

**Dispersal, Phenology and Habitat Preference of Subalpine Whirligig Beetles
(Coleoptera: Gyrinidae: *Gyrinus*)**

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Abstract

Whirligig beetle populations from five temporary kettle ponds and one marsh near the Rocky Mountain Biological laboratory, Gunnison County, western Colorado U.S.A. were studied during summer 2010. The purpose of the study was to measure the effects of extreme fluctuating environmental conditions including seasonal habitat drying, and disturbance by cattle grazing on the phenology, habitat preference and dispersal of two species of Gyrinidae. The phenology of these beetles was compared among the ponds by observing the timing of emergence from pupa to imago as determined by elytral condition. In general, beetles were observed to emerge in early July, earlier than previously recorded in North America, possibly accelerated as an adaptation to the high elevation conditions. Beetles varied in emergence times among ponds, and two sites had no adult beetles until they were populated by emergent beetles in 8, July and 15, July. Relative population size of beetles in the ponds was estimated by comparing the total numbers of beetles collected biweekly and correcting those totals by sampling effort (people hours collecting beetles). Total pond area, area of aquatic vegetation, average surface water temperature and change in temperature range from the beginning to the end of the study did not explain the observed variation in relative population size. However, relative population size decreased with increasing habitat loss among ponds, suggesting that beetles preferred more permanent ponds. Active dispersal was observed and recorded using a mark-recapture system that involved small brands on the elytra using a tungsten needle. Over 600 beetles were marked and released in their natal ponds, and 82 were recaptured in the same pond. However, three marked beetles were recaptured in different ponds, demonstrating that they flew as far as 800 meters. Mass dispersal was also observed when cattle disturbed one pond, and another pond dried. Adults also dispersed en masse from a pond just before a second generation of beetles emerged, suggesting that dispersal may a natural life history phenomenon.

Keywords: Coleoptera, Gyrinidae, Dispersal, Phenology, Emergence, Temporary Pond, Habitat Preference, Hydroperiod

Introduction

Dispersal is broadly defined as, “[the] outward spreading of organisms or propagules from their point of origin or release; one-way movement of organisms from one home site to another” (Lincoln et al. 1998). Behavioral and habitat factors are often strong influences on dispersal. For example, organisms in an unstable environment (such as temporary ponds) often respond by redistributing themselves to more favorable habitats (Nürnberger and Harrison 1995). Additionally, Grant (1978) proposed that dispersal was caused by increased aggression due to crowding from natal recruitment.

Active dispersal by flight is common in adult freshwater insects (Bilton et al. 2001), including Gyrinidae beetles (Nürnberger and Harrison 1995). Scant information is available on the dispersal behavior of *Gyrinus* beetles. Davy-Bowker (2002) conducted a mark recapture experiment with predacious diving beetles (Coleoptera: Dytiscidae) in Cheshire (UK) and found dispersal in many species; and Nürnberger and Harrison (1995) marked 3,911 *Dineutus assimilis* whirligig beetles from 31 ponds and recaptured 68 after they had flown to another pond, some of which had flown up to 20 kilometers. Svensson (1999) observed frequent dispersal in *Gyrinus opacus* populations from a Swedish peninsula. However, no further work has been conducted on *Gyrinus* dispersal, and a review of the literature reveals no studies have been done on dispersal of the Gyrinidae of the Rocky Mountain region of North America.

Beetle populations in several temporary ponds and a marsh south of The Rocky Mountain Biological Laboratory in Gothic, Colorado U.S.A. were studied because of their potential for dispersal. These populations live in temporary ponds with severely fluctuation conditions. Additionally, these ponds are unpredictably disturbed by cattle grazing starting in mid- July.

The broad objective of the present study is to investigate the dispersal, phenology, and habitat preference of whirligig beetle populations in a subalpine environment in an attempt to answer the following questions:

1. When do subalpine whirligig beetles emerge from pupation? Do the emergence times vary among ponds with different hydroperiods?
2. What environmental factors explain variation in relative population size? Do average temperature, change in temperature range, total pond area, area of aquatic vegetation and habitat permanence explain habitat preference?
3. Do whirligig beetles disperse in a subalpine environment? If so how far? What factors cause mass dispersal?

