Butterfly Monitoring for Conservation

Doug Taron and Leslie Ries

Abstract Monitoring butterfly populations is an essential component of their conservation. Some survey techniques measure occupancy, and simply determine the presence or absence of species, whereas other techniques measure butterfly abundance. Mark release recapture techniques involve marking the wings of a subset of a population, releasing and then recapturing them, and determining the proportion of marked individuals in the re-sampling. Distance sampling takes advantage of the decrease in probability of detection of individual butterflies as a function of increased distance from the observer. These techniques can both be used to estimate actual population size. Mark release recapture is the most rigorous, but also the most labor-intensive technique. It also carries risk of damage to individuals during the marking process. Distance sampling is statistically robust and doesn't risk damaging butterflies by marking them. In some cases, the requirement for survey transects to be placed randomly within the population, and the assumption that the butterflies are distributed uniformly limit the application of the technique. For Pollard walks, surveyors walk a set route at a uniform pace. They count all butterflies within a prescribed distance (generally about 20 m). In addition to these systematic survey techniques, a variety of less formal monitoring protocols are also used. These include count circles, field trips, and wandering surveys. There are also a wide variety of online opportunities for interested individuals to submit butterfly observations. Researchers should consider the assumptions, advantages and disadvantages when selecting a technique.

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Introduction

Numerous facets of the conservation of imperiled butterflies require knowledge of population trends, which in turn requires knowledge of population size. Monitoring populations is a key aspect of management because it provides information about how populations are faring and may provide critical cues to when management should be modified (Holling 1978). Monitoring is usually motivated by one of two goals: (1) targeted monitoring of specific species or populations that are known to be in jeopardy or (2) general monitoring to track trends in the overall butterfly community. Here, we describe the different types of monitoring protocols which are most frequently used for both targeted and general butterfly monitoring. Targeted monitoring is usually carried out by agencies or organizations focused on the conservation of a single, often rare, species or a local population and several examples are described in detail in chapters "Developing a Rare Butterfly Database for Conservation Purposes: An Example in Florida Using Citizen Scientists" and "Managing Land for Butterflies" of this volume. Due to their popularity, monarch butterflies (*Danaus plexippus*) are also monitored, but those efforts have been exhaustively described elsewhere (Oberhauser et al. 2015; Ries and Oberhauser 2015).

General monitoring, where all species are monitored, can be carried out by agencies or academic programs but increasingly these types of programs are accomplished through networks of citizen science volunteers. These groups are organized at local, regional, national, or even continental scales. General butterfly monitoring has produced a wealth of ecological information about the dynamics of butterfly populations in Europe, where butterfly monitoring has been well-established for many years (van Swaay et al. 2008). We focus the majority of this chapter on the network of general monitoring programs that have been rapidly growing throughout North America and describe the efforts of a new group, The North American Butterfly Monitoring Network (www.nab-net.org), to support growth of monitoring efforts and provide resources to collect, manage and share data. Achieving these goals is vital because while butterfly monitoring in North America has grown, the use of the data have not. To date, the use of monitoring data, either for research or to guide direct conservation action, has been very slow, lagging behind both butterfly monitoring programs in Europe and various bird monitoring programs.

Occupancy vs. Abundance

There are two main classes of data collected by monitoring programs: abundance and occupancy data. As its name implies, abundance data are used to quantify the size or density of a particular population, whereas occupancy data simply determine presence or absence of a taxon on a particular site or in a particular cell of a survey grid. Any monitoring method that can measure abundance can also measure occupancy, but there are some monitoring methods that are only suitable to track occupancy dynamics or define ranges.

Abundance data are typically collected either by marking, releasing, and recapturing individuals in a study area, or by observing and counting individuals in a defined area or along a transect. More recently, there have been advances in statistics that allow the development of abundance indices from more casual protocols like field trips and counts (Isaac et al. 2014). In most respects, abundance information can constitute a more powerful data set than occupancy data because change in abundance is a more sensitive indicator of population dynamics (Royle et al. 2005). Depending on the details of the data collection method, abundance methods can determine demographics, mobility, and lifespan in ways that occupancy cannot.

Despite the greater potential for diverse analyses of abundance data, there are situations where occupancy has decided advantages. In particular, species present at very low densities or that are very difficult to detect may not be suitable for the collection of abundance data (Bried and Pellet 2012; MacKenzie et al. 2005). Furthermore, certain monitoring techniques are only able to capture occupancy.

The following sections will examine in more detail several approaches to the collection and use of both abundance and occupancy data. Assumptions, strengths and weaknesses, and comparisons of the use and efficacy of the various methods will be discussed. We separate the all the different types of monitoring programs into two groups: systematic surveys, which employ more rigorous protocols, and informal methods such as counts, field trips, and sightings programs.

