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1

Guidelines for Standardised Global Butterfly Monitoring

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Guidelines for Standardised Global Butterfly Monitoring

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EXECUTIVE SUMMARY

This publication presents guidelines to support the development of butterfly monitoring at local, national, regional, and global levels. Set out within this document are a suite of standard field protocols that can measure butterfly population change over various spatial and temporal scales, and that can be applied in any part of the world. Two field protocols are recommended here; they are transect counts and fruit baiting. Transect counts entail counting the numbers and species of butterflies along a fixed route ('transect') on a regular basis throughout the flight season. Fruit baiting entails counting the number and species of butterflies caught in a hanging trap baited with fermenting fruit on a regular basis throughout the flight season (Table 1). Additional supplementary protocols are described for specific situations and circumstances.

The target audience of these guidelines are scheme coordinators, i.e. people wishing to establish butterfly monitoring in any part of the world. The guidelines explain how to set up butterfly monitoring that can provide consistent and comparable results between sites and between years, consistent with international standards. The information in these guidelines is not meant to be exhaustive, as each situation will vary according to country or region and over time. However, it should serve as a useful starting point.

Our ambition is that butterfly populations around the world are well monitored, thereby providing vital information on how these insect populations and other parts of biodiversity are changing. This information is important for feeding into local, national, regional, and global decision-making to help reduce biodiversity loss as well as raising awareness of butterflies and biodiversity in general. It is hoped that these guidelines will facilitate increased levels of butterfly monitoring, and in so doing, help to achieve this ambition.

CONTENTS

Table 1: Summary of the two recommended methods

	Recorder Group	Transect counts	Fruit baiting
Where		Everywhere. However there can be (sub-) tropical forests where it can be difficult to perform.	Forests, especially in the (sub-) tropical region. However, in some regions in the tropics numbers are too low with fruit baiting, and transects perform better. In temperate zones this might be a useful method for various canopy dwelling species (e.g. large nymphalids such as Apaturinae in Europe), though more research is needed.
Which species		All species. However, there are families which can be very difficult to identify while walking a transect in some regions (e.g. *Hesperiidae* and *Lycaenidae*). In such cases 'super-species' or morpho-species can be considered.	Fruit feeding species, almost exclusively *Nymphalidae*.
When	*Volunteer citizen science/ parataxonomists (i.e. non-expert field assistance)*	During the flight season when weather requirements are fulfilled. In temperate zones this will exclude winter. In tropical and sub-tropical regions the whole year, though there can be differences between the rainy and dry seasons.	In (sub-) tropical regions year-round. In temperate zones only in the flight period of the target species.
	Professional	During the flight season when weather requirements are fulfilled. In temperate zones this will exclude winter. In tropical and sub-tropical regions the whole year, though there can be differences between the rainy and dry seasons.	In (sub-) tropical regions the whole year. In temperate zones only in the flight period of the target species.
How often	*Volunteer citizen science/ parataxonomists (i.e. non-expert field assistance)*	Weekly, although some weeks will be missed due to bad weather or other reasons. At least three visits in the flight period of a butterfly are needed for trend calculation. More than once per week also allowed. Can be done once in two weeks if flight season is particularly long.	Every two weeks. Traps are deployed four days in a row.
	Professional	Weekly, or more often if needed.	Every two weeks. Traps are deployed four days in a row.
How much	*Volunteer citizen science/ parataxonomists (i.e. non-expert field assistance)*	1-3 transects of 300-1000m per volunteer, though some schemes use longer transects (up to several km)	1-3 sampling units of 4 traps each.
	Professional	3-10 transects of 1km length per working day, depending on the travel distance in between. However, length of transects can also change depending on research design.	5 sampling units of 4 traps each.

1. INTRODUCTION

1.1 Background to these guidelines

Monitoring butterflies is one of the oldest examples of citizen science. The success of Butterfly Monitoring Schemes (BMS's) is due to many factors, not least that the techniques are easy to learn and the field work fun to do. The results of such schemes have proven invaluable in providing robust data on changes in butterfly populations in nature reserves, local areas, countries and even whole regions, such as Europe. Therefore, each individual recorder becomes part of a joint effort to track butterfly fauna and biodiversity in their local area, country, region, and even the whole world as we plan to move towards a Global Butterfly Index. Currently butterfly monitoring is well established in temperate regions such as Europe and North America. The focus of these guidelines is to outline generic field protocols for monitoring butterfly populations (as opposed to species inventories or distributions) that can be applied in any part of the world. Thereby, these guidelines will enable the growth of butterfly monitoring around the world and make possible the creation of a Global Butterfly Index.

The proposed Global Butterfly Index would be similar to, or could feed into, the Living Planet Index (McRae *et al*., 2014), one of the most well-known biodiversity indicators, that measures the state of biodiversity and highlights trends in thousands of vertebrate species populations over large regions of the world. Furthermore, population abundance of species is one of the Essential Biodiversity Variables recently proposed as a minimum set of essential measurements to capture major dimensions of biodiversity change (Pereira *et al*., 2013). In order to compare population abundance data from different locations and bring these data together to create national and international indicators, it is essential to ensure that data collected are based on sound methodology and standards. These guidelines, therefore, propose a standard set of field protocols that measure butterfly population change over specific spatial and temporal scales.

These guidelines arise from a workshop led by the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and Dutch Butterfly Conservation (De Vlinderstichting) with the support of The Group on Earth Observations Biodiversity Observation Network (GEO BON) and the EC FP7 project 'EU BON – Building the European Biodiversity Observation Network', and involving a wide range of collaborating partners from around the world.

These guidelines were developed for those who want to organise butterfly monitoring in any part of the world, i.e. scheme coordinators (either undertaken professionally, or by citizen scientists or parataxonomists (i.e. non-expert field assistants)). It explains how to set up butterfly monitoring that can provide consistent and comparable results between sites and between years, consistent with international standards. The target audience are those concerned with the development of butterfly monitoring, including NGOs, representatives of government agencies, academia, and research institutes, as well as individuals or groups of butterfly enthusiasts who want to start up butterfly monitoring. The aim is to enable the expansion of butterfly monitoring from a temperate context, to a global context and in consideration of: a) all possible habitats; b) climatic differences; c) knowledge gaps in hyper-diverse regions; and, d) a range of audiences from professionals to interested naturalists. The information in these guidelines is not meant to be exhaustive, as each situation will vary according to country or region and over time. However, it should serve as a useful starting point.