Methods

Study sites and organisms

Beetles were collected from five kettle ponds and one marsh (K1, K2, K4, K5,K6; M2) located south of the Rocky Mountain Biological Laboratory in Gothic, CO U.S.A. (2900 m above sea

level). Study sites were fishless, surrounded by grazed alpine meadow, had silt and mud bottoms, contained varying amounts of aquatic emergent and riparian vegetation, and were less than 1 m. deep on average. Ponds also varied in size and shape. All sites contained salamanders, populations of aquatic insects and zoo plankton and some were disturbed by grazing cattle. Ponds varied in hydroperiod, and during the study some sites dried out, lost adult beetle populations or gained adult beetle populations. Variable permanence and susceptibility to being disturbed by cattle were key factors analyzed to explain variation in beetle phenology, relative population sizes, and dispersal.

The Gyrinidae is a modest sized (650 species and 11 genera) cosmopolitan family; 56 species of *Gyrinus* are found in North America (North of Mexico) (Oygur and Wolfe 1991). Whirligig beetles are holometabolous insects in the order Coleoptera. Their eggs and larvae are aquatic, pupae are terrestrial, and adults live on the water surface. Larvae are predatory and cannibalistic (Istock 1966) and adults are predators and primarily scavengers of insects trapped on the water surface. Dense aggregations of adults have been observed on the surface of mountain ponds, woodland lakes, creeks, streams, rivers and even road side ditches. Gyrinidae commonly form multi-genera and multi-species aggregations (Realzola 2007). Two species of whirligig beetle, *Gyrinus picipes* and *Gyrinus pleuralis*, were collected from our study sites. Species were not distinguished for this study, so it is unknown whether different ponds had different species or the phenologies of the two species differed.

Pond conditions as potential explanatory variables

The following data were recorded to relate to phenology, dispersal and pond preference of beetles: total pond area (before and after habitat loss) and area of aquatic emergent vegetation,

using GPS and GIS techniques using *ArcGIS*, Version 9.0 (Environmental Systems Research Institute, Inc., Redlands, Calif.) and a Trimble® GeoXT GPS receiver. We also recorded surface water temperature, recorded every 30 min. using Hobo data loggers (Onset Computer Corporation, Pocasset, Massachusetts) installed over the course of the study. We estimated habitat loss over the course of the study as the ratio of the initial area of each pond to the area of the pond at the end of the study.

Mark and recapture study

To estimate relative population sizes and dispersal, whirligig beetles were collected from the ponds from 17 June to 4 August 2010. Collections were generally conducted biweekly (two ponds each week in alternate weeks) using a long handled speed net and beetles were transported to the laboratory in plastic containers. Beetles were marked with a dot code brand on the elytra using a sharp tungsten needle and a dissecting microscope. The marking method and elytral conditions are adapted from the methods of Svensson (1985).

Beetles were checked for markings in the laboratory using a Wild M5 dissecting microscope, and unmarked beetles were marked. The dates of capture, location of capture, quantity, sex and elytral condition of the beetles were recorded. Elytral condition was classified as: soft (newly emerged teneral, estimated maximum age of 2-3 weeks), shiny (0 year individuals, emerged the same year), dull (1-2 year individuals having overwintered at least one year) and slightly dull (Beetles in which elytral condition between Shiny and Dull). Elytral condition data was used to determine if individuals had overwintered (dull elytra) and when emergence began (soft elytra) and was corroborated by Svensson (1985).

Data from these collections were used to estimate the proportion of newly emerged beetles, the relative population sizes, to determine how many beetles dispersed to and from each pond, and whether phenology, relative population size or dispersal depending on pond conditions.

Statistical analysis

Potential explanatory variables were plotted as independent variables and relative beetle population size was the dependant variable. Relative population size was calculated based on a “catch per unit effort” as follows: dividing cumulative number of beetles collected from a site by person hours spent collecting (hours spent collecting multiplied by number of people collecting). The reason for this calibration was because ponds were not visited the same number of times, nor was time spent or the number of people doing the collections standardized, correcting the catches by effort enable comparisons to be made over dates within ponds and between ponds.

The independent variables are: initial pond area, area of emergent aquatic vegetation (a potential refuge for beetles), percent habitat loss (final area subtracted from original area), change in temperature range (change in temperature range on the final day minus the temperature range on first day), and mean surface water temperature. These variables were selected because temperature extremes are a potential stressor for beetles and average temperature is an indicator of pond productivity. Due to extreme differences in size and shape the marsh M2 was omitted as an outlier from our analysis of area, percent habitat loss and aquatic vegetation area.