Systematic Surveys

Systematic surveys are those with the strictest protocols. Survey sites are established and usually visited multiple times within and between seasons. The same monitor or group of monitors often return to the same site and perform the same roles. Finally, the area is usually searched more exhaustively and the exact area of search is usually known. For this reason, these systematic surveys are more similar to academic protocols, with the major exception that random placement of survey sites is rarely used. However, overall, the protocols are usually much more consistent between surveys and thus much more comparable, making patterns over space and time much easier to describe.

Pollard Walks

Overview

Pollard walks, sometimes called Pollard transects, are named for Ernest Pollard, who pioneered the technique (Pollard 1977). Pollard's goal was to develop a technique that could be used to detect long-term changes in butterfly populations, and that could make use of recorders who might not have formal training in

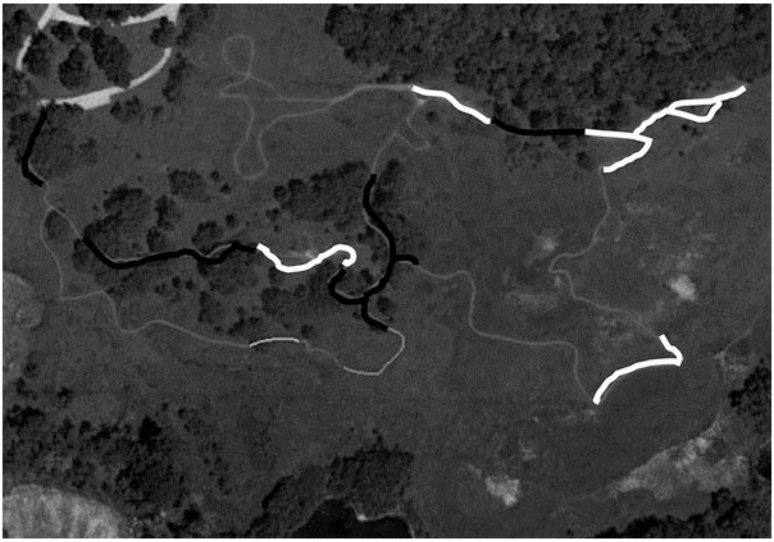

Fig. 1 Pollard routes are established as walking paths that often go through several habitat types. In the above example, the route is divided into several sections based on habitat type (shown by the different shades). For most programs, butterflies are recorded separately by habitat type (section), but those sections do not need to be contiguous. When surveys are performed, observers walk slowly along the route and observe butterflies only within a window of a set size, which may vary between programs

entomology. Pollard's techniques were developed at Monks Wood, a nature reserve in Cambridgeshire, England. Pollard employed his technique to evaluate effects of site management (Pollard 1982), phenology (Pollard 1991), and effects of weather (Pollard 1988) on butterflies, as well as to augment general understanding of butterfly ecology (Pollard and Yates 1993).

As initially described, the method involved walking a defined transect at weekly intervals and counting all butterflies seen at a defined distance (Fig. 1). The transects were divided into segments, and data were collected only under certain weather conditions (Pollard 1977). Since the initial description, many modifications to the protocol have been employed, typically involving the frequency of monitoring, acceptable weather conditions, and division of the walking route into subsections (Pollard and Yates 1993). Subsections are typically divided up by habitat (Fig. 1) although divisions are also made for other logistical reasons.

What It Measures

It's important to bear in mind that Pollard data do not return an actual population size, either over the entire generation of butterflies or restricted to the day of the survey. This is due to the fact that butterflies may be, and typically are, missed by the spotter (Haddad et al. 2008; Harker and Shreeve 2008; Pellet et al. 2012) or individuals may be counted multiple times. Although even a single Pollard survey will return information regarding distribution and phenology of butterflies, relative abundance data are most powerful when collected over extended period of time and used for detecting spatial or temporal changes in butterfly populations.

The Pollard method allows for correction for survey effort by adjusting by the length of the transect or by time, the latter requiring the recording of survey start and end times. This enables observations to be evaluated in terms of observations per unit time or distance. Because the technique is a general survey, it allows monitoring of most butterfly species.

Assumptions

An important assumption of the Pollard walk is that the counts are directly proportional to the actual population size (Haddad et al. 2008). Further, unless death rates are known, then integrating counts over time to develop a yearly index will not correctly account for population turnover within the season (Nowicki et al. 2008). Thus, yearly indices from uncorrected Pollard counts are often interpreted as the number of "butterfly-days" and not a true index of butterfly abundance, although new techniques to account for this have been proposed (e.g., Matechou et al. 2014). Despite these issues, there are various reports of differing degrees to which Pollard walk count indices do (Pollard 1977; Thomas 1983; Collier et al. 2008; Haddad et al. 2008; Isaac et al. 2011; Pellet et al. 2012), or do not (Harker and Shreeve 2008) correlate well with population size.

