Population size and mobility of *Cicindela maritima* Dejean, 1822 (Coleoptera: Carabidae)[1]

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[1] Dedicated to Prof. Gerd Müller-Motzfeld (†) in remembrance of many interesting talks and excursions

Abstract: In 2008, 2009, and 2010 the Dune Tiger Beetle (*Cicindela maritima* Dejean, 1822) was investigated on a 110 m long beach north of the city of List on the barrier island of Sylt, northern Germany. Population size was determined using the mark-and-recatch method. Ten marked specimens were observed over periods of 0.5 to 1.5 hours and travel distances measured. Site population size was calculated to be 17 specimens in 2008, 12 – 13 in 2009, and 26 in 2010. Daily activity observations indicated maximum diurnal activity at 11:30 hrs CEST (12:30 hrs CET). Mean travel distance per hour was 125 m, mean range covered per day was 54 m. It can be derived from these data that a population of 100 specimens requires a one-kilometer stretch of beach and dune environment that is closed to public access.

1 Introduction

The Dune tiger Beetle (*Cicindela maritima* Dejean, 1822) is extremely endangered in Germany and in Europe as a whole; populations have been decreasing for several decades. The species is classified as "nationally rare" in Great Britain, where it can be found at only a few localities, e.g. Bristol Channel, Norfolk and Kent (HYMAN & PARSONS 1992). In the first half of the 20th century it was frequently found along the German coasts of the North Sea and the Baltic Sea. Today, it is recorded in Schleswig-Holstein from only two sites at the North Sea coast, a doubtful site at the Baltic Sea, and from sandy beaches in the estuary of the Elbe River. The highest number of records is from Mecklenburg-Vorpommern, where more than 4 sites are known. According to SCHMIDT & POMMERANZ (2001), however, the species is extinct in Mecklenburg and found with frequency in Vorpommern only on beaches closed to tourists.

The species can be easily confused with Northern Dune Tiger Beetle, *Cicindela hybrida* (Linnaeus, 1758). For this reason, at the beginning of the 20th century, it was regarded as a subspecies of *C. hybrida* (LENGERKEN 1929). *C. maritima*, however, is a distinct species and can be differentiated from *C. hybrida* by the pubescence of the forebody and the shape of the white spots of the elytra (Fig. 1). In Germany, *C. maritima* is rarely found outside a narrow coastal strip of sandy beaches and primary dunes. In contrast to Central and Western Europe, the species has been recorded in habitats of interior Russia and Scandinavia (SCHMIDT 2002). Autecological and ethecological information has been provided only as a result of dated investigations by LENGERKEN (1929). According to his investigation, *C. maritima* takes to flight on the beaches from end of April to mid of September. The diurnal activity cycle shows a maximum at midday. For the resting period from late noon to the next morning, the species constructs a sloped tube of approximately 3 cm length into the loose sand within one minute. In order to gather water from the sand grains, it appears that tiger beetles prefer beaches with sufficient sand surface moisture.

The larvae subsist in the loose sand, thus offering a plausible explanation for the species' extreme sensibility to trampling and past decreases in population. Investigations are not available concerning population ecology, space demand, and the larval ecology, all of which are required for conservation management. Short-time investigations on the coastal island of Sylt in northern Germany yielded preliminary information on population ecology, mobility, and space demand. Unfortunately, the larval ecology is poorly under-

Fig. 1: The Northern Dune Tiger Beetle (*Cicindela hybrida*, left side) und the Dune Tiger Beetle (*C. maritima*, right side). *C. maritima* shows a denser pubescence on head and pronotum and a more strongly curved white spot in the centre of the elytra than *C. hybrida*.

stood. This study concerns the following questions: 1) How large is the population of *C. maritima* with respect to the beach length, 2) how large is the home range of adult beetles, and 3) which conclusions useful to conservation can be drawn from the study results?