1.2 Why is it important to monitor butterflies?

Central to addressing biodiversity change are appropriate policies, plans and actions at local, national and regional scales. Both the implementation and the assessment of effectiveness of such policies require the availability of timely and relevant information about the status of biodiversity and ecosystem services. Yet there are large gaps in our biodiversity knowledge (Tittensor *et al*., 2014). These gaps are taxonomic, geographical and temporal. One of these gaps is in our knowledge of the conservation status of insects. Insects are the world's most diverse group of animals representing over 50% of global terrestrial biodiversity, yet we have poor understanding of their diversity, conservation status, and ecologies (Thomas, 2005).

Contrary to most other groups of insects, most butterflies are well-documented, relatively easy to recognise, and popular with the general public. In addition, they are highly sensitive to environmental changes, such as climate change, farmland intensification or abandonment, and habitat fragmentation. These factors, among others, make butterflies one of the best species groups for monitoring changes in biodiversity (Thomas, 2005).

Well-designed butterfly monitoring programmes make it possible to assess the trends of butterfly populations across time and space (Van Swaay *et al*., 2008). This allows us to track population changes on a local scale as well as nationally, regionally, or globally. These trends can be used as indicators of biodiversity and environmental change (see e.g. Parmesan, 1996; Devictor *et al*., 2012).

Systematic, standardised monitoring of butterflies began in 1976 in the UK (Pollard and Yates, 1993). Since then, well organised schemes have established across Europe and North America. Recently, new initiatives have started up around the globe, sometimes using different techniques like fruit baiting or timed counts. Even where there is no formal scheme for a region or country, single or small groups of transects, fruit bait traps, and timed counts are still very valuable, both as local descriptors of changes in butterfly diversity, as well as contributing to wider programmes where butterflies can be used as indicators.

1.3 Why international guidelines?

Butterfly monitoring is usually organised on a national or state level, and most countries have developed their monitoring schemes independently. These schemes are organised mostly by NGOs with various involvement from other institutions and individuals (governmental agencies, university researchers, research institutes, etc.). National butterfly monitoring schemes employ an array of different field protocols, such as 'Pollard walks' in the UK (Pollard and Yates, 1993) or fruit-bait trapping in Brazil (Freitas *et al*., 2014). If these monitoring schemes use standardised methodologies and document the results of their schemes according to agreed standards and formats, then trends in butterfly populations can be assessed at local, national, regional, and even global scales. The aim of these guidelines, therefore, is to document the agreed, standard methodologies for monitoring butterflies in different ecosystems, biogeographic regions and climatic zones.

These guidelines will assist in the implementation of new butterfly monitoring schemes, especially in gap areas where information on biodiversity change is still very sparse, e.g. the tropics. They describe how to choose, establish, and implement an appropriate butterfly monitoring field protocol; how to design a butterfly monitoring scheme; and how to analyse the resulting data. The overarching aim of this document, therefore, is an introduction to, and guidelines for, monitoring butterfly populations in order to enable the development of local, national, regional, and global butterfly indicators.

2. SCHEME DESIGN

How is biodiversity changing in my country? Are butterfly populations changing? If so, why are they changing? To answer such questions, butterflies must be counted in a standardised way over a long period of time. These guidelines explain how to establish a butterfly monitoring scheme in order to monitor the changes in butterfly population size and community composition, as opposed to monitoring changes in species distributions.

Butterfly monitoring programmes deliver information on changes in biodiversity, contributing to one of the Essential Biodiversity Variables (Pereira *et al.*, 2013). They detect population changes over specific spatial and temporal scales. The unit of area can be as small as a large garden monitored by one person, and as large as the total worldwide range of a species. The unit of time can be as short as a day and as long as a decade. For practical reasons, we will focus on transects and fruit-bait traps as the sampling unit (refer to Chapter 3 for more detail) and generations or years as the temporal unit.

Designing a butterfly monitoring scheme involves making a number of decisions around field protocol, location and number of monitoring sites, and frequency and timing of counts. The coordinator also has to arrange validation and quality control, organise the analysis of the data, and provide feedback to the recorders. This chapter provides recommendations on location and number of monitoring sites, when and how frequently to count, the size of the monitoring site, and data logging. In Chapter 3 the field protocols are described and in Chapter 4 practical implications of setting up and running a Butterfly Monitoring Scheme are discussed.

2.1 Location of monitoring sites

Individual recorders are free to choose the location of monitoring sites (many of the volunteer-based citizen science schemes work like this), but site location should also be consistent with pre-defined selection procedures for an entire scheme. This is either a random or grid-based design. Random or grid-based schemes have the advantage of delivering the most statistically robust data for further analysis. However, if rare, local, or threatened species are one of the focuses of your scheme, then you may need to establish targeted sampling to ensure complete coverage. As an example, butterfly monitoring schemes for national parks will likely require different design considerations compared to that of national schemes.

When designing a butterfly monitoring scheme keep in mind:

- Once chosen, monitoring sites are fixed to provide consistency between years.
- At monitoring sites there are two main field protocols:
  1. Transect counts, where transects can be divided into one or multiple sections (the length of these sections can be variable, although many countries use a fixed length of 50m).
  2. Fruit baiting, where traps are placed in sampling units (a sampling unit consists of a number of traps). Distance between two traps <u>within</u> a sampling unit should be 30m - 60m, and distance <u>between</u> sampling units in the same habitat should be about 500m - 1000m.
- It is important that the exact length and location of the transect or sampling unit is recorded, as well as the exact location of the transect sections or the fruit-bait traps.
- Cover only <u>one</u> habitat[1] type per monitoring site.
- For a Butterfly Monitoring Scheme all monitoring sites together should give a good representation of all possible habitats (N.B. again, this will be dependent on the aim of the specific scheme).
- To the extent that is practical, monitoring sites should be close to the recorders' residence or workplace, particularly for programmes that use volunteers (in order to facilitate easy and regular monitoring). For a scheme that is run professionally this can be different.
- The recorder should not in any way change or even damage a location by the monitoring effort. For this reason, on vulnerable vegetation (e.g. bogs), adapted methods should be used (see paragraph 3.3).