Advantages

One significant advantage to the Pollard approach to butterfly monitoring is its simplicity. The protocol, while rigorous, is uncomplicated, and can be readily taught to people who have little or no formal science training. The main challenge for nonscientists in conducting Pollard surveys is typically one of species identification rather than survey protocol.

Because this technique can be used by citizen scientists, the Pollard method has formed the basis of numerous citizen science programs that survey butterflies. The oldest is the British Butterfly Monitoring Scheme (Pollard and Yates 1993), founded in 1976 and now merged with other programs to be part of the United Kingdom Butterfly Monitoring Scheme (UKBMS) (www.ukbms.org). Since that time, the UKBMS has conducted more than 250,000 surveys and the program has expanded to more than ten European countries (van Swaay et al. 2008). The Illinois Butterfly Monitoring Network (Taron 1996), which also uses a protocol based on the Pollard walk, was founded in 1987. Through these efforts, a considerable body of literature has been amassed based on analyses of Pollard transect data. (See UKBMS website, www.ukbms.org/reportsAndPublications.aspx, for an extensive bibliography).

Limitations

Whereas the Pollard survey method is a robust technique that has produced a large body of data, multiple analyses, and numerous publications, it has several limitations and is not ideal in all situations. As previously mentioned, this survey technique is used to measure relative abundance rather than absolute population size.

Various deviations from the assumptions inherent to the technique have been reported. Many involve variations in detectability. Species that reside in the canopy of wooded areas, species with cryptic color patterns, and species such as some metalmarks that spend large amounts of time perched on the undersides of leaves will be detected with less efficiency than species with more conspicuous flight patterns (Shuey and Szymanski 2010; Isaac et al. 2011). Moreover, detectability of butterflies may vary in space, in time, or by species (Dennis et al. 2006; Gross et al. 2007; Harker and Shreeve 2008; Haddad et al. 2008).

Additionally, monitoring data are frequently applied to the detection of changes in butterfly population sizes that result from environmental changes such as those due to climate change or site management. Although these changes may well influence expansion or contraction of butterfly populations, they also affect vegetation in ways that may either enhance or hinder detectability, raising the possibility of confounding environmental and detectability effects (Isaac et al. 2011).

As is the case with many of the abundance techniques, species that are encountered on Pollard walks at very low densities may not always be detected as readily as more abundant species. Further, Pollard walks were designed to capture the maximum amount of information on the most species, whereas researchers wishing to monitor species that, for any of these reasons, are poorly detected by this method may adopt methods that are more tailored for those individual species. For instance, some species are best detected through surveys of leaf damage (e.g., the Karner blue butterfly). For species that locally exist in very low numbers researchers might wish to consider occupancy techniques as an alternative to abundance techniques.

Ease of Use/Time Commitment

A single Pollard transect can typically be run in anywhere between about an hour and about 3 h. In the various Pollard-based networks, individual surveys are conducted anywhere from a minimum of six times per season (Taron 1996) to weekly throughout the growing season (Pollard and Yates 1993; van Swaay 2008).

The larger data sets that are needed, for example, to detect long-term population trends have typically been collected by citizen science networks. Although the collection of Pollard transect data on a single site is a modest endeavor, developing and running a citizen science network will take considerably more planning and effort.

Timed Surveys

Timed surveys are similar in technique to Pollard walks and have many of the same assumptions, advantages and limitations. For most Pollard surveys, a transect is established and the amount of time it takes to complete the survey is typically recorded, but not set. In timed surveys, a survey area is usually defined and a "zig-zag" method for completely covering the area. Survey time is pre-set by the researcher and always the same between surveys within a particular project. This method can be ideal to better survey a more restricted area and capture a higher proportion of species and individuals (Kadlec et al. 2012).

Mark Release Recapture

Overview

In contrast to the Pollard method, which measures relative abundance of butterflies, mark release recapture (MRR) provides an estimate of actual population size. In this technique, a subset of members of a population is captured and marked, typically by writing on the wings with a fine-tip indelible marker. The marked individuals are released back into the population and a brief period of time is allowed to elapse so that the marked individuals can mix in with the remainder of the population. The population is then re-sampled and the numbers of marked and unmarked individuals in the sample are recorded. The proportion of marked individuals in the sample should be the same as the proportion of marked individuals in the population. Because the total number of marked individuals is known, this proportion can then be used to calculate the total population size.

Assumptions

Chief among the numerous assumptions in the MRR method is the requirement for a closed population – that during the survey, the population size does not change due to emergence of new adults, death, immigration, or emigration. Methods exist to correct for some of these effects (Pradel et al. 1997; Harker and Shreeve 2008). The method also assumes that there are no behavioral or detectability differences between marked and unmarked individuals.

What It Measures

MRR data are considered the best for obtaining true population estimates. In addition to measuring the size of a population, MRR can be used to study dispersal of marked individuals by observing where marked individuals are recaptured, making it a useful technique for studying dynamics of butterfly metapopulations (Hanski et al. 2000; Ricketts 2001; Polic et al. 2014).