Results

Study organisms

Our collections reveal new locality records. *Gyrinus picipes* was previously recorded in Colorado from Baca Co., Cheyenne Co., Las Animas Co., Lincoln Co., Pitkin Co., and is now documented also from Gunnison Co. *Gyrinus pleuralis* is herein also recorded from Gunnison Co., adding to its known western Colorado distribution (Conejos Co., Delta Co., Dolores Co., Jackson Co.).

Phenology

Populations in our study were observed emerging starting in early July and tapering off in early August (Figure 1). Beetles with dull elytra, which we considered to have overwintered at least one year, comprised 0.9% of all beetles collected. The last beetle that had overwintered was collected on 8 July 2010.

Pond conditions as potential explanatory variables of relative population size

Ponds varied greatly in all potential explanatory variables: pond area, area of emergent aquatic vegetation, average surface water temperature, change in surface temperature range, and permanence (Table 1). The following variables explained only a small proportion of the variation in relative population size among ponds: pond area ($R^2 = 0.43$), area of emergent aquatic vegetation ($R^2 = 0.26$), average surface water temperature ($R^2 = 0.40$) and change in temperature range ($R^2 = 0.36$). However, pond permanence did explained a high proportion of the variation in relative population size ($R^2 = 0.87$) (Figure 2).

Dispersal

We marked and released 602 beetles of which 14% were recaptured (Table 2). Most of the recaptures occurred in the same pond from which beetles were originally captured, with only three beetles being caught in a different pond (0.5% dispersal).

Attempts were made to collect as many beetles as possible for marking. However, it was often difficult to collect all beetles from a site, a factor that may have led to less recorded dispersal than that of previous, more comprehensive studies (Nürnberg and Harrison 1995).

In addition to the three individuals that were recaptured in different ponds from where they were marked (Table 2), three instances of apparent mass dispersal were observed in beetles that were not part of our mark-recapture samples (Figure 3).

On 8 July 2010 a shiny female *Gyrinus pleuralis* from K1 and a shiny male *Gyrinus pleuralis* from K2 were recorded from K6. These beetles flew 130 meters (from K1) and 800 meters (from K2). On 4 August 2010 a shiny female *Gyrinus pleuralis* flew 271 meters from K5 to K1.

On 29 June 2010 a very large aggregation of beetles was observed in K1 and two days later only a small aggregation (approx. 20%) was present. A similar observation was made on 15 July 2010 when K4 was almost completely dry, with only a few very shallow puddles filled with dozens of beetles. The following day the pond was completely dry and no beetles were found in the dry pond bed, although other aquatic insects had been stranded and died (e.g. Corixidae). Many beetles were observed in K2 on 1 July 2010, but none were present on 15 July 2010.

Discussion

Phenology

Beetles in different ponds had different phenologies, as indicated by the timing of emergence from the pupae to the adult stage (appearance of individuals with soft elytras). Previous work states that *Gyrinus* emergence in North America (North of Mexico) occurs from August to September (Oygur and Wolfe 1991). Populations in our study were observed emerging earlier starting in early July and tapering off in early August. There were already populations of beetles present when the study began, 17 July 2010, indicating that the emergence observed is at least the second of the year. The very small number of beetles with dull elytras indicates that overwintering as adults is uncommon.

Pond conditions as potential explanatory variables of relative population size

The only pond condition that explained a substantial proportion of the variance in beetle population size was pond permanence. Other variables (pond size, area of emergent aquatic vegetation, mean surface water temperature and temperature variation) did not explain variation in beetle population sizes. Whirligig beetles are surface-dwellers and their Johnston's organs, located at the base of the antennae, allow them to detect slight water vibrations made by predators, prey and other whirligig beetles (Oygur and Wolfe 1991). Increased aquatic vegetation may hinder their ability to communicate with water waves and may therefore be undesirable. Whirligig beetles are very adaptable to temperature changes. Warm beetles are more active, suffer less predation and are less likely to need the protection of an aggregation (Romey and Rossman 1995). This adaptability to the thermal environment may explain why temperature variables did not affect relative population size. Likewise, total area may not be as important as

habitat loss for beetles. The whirligig beetles in our study are small (4.6-5.6 mm) and often form compact groups, a large amount of surface area may not be needed to provide adequate food and range. More permanent water bodies can have a more stable hydroperiod and allow the beetles' fully aquatic larvae to undergo complete metamorphosis. When beetles lay their eggs it would be advantageous to do it in a body of water that has less habitat loss. More beetles may be present in sites with less habitat loss because more eggs were laid there the previous year.

