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Abstract	This document is a summary of insect data collection methods from the Tatort Streetlight citizen science project
Keywords	Aquatic insects, illumination, artificial light at night, road lighting, insect monitoring, road light design, eclector traps, emergence traps

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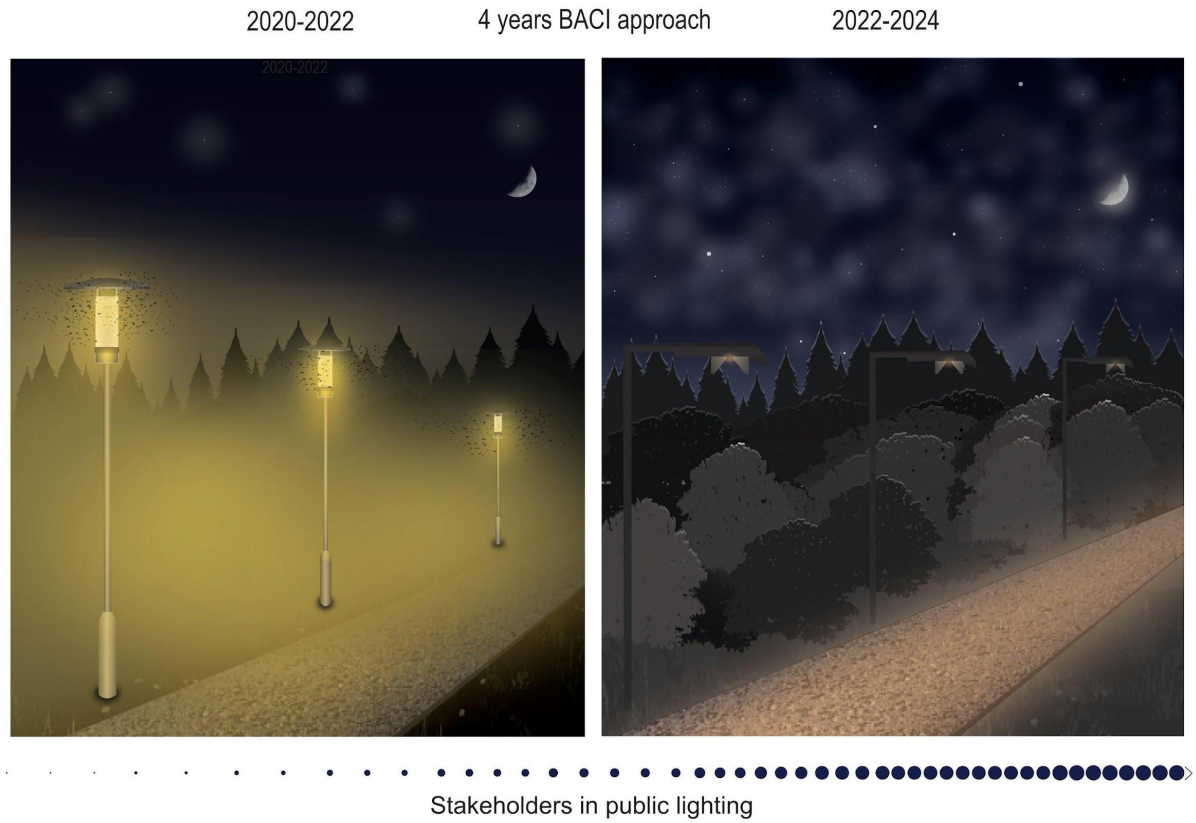
EXECUTIVE SUMMARY