Advantages

MRR has been described as “the most rigorous approach to population estimation because it incorporates the greatest amount of information into well-developed statistical methods” (Haddad et al. 2008). By providing a larger quantity of demographic information than transect counts, MRR allows for the possibility of estimating longevity, dispersal, and detectability of the taxa surveyed. Because death rates are known unlike for Pollard methods, within-season turnover can be accounted for when developing population estimates.

Limitations

In addition to those mentioned previously, limitations of MRR include the possibility of damaging individuals during the process of capture and marking (Murphy 1987). This limitation is of particular concern when working with small, vulnerable populations of species that are of conservation concern.

It is also possible that the process of capturing and marking individuals changes their propensity for recapture, either by changing their detectability or their susceptibility to recapture (New 1991; Haddad et al. 2008) relative to unmarked individuals. One MRR study of *Neonympha mitchellii francisci* showed no negative effects of handling on behavior or survival of marked butterflies (Kuefler et al. 2008), however other MRR studies have shown increased mortality (Morton 1982) and emigration (Singer and Wedlake 1981) following marking.

It is difficult to apply MRR to small species, such as those in the families Lycaenidae, Riodinidae, and Hesperiidae, because they can be very difficult to mark and are easily damaged. For small and low density populations it can be difficult to find and mark a sufficient number of individuals to allow marking a sufficient sample size.

Ease of Use, Time Commitment

MRR is a time consuming, labor-intensive and therefore relatively expensive method (Haddad et al. 2008). It requires training in correct handling and marking of the butterflies. For this reason, it has never been and is unlikely to ever be a protocol method adopted by a citizen science network and therefore large-scale or long-term data are almost never collected (Nowicki et al. 2008).

Distance Sampling

Distance sampling is a method for estimating population density which, when combined with knowledge of area occupied, can be used to calculate population size rather than relative abundance. The principle of distance monitoring is based on the decrease in detectability of a study organism as a function of distance from the observer. By fitting a curve to a histogram of observed individuals at increasing distance from the observer and integrating under the curve, density of individuals over the study area can be calculated, thus determining the total population size (Brown and Boyce 1998; Thomas et al. 2010; Isaac et al. 2011).

Assumptions

Distance sampling assumes that transects are placed randomly relative to butterflies (Haddad et al. 2008; Isaac et al. 2011), that the study organism is distributed uniformly along the transects from a distance of zero out to the limit of detectability (Haddad et al. 2008), that there is complete efficiency in detecting the organism at zero distance from the observer, that the study objects do not move, and that the distance measurements are exact (Thomas et al. 2010).

Advantages

Distance sampling estimates density rather than relative abundance, as does MRR, but without risking potential damage to sensitive species due to handling and marking them. Provided that the assumptions are met, it provides an unbiased estimate of population density (Brown and Boyce 1998; Thomas et al. 2010; Isaac et al. 2011). Rigorous in both protocol and statistics, distance sampling has an extensive track record of application in peer-reviewed studies (Isaac et al. 2011).

Limitations

Note that distance sampling improves estimates obtained within a single-transect, but does not account for the problem of within-season turnover, confounding yearly indices (see Pollard section above). In addition, many of the assumptions inherent in distance sampling limit its application. For example, due to site fragility, physical barriers to access, or non-uniformity of habitat it may not be possible to set transects that are randomly located within a population (Haddad et al. 2008). A threshold sample size of 60 required for accurate modeling limiting the utility of distance sampling in populations that are sparse or have low detectability (Thomas et al. 2010; Isaac et al. 2011; Pellet et al. 2012).

Ease of Use, Time Commitment

Transects for distance sampling are somewhat more involved to set up than are those for Pollard Walks, as they must be placed randomly in areas known to have uniform density of the study species. They provide a snapshot of population density at a particular time, and must be combined with another method, such as MRR, in order to determine population size across an entire generation (Haddad et al. 2008). Data collectors must be trained to collect accurate distance measurements (Thomas et al. 2010). Distance sampling is typically applied to a limited number of species in any given study due to the difficulty of collecting distance data on multiple species simultaneously (Isaac et al. 2011). Although distance sampling used to be the primary method of accounting for detectability, more modern techniques allow detectability to be estimated through occupancy modeling (Royle et al. 2005), although because of the change in abundance during the flight season, it may be difficult to meet some of the necessary assumptions of occupancy modeling.