2 Sites and methods

The investigations on *C. maritima* were performed on June, 8th to 10th in 2008, on June, 26th and 28th, 2009, and on June 6th and 8th in 2010 at "Listerhaken" (8° 25.36' E, 55° 01.52' N) located about 1 km north of List on the island of Sylt (northern Germany, Schleswig-Holstein). The study site, lying between a dike and the small island of "Uthörn", is a dune and beach area, which is situated within the highly protected area of the National Park "Nordfriesisches Wattenmeer" and is closed to tourists. In this area, beetles were counted, marked (Fig. 1) and released during the study periods on a beach length of 110 m. Specimens were marked on elytra using a white lacquer pencil according the method described by Mühlenberg (1993). Individually marked specimens were observed during a time span of maximum 1.5 hours. A distance of at least 3 to 4 m between observer and specimen was maintained in order to avoid disturbance. In this distance the marked specimens and the different white lacquer spots on elytra could be detected without binocular. There was no indication that the lacquer disappeared during the two day period. Movements of the observers were calm and slow. A bent down position of the observer was maintained, being also a precondition for capture of specimens for marking, since specimens will fly away if approached with 4 to 5 m by an erect and walking human. Exact times of capture and release were noted. For population calculations, the morning and the afternoon data were separated, and this calculation was performed using the Schnabel-Schumacher-method of the program Ecological Methodology of Krebs (1994). The Schnabel-Schumacher method is an extended Petersen method for a series of samples with implication of a correcting linear regression. The formula is as follows:

$$\hat{N} = \frac{\sum_t (C_t M_t)}{\sum_t R_t}; \quad M_t = U_1 + U_2 + U_3 + \ldots U_t$$

where $\hat{N}$ = mean number of individuals in the population, C_t = total number of specimens in the sample t, R_t = number of marked specimens in the sample t, M_t = number of marked individuals in the population just before t^{th} sample is taken, U_t = number of newly marked and released specimens in the sample t.

For the analysis of the movement pattern each change of direction was marked by the observer, and the distances between the marked points were measured. The distance between the two outermost

points was used as maximum range.

The diurnale activity pattern was determined by summing up hourly the number of specimens observed. Soil surface temperature and the wind velocity was measured every half hour during the investigation period.

3 Results

3.1 Population size

At the three days in 2008, the two days in 2009, and the two days in 2010 a total number of 15 specimens, 9 specimens, and 25 specimens, respectively, was marked and released. Out of the 15 specimens in 2008, 11 specimens were recaptured; out of the 9 specimens in 2009, 7 specimens were recaptured, and out of the 25 specimens in 2010, 13 specimens were recaptured. Thus, the recapture rate in the first two years was higher than 70 %, in the last year higher than 50 % (Tab. 1).

The high recapture rates suggest that specimens rarely left or entered the beach section on the investigated days. The hatching or mortality rates can be ignored due to the short investigation periods. According to the Schnabel-Schumacher method, the population size in 2008 is estimated at 16.9 (respectively 16.7, if the linear correction is applied) with a confidence interval (95 %) between 11.1 and 33.9. In 2009, similar values are obtained and ranged between 12.7 and 12.2 (with linear correction) and a confidence interval (95 %) between 7.6 and 31.8. In 2010, higher values are estimated at 26.6 and a confidence interval (95 %) between 16.2 and 45.9. Regarding these results, an average of 11 to 24 individuals can be expected on a 100 m long beach section. As the large range between the confidence intervals shows, the results have a high variance, but are still in a normal range for population size estimations.

3.2 Movement pattern and home range

The hourly accumulated individual counts demonstrate maximum activity at 11:30 hrs CEST (12:30 hrs CET) (Fig. 2). At noon, mobility rapidly decreased. After 17:00 hrs, no beetles were observed. At the activity maximum, the temperature on the soil surface ranged between 34 to 36 °C. However, wind velocity was different in each year. In 2008 it was very calm during the study days, wind velocity ranging between 2.5 and 3.0 m/sec. In contrast, in 2009, wind velocity was high, ranging between 20 m/sec on June, 26th and 10 m/sec at June, 28th. Nevertheless, several individuals were active even at the very windy day, though drifting significantly during flights. As the wind was from offshore, they drifted towards the dunes and not towards the sea. The movements on the ground seemed not to be influenced by the strong wind.

During their active phase, the beetles were running parallel to the coastal line with incidental flight phases. In nearly all cases, the flying individuals were found a short distance along the coastal line from the starting point. The movement patterns of two individuals are shown in fig. 3.

In total, ten individuals were observed over varying time periods. In 2008, observation times were longer than in 2009 and 2010 because a higher number of observers were available. In 2009 and 2010, some observations were ended, although the beetles were active for a longer period. In 2008, the beetles were observed during their total activity peri-

Tab. 1: Captures of *C. maritima* in the years 2008, 2009 and 2010. The recaptures 1 to 3 refer to the preceding time interval, mor.: morning.