Dispersal

Anecdotal observations of dispersal events are consistent with the hypothesis that three potential causes of mass dispersal include habitat extinction, cattle disturbance and a life history event (dispersal to avoid competing with a new generation). These hypotheses can be tested with further research.

A potential cause for dispersal away from K2 to K6 on July 8, 2010 is grazing cattle, which had access to K2 beginning on the first week of July. The cattle did not have access to K6 at this time. No beetles were observed in K2 on July 15, 2010 (Figure 4). Several cattle were observed around and in the pond and the smell of manure was very strong around the pond. These factors may have presented an unfavorable environment for the beetles. The study site has been grazed since at least 1928 (Billick, personal communication). Cattle had access to all sites, but were only observed around and in K1, K2, K5 and K6.

It appears that for newly emerged beetles, the selection pressure to avoid pond drying must be high enough to stimulate mass dispersal. Beetles were observed swimming in very shallow puddles on K4 only one day before the pond completely dried up. A day later no beetles were

found in the dried out pond bed (Figure 4), but a few dead water boatmen (Hemiptera: Corixidae) were present.

No catastrophic event was recorded before the mass dispersal from K1 on 1 July, 2010.

However, the next collection on 20 July 2010 contained the first newly emerged beetles (Figure 4), indicating that mass dispersal may be linked to a life history event (dispersal to avoid competing with a new generation).

Conclusions

1. When do subalpine whirligig beetles emerge from pupation? Do the emergence times vary among ponds with different hydroperiods?

In general, beetles were observed to emerge in early July, earlier than previously recorded in North America, possibly accelerated as an adaptation to the high elevation conditions. Beetles varied in emergence times among ponds, and two sites had no adult beetles until they were populated by emergent beetles in 8, July and 15, July.

2. What environmental factors explain variation in relative population size? Do average temperature, change in temperature range, total pond area, area of aquatic vegetation and habitat permanence explain habitat preference?

Total pond area, area of aquatic vegetation, average surface water temperature and change in temperature range from the beginning to the end of the study did not explain the observed variation in relative population size. However, relative

population size decreased with increasing habitat loss among ponds, suggesting that beetles preferred more permanent ponds.

3. Do whirligig beetles disperse in a subalpine environment? If so how far? What factors cause mass dispersal?

Whirligig beetles do disperse in a subalpine environment. Three marked beetles were recaptured in different ponds, demonstrating that they flew as far as 800 meters. Mass dispersal was also observed when cattle disturbed one pond, and another pond dried. Adults also dispersed en masse from a pond just before a second generation of beetles emerged, suggesting that dispersal may be a natural life history phenomenon.

Future Research

A more thorough mark and recapture study can be conducted with more marking and collection to determine if dispersal is more common. This new study can also include species identification and help determine if source-sink dynamics are present.

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Tables

TABLE 1. Independent variables potentially affecting dispersal and relative population size.

Summary of Potential Explanatory Independent Variables					
Site	Total Starting Area, (m ²)	Aquatic Vegetation Area, (m ²)	Change in Temperature Range, °C	Mean Temperature, °C	% Habitat Loss
K1	1988.7	874.7	3.86	18.61	19.1
K2	1168.0	Unavailable	4.72	18.9	66.4
K4	94.0	0	9.16	18.12	100
K5	894	669	4.91	20.00	50.7
K6	1107	209	4.13	19.76	31.2
M2	21067	Unavailable	4.06	18.95	22.9

TABLE 2. Data collected from beetle collections including the dependant variable (Relative Population Size).

Site	Total Beetles Collected	Number Marked and Released	Recaptured beetles (which stayed in same site)	Proportion Recaptured	Number Dispersed In	Relative Population Size (corrected for effort)
K1	260	111	3	0.04	1	727
K2	184	134	20	0.15	0	115
K4	26	20	0	0.00	0	50
K5	186	102	16	0.16	0	434
K6	743	222	50	0.22	2	1439
M2	30	15	0	0.00	0	77

Figures

FIGURE 1. Proportion of newly emerged beetles based on site and date.