Comparative Studies of Systematic Survey Methods

Because of the limitations of MRR, both in terms of the intensity of effort required and the potential for damaging individuals in the marking process, it would be desirable to be able to use transect-based counts as an alternative. Isaac et al. (2011) showed strong correlation between data obtained via distance sampling with estimates of absolute population size obtained with MRR. Other studies (Thomas 1983; Collier et al. 2008) reported similar findings in comparing distance sampling with MRR, however Harker and Shreeve (2008) and Pellet et al. (2012) reported poor correlation. Haddad et al. (2008) also compared yearly population indices with MRR and transect methods, finding such indices to have the advantage of producing survivorship estimates without the risks that accompany handling the butterflies for marking. The index methods produced higher variation than either MRR or Pollard, and may be of limited use for small populations. Several authors (Gross et al. 2007; Haddad et al. 2008; Pellet et al. 2012) have suggested that combining one of the transect sampling methods with a limited MRR study might allow for improved estimates while moderating the limitations of the MRR method.

Surveys That Use Informal Protocols

In contrast to the rigorous protocols used for systematic surveys, a number of methods use more informal protocols. These efforts are almost entirely restricted to citizen science volunteer programs. Fewer sampling parameters are defined, and protocols may permit more variability in the precise location of sampling, frequency of sampling, and number of observers in the survey team. In addition, observation areas are usually large relative to the actual area that is searched. These protocols are often used primarily as outreach to engage people in butterfly watching, but a complete inventory of all species observed and the number of each species observed are typically reported.

Count Circles

The Count Circle technique is employed by the North American Butterfly Association's (NABA's) Count Program. The program was started by the Xerces Society in 1975, but taken over by NABA in 1992. The protocol was adapted directly from the Christmas Bird Counts (Swengel 1990). Count circles are study areas 7.5 miles in radius and are surveyed by one to several parties (a party can be comprised of one to several individuals) within a single 24-h period, usually in June or July. Since 2008, monitors have been encouraged to conduct counts once in the spring, summer and fall. For that reason, the program is now officially known as the Seasonal Counts although the original name was the 4th of July Butterfly Counts (www.naba.org). Effort is measured by counting "party-hours" the sum of the total number of hours each party (regardless of individual numbers of observers) completes during the count day (Swengel 1990). Currently, counts must be conducted for a minimum of six party-hours by a minimum of four individuals, although before 2009, there was no minimum amount of participation.

The main advantages to the count circle method are the ability to generate very large data sets at large scales and a long history of data collection. Data have been recorded annually since 1975 (Swengel 1990) and through 2014 have produced data from over 10,000 surveys. Currently, there are about 400–450 count circles are conducted every year.

Advantages

The simple protocol and wide geographic scope of the program allow for the collection of large quantities of data. There is greater latitude available for the placement of count circle centers than there is in the placement of Pollard or distance sampling transects, allowing for surveys in locations that are less amenable to either of those two methods. Although this method uses less standardization than other methods, the data are amenable to detection of trends (O'Brien et al. 2011; Link et al. 2006).

Limitations

The simple protocol collects less information than other protocols including Pollard walks, which provide finer spatial resolution of observations. Most published studies have evaluated species that are conspicuous, widespread, and generally abundant, such as painted ladies (Vandenbosch 2003), monarchs (Swengel 1995; Koenig 2006), and a few other abundant species (Ries and Mullen 2008, however, see O'Brien et al. 2011). Most counts are only done once a year, although sometimes once each season (spring, summer and fall). Therefore, phenology (the pattern of flight across the season) has the potential to bias the development of abundance indices to a much greater degree than protocols that collect data multiple times within and across seasons.

Ease of Use

The program has been designed to be easy to use. Protocols, data entry and instructions for new participants to become involved in the program are well-established. The ease of use of the count circle method is essential for the method to express its main strength: the involvement of large numbers of participants in order to collect a very large data set.

Field Trips or Wandering Surveys

Field trips are also usually planned as an outreach or participation exercise, such as for a butterfly club. Trips are usually to designated locations like parks, and so the area of search is specified, but the specific areas that are covered during the field trip are often unknown. However, all species and individuals seen during the field trip are generally reported and time and number of observers are often also known. Although less rigorous than counts, new statistical techniques have been developed to compare population indices across years (Isaac et al. 2014). These types of data have been successfully used to track long-term trends (Bried and Pellet 2012).

Wandering Surveys have been used as a low-cost method of intensive survey of species of interest throughout their flight periods. They follow no fixed route, rather they attempt complete coverage of a site or of a particular habitat within a site (Longcore et al. 2010), typically with emphasis on detecting individuals of a single species or small suite of species that are of conservation concern. The survey designs are opportunistic, and survey routes frequently cannot be closely replicated from survey to survey. Wandering survey data of the mission blue and callippe fritillary in the San Bruno Mountains of California were useful when treated as occupancy rather than abundance data (Longcore et al. 2010).

Although wandering survey design "violates most tenets of survey design" (Longcore et al. 2010), such data can, nonetheless, be informative for butterfly conservation. Particularly when species of interest are present at very low density (Bried and Pellet 2012), or occupy large numbers of fairly discrete patches (WallisDeVries 2004), occupancy data may be a viable alternative to abundance data.