Tatort Streetlight is one of the ACTION pilot projects. Tatort Streetlight is introducing a new insect friendly road light design. To analyze the effect of a new insect friendly street light design on the flight to light behavior of mainly aquatic insects, a four years BACI (before-after-control-impact) approach has been developed. The effect of the new street lighting design is analyzed in four partner communities. Insects are collected once per month at the vanishing moon, from (a) the next freshwater body, (b) at the road luminaires and (c) in the area behind the road lighting in order to analyze the fragmentation effect of illumination within the insect habitat. Citizen scientists are involved in the collection and identification of insects collected in these traps. In this report we present the experimental methods and how citizen scientists are involved in (a) the protocol for the collections and (b) insect identification. We introduce the labeling systems of the collections to make each individual specimen traceable in this huge data set of insect collections from four partner communities. Further, we introduce the work of the local coordinators, the environmental training for newcomers in the research fields of entomology and taxonomy, and how experienced layman taxonomists can get involved in either working at the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), where the insect collection is stored, or borrowing parts of the collection to do identifications remotely. This report presents methods of how to involve citizen scientists in a long term monitoring on the effects of artificial light at night on insect biodiversity. The methods are relevant in association with an amendment of German environmental law, which demands insect protection and monitoring. One part of the amendment, which will come into force in March 2022, considers insect friendly lighting solutions including public and roadway luminaires. Tatort Streetlight is gathering evidence for the design and technology of insect friendly road light solutions, is raising public awareness of the adverse effects of artificial light at night, and invites the public to participate in implementing the changes in public lighting. Successful results can advance the insect friendly lighting solution to become the best choice for modernization and new installations of public lighting in order to obey the law.

1 INTRODUCTION

Tatort Streetlight has various components to involve citizen scientists, for the identification of insects and the measurement of the night sky brightness. Furthermore, the project is in need of awareness as the light situation will be changed and residents might not appreciate the change if knowledge about the benefits is not transferred. Hence, Tatort Streetlight is a rather interesting project to analyze citizen science engagement and vice versa the project is in need of tools to facilitate the organization of citizen science activities, motivation to participate and the data management. The project analyses the attraction behavior of insects, foremost aquatic insects, at road lighting, in a four years BACI (Before-after-control-Impact) approach. The road lights will be changed from conventional column lights to a new insect friendly road lighting design (Figure 1). Two years before and after the transition the attraction of insects to the lights will be analyzed. A direct comparison will be done additionally by leaving parts of the road lighting unchanged. The data and the method developed in Tatort Streetlight are relevant for authorities especially when the new amendment[1] of the German environmental law will come into effect.



[1] https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Gesetze/3_aenderung_bnatschg_bf.pdf accessed 16/12/2021)

Figure 1: Two years before and after the transition from conventional column luminaires (left) to a new insect friendly road lighting design (right) Tatort Streetlight analyses the occurrence of flying insects and increases stakeholders of public lighting by inviting citizens to participate in the research and the protection of insects, from adverse effects of artificial light at night. (Schroer et al. 2021).

Insects are declining by an estimate of more than 75% biomass (Hallmann et al. 2017). Light pollution is one stressor in insect habitats for which the extent of the impact on this decline is still unknown (Grubisic et al. 2018). The German environmental ministry has developed amendments of the environmental law to better protect insects from anthropogenic stressors and demands. Long term monitoring of insects and careful assessments of the impact of artificial light at night on insect fauna and habitat are urgently required. Kalinkat et al. (2021) summarize the importance of a comprehensive data collection, to improve the quality and relevance of studies addressing artificial light at night. Long term monitoring studies of insect occurrence at illuminated areas, replicated at large spatial scales are still very rare as they bear a lot of logistics, from the management of the traps to the maintenance of huge data sets (Hölker et al. 2021). Tatort Streetlight is creating a unique dataset for the effects of different technological lighting solutions which are relevant for authorities to develop evidence based guidelines in order to reduce the adverse effects on flying insects by public lighting.
We present here (a) a method of insect collections, demonstrating the used insect traps and the sampling protocol, and (b) a method for taxonomic identification. First, the insects are identified to order level and further to family or species level by citizen scientist long term experts. The protocol for remote insect identifications is described in detail (Section 2.2). Careful labelling of the samples is important to organize the huge dataset from 4 regional partners and one experimental field site. For specific research questions the collection needs to be organized to be able to find certain insect orders for individual day- or night-times, or specimen from individual trap locations. Thus the order of labelling and of the collections must be exact and followed by all research contributors.

