Close Encounters – Analyzing Disturbance Events between Deer and Visitors in a Recreational Forest

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Summary

Disturbance events between wild animals and visitors of a recreational area are an excellent example to study interaction movement patterns. This paper presents computational movement analysis methods for studying disturbance dynamics, especially when both animals and visitors are tracked. The first method combines trajectory segmentation with animal homeranges aiming at detecting flight events. The second method formalizes the sequence pattern "disturbance-flight-seek cover". The pattern is then applied searching for differences between different disturbance categories.

KEYWORDS: Computational Movement Analysis, Movement Ecology, Trajectories, Movement Patterns, Semantic Gap.

1. Introduction

Animal ecology mostly studies the spatio-temporal behaviour of individuals in undisturbed remote areas. Less behavioral ecology research focuses on disturbed habitats, such as, for example, highly frequented peri-urban recreational forests (Frid and Dill 2002, Beale 2007). The work presented in this paper addresses this research gap and explicitly explores the spatio-temporal characteristics of encounters between roe deer and visitors in a recreational forest in the vicinity of Zurich.

This paper aims at conceptualizing and applying a set of computational movement analysis (CMA, Laube 2014) techniques tailored specifically at unlocking the spatio-temporal dynamics of disturbance events. First, a technique is proposed for detecting disturbance events in a comprehensive tracking data set monitoring the *intraspecific*, year-round behavior of the deer. Second, for a series of staged disturbance experiments, both the animals *and* the disturbing agents were tracked allowing the study of i*nterspecific* disturbance and flight/cover dynamics. The research questions are:

1. How can disturbance events be conceptualized and separated from undisturbed space-use from coarsely sampled trajectories of site-loyal, large animals?
2. When both trajectories of animals and the disturbing agents are captured in staged disturbance experiments, can different kinds of reaction patterns be identified and do these correspond to the known and staged set of disturbance types?

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2. Case Study and Data

The Wildnispark Zürich (http://www.wildnispark.ch/f_e/f_e/) is a mainly forested area featuring the typical fauna and flora of a Swiss midland mixed forest. Given the increasing pressure from the recreational use, the interdisciplinary research project investigates its impact on the animal welfare. Between 2013 and 2015, 15 roe deer (*Capreolus capreolus*) were equipped with GPS sensors (GPS PLUS VECTRONIC Aerospace GmbH, Berlin). Albeit all being located close to urban dwellings, roe deer habitats could be categorized into "disturbed" and "undisturbed". Given the cost of trapping, the regular "monitoring mode" sampled fixes every 3 hrs, optimizing for a long battery life. However, for the occasional experimental "event mode" the sampling rate could be remotely reduced to a much finer 5 minutes.

This study used monitoring mode data for 12 animals from October 2013 until April 2014, with an average of approximately 1200 fixes per indivudual. For the disturbance experiments, a total of 51 events were staged, always with concurrent tracking of the disturbing agents. The biggest sample emerged from pairs of mountain bikers deliberately passing by the known locations of deer at dawn and during nights (n = 35). The event mode was also applied during three orienteering contests and six battues in the area. For the hunting events (battues), hunters, dogs and beaters were tracked. Finally, on 7 occasions, the scientists themselves had to track down their study subjects in order to check the presence of fawns.

3. Methods

The CMA methods proposed here draw from GIScience, exploratory spatial data analysis, information visualization, and movement ecology. A combination of ESRI ArcGIS and R (adehabitatHR and move packages) was used.

3.1. Stepping out of the comfort zone

The first study investigates deer only data in monitoring mode (dt = 3hrs). The key assumption is that "disturbance" is often followed by "flight", the latter conceptualized as a segmentation filtering for the 5% longest steps of a trajectory (Figure 1a, 1b).