1 Though there are different meanings and perceptions of what constitutes a habitat, the meaning here is in its general sense including a subjective at a glance assessment or a detailed assessment of an area as a relatively homogenous habitat unit or habitat type.

2.2 How many monitoring sites?

The more monitoring that is conducted, the better the data will be. Aim for as many monitoring sites as practicable and that these sites are monitored for as many years as possible. Trends in butterfly abundances may only be detected after five to ten years. However, over the shorter term, the information gathered is important for improving the knowledge of specific butterfly species' distributions and ecologies (Staats and Regan, 2014) and increasing the public's interest in butterflies. Based on Van Strien *et al.* (1997), 25 sites should be sufficient for most species as a rule of thumb. According to Schmucki *et al.* (in press), in Europe, 15-20 sites for a univoltine species (i.e. one generation per year), counted at least every two weeks, results in a 80% statistical power of detecting a 10% change over ten years. These numbers are based on available power analysis studies for European Butterfly Monitoring Schemes but might be different for other regions. Among other factors, the power depends on the year-to-year, year-to-site, and site-to-site variance of the species, thus leading to different numbers of sites for each species. Species with little variance (e.g. by comparable numbers, fluctuations and trends at many sites and over the years) need fewer transects in order to achieve a high power to detect population trends.

2.3 When and how frequently to count?

Monitoring butterflies on transects is only possible when butterflies are active (i.e. during their flight season). Weather is the key factor for deciding on time of day and time of the year for monitoring. In general, butterflies are active at temperatures between 13°C and 33-35°C, with no rain or strong winds. Between 13°C and 18°C, sunny conditions are required. When temperatures rise well over 30°C some species will stop their activity, making standardised counts difficult. In very hot weather, counts should preferably be made in the morning before it gets too hot. For a transect count it is preferable to monitor in good weather (as set out above), while a fruit-bait trap should be set for several days during good weather conditions, where possible. However, the coordinator of a scheme can deviate from these rules according to the optimum situation for their scheme.

Butterflies should be monitored at least two to three times during their flight period; this applies to both transect counts and fruit baiting. This means, in practice, that monitoring should aim at weekly counts during the flight season (for a minimum of three months), accepting that some weeks will be lost because of bad weather or social obligations and commitments of the volunteer recorders in the case of citizen science schemes. For fruit baiting, the traps are deployed for four days in a row, and this is repeated every two weeks.

Monitoring could cover the entire year, although there is seasonality everywhere, which can be more or less pronounced. The coordinator should take this into account when designing the scheme. For example, during peak conditions in rainy or wet seasons, all butterfly activity can cease, even in the most diverse forests. But butterflies can be seen throughout the year. In temperate zones, winter brings an end to the suitable weather conditions during which counts can be made for a period of several months.

For volunteer-based Butterfly Monitoring Schemes it is important to keep in mind that recorders also need some time off (approximately three months), otherwise weekly counts can become too demanding. Fruit baiting, in general, can be done for three to four months in a row (or throughout the year if sufficient volunteers are available).

The main objective of butterfly monitoring is to detect changes in population size on an annual basis. For significant trends with good statistical power, this will require the Butterfly Monitoring Scheme to have as many transects counted as possible for as long as possible during the favourable weather conditions.

2.4 Size of monitoring sites

Avoid making monitoring sites too big. Depending on density and number of species, a 1 km transect will take about 45-60 minutes to count, and four fruit bait traps (one sample unit) could take 15-45 minutes to check. For this reason, the length of the total transect in some countries is restricted to a maximum of 1000m (although some schemes allow for much longer transects), and the number of fruit bait traps in one sample unit to 4 traps. If the site is big and you want to sample more habitat types, it is better to establish several smaller monitoring sites. If the site is too small, a limit should be put on the time spent in the site. In such cases we suggest reverting to an alternative method (paragraph 3.3).

If species composition is one of the goals of the Butterfly Monitoring Scheme, the coordinator should undertake an analysis to identify a minimum transect length or minimum number of fruit-bait trap sample units by calculating a species' accumulation curve[2]. In temperate zones, 300 m has proven to be a good minimum for such transects. In general, it requires many more transects or trap sampling units than used when establishing population trends for the most common species.

2.5 Documenting the monitoring site

For each monitoring site the following information must be documented:

- Location (list site and transect coordinates, and indicate as best possible on a site map): this should include the sampling points (in the case of baits) and, as a minimum, the beginning and end of each transect section.
- Transect length or the number of fruit bait traps including the distance between them.
- Height of fruit bait trap from ground.
- Fruit bait: exact details of bait used in traps (especially if the standard banana bait has not been used or has been altered).
- Recorder(s) name and contact details.
- Habitat type: standards will differ from country to country and continent to continent. However, it is important that recorded habitat types can be easily related to the main biome types. Habitats will include forest, grassland, desert, chaparral, heathland, wetlands (including ponds, lakes, fens, swamps etc.), urban (including gardens and parks), agricultural, other (e.g. coastal, rock/scree, barren, mangrove, etc.), or important ecotones (e.g. forest-grassland edges, or hedgerows/ditches in agricultural areas). N.B. if transects are located on the edge or periphery between two habitat types, please record this information also.
- Land tenure (i.e. who owns the land), in a way consistent with global categories: e.g. farming, nature conservation, public, private person, private company, military, forestry or unknown.
- Land management (up-scalable to global relevant categories): no-management, forestry, grazing, mowing (or other vegetation clearance, e.g. herbicide spraying, burning etc.), pest management (e.g. insecticide spraying), land drainage, or extraction (e.g. turf/sod/peat cutting, aggregate extraction, topsoil stripping etc.).
- If monitoring at an existing site starts or stops, document the reasons for this in order to aid interpretation of the data. The difference between monitoring stopping because the site has changed due to development (e.g. construction) or due to the recorder moving house has different implications for butterfly trends.

[2] The species accumulation curve is a graph recording the cumulative number of species as a function of the transect length.

3. FIELD PROTOCOLS

There are many different protocols for counting butterflies in the field, but none that can uniformly be considered the best. Every field protocol has its advantages and disadvantages, and all field protocols miss some part of the butterfly fauna. However, two main standard types of field protocols are recommended here: 1. transect counts (or 'Pollard walks'); and, 2. fruit baiting.