2 METHOD OF THE MONITORING

2.1 Insect collections

Four partner communities are involved in the studies. They will replace parts of their road lighting system with the new insect friendly lighting design after two years of data collection. Tatort Streetlight has a focus on aquatic insects, in order to be able to allow analyses of a barrier effect by road lighting on the insects' flight paths. The source of aquatic insects is predictable and thus insects being caught beyond the streetlight from the direction of the next freshwater body have crossed the potential barrier caused by illumination (Schroer et al. 2021). In Figure 2 we present the location of the traps.

Figure 2. Location of Tatort Streetlight partner communities in Germany (left, open street map, https://www.openstreetmap.org) and the location of the luminaires equipped with eclector traps (yellow marks) and the emergence traps in the water (blue marks) at the four research areas (Schroer et al. 2021).

2.1.1. Experimental design

Insects are monitored in the water, at road luminaires and in adjacent green spaces monthly at the vanishing moon in order to allow comparable natural light conditions (Fig. 3). At the river Fulda activating and emptying of the emergence traps can be cumbersome due to the river's current. The actions are facilitated by the engagement of the local canoeing club the "Kanu Club Fulda e.V." (Figure 3C). Interested bystanders, residents and students often help activating the air eclector traps at the road luminaires and the light traps, which are installed to track the impact of the barrier effect.

Figure 3. Activation of different traps. Eclector traps (A) that are installed at the luminaires (B). Emergence traps, activated by members of the canoeing club, the Kanu Club Fulda e.V. (C) and by the local coordinator in Neuglobsow (D). Light traps to record the occurrence of insects after crossing the streetlights (E).

2.1.2. Protocol of the insect collections

The collection of insects to analyze their occurrence at light sources is a delicate task, as it is an intervention in the insect fauna. For the broad spectrum collection of flying insects the German environmental authorities are requesting a species protection exemption. For activities to fall within this exemption, they must be supervised by an authorized person. Thus, citizen scientists can support the action, but cannot do the collections themselves.
The protocol to collect insects in Tatort Streetlight is therefore only available to all local coordinators (see Annex 1). No open access of this document is needed, as the collections can only be done with a specific species protection exemption.

2.2 Insect identification

Citizen scientists are asked to identify collected insects either to the taxonomic level of insect order or to the level of family or species. The insects are taken in bottles from the insect traps. In a first step, the local coordinators and citizen scientists identify the specimens to insect order. The specimens are cleaned from debris, identified to the level of insect order and stored in individual vials per order, trap, location and time of sampling. Further identifications to the level of insect family or species are done by experienced layman taxonomists, citizen scientists with special expertise in specific insect orders.

2.2.1. Environmental education

The identification of insects to order level is best suited for environmental education about the local insect fauna. Supervised by the local project coordinators, Tatort Streetlight offers workshops to students of different grades (3-11), to teachers and interested residents. In the ACTION deliverable 6.4 the number of offered workshops are summarized. The participation was hampered by the COVID-pandemic, but workshops with students were possible as one of the local coordinators is working also as a teacher and therefore had an exempt to do workshops with students.

2.2.2. Involvement of experienced layman taxonomists

Specialized knowledge is needed to identify insects to the level of family or species. Experienced layman taxonomists are invited to observe the collections and identify samples. Insights in the collections can be made at workshops, at the Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB) or at facilities of the partner communities. Specimens can be taxonomically identified at the institute, borrowed for workshops at other facilities or for identifications at private homes.
Previous to the loan, citizen scientists need to file a lending agreement in which they sign to handle the samples with care, to not add or remove material and to return the loan and data according to a

scientific conduct. Requests of specimens to be held in external collections, for example to provide evidence of occurrence to museums, can be granted but the location has to be stated and is not allowed to be changed without further notice. The location of each insect from the Tatort Streetlight collection must be traceable according to the label of the sample.
The citizen scientists involved in the taxonomic identification can join a chat group on Telegram if they wish. Taxonomists can post photos of insects and questions if they are unsure of the taxonomic identification. Early stage taxonomists can learn from the experience of long term experts and special knowledge can be queried. As the group of participating experts grows, the chat group will be moved to a website where the ability to forward messages to phones will be established to allow for quick responses.