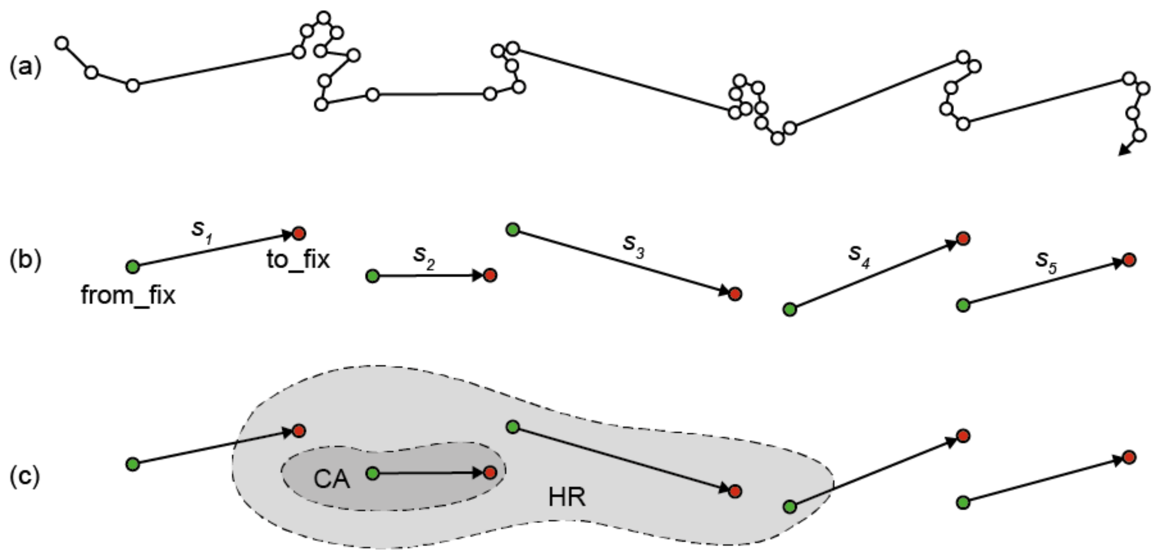

Figure 1 Relating long steps to the home range (HR; 95% of space used by animal) and core area (CA, 50% of space used by animal). s_1: "out-in", s_3: "in-in", s_4: "in-out", and s_5: "out-out".

These long steps are geographically related to the established concept of the home range, representing the 95% utilization space of an animal (Gitzen et al. 2006). Specifically interested in the level of disturbance in their respective habitats, the approach then investigates whether the long “flight” steps occurred within the home range (“in-in”), entirely outside (“out-out”), stepped out of (“in-out”) or into the home range (“out-in”, Figure 1c).

3.2. Close encounters

The second study conceptualizes the interspecific interaction pattern “disturbance-flight-seek cover” as a sequence of co-location patterns (Stanckowich 2008, Bleisch et al. 2014). The pattern is triggered with a disturbance event, here formalized with a disturbance threshold distance of r_d (Figure 2, t_0). Then the animal flees and seeks cover. The latter means hiding immobile persistently for a given time interval i_c within a disc of radius r_c around the first fix within i_c. For a potential causal relation, all patterns of the sequence must happen within interval i_s. In roe deer, the flight part is often skipped and disturbance is immediately followed by seeking cover in the immediate underwood (Figure 2b). The circumscribing circle around all fixes of the cover interval i_c defines the cover area A_c. Within the wider context of the project, the ecological and spatial properties of the A_c are then studied, with a comparison with a reference area A_r positioned randomly near A_c.

