofluvial deposits over clayey glaciolacustrine deposits.	This soil is very deep and well drained. The parent material consists of gravelly loamy glaciofluvial deposits over clayey glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from 18 to 33 inches. Shrink-swell potential is moderate. Available water capacity is moderate

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River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
Fillmore-Houghton	Allegany	Gravelly silt loam	81E Varysburg gravelly silt loam, 25 to 35 percent slopes	Consists of gravelly loamy glaciofluvial deposits over clayey glaciolacustrine deposits.	This soil is very deep and well drained. The parent material consists of gravelly loamy glaciofluvial deposits over clayey glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from 18 to 33 inches. Shrink-swell potential is moderate. Available water capacity is moderate
Belfast-Houghton	Allegany	Gravelly silt loam	81F Varysburg gravelly silt loam, 35 to 50 percent slopes	Consists of gravelly loamy glaciofluvial deposits over clayey glaciolacustrine deposits.	This soil is very deep and well drained. The parent material consists of gravelly loamy glaciofluvial deposits over clayey glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from 18 to 33 inches. Shrink-swell potential is moderate. Available water capacity is moderate.
Belfast-Houghton	Allegany	Loamy-skeletal	100D Udorthents, loamy-skeletal, 0 to 25 percent slopes	Soil characteristics of this component can vary widely from one location to another.	Soil characteristics of this component can vary widely from one location to another. On-site investigation is needed to determine the suitability for specific use.
Fillmore-Houghton	Allegany	Gravelly loam	125C Howard gravelly loam, 8 to 15 percent slopes	Consists of gravelly loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits, containing significant amounts of limestone.	This soil is very deep and well drained. The parent material consists of gravelly loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits, containing significant amounts of limestone. Depth to the top of a seasonal high water table is greater than 60 inches. Shrink-swell potential is low. Available water capacity is moderate

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River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
Fillmore-Houghton	Allegany	Silt loam	135E Hudson silt loam, 25 to 35 percent slope	Consists of clayey and silty glaciolacustrine deposits.	This soil is very deep and moderately well drained. The parent material consists of clayey and silty glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from 16 to 24 inches. Shrink-swell potential is moderate. Available water capacity is high.
Belfast-Houghton	Allegany	Loam	300A Tioga loam, rarely flooded, 0 to 3 percent slopes	Consists of loamy alluvium.	This soil is very deep and well drained. The parent material consists of loamy alluvium. Depth to the top of a seasonal high water table ranges from 36 to 72 inches. Annual flooding is rare. Shrink-swell potential is low. Available water capacity is high
Belfast-Houghton	Allegany	Silt loam	5A Wayland silt loam, 0 to 3 percent slopes	Consists of silty and clayey alluvium washed from uplands that contain some calcareous drift.	This soil is very deep and poorly drained. The parent material consists of silty and clayey alluvium washed from uplands that contain some calcareous drift. Depth to the top of a seasonal high water table ranges from 0 to 6 inches. Annual flooding is frequent. Shrink-swell potential is low. Available water capacity is high
Fillmore-Houghton, Belfast-Houghton	Allegany	Silt loam	800A- Holderton silt loam, 0 to 3 percent slopes	Consists of loamy alluvium.	This soil is very deep and somewhat poorly drained. The parent material consists of loamy alluvium. Depth to the top of a seasonal high water table ranges from 6 to 18 inches. Annual flooding is occasional. Shrink-swell potential is low. Available water capacity is high

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River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
Portageville	Wyoming	Silt loam	AlA-Allard silt loam, 0 to 3 percent slopes	Consists of silty eolian, glaciolacustrine, or old alluvial deposits over sandy and gravelly glaciofluvial deposits.	This soil is very deep and well drained. The parent material consists of silty eolian, glaciolacustrine, or old alluvial deposits over sandy and gravelly glaciofluvial deposits. Depth to the top of a seasonal high water table is greater than 60 inches. Shrink-swell potential is low.
Letchworth	Wyoming	Alluvial	Am-Alluvial land	A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes.	A low, outspread mass of loose materials and/or rock material, commonly with gentle slopes. It is shaped like an open fan or a segment of a cone. The material was deposited by a stream at the place where it issues from a narrow mountain valley or upland valley or where a tributary stream is near or at its junction with the main stream. The fan is steepest near its apex, which points upstream, and slopes gently and convexly outward (downstream) with a gradual decrease in gradient. Also defined as Fluvaquents and Udifluvents
Portageville	Wyoming	Silty clay loam	CeE3-Caneadea silty clay loam, 25 to 50 percent slopes, eroded	Consists of clayey and silty glaciolacustrine deposits.	This soil is very deep and moderately well drained. The parent material consists of clayey and silty glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from 6 to 24 inches. Shrink-swell potential is moderate. Available water capacity is high