2.2.3. Data management

Most important is the traceability of the collected insects, thus a code for the metadata of the collections has to be followed: e.g. “2020/12/03 5:28:07 pm CET,"C (01), N Fulda”. The code describes the date and time of the start of the collection, the number of the trap, the daylight occurrence labelled by D for Day and N for Night, and the name of the location. This code will be transferred throughout the process of identification for each individual sample.A list of all insect samples is continuously maintained at the IGB. To enter the data, citizen scientists can use either the website https://five.epicollect.net/project/tatort-streetlight or a printed template with the specific metadata of the samples. The metadata needed from the identifier is the name (a registered nickname to stay anonymous), the date of identification, and the code of the sample. This code refers to the metadata of the collection, sampling date and time, trap number and location and the identified insect order. The identifier can then add the name of the suborder, family and species. Data that is recorded on printed templates need to be returned with the loan of insect samples to the IGB. Both, the data from Epicollect and the data from the printed templates are entered into the main database at the IGB. The Epicollect data is automatically converted to the Excel format of the main data bank. The database collects the entries for single insect specimens from four collection sites, with monthly collections for day and night (24h), using 6 eclector traps and 3 light traps per location. Furthermore data is collected from 3 emergence traps per location which are emptied only after one week, to ensure enough samples for aquatic insects emerging the water body. Additionally, 3 further emergence traps are used at the location Neuglobsow (in total 6), because two different freshwater bodies provide different insect fauna at this location.

2.2.4. Summary of preliminary data

The monitoring season in the partner communities was conducted with eight samplings per year from March until October. Unfortunately the energy saving settings were still active in the partner communities which was only noticed by late summer. The road lighting had different time settings at the partner communities, after 22:30 every second luminaire was turned off in the Krakow am See and Neuglobsow communities and all luminaires were turned off in Fulda. Thus, the first results for this monitoring period do not present the full spectrum of nocturnal insect species

occurring throughout the night, except for the Gülpe project area. In this report we present a general and preliminary overview of insect orders and suborders and the respective numbers per trap and location. More detailed information on the insect collections can be found in Schroer et al. 2021.

On a single night and in a single air eclector trap, up to 800 insects were collected per hour. In the month of June, more than 2,000 Nematocera were collected per hour in the sum of all air eclector traps in Gülpe and more than 700 Ephemeroptera per hour in Krakow am See. Subtracting the mass occurrence of Ephemeroptera and Nematocera, still over 50 and 200 insects were collected per hour in Gülpe in the warmer months June and August, respectively. In order to present an overview over the collected insect orders at day and night time, without the mass occurrence of single insect orders, we present the numbers of traps with at least one insect per taxon (Figure 4). The orders Lepidoptera, Ephemeroptera, and Trichoptera presented higher night-time activity compared to the daytime collections. Further studies will focus on the orders Ephemeroptera and Trichoptera, as these orders are 100% aquatic and can be expected to have traveled from a nearby freshwater body.