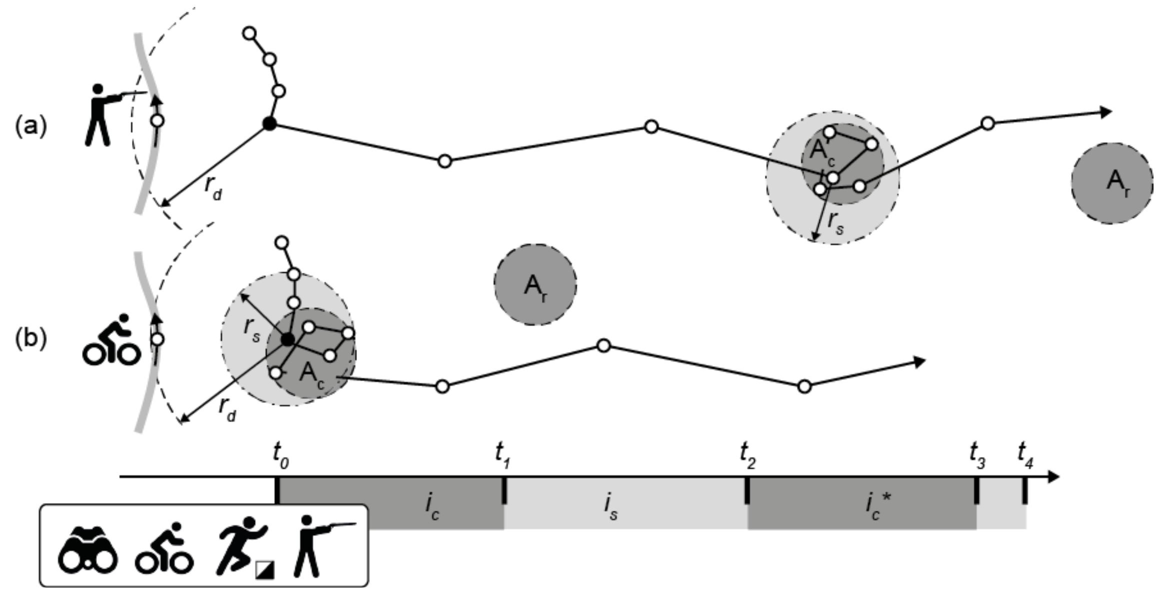

Figure 2 Formalization of sequence pattern “disturbance-flight-seek cover”. In (a) disturbance leads to flight of the animal and thereafter to seeking of cover. In (b) the flight phase is missing.

4. Key results

The presentation of results focusses on methodological insights and less so on the ecological implications of the studies. However, if it suits the clarity of the text, ecological implications are mentioned.

Figure 3 maps the home range (HR) and core areas (CA) of two exemplary roe deer and the corresponding long steps, i.e. potential flight events. For the studied individuals the method reveals notable differences. Deer #8 makes hardly any long steps beyond its undisturbed HR. By contrast, deer #1 makes much more steps out of its disturbed HR (out-out, in-out, and out-in), indicating potential flight events caused by disturbance. Figure 4 confirms this impression. Exemplary individuals with disturbed habitats express a tendency towards more and also longer steps leaving, entering, and outside the HR.