	Timeframe/day	Capture	Recapture 1	Recapture 2	Recapture 3	Accumulated total capture
1	8.6.08	6				6
2	9.6.08 mor.	9	3			12
3	9.6.08 noon	2	1	1		12
4	10.6.08	9	3	3	0	15
1	26.06.09	2				2
2	28.6.09 mor.	8	2			8
3	28.6.09 noon	6	0	5		9
1	6.6.10 mor.	11				11
2	6.6.10 noon	12	8			15
3	8.6.10	16	4	2		25

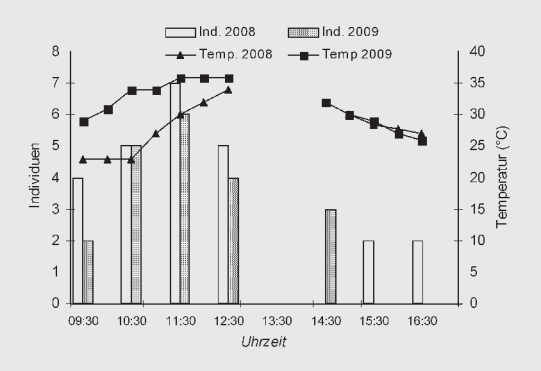

Fig. 2: Number of active *C. maritima* / hour in 2008 and 2009 during the day compared to the half-hourly measured temperature at soil surface.

od until they disappeared from the beach, usually by flying. The movement distances of the ten observed individuals show that *C. maritima* is an extremely active runner covering large distances (Tab. 2). The covered distances are partly extremely long regarding the short time intervals. The longest distance included flight intervals and was exhibited by individual No. 13. Individual No. 10 exhibited a high mean movement speed wherein a flying interval was likewise observed. In contrast, individual No. 2 shows that long distances can be covered also without flight. On average, beetles covered distances of more than 100 m per hour. The running activity was not continuous, but occurred stepwise. After a phase of fast running that was usually a straight forward movement, the beetles rested for short time intervals to orientate and to look for prey before continuing the forward running or flying phase.

Tab. 2: Parameters of mobility of *C. maritima* in 2008, 2009, and 2010; Mean, S.D.: standard deviation, conf. (95): Confidence interval at 95 % error.

Beetle no.	Distance (m)	Time (min)	Mean (m/h)	Maximum Range (m)
2	115.4	120	57.6	71
12	89.5	95	96.0	65
13	205.8	105	117.6	88
4	69.0	30	138.0	57
5	15.3	35	25.8	4
8	81.2	25	194.4	68
2	35.4	15	141.5	35
10	69.8	12	349.0	63
1	82.0	69	71.3	55
5	43.8	45	58.4	33
Mean	80.7	55	124.9	54
S.D.	52.6	39	93.1	24
Conf. (95)	43 - 118	27 - 83	58 - 191	37 - 71

Fig. 3: Movement patterns of two *C. maritima* individuals on the investigated beach section. The punctuate lines show the flying distance. Length of the figured beach section is 110 m.

4 Discussion and conclusions for the conservation

According to Riecken et al. (2006), the area of semi-natural beaches and dunes in Germany decreased in the last 70 years by 14.5 % along the North Sea coast and by approximately 12.6 % along the Baltic Sea coast. This disappearance of semi-natural dunes and beaches, coupled to their species-rich habitats containing high numbers of specialised species (Verhoeven 1999, Koehler 1999) supports a clear need for increased conservation efforts. In spite of their status as "highly threatened" in category 2 or moderately threatened in category 3 in the Red List of habitats in Germany, and despite the specific responsibility of the state of Schleswig-Holstein for their protection, priorities for these habitats, both for research and for conservation has been very low. This was already criticised in the conservation concept for the National Park „Schleswig-holsteinisches Wattenmeer", because these habitats were excluded from the National Park with very few exceptions (Stock et al. 1996). The steady population decline of *Cicindela maritima* within the last 50 years is proof of limited success in conservation efforts. At the North Sea coast the establishment of

the National Park in 1985 has prevented the species from extinction as can be shown by the fact that all records of the species at the North Sea coast are located within the area of the National Park, today.