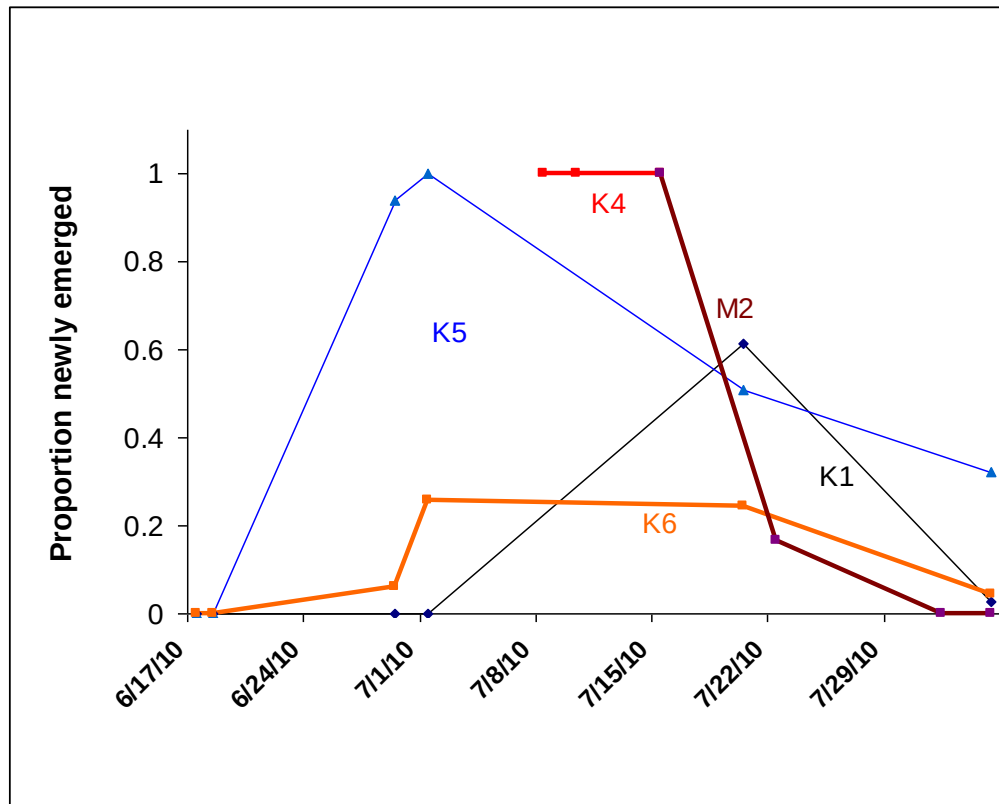


FIGURE 2. Percent habitat loss and relative population size for 5 ponds. Relative population size grew exponentially with less habitat loss.