Sightings

Sightings refer to opportunistic reports of one or multiple species that are not part of a formal or even casual field trip, count, wandering survey or systematic survey. One of the distinguishing features of a sightings report is that nothing about effort is known; not the area of search, the time of search, or whether all observed butterflies seen were reported. For systems that only allow one sighting per record, it is assumed that not all individuals seen were reported. Several online databases currently exist that can accept this type of opportunistic data. Most current platforms require photographs (e.g., butterfliesandmoths.org), but not all (e.g., NABA's Butterflies I've Seen platform). Platforms can be specific to butterflies or general platforms like inaturalist.org, projectnoah.org, or observation.org. eButterfly (e-butterfly.org) is another sightings platform, but it also accepts a range of protocols, from trips to Pollard walks. The submissions to these platforms are generally vetted by experts for quality control. When photographs are supplied, identification is vetted; otherwise, only unlikely (out-of-season, out-of-range) reports are flagged. Sightings data are most useful to draw range maps (e.g., via niche modeling), although they may also be useful to track some phenological pattern, or to contribute to species inventories (Matteson et al. 2012).

Inventory of North American Butterfly Monitoring Programs

The oldest formal butterfly monitoring program in North America was started by Art Shapiro (Forister et al. 2011). This academic-based program has been collecting data on 11 transects across an elevational gradient in central California since 1972. Transects are surveyed every other week, always by Art Shapiro and, in most cases, only presence/absence data are collected. The NABA program described above remains the longest-running, largest-scale butterfly citizen science program in existence. In 1986, the Illinois butterfly monitoring program was launched, patterned after the UK Butterfly Monitoring Scheme. This program was the impetus for many other state and local based butterfly monitoring programs, including Ohio (started in 1995) and Florida (started in 2003). Since the mid-2000s, there has been a sharp increase in the number and types of general butterfly monitoring programs and resulting in approximately 1,000,000 records collected through monitoring programs by January 2015 (Fig. 2). These programs span the range of protocols described above and have been implemented at a range of geographic scales, from very local (e.g., ranches managed for conservation) to continental.

In this section, we provide an inventory of general butterfly monitoring surveys in North America (Table 1), with the goal to give as complete a list as possible of

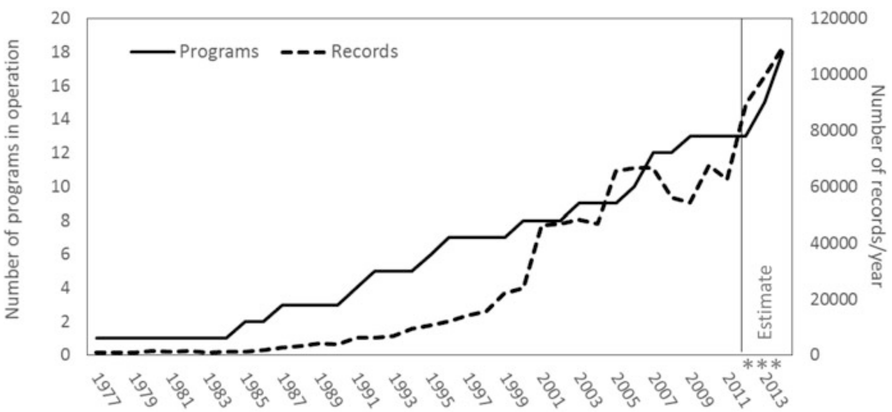

Fig. 2 An inventory of North American monitoring programs that survey the entire butterfly community (as opposed to a single species). Only citizen science programs are included here. Best estimates are given for 2012–2014 since not all records have been received from the programs. Just over 1,000,000 species records are predicted to be recorded through December 2014

Table 1 Known general butterfly monitoring programs in North America as of January 2015