To evaluate the endangerment of the species more or less correctly, the question concerning the population size will be analysed for the total area of Schleswig-Holstein. According to our investigations at List on the island of Sylt, the population ranged between 12 and 26 individuals per 100 m of beach section. During several years of investigation, the species was found north of List only on the beaches of „Listerhaken", and "Uthörn" which are closed to public access. The total length of the beaches accounts for about 3000 m. Taking this area into account, between 450 and 570 individuals are estimated to live on these beaches. In spite of intensive investigations, the species was not found on other beaches of the area, all which are visited by tourists. The beetles were neither found on beaches of the „Lister Ellenbogen" nor at the beaches located on the eastern side near List which are frequently used by tourists for walking or bathing.. However, older records exist from the beaches on the eastern coast of List, where the author found only *C. hybrida* in the last 10 years. If a population of the beetle is found there in spite of the lack of new records, it is presumed to be much smaller than of the investigated beaches. A population of 200 individuals is estimated for this location. A further population exists on beaches near the village of St. Peter Ording, and might have a size similar to the investigated population near List. Thus, at this location a population of about 500 individuals is estimated. If the population on sandy beaches of the river Elbe is estimated to range between 500 and 1000 individuals, the total population in Schleswig-Holstein may comprise 1500–2000 individuals. The only potentially existing population at the Baltic Sea coast „Sehlendorfer Binnensee" near the village of Hohwacht would be restricted to an extremely small beach area and could include a maximum of only 20 individuals. In spite of an extensive search along the Baltic Sea coast in Schleswig-Holstein, no further local populations of the species were found.

Unfortunately, no investigations are available concerning minimal viable population sizes for ground beetles or other beetles to deduce to the minimal viable population size of *C. maritima*. Regarding comparative studies on vertebrates, a minimal viable population should account to about 7000 individuals (Reed et al. 2003). This population size seems be appropriate for arthropods, because Griebler & Gottschalk (2000) found numbers of 13,000 to 15,000 individuals needed for a minimal viable population of the Dark Bush Cricket (*Pholidoptera griseoaptera*). Compared with these data, the population size of *C. maritima* in Schleswig-Holstein is extremely low. Thus, it follows that isolated populations of 20 to 50 individuals can not establish long-term, viable population sizes without interacting with adjacent populations.

In recent years, more concentrated efforts have been made to conserve beach areas of the Baltic Sea coast; therefore, potential habitats for *C. maritima* may exist there. To estimate the spatial extend of potential beach sections for viable populations of *C. maritima*, the home range of the species is compared with other ground beetles (Tab. 3). Unfortunately, comparisons between the mobility of *C. maritima* and other ground beetles suffer from different calculation methods for the individual species. *C. maritima* exhibits a high mobility of about 100 m/h. If a daily active phase of 1 to 3 hours is presumed, a distance of 100 to 300 m/day might be covered. Even much larger

Tab. 3: Movement parameters and range of ground beetles using direct observations or radar tracing.

Species	Mean distance (m/day)	Maximum range (m)	Reference
Carabus auronitens	3.5 – 15.0	28 – 94	Niehues et al. 1996
Abax parallelepipedus	0.2 – 0.6	0.2 – 0.4	Charrier et al. 1997
Poecilus versicolor	4.0 – 13.0	2 – 87	Baars 1979
Calathus melanocephalus	1.2 – 3.9	1.5 – 36	Baars1979
Carabus glabratus	4.2	1.8	Assmann 1995
Carabus problematicus	17.3	13.7	Assmann 1995
Pterostichus melanarius	24 – 29	4.4 – 5.3	Wallin & Ekbom 1988
Pterostichus niger	41 – 78	10.5 – 16.3	Wallin & Ekbom 1988
Harpalus rufipes	36	7.3	Wallin & Ekbom 1988
Carabus nemoralis	28	5.4	Wallin & Ekbom 1988

species, e.g. *Carabus auronitens* and *Carabus nemoralis*, do not cover such long distances, with exception of *Pterostichus niger* that nearly covers distances per day at rates similar to *C. maritima*. However, this species is nearly twice as large as *C. maritima*. The home range of *C. maritima* is also extremely large compared to other ground beetles. On average, *C. maritima* needs about 60 m beach section for preying. Compared with other ground beetles, *Carabus auronitens* and *Poecilus versicolor* only need similarly high home ranges. Even, if several individuals of *C. maritima* prey on overlapping areas, as was determined by investigations on the island of Sylt, the mean density of 1 individual per 10 m beach section shows that the overlapping areas are limited. If 100 individuals are supposed to define viable populations, the beach section must cover at least 1 km distance. If convenient habitats for viable populations at the Baltic Sea coast in Schleswig-Holstein are to be established, beach sections of this length must be closed to public access in at least parts of the beach during the spring and summer months.

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