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River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
Portageville	Livingston	Fine sandy loam	Cu-Chagrin fine sandy loam, high bottom phase	Consists of loamy alluvium.	This soil is very deep and well drained. Slopes range from 0 to 3 percent. The parent material consists of loamy alluvium. Depth to the top of a seasonal high water table ranges from 36 to 72 inches. Annual flooding is occasional. Shrink-swell potential is low. Available water capacity is high.
Portageville	Livingston	Silt loam	Eb-Eel silt loam	Consists of silty alluvium.	This soil is very deep and moderately well drained. Slopes range from 0 to 3 percent. The parent material consists of silty alluvium. Depth to the top of a seasonal high water table ranges from 18 to 24 inches. Annual flooding is occasional. Shrink-swell potential is low. Available water capacity is high.
Portageville	Wyoming	Silt loam	Hc-Hamlin silt loam	Consists of silty alluvium mainly from areas of siltstone, shale, and limestone.	This soil is very deep and well drained. Slopes range from 0 to 3 percent. The parent material consists of silty alluvium mainly from areas of siltstone, shale, and limestone. Depth to the top of a seasonal high water table ranges from 36 to 72 inches. Annual flooding is occasional. Shrink-swell potential is low. Available water capacity is high.
Letchworth	Livingston	Alluvial	Rc-Riverwash	Fluvaquents and Udifluvents	Fluvaquents and Udifluvents

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River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
Letchworth	Wyoming	Bedrock	Ro-Rock outcrop	An exposure of bedrock at the surface of the earth.	An exposure of bedrock at the surface of the earth. Not used where the named soils of the surrounding map unit are shallow over bedrock or where "Rock outcrop" is a named component of the map unit.
Portageville	Livingston	Steep broken land	Sl-Steep broken land, Caneadea soil material	Consists of clayey and silty glaciolacustrine deposits.	Hudson— This soil is very deep and moderately well drained. Slopes range from 25 to 50 percent. The parent material consists of clayey and silty glaciolacustrine deposits. Depth to the top of a seasonal high water table ranges from 18 to 24 inches. Shrink-swell potential is moderate. Available water capacity is high
Letchworth	Livingston	Steep ledgy land	Sp-Steep ledgy land	Consists of loamy till derived mainly from acid sandstone, siltstone, and shale. Depth to a restrictive feature is 10 to 20 inches to bedrock	Arnot— This soil is shallow and somewhat excessively drained. Slopes range from 25 to 80 percent. The parent material consists of loamy till derived mainly from acid sandstone, siltstone, and shale. Depth to a restrictive feature is 10 to 20 inches to bedrock. Depth to the top of a seasonal high water table is greater than 60 inches. Shrink-swell potential is low. Available water capacity is very low.
Belfast-Houghton, Fillmore-Houghton, Letchworth, Portageville,	Allegany Livingston, Wyoming	Water	W-Water	Soil data not provided for this component	Soil data not provided for this component

River Section	County	Category	NRCS - Soil Map Unit Name	Short Definition	Definition
Portageville	Livingston	Silt loam	Wd = Westland silt loam	Consists of loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits.	This soil is very deep and very poorly drained. Slopes range from 0 to 1 percent. The parent material consists of loamy glaciofluvial deposits over sandy and gravelly glaciofluvial deposits. Depth to the top of a seasonal high water table ranges from 0 to 6 inches. Annual ponding is frequent. Shrink-swell potential is low. Available water capacity is high.

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APPENDIX 3. --COBBLE BAR INFORMATION FOR 2008 AND 2009

nynhp are cobble bars surveyed between 2000 and 2002. Beetles Observed - A = *Cicindela ancocisconensis*, M = *C. marginipennis*, R = *C. repanda*; **bold** identifies cobble bars where mark – recapture study occurred for 2008 and 2009.