The choice between these two main field protocols depends mostly on the situation. Transect counts are suitable for open habitats such as grasslands, heathlands, dunes, etc., though they can be applied in many forests as well (e.g. where vegetation is more open in clearings, paths, and less dense areas, see also Basset *et al.*, 2015), while fruit baiting can be more suitable in some dense tropical and sub-tropical forests. For example, as it enables the sampling of a guild of butterflies rather than the whole butterfly community (i.e. 50-200 species instead of 500-1000, for example); this therefore, makes the task of specimen identification easier. It is also possible to combine both methods and/or make point observations (see section 3.3) in open spots in the forest. However, consult with regional experts to help guide your choice.

The following sections (3.1 and 3.2) describe how to implement these two field protocols as well as supplementary protocols for specific cases (3.3).

Every method will miss some part of the butterfly fauna. Fruit baiting in the tropics will miss species which are not attracted to fermenting fruit. Transect counts will miss those species that tend to be found in the canopy of the forest and are thus out of sight. Therefore, these guidelines focus on a pragmatic approach by specifically monitoring changes in a proportion of the butterfly population rather than monitoring the whole species assemblage. These methods are sufficient to develop an indication of how butterfly populations are changing. The aim is to monitor changes in butterfly populations as a proxy for biodiversity changes.

For some species that are missed by transect counts or fruit baiting, there is a group of other methods including timed counts, point counts, area counts, and other techniques that can be used (for example, if they need to be monitored because they are legally protected). These methods are described in section 3.3. However, these are mostly regarded as supplementary processes to transects or fruit baiting.

3.1 Transect counts

Transect counts or 'Pollard walks' (Pollard, 1977) are the most widely used field protocol for monitoring butterfly populations. The protocol is well tested and can be used by both volunteers as well as professionals. This approach has become the basis of many monitoring schemes around the world. Transect counts entail counting the numbers and species of butterflies along a fixed route ('transect') on a regular basis (e.g. weekly) throughout a given time of the year (see Figure 1 for an example of a butterfly monitoring transect and its sub-divided sections). It is practical to divide a transect into smaller sections. This makes it easier to keep an overview, process the data, and offer extra possibilities to analyse the results.

Figure 1: An example of a butterfly monitoring transect divided into 11 sections. Transect counts are the most widely used field protocol for monitoring butterfly populations.

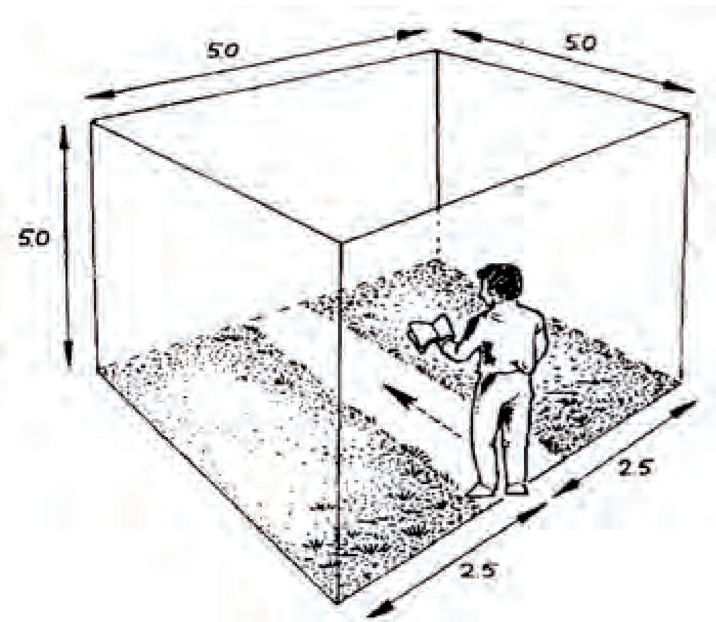

Figure 2: The counting cube area used when conducting a 'Pollard walk' line transect butterfly monitoring (© Dutch Butterfly Conservation).

How to count

- Walk transects at a slow, constant pace.
- Count all butterflies by individual species in an imaginary box, 2.5m to each side and 5m in front and above you (see Figure 2).
- Stopping to identify a butterfly for identification is allowed, but do not continue counting when stationary, since this would substantially increase sampling effort.
- For each transect section, record the number of butterflies per species.
- If permitted, a net to catch butterflies can sometimes be helpful for relatively inexperienced recorders. However, if using a net, it is likely that the recorder will deviate from the transect (or counting cube area) in order to capture a butterfly. In such instances, identify then release the specimen, and return to the exact point from which the transect was deviated. Whilst netting and identifying do not count any additional butterflies between leaving the route and returning to it.
- A photograph can be useful for later identification.

Some volunteers can be eager to record rare or interesting butterflies which they may see outside the standard monitoring timeframe. These additional records can be included as part of the monitoring, but they should be clearly stated as "extra butterflies seen on site". This way oversampling by recorders is avoided.

3.2 Fruit baiting

Many species found in the tropics and sub-tropics are frugivorous and can be attracted by using fermenting fruit as bait; this is called fruit bait trapping (Freitas *et al.*, 2014). This field protocol offers a useful way to monitor changes in frugivorous species composition and abundances over time and between sites. In addition, sampling effort is easily standardised and monitoring can be undertaken by one person simultaneously at several sites. Fruit baiting entails counting the numbers and species of butterflies trapped in a fruit bait trap on a regular basis throughout the flight season.

This method detects population trends for a subset of the common fruit feeding butterflies. For an overview of all frugivorous species, much higher sampling effort is required.

Trap design

- The basic configuration of a trap is a net cylinder, closed at the top, attached to a platform, with a narrow opening at the base between the netting and the platform (approximately 5 cm between the platform and the cylinder (4 to 8 cm is a good range); see Figure 4 and Figure 5). Traps should be at least 1 m tall and 25 cm in diameter to minimise the escape of the butterflies. An internal narrowing at the entrance can reduce the likelihood of butterflies escaping. The platform should be wider than the cylinder, allowing butterflies to land before entering the trap. Dark coloured netting, such as greens, browns, greys, and black, are more suitable than light colours (Figure 3). It is possible to tailor these traps to make them suitable for site specific conditions, for example, by adding plastic rain covers.
- There are several options when building a trap. The cost may vary from US$10 to US$20 per trap, depending on the cloth used and whether a sewing service has been employed. A cheap and simple solution which works very well is a modification of a storage net from IKEA (described in detail in Sáfián *et al.*, 2010).
- The basic sampling unit for fruit baiting is four fruit bait traps over four days and repeated every two weeks.