Program (Acronym, start year)	Protocol type[1]	Program web address
(a) General butterfly programs: continental		
Butterflies and Moths of North America (BAMONA, 2005)	Sightings	www.butterfliesandmoths.org
eButterfly (eBFLY, 2011)	Trips/sightings	www.e-butterfly.org
North American Butterfly Association (NABA)		
Seasonal Count Program (1975)	Counts	www.naba.org/butter_counts.html
Butterflies I've Seen Program (2000)	Trips/sightings	www.nababis.org/
Recent Sightings Program	Sightings	http://sightings.naba.org/
(b) General butterfly programs: regional		
Carolina Butterfly Society (CA-LEPS, 2000)	Field trips	www.carolinabutterflysociety.org/
Cascades National Park BMN (C-BMN, 2011)	Pollard surveys	www.butterfliesandmoths.org/project/CNP
Colorado-BMN (CO-BMN, 2013)	Pollard surveys	No web site
Florida-BMN (FL-BMN, 2003)	Pollard surveys	www.flbutterflies.net/
Iowa-BMN (IA-BMN, 2007)	Pollard surveys	www.reimangardens.com/collections/insects/iowa-butterfly-survey-network/
Illinois-BMN (IL-BMN, 1987)	Pollard surveys	www.bfly.org
Massachusetts Butterfly Club (MBC, 1992)	Field trips	www.naba.org/chapters/nabambc/field-trips/asp
Michigan-BMN (MI-BMN, 2011)	Pollard surveys	www.michiganbutterfly.org/
Missouri-BMN (MO-BMN, 2014)	Pollard surveys	No web site
Ohio-BMN (OH-BMN, 1995)	Pollard surveys	www.ohiolepidopterists.org/bflymonitoring/
Tennessee-BMN (TN-BMN, 2014)	Pollard surveys	No web site
Swengel Monitoring (Swengel, 1985)	Timed surveys	No web site
(c) General butterfly programs: local		
Art Shapiro Monitoring (Shapiro, 1972)	Academic	http://butterfly.ucdavis.edu/
Boulder Open Space (BOS, 2007)	Surveys	No web site
Ft. Collins-BMN (FtC-BMN, 2014)	Surveys	No web site
Great Basin Monitoring (GBM, 1995)	Academic	No web site

(continued)

Table 1 (continued)

Program (Acronym, start year)	Protocol type[1]	Program web address
Greater Yellowstone Monitoring (GYM)	Academic	No web site
Irvine Ranch Conservancy-BMN (IRC-BMN, 2012)	Pollard surveys	No web site
MPG Ranch (MPG, 2014)	Pollard/timed	No web site
Occoquan Monitoring Program (OCC, 1991)	Pollard surveys	No web site
Rocky Mountain BMN (RM-BMN, 1995–2011)	Pollard surveys	http://www.nps.gov/romo/naturescience/rocky-mountain-butterfly-project.htm

Programs are separated into continental (a) and regional (b) and local (c) programs. Each record includes the program name, acronym (when referred to in other figures in this chapter), program type, start year, end year (if applicable), and program web address (if any). *BMN* Butterfly Monitoring Network. Monarch and other single-species focused programs are not included. Monarch-centric programs are described in detail in Oberhauser et al. 2015 and Ries and Oberhauser 2015.

[1]Note that this list only includes programs focused specifically on butterflies; general platforms like iNaturalist, Project Noah, and Observado are not included.

all programs currently in existence and to present several metrics of both the growth and activity of the programs. Our goal is to illustrate the scope of this growing resource so it can be better utilized by the conservation community. We focus here solely on general butterfly surveys, not those focused on individual species.

To understand the type of programs currently operating in North America, we arranged the programs on a diagram organized across two axis: strictness of protocols on the X-axis and geographic scope on the Y-axis (Fig. 3). Another interesting axis is time; however the majority of programs endeavor to operate in perpetuity so that metric becomes a function of when they were launched (indicated in Table 1). Note that the majority of programs cluster in two areas of the panel: large-scale programs with more casual protocols in the upper left-hand corner and regional and local programs following strict Pollard-like protocols in the mid- to lower-right hand corner. This clustering of programs makes sense as larger-scale programs are unlikely to be able to provide the training and volunteer management necessary for Pollard-based programs, which tend to be smaller-scale.

The North American Butterfly Monitoring Network

In May 2012, a meeting at the Socio-environmental Synthesis Center (sesync.org) in Annapolis, Maryland brought together leads of many long-lived, new, or developing butterfly monitoring programs. The group decided to form a network and thus was launched the North American Butterfly Monitoring Network (www.nab-net.org). The network has six goals which we review below. All of these goals are meant to expand participation, ease management of, and maximize the usefulness of butterfly monitoring data.