	Beetles Observed[1]						
Cobble Bars	2008	2009	Area (m^2)	Perimeter /Area	Elevational Difference (m)	Nearest Cobble Bar (m)	Latitude /Longitude
B1		R	2010	0.168	16	33	N42.34251 W78.10286
B2			1800	0.116	4.27	281	N42.34382 W78.10292
C1		M,R	6166	0.096	17	24	N42.37485 W78.14174
CA1		R	10659	0.074	32	86	N42.4037 W78.16888
CA2		M,R	7352	0.078	33	86	N42.40765 W78.16866
CA3		A,R	17104	0.069	9	34	N42.41308 W78.16269
CA5		A,R	16947	0.056	9	34	N42.41228 W78.15583
CA6		M,R	39068	0.034	15	43	N42.41916 W78.15212
CA8		A,R	23082	0.036	15	11	N42.41763 W78.1464
CA9		M,R	6408	0.084	-	-	N42.41861 W78.14375
F0A		R	7141	0.084	17	203	N42.46082 W78.11032
F0C		M,R	8925	0.060	45	15	N42.46297 W78.10626
F1		M,R	16920	0.034	8.23	24	N42.46371 W78.10684
H1 nynhp	R	A,M,R	9253	0.060	53	29	N42.42079 W78.14175
H10		M,R	5358	0.080	20	74	N42.44452 W78.12301
H2		M,R	8154	0.076	68	29	N42.42299 W78.14165
H3		M,R	11532	0.055	13	58	N42.42705 W78.14285
H6		M,R	5347	0.075	8	22	N42.43059 W78.13833
H7		R	11529	0.095	35	22	N42.43117 W78.13623
H8		R	3372	0.114	9	46	N42.43991 W78.12853
H9		M,R	17758	0.045	21	46	N42.44246 W78.12657
LL1	A,R	R	644	0.170	11	89	N42.59801 W78.00382

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	Beetles Observed[1]						
Cobble Bars	2008	2009	Area (m^2)	Perimeter /Area	Elevational Difference (m)	Nearest Cobble Bar (m)	Latitude /Longitude
LL2 nynhp	R	R	10829	0.064	25	41	N42.59823 W78.00736
LL4	R		11468	0.072	55.17	219	N42.59856 W78.01621
LL5	R	A,R	5687	0.126	93.57	426	N42.59635 W78.0222
LL6 nynhp	M	A,M,R	34126	0.063	84.73	464	N42.60363 W78.02253
LL7	R	A,R	3613	0.083	174.04	630	N42.61197 W78.01343
LL8		R	2864	0.114	23.16	991	N42.61045 W78.00474
O1	R	R	12307	0.060	14	79	N42.36441 W78.12755
O3			1277	0.159	3	119	N42.36798 W78.13138
O3a			289	0.266	-	-	N42.36660 W78.12989
O4		M	25044	0.049	17	38	N42.37334 W78.13572
O5 nynhp		M	3284	0.102	11	38	N42.37468 W78.13826
P0 nynhp	A,M,R	M,R	8135	0.075	51	159	N42.56739 W78.0345
P1 nynhp	M,R	A,M,R	36548	0.052	19	80	N42.56986 W78.03459
P2			705	0.270	4.57	80	N42.57324 W78.03247
R0 nynhp	M,R	A,M,R	18767	0.045	55	24	N42.3761 W78.14496
R1 nynhp	M,R	A,M,R	20744	0.046	68	31	N42.37905 W78.15087
R2	M,R	M,R	12321	0.066	64	25	N42.38175 W78.1528
R2a		R	1483	0.128	-	-	N42.38311 W78.15331
R5		M,R	15396	0.041	8	35	N42.39266 W78.14344
R6		M	4274	0.092	12	35	N42.39433 W78.14436
R7			1989	0.125	6	47	N42.39562 W78.14579
R8		M	9440	0.056	9	78	N42.3977 W78.15062
R9			1327	0.164	0	78	N42.39981 W78.152
RC1		M,R	9083	0.056	11	18	N42.46588 W78.09551
RC2			11306	0.044	8.23	12	N42.46754 W78.09617
SH1	R	R	25726	0.051	35.36	643	N42.61575 W77.99166
SH1a			244	0.261	-	-	N42.61779 W77.98897

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	Beetles Observed[1]						
Cobble Bars	2008	2009	Area (m^2)	Perimeter /Area	Elevational Difference (m)	Nearest Cobble Bar (m)	Latitude /Longitude
SH1b		R	1784	0.154	-	-	N42.61839 W77.98781
SH1c			6279	0.085	-	-	N42.61989 W77.98724
SH2 nynhp	R		6751	0.066	13.72	71	N42.62351 W77.98877
SH3			3697	0.088	17.37	587	N42.62541 W77.98892
SH4 nynhp			15814	0.042	-	-	N42.63008 W77.98485
SH5 nynhp					-	-	N42.63516 W77.98061

APPENDIX 4. -- 2009 INDIVIDUAL-LEVEL DISPERSAL TRANSECTS FOR COBBLESTONE TIGER BEETLES (*CICINDELA MARGINIPENNIS*) - PROGRAM: DISTANCE, PORTAGEVILLE, NY