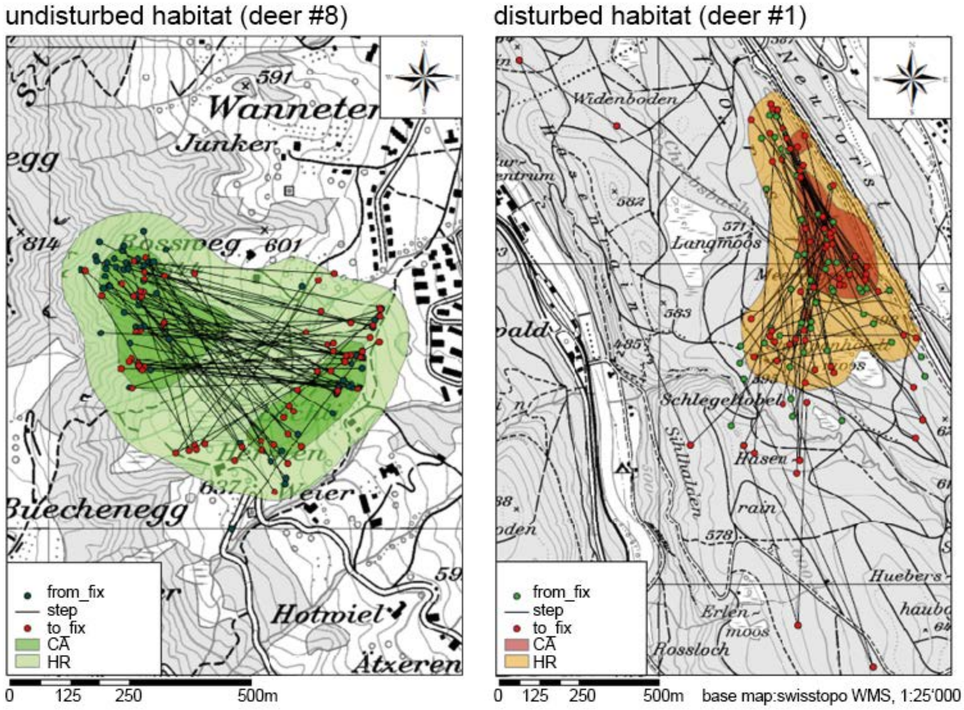

Figure 3 Long steps relative to home range (HR) and core area (CA).

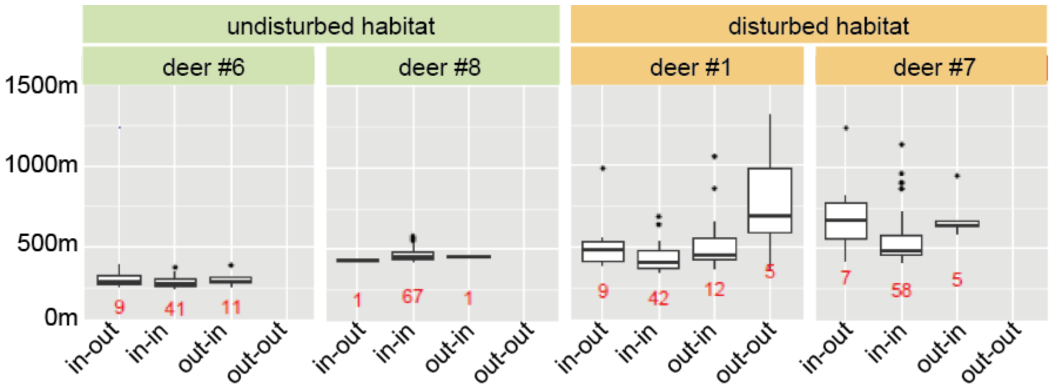

Figure 4 Long steps relative to HR: step length and number of steps.

Figure 5 summarizes initial results of the disturbance experiments. The box plots illustrate three ecological properties of the cover area (A_c) and its respective reference area (A_r), all captured in the field: (i) visibility through the foliage, (ii) the density of foliage cover of the bush layer, and (iii) the distance to the next path. Overall, the cover areas feature a lower visibility, a denser bush layer, and are further away from the paths. The results indicate (although the respective sample sizes are small) that more intrusive disturbances, especially those with the disturbing agents leaving the paths (hunting, orienteering, and scientific observation) have a higher impact on the animals as mirrored in more "protective" cover areas.