Figure 3: Fruit bait trap constructed using black netting.

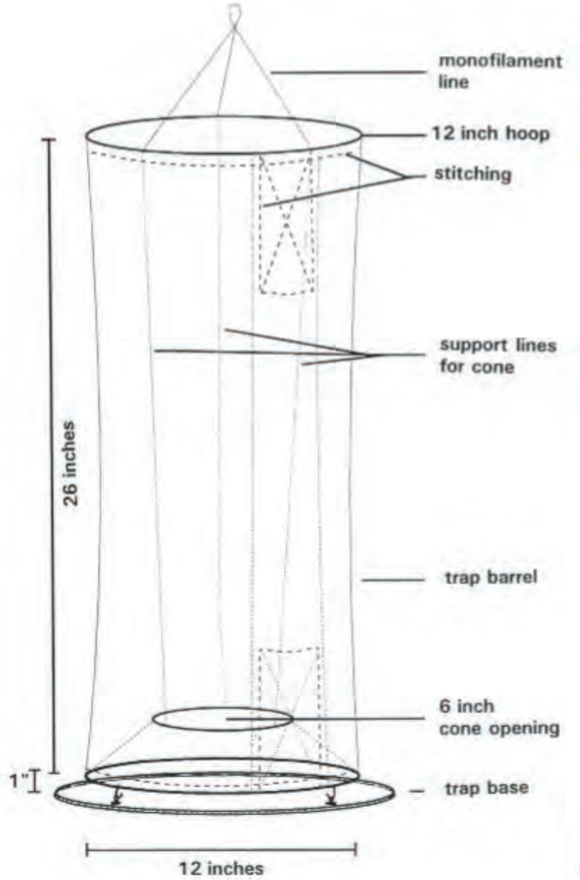

Figure 4: Schematic of an example design of how to set up a fruit bait trap (Shuey, 1997)

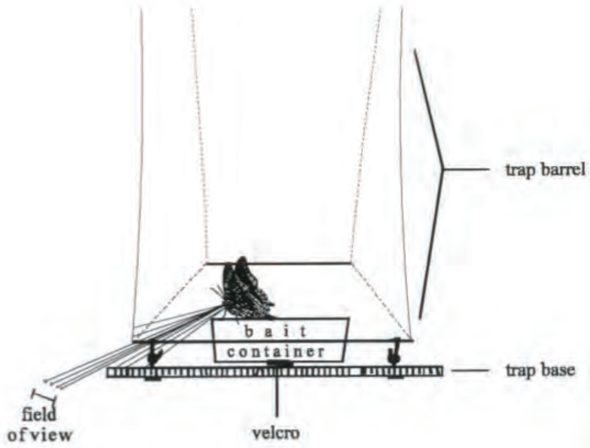

Figure 5: Detailed view of the base of a fruit bait trap (Shuey, 1997)

Bait

- Bait is made from pure bananas (peeled for higher sugar content). It is cheap, widely available, can be transported and can be purchased green, providing another 4-5 days before the bait will need to be used. Mash the bananas and keep them in a covered bucket before use. Do not refrigerate the bait. Leave for two days, releasing the gas whenever necessary. In cooler environments it may be necessary to leave the bait for another day to complete fermentation; otherwise yeast can be added to speed up the process. **Please note, it is very important that bait is always made in the same manner**. Stir the bait regularly to avoid a serious drop in sampling efficiency and replace the bait entirely after a few days (if the trap is kept active).
- Bait should be put in 50ml - 150ml pots. Occasionally, a perforated cover may be added to the pot to avoid feeding by other insects, to reduce evaporation, and to prevent small butterflies from drowning (Hughes *et al.*, 1998). The pots should be placed at the centre of the platform, and the pots should be as tall as the distance between the platform and the cylinder, therefore making it difficult for captured butterflies to escape.
- If you have to vary the bait between seasons or elevations, then it needs to be controlled systematically and well-documented, such that your data are consistent enough to be useable. For example, if bait dries up too fast, the protocol may have to account for this by requiring that the bait is refreshed every day during the monitoring period (or alternatively – never refreshed).

Setting a trap

Setting a fruit baiting trap in the field involves a sequence of steps, as set out in Figure 6:

Steps 1-4: Choose a tree where you can position the trap so that the platform will hang approximately 1m above ground. In some regions this might not work, so always discuss placement of traps with local experts.

Steps 5-6: Tie the trap platform to minimise swinging in the wind. If ants are common at the site, apply any greasy material (e.g. oil, grease, polish) to the hanging string/rope to form a physical barrier.

Steps 7-8: Fill the pot with the fermenting bait and place it in the middle of the platform.

Steps 9-12: Leave the traps in the field for approximately 24 hours (as some fruit-feeding butterflies would enter the traps late in the afternoon or even at dusk or dawn). Cautiously approach the traps before checking them, to avoid startling butterflies, especially those that are on the platform. Lift the platform to close the gap between the base and the cylinder to prevent escape.

Steps 13-14: Use a clothes-pin (safety pin) to hold the trap shut. Be careful to avoid stinging and/or biting invertebrates (e.g. wasps, ants, bees, spiders or beetles) present in the trap. Pick up each butterfly carefully, to avoid harming it.

Steps 15-17: Identify or photograph and record every trapped butterfly before releasing. Photographs should be taken of both upper and under sides, including a magnified picture of any special features. Please consult experts with regards to difficult groups requiring extra consideration for identification. In some cases the coordinator of a BMS can consider to collect voucher specimens. This is, however, not always appreciated by all volunteers or the general public, although there is no scientific proof that it threatens populations if done with care.

Steps 18-20: After releasing the butterflies and other insects from the trap, stir the bait. The traps are deployed for four days in a row, and this is repeated every two weeks. After four days throw the old bait into a sealed rubbish/trash container. Never throw the old bait on the ground close to the trap.