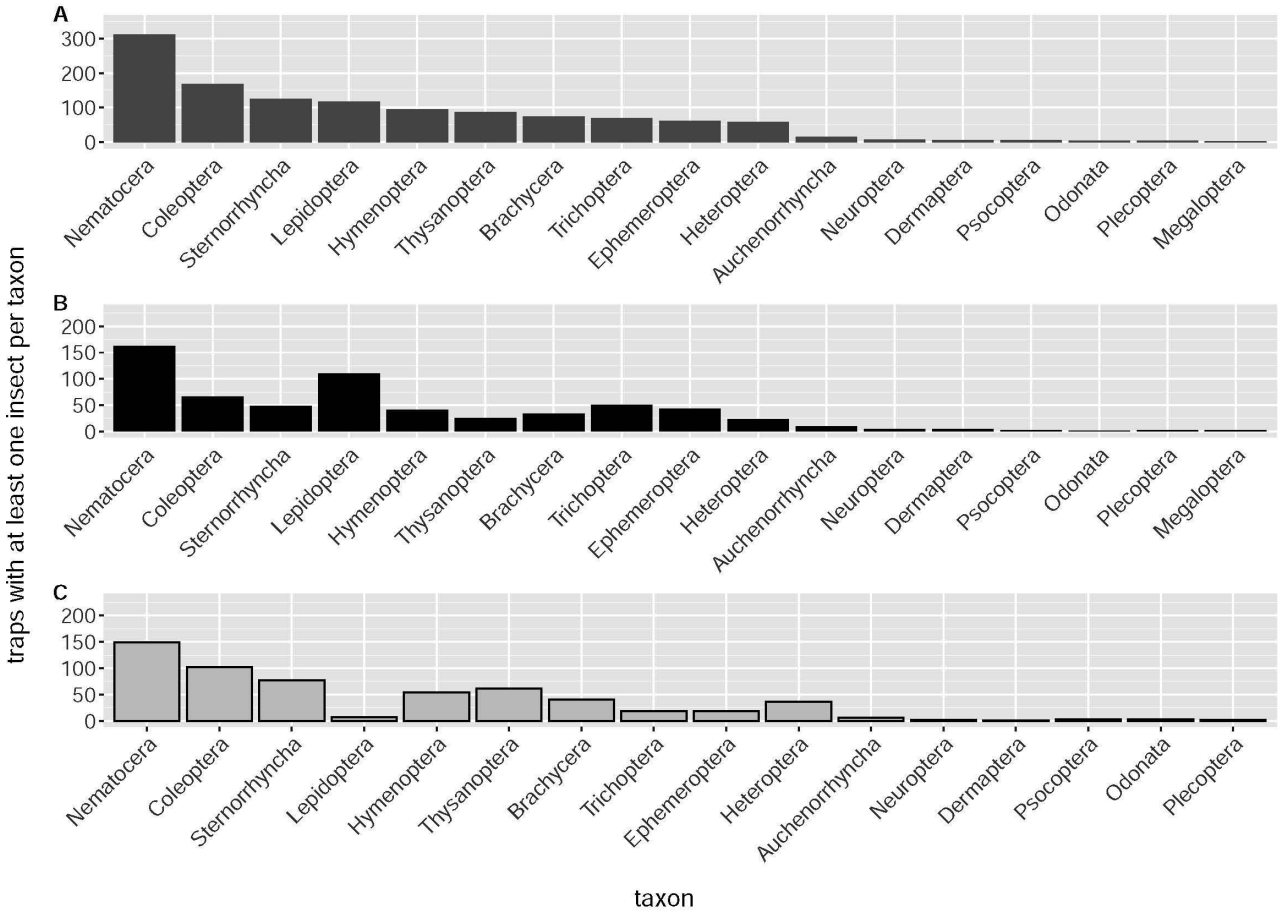


Figure 4: Distribution of taxonomic groups of flying insects in the air eclector and emergence traps, shown as the sum of all traps (A), for night (B), and day (C), respectively. The bars present the numbers of traps that had ≥1 of individuals of the specific groups to normalize peaks of occurrence

of specific groups with very high individual sampling events, particularly Nematocera (Schroer et al. 2021).