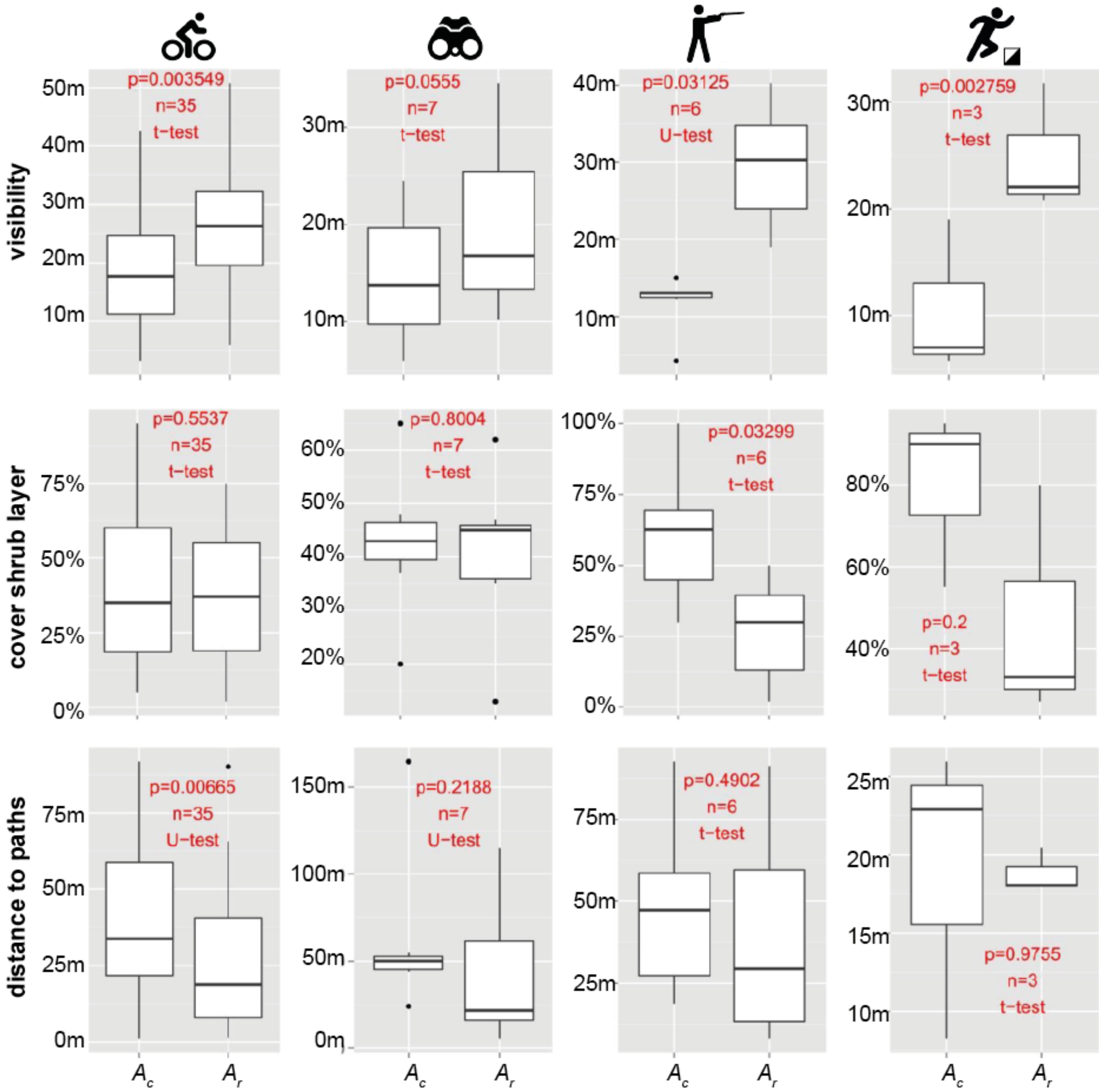

Figure 5 Disturbance experiments for mountain bike, scientific observation, hunting (battues), and orienteering, cover area A_c vs. reference area A_r.

5. Conclusions and Outlook

The methods presented in this paper emerged a very close collaboration between GIS and domain experts in an applied movement ecology study. Both methods delivered unexpected and promising insights and were very warmly welcomed by the ecologists in the project. Validating new methods in CMA is always challenging because the semantics of the observed movement processes are not easily captured. Aiming at bridging this semantic gap, this paper proposes staging controlled movement and interaction experiments and the tracking of all involved agents, resulting in rich data sources allowing for validated method development. Looking ahead, the ongoing project will produce larger data and hence more reliable sources and sample sizes and also aims at integrating concurrent accelerometer measurements.

6. Acknowledgements

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7. Biographies

Benjamin Sigrist has recently graduated as an environmental engineer. The work presented in this paper emerges one of Beni's semester projects and his BSc thesis. Patrick Laube is head of the Geoinformatics research group and has a keen interest in Computational Movement Analysis. Senior lecturer Claudio Signer and Professor Roland Graf represent the institute's wildlife management research group and are biologist and environmental scientist, respectively.

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