> This procedure should be repeated every two weeks.
> **This fruit baiting field protocol still needs further testing in different situations and countries.**

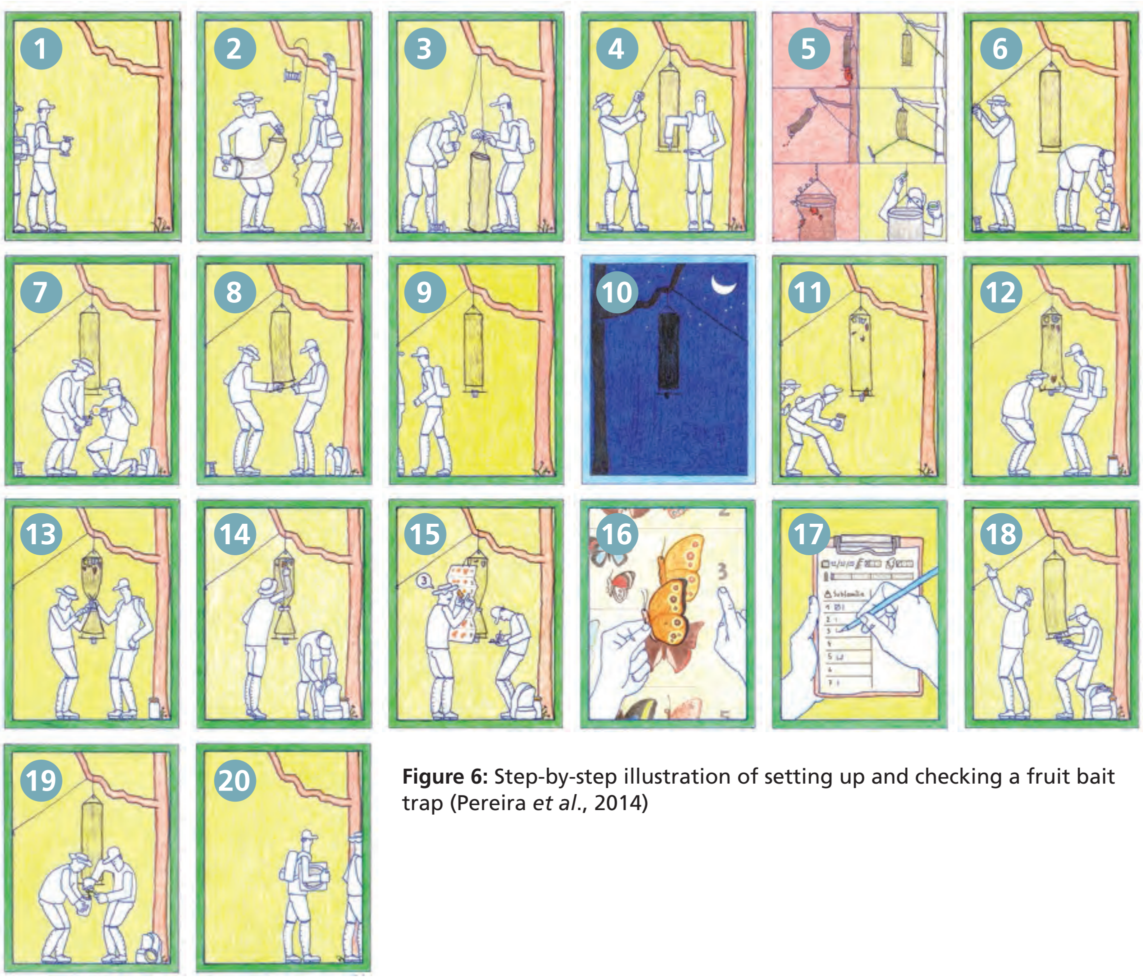

Figure 6: Step-by-step illustration of setting up and checking a fruit bait trap (Pereira *et al.*, 2014)

3.3 Supplementary methods

These guidelines focus specifically on monitoring population changes in a proportion of the butterfly species rather than monitoring the entire species assemblage. Transect counts and fruit baiting are sufficient to develop an indication of changes in butterfly populations that can be used as a proxy for overall biological diversity. However, both of these field protocols will inevitably miss certain species.

If there is a need to monitor the populations of species that are poorly detected by these methods, there is another group of methods which can be used to measure their populations. However, these are mostly regarded as supplementary processes to transect counts or fruit baiting. This chapter will give a short description of these main alternative approaches.

Urban garden monitoring (or other small habitat patches)

Although it is possible to have a transect in some gardens, many are too small to walk a transect at a slow, constant pace and count all butterflies by individual species in an imaginary box of 5x5x5m. Therefore, the urban garden monitoring protocol can be used. This defines a fixed (and feasible) area (mostly a private garden), as well as minimum and maximum duration for sampling, in which records of the number of butterflies of each species observed during a monitoring period are captured. There is no need to define a fixed route and count in a box of 5x5x5m for urban garden monitoring – instead, it is for the observer to decide what area of search to use (mostly while slowly walking through the garden), noting that small butterflies cannot be identified at a distance greater than 5m. In some cases a time-limit (e.g. 15 minutes) can be applied. The frequency of the counts is at least weekly, but as they require only little time, they may be conducted more often, even several times per day.

This protocol can also apply to other small habitat patches.

Point observation

Point observation (in which only monitoring time is pre-defined) is a second example of habitat specific recording. Point observations are necessary where counts can only be made from a point, and not along a transect, e.g.:

- when sampling canopy butterflies - canopy-walks or towers cover only short distances or points.
- monitoring hill-topping butterflies: some butterfly species can aggregate on hilltops or other elevations (e.g. trees, castles or high buildings (including Mayan temples etc.)).
- when monitoring bog-butterflies, as bogs can be dangerous to enter. Recorders should seek to traverse a safe route to a single observation point where counts can be conducted safely.
- when counting butterflies in an open spot in the forest.

Often, point observation protocols rely upon using greater distance to count butterflies than 5m (e.g. in the canopy of trees). Inevitably this means that sometimes some butterfly species are unidentifiable to species level, and also that differences in detection probability lead to larger differences between species and recorders (and their combination). In some cases a time-limit (e.g. of 15 minutes) can be applied. The frequency of the point observation counts is weekly (comparable to transect counts); indeed, all other aspects, for example point location selection and weather conditions, are also comparable to those of transect counts.