3 CONCLUSIONS

This report gives a summary on the complex method to analyze the occurrence of flying aquatic insects in different research areas. Of the uttermost importance is to prepare the right labeling and codes, which can be used for long term studies and enable traceability of all insect samples across multiple locations and collections. Especially when samples are being offered to citizen scientists for identification and workshops the labels and codes need to be used consistently in order not to lose any samples.
Tatort Streetlight has elaborated an experimental design and a labeling system according to the recommendations of Kalinkat et al. (2021). The project describes how to involve citizen scientists in the insect monitoring and how to raise awareness on the adverse effects of artificial light at night on insect fauna (Schroer et al. 2021). The insect monitoring method provides the basis for further studies tailored to different research questions on the effect of artificial light at night on flying insects. Illumination is increasing globally and thus the research on insect attraction towards different lighting technologies is timely and urgent. Hence, the professional storage and traceability of insects is of importance to hold evidence for the occurrence of rare and strongly declining species and to draft action guidelines for their protection, if necessary. The insect collection of Tatort Streetlight will increase annually and offers already a huge library of insect specimens which are today sorted by order and suborder and need to be further identified to species level. A core group of citizen scientists with expertise in the orders and suborders will be involved for this work. The results of Tatort Streetlight will be a major contribution to the amendment of the German environmental law.

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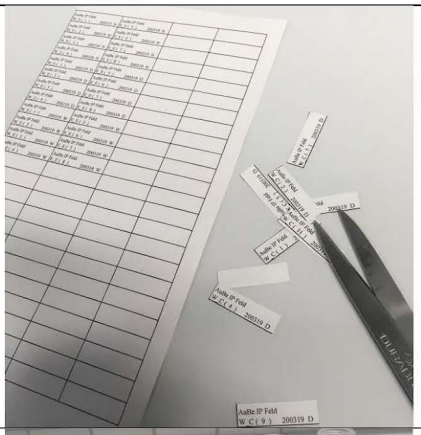
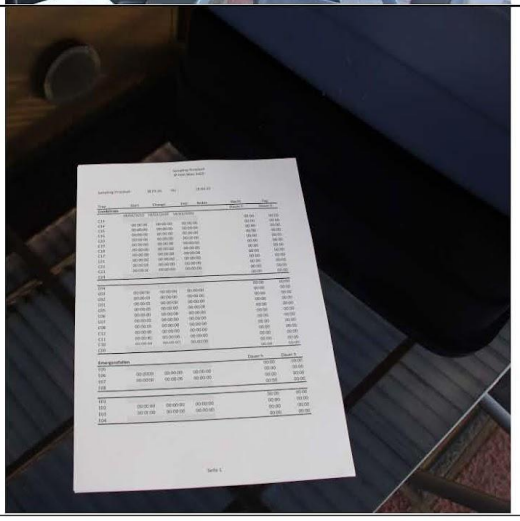
ANNEX 1

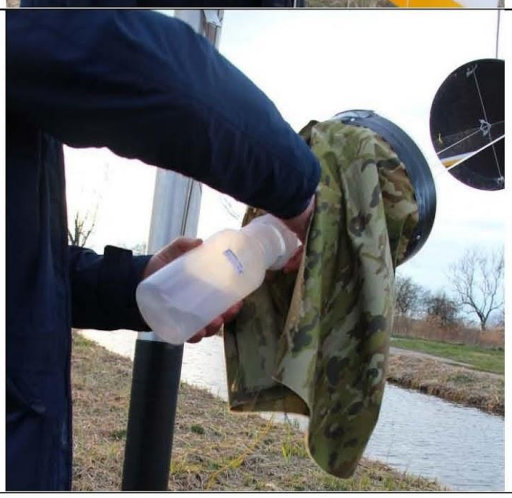
The sampling protocol for the local coordinators in Tatort Streetlight (in German)