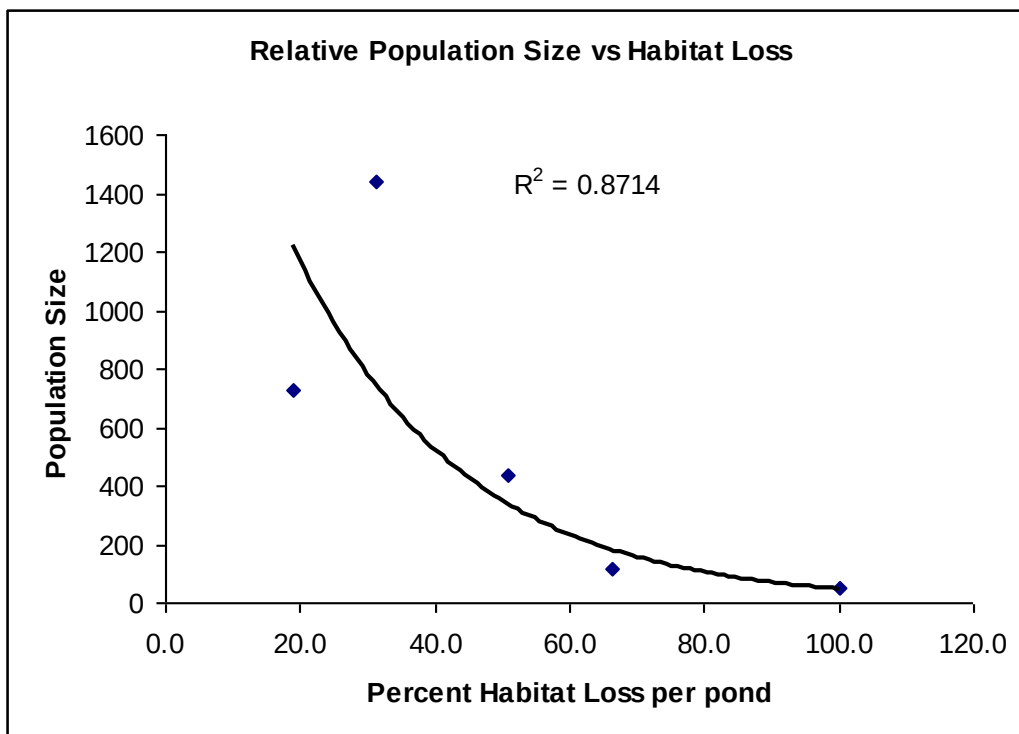


FIGURE 3. Location of six study sites. Arrows indicate dispersal direction, date and distance.

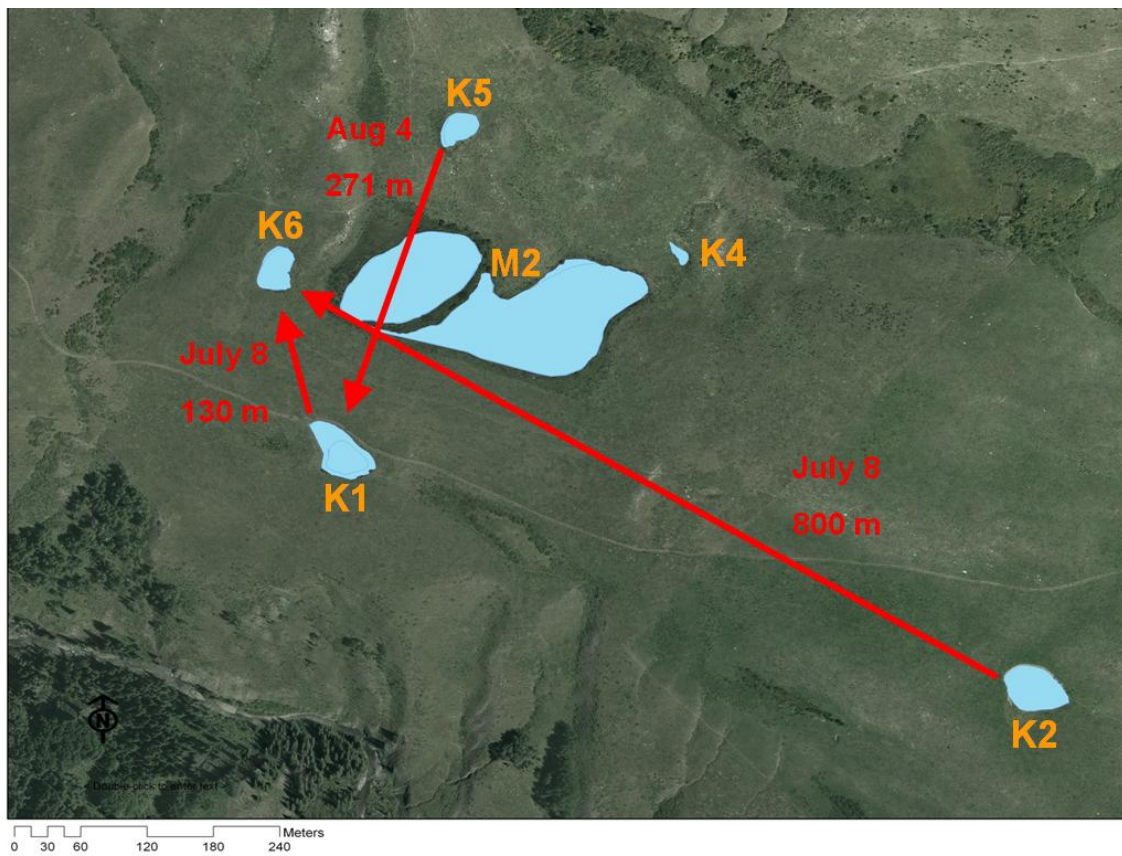


FIGURE 4. Proportion of beetles dispersed based on date for three ponds. Arrows indicate potential causes for dispersal: habitat extinction, cattle disturbance and emergence of a new generation of beetles.