Large area monitoring

For monitoring of rare species, especially if they have a dynamic use of the landscape, a large area can be defined and searched for the focal species for a given amount of time. This method is used for monitoring rare species that live in extensive areas of upland or woodland habitats, such as *Melitea athalia* and *Argynnis adippe* in the United Kingdom and *Tomares nesimachus* in Israel. The frequency of the counts should be at least every two weeks, preferably every week, but only during the flight period of the target species.

Monitoring other life-stages

For some species, especially if the adults occur in low densities, the monitoring of other non-adult life-stages as eggs or larvae, can be the most effective way to monitor changes in population size. Plots are generally defined between $50m^2$ and 1ha depending on the density of the species and its food-plant; it should be possible to search these areas in 30-60 minutes. Counts must be made in the same stage of development (e.g. shortly after the eggs are laid, or just after they have hatched, or just before they pupate) to avoid differences between counts resulting from mortality differences. Usually one or two counts are enough as eggs do not move, and larvae only move short distances. The best time of day to count larvae depends on the biology of the species, as some species can be inactive and hard to find during the day or night. Weather conditions (e.g. low temperatures and cloud) also affect activity levels and should therefore be taken into account.

However, in tropical regions there is generally much less available information and/or knowledge for the identification of immature life-stages for many butterfly species. As such, monitoring in this fashion might not be practical.

Mark-release-recapture

The mark-release-recapture (MRR) method is a tried and tested technique to estimate absolute abundance of butterfly populations. The method is highly labour intensive and requires capturing, handling and marking individual butterflies. For these reasons, MRR is not a practical option for wide-scale annual monitoring of butterfly populations.

Distance sampling

This is a group of techniques used to estimate the absolute population size or density of wildlife populations that live in open habitats. Distance sampling works on the assumption that the further away you look and record, the fewer individuals will be seen, and that this relationship can be described mathematically through a detection function. The method is a less labour intensive alternative to MRR, but is technically demanding and the analysis of the data is complicated. For these reasons, it is chiefly used to assess the population size of rare species in special cases by professionals.

Puddling

In some locations some butterfly species aggregate in wet conditions, demonstrating behaviour known as 'puddling'. When puddling, butterflies are relatively easy to find and count. However, monitoring methods for puddling butterflies have yet not been tested for long enough to determine whether robust data on population changes can be established. One method which has been developed uses photography to facilitate the counting of numbers of puddling butterflies. But this has only been tested on *Trogonoptera brookiana albescens* and only for a period of 2 years (Phon *et al.*, in prep.). It is hard to create a standardised protocol based on this behaviour given the haphazard nature of puddling locations. For these reasons, monitoring of puddling butterflies requires longer field testing to enable the standardisation of the method.

Occupancy modelling with opportunistic data

In recent years, the number of opportunistic records (observations collected without standardised field protocol and without a design ensuring the geographical representativeness of sampled sites) has increased greatly by the emerging of online citizen science databases in many countries, with data entry facilitated through internet portals. This opportunistic data may vary from single records of species to complete day-lists of species, i.e., records of all species collected by a single observer on one site and date. These data are a potentially valuable source of information on changes in species ranges (Schmeller *et al.*, 2009).

Isaac *et al.* (2014) show that by using occupancy modelling, it is possible to use such opportunistic data to produce reliable distribution trends. Strong trends in monitoring data were never missed when using the opportunistic data (Van Strien *et al.*, 2013). Non-standardized data can deliver unbiased and precise species trends if adequately analysed. This is in particular true when the interest is in trends in range rather than in abundance trends, because occupancy models cannot be used for monitoring abundance.

3.4 Data logging

Chapter 2 describes the information that needs to be logged for each monitoring site. In addition, regular butterfly counts need to be logged along with other information. Please log the following data for each transect visit or fruit baiting episode:

- Name of the person recording
- Section of the transect count or fruit bait trap ID
- Species* and numbers of the butterflies# observed or trapped
- Date
- Start and stop time
- Basic weather conditions: temperature, wind speed and cloud cover. The coordinator can also consider using standardised measurements from the internet to avoid recorder bias. More information on conditions in the tropics can be found in Basset *et al.* (2013).
- Significant notable events (e.g. mown vegetation (or other notable management practices), logged trees, fallen traps, bait removal, evidence of butterfly predation inside the traps, significant seasonal events (e.g. flowering or fruiting)).

*For difficult-to-identify species, it is advisable to take a photograph (upper and under sides of wings if possible) for later validation or identification. In certain circumstances and, if allowed, a specimen may also be collected. Efforts should be taken to ensure that photographs and specimens are easily traceable to the transect, and transect section, from which they were collected.

#When no butterflies have been observed please remember to enter '0/zero' - zero-counts provide important data too!

4. COORDINATING A BUTTERFLY MONITORING SCHEME

4.1 Manual

These guidelines are directed at coordinators of Butterfly Monitoring Schemes. To be of practical use to the recorders, these guidelines should be translated to a short manual which addresses the practicalities of monitoring butterflies in the region or country involved. Where these guidelines offer several methods and different ways to handle the monitoring sites and counts, the manual for recorders should be clear, offering one method and include final guidance on suitable weather parameters, best time of day, frequency of the counts, identification problems and how to deal with them, etc.

The manual should also describe precise protocols for data collection and submission.

4.2 Data

After count data has been collected by the recorders, records must be submitted to the coordinator for analysis of butterfly population trends. Count data can be submitted as hard-copy field records, online submission, or the use of 'smart' applications (or 'apps'), depending on the infrastructure available in your country. Submitted data should be stored in a database.

Taxonomy, database systems and apps change rapidly. It is important to liaise with other BMS coordinators, and to attend (international) conferences and meetings to remain up-to-date with the latest developments in terms of recording and monitoring, and relevant associated technology in order to apply the latest standards.

4.3 How to find and retain recorders

After a coordinator has set-up the standardised method for counting butterflies, written the manual and designed a way to collect the data, the next important step is to recruit recorders. Recorders can be professional or volunteers. These guidelines focus on working with volunteers as part of citizen science projects.