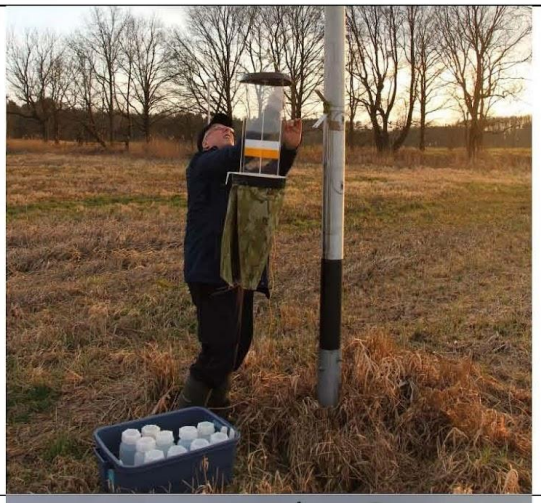
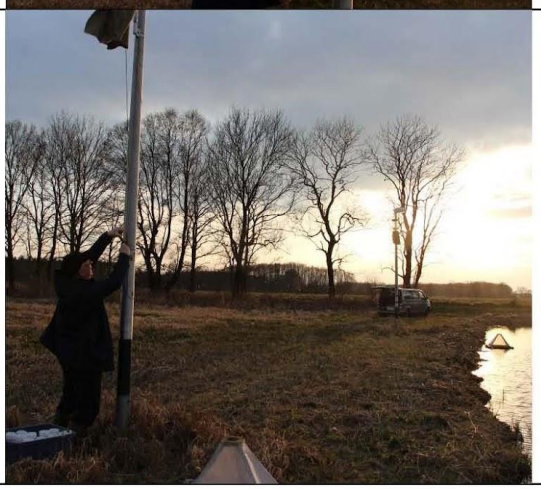
Sampling Protokoll AuBe (Artenschutz durch umweltverträgliche Beleuchtung)

AG Lichtverschmutzung und Ökophysiologie, IGB

A. Vorbereiten: A1: Etiketten ausdrucken und Probenbecher vorbereiten; am besten alles doppelt beschriften, mit den Druck-Etiketten innen und zusätzlich die Probenbecher von aussen	
	
A2: Fangflüssigkeit (EtOH etc) vorbereiten und vorportionieren. Bitte beachten das je nach Dauer der Fangzeit unterschiedliche Mengen benötigt werden, da insbesondere an warmen Tagen (viel) Flüssigkeit verdunstet	

A3: Immer alles schön beschriften!	
A4: Für die Emergenzfallen besonders wichtig dass die Deckel fixiert werden (hier mit Duct-Tape)	
A5: Protokoll nicht vergessen! Dabei die genauen Uhrzeiten für Anfang & Ende des Samplings sowie besondere Vorkommnisse dokumentieren	

B: Es geht los! Das erste Aktivieren der Fallen (üblicherweise fangen wir mit dem Nachtsampling an; bei entsprechenden Wetterbedingungen (bspw. Starkregen) kann es teilw. sinnvoll sein auf den Morgen zu warten). B1: Wir fangen mit den Combitraps a.k.a. Lufteklektoren an	
B2: Immer darauf achten dass die Fallen-ID am Sampling-gefäss zur Lampen-ID passt! Wie man hier gut sehen kann, habt ihr die Fangflüssigkeit schon vorbereitet ;)	
B3: Reinschrauben!	

B4: Hochziehen	
B5: Spannseil befestigen	
B6: Und das zweite Seil für die Fixierung nicht vergessen	

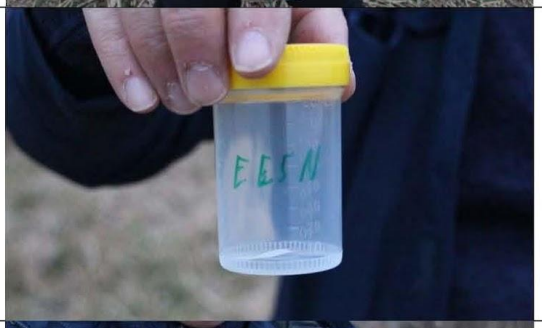
Combitraps hängen!	
C: Jetzt die Emergenzfallen aktivieren!	