There are a wide variety of avenues by which data recorders can be recruited. Traditional ones include serving as a guest speaker at regular meetings of nature groups, such as birding and garden clubs, and writing newspaper, online, or blog articles. The development and sharing of a website provides a central place where all this information can come together. Additionally, social media streams can also provide quick and efficient methods to gain attention. For example, by starting a Facebook group, entering your ideas on Twitter, and using LinkedIn, you can reach out to interested parties and develop a network of contacts.

Regular feedback is important to keep volunteers interested. The publication of results on social media, in newspapers, or via other avenues, will provide opportunities to share this information and to stimulate interest and participation.

4.4 Species identification

Correct species identification is vital for accurately detecting trends. Although field guides and websites are available in many countries and continents, there are still important parts of the world where such aids are not available. In such cases BMS coordinators should consider how to produce an overview of the most important species in the monitoring sites and how they can be distinguished. Monitoring scheme coordinators should encourage recorders to collect photographs to aid future identification. Furthermore, scheme coordinators or other suitably experienced individuals could consider collecting voucher specimens to develop a local reference collection in order to further facilitate future identification.

4.5 Validation and quality control

Validation is crucial for a robust Butterfly Monitoring Scheme and should focus on:

- The visit (date, time of day, weather conditions, etc.): were the date, time of day and weather conditions suitable for counting?
- Identification:
  - *Geographical range*: Is the record within the known range of the species (as far as we can tell)? Photographs or voucher specimens can help to get a positive identification afterwards.
  - *Flight period*: Is the species typically flying on this date and at this time? In an area where the butterfly fauna is well known this can be a good step to help validate records. If there is no detailed knowledge of this information available, the records from other monitoring sites can help.
  - *Behaviour*: Are the numbers unusual? Some species are rarely ever seen in large numbers, therefore a report of 50 would be suspicious.
  - *Rare species*: Are there odd patterns involving rare species? For example, does the same recorder see completely different suites of rare species from year-to-year, rather than documenting resident populations of the same rare species year after year?
- If a 'smart' application is used for reporting in situ, or reporting is done online, an initial first screening can be done automatically for the first stage of the validation process. This could potentially save a lot of time for coordinators.

4.6 Data analysis

After all records have been collected and validated, the first step in the analysis is to remove counts which can't be used, for example:

- If a transect is counted only a few times, there might not be enough counts in the flight period for further analysis. As a minimum requirement, Schmucki *et al.* (in press) demonstrate that at least 50% of the weeks in the flight period are required to be recorded to capture sufficient data for analysis. As the flight period of many butterflies is generally 5-8 weeks, this means that, as a rule of thumb, a minimum of three counts of the same transect during the flight period are required.
- Combining counts (e.g. on the basis of climate or vegetation on the transects or sampling units), also with attention to using regional Generalised Additive Models (GAMs) (Schmucki *et al.*, in press): this enables a more robust analysis of the data.
- If transects were selected by the free choice of the recorder this can lead to the over-representation of protected sites in natural areas and the under-sampling of the wider countryside and urban areas (Pollard and Yates, 1993). Obviously, in such a case, the trends detected may be only representative for the areas sampled, while their extrapolation to national trends may produce biased results. Such bias can, however, be minimised by post-stratification of transects. This implies an a posteriori division of transects by e.g. habitat type, protection status and region, where counts per transect are weighted according to their stratum (Van Swaay *et al.*, 2002).

If species have more than one generation a year it is best to treat the generations separately. However, generations can be hard to distinguish, particularly for widespread species with overlapping generations. In such cases the whole flight period should be analysed.

There are a number of software programmes for analysing butterfly monitoring data including TRIM (Pannekoek and Van Strien, 1998) and a new method based on Generalised Additive Models (GAMs) (Dennis *et al.*, 2013).

The results of national indices and trends per species, per country or region, can be combined to produce indicators. More information on this process can be found in Van Swaay *et al.* (2015) and is similar to the Farmland Bird Indicator (Gregory *et al.*, 2005). This method is similar to the Living Planet Index (WWF, 2014).

This provides only a short summary of data analysis. Furthermore, there are many new developments in this field. It is highly recommended that Butterfly Monitoring Scheme coordinators contact neighbouring coordinators for the exchange of experience and ideas.

4.7 How many monitoring sites are needed?

The determination of the number of monitoring sites needed to robustly detect changes in populations for a butterfly species is crucial. For species which are recorded at a minimum of 20-30 sites per year, it will be possible to reach an 80% statistical power to detect a 10% change over 10 years. For fruit bait traps this is still unknown. However, even a small number of monitoring sites will improve our knowledge of species' ecologies, population fluctuations, etc., and, in turn, improve these monitoring protocols. The above recommendations are based mainly on experiences from temperate regions and will be refined as tropical monitoring expands.

4.8 Cost and time involved

If a Butterfly Monitoring Scheme is run as described in these guidelines, these are rough estimates of the time and costs needed:

- For the coordinator (national level): approximately 0.5 Full-Time Equivalent (FTE)
- For volunteers conducting transect counts: approximately one - two hours per week, excluding travel time, during the butterfly season.
- For volunteers conducting fruit baiting: approximately one hour per day to empty the traps and record the butterflies, for four days every two weeks, for three to four months a year.
- Fruit baiting traps generally cost USD $10-20/trap. The IKEA adaptation is cheaper.

5. FINAL THOUGHTS

This is the first attempt to develop global guidelines for butterfly monitoring. We plan to review and update regularly as butterfly monitoring in areas such as the tropics grows. In the meantime, we believe that this document will help new butterfly monitoring schemes establish and develop. It aims to be a generic framework that should be applicable in most situations. Butterfly monitoring should be consistent with these generic guidelines to be comparable with monitoring in other regions but also so that it can be aggregated into regional or global indices. Each region, however, may require slightly different monitoring protocols within this generic framework and this should be decided by the scheme coordinator in consultation with regional experts.

The authors of this document are happy to advise on new monitoring schemes and welcome feedback on how these guidelines can be improved. A website has been established whereby the authors can be contacted, feedback submitted, and butterfly monitoring schemes listed - http://butterfly-int.wix.com/international. Our ambition is that butterfly populations around the world are well monitored, thereby providing vital information on how insects and other parts of biodiversity are changing. This information is important for feeding into local, national, regional, and global decision-making to help reduce biodiversity loss as well as raising awareness of butterflies and biodiversity in general.

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