C1: Das Verbindungsrohr darf nicht fehlen! (Vorsicht! Das Rohr sitzt manchmal etwas locker und ist dann beim Herausnehmen auch schon mal ins Wasser gefallen!)	
C2: Vorbereitete Fangflüssigkeit in den Fangbehälter geben!	
C3: Deckel festmachen	

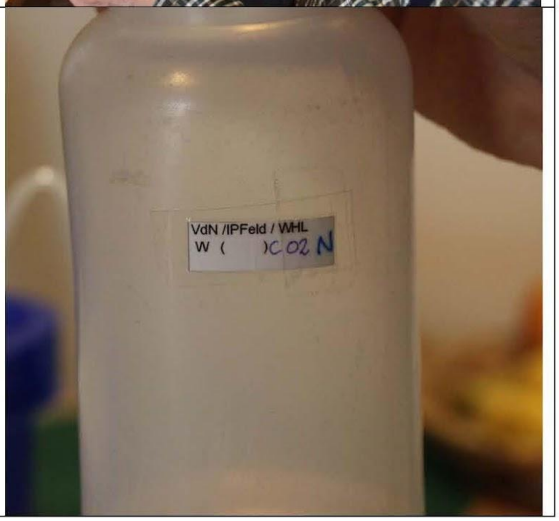
C4: Fangbehälter aufsetzen	
C5: Emergenzfalle aktiviert!	
D: Jetzt heisst es den Austausch der Fangbehälter zum Sonnenaufgang vorzubereiten D1: Hier sieht man die vorbereiteten Gefässe für die Emergenzfallen; links mit den gelben Deckeln die Becher für die Proben, in der Mitte Spritzflasche, Messbecher und Sieb zum umfüllen der Proben und rechts die vorbereiteten Mengen Fangflüssigkeit (beachte unterschiedliche Mengen für Tag/Nacht- und Wochensampling wg. Verdunstung)	

D2: Vorbereite Gefässe für die Combitraps sind natürlich auch dabei	
E: wechseln der Fangbehälter, üblicherweise zu Sonnenaufgang (siehe B) E1: Austausch der Behälter an den Combitraps; Falle runterlassen,	
E2: Behälter mit Insekten einsammeln, leere Behälter für die neue Fangperiode einsetzen. Auf Beschriftung achten!	

E3: Falle wieder aufhängen wie gehabt	
F: Jetzt kommt das Leeren und erneute Aktivieren der Emergenzfallen F1: Behälter abnehmen. Vorsicht mit dem Verbindungsrohr!)	

F2: Fänge überführen; zuerst ins Sieb	
F2: jetzt den vorbereiteten Probenbecher (von aussen beschriftet und innen mit Etikette) bereithalten	
F3: dann mit Spritzflasche in Probenbecher überführen und dann die Emergenzfalle wieder aktivieren wie gehabt	

F4: Gefilterte Fangflüssigkeit zur Wiederverwertung sammeln	
G: Aufbereitung der Proben aus den Combitraps für die weitere Bearbeitung G1: Umfüllen der Proben aus Fangbehältern in die Probenbecher	
G2: Wie immer: auf ausreichend Beschriftung achten!	

G3: Proben wieder mit Sieb, Trichter und Messbecher überführen	
G4: Leave no fly behind! Die Spritzflasche hilft dabei.	
G5: Immer darauf achten, dass die Beschriftung zwischen Sammelbehälter und Probenbecher übereinstimmt!	

G6: die Wichtigkeit der Probenbeschriftung kann gar nicht oft genug wiederholt werden	
H: das Combitrap-Sampling wird beendet indem man nach 24 h die Fangbehälter der Combitraps einsammelt. Überführung der Fänge von den Sammelbehältern in die Probenbecher macht man dann nach der Rückfahrt im heimischen Labor H1: anschliessend werden die inaktiven Fallen unten am Mast fixiert (oder ganz abmontiert und einlagert)	
I: Die Emergenzfallen werden dann noch mal für eine Woche aktiviert. Die Prozedur für das Leeren der Fallen ist genau wie unter F beschrieben. Auf unterschiedliche Mengen bei der Fangflüssigkeit achten, damit keine Fänge eintrocknen!	

Alle Fotos: Gregor Kalinkat; vielen Dank an Stefan Heller für die Hilfe! Stand: 03.04.2020