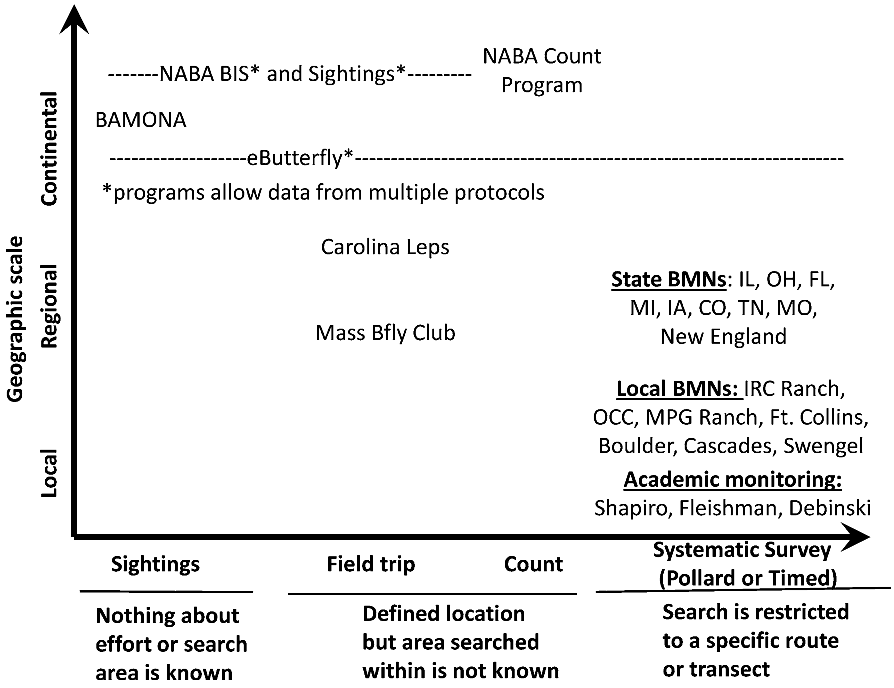

Fig. 3 Diagram showing all currently operating (as of January 2015) general butterfly survey programs organized by type of protocol (x-axis) and geographic scope (y-axis). eButterfly and NABA programs span multiple protocols and that is reflected in the lines (See Table 1. for start year and website information)

Goal 1: Track All North American Butterfly Monitoring

Keeping track of all programs collecting monitoring data on butterflies allows the public to find programs that they may be interested in volunteering for and makes it possible to discover butterfly data resources for scientists, those involved in conservation or policy, and the general public. The inventory as of January 2015 is shown in Table 1 and an updated list is curated at www.nab-net.org.

Goal 2: Standardize Protocols as Much as Possible

No program is compelled to adhere to specific protocol guidelines in order to be a member of nab-net. However, programs are encouraged to develop and describe their protocols, keep track of protocol changes, and tweak their protocols when possible to conform to best practices. Some protocol changes will affect data comparability pre- and post-change (e.g., changing the size of the detection window) while others will not (e.g., encouraging programs to start surveys earlier, end later, or perform more surveys during a year). When there is a long history of data collection, protocol changes that affect data comparability are discouraged.

Goal 3: Develop or Enhance Data Management Systems

All continental-scale programs (Fig. 3, Table 1) have online portals and systems to manage their data. However, the regional programs have a much greater challenge in collecting, managing, and sharing data especially since most are either run out of small institutions, often with small budgets, or are not affiliated with any institution. Further, the nature of the data collected through systematic surveys such as Pollard walks did not fit well on the major platforms, which would also not allow program managers to maintain control of the quality or use of their data. Indeed, data management was one of the biggest barriers to program growth, both for creating new programs or expanding existing ones.

In order to bridge this gap in a way that would benefit the maximum number of programs, the regional monitoring groups decided to collaborate with the group that runs Butterflies and Moths of North America to develop a platform specifically for regional programs that run Pollard-based surveys. The new platform, PollardBase, was launched in 2014 with seven of the programs using the system and most other programs planning to adopt it in the future. PollardBase has relieved much of the data management burden that most programs have by allowing volunteers to directly enter and proof their data, which are then vetted by program managers. Data can then be easily shared with local landowners, institutions, or the public. While the PollardBase initiative is working to meet the most critical need identified at the start of the network, there remains a broad goal to help support the best data management practices and make sure that tools are available and shareable between programs so that data collected by volunteers will not go to waste.

Goal 4: Share Data

Nab-net promotes the sharing of data and developing systems that promote sharing of data. Most programs are happy to share their data, but have challenges both in being able to format data (especially historical data for some programs) and also in developing robust data sharing policies. As of January 2015, few programs had yet been contacted to share their data, but as knowledge of butterfly monitoring programs has grown, requests for data were starting to come in. As of this date, the continental program whose data had been most requested for use in scientific publications on monarchs were NABA's and for regional programs were Illinois and Ohio's (Ries and Oberhauser 2015) and this is true for other species as well.

Goal 5: Expand Program Participation

Nab-net is developing or planning to develop a series of tools to promote program participation. To encourage new programs to start, there will be templates for timelines from program development, protocol guidance, training materials and access to systems like PollardBase. To expand participation of existing programs, there are guidelines to working with volunteers and land owners, all critical elements of running a sustainable program. In addition, by being part of a network, programs can inform their volunteers of other programs they may want to participate in.

Goal 6: Develop Analytical Tools

There have been many statistical models developed to analyze butterfly monitoring data, especially in Europe. However, many of these methods have difficulty being transferred to North American protocols because in general, most programs don't have as high a density of participants per unit area (so surveys are sparser on the ground) and volunteers also tend not to survey as frequently. That makes transferring modeling frameworks difficult. For instance, the most widely used approach to develop abundance indices for Pollard Surveys originally required transects to be visited nearly weekly (Rothery and Roy 2001), but then were adapted to allow as many as 30 % of weeks to be missed (Dennis et al. 2013). However, even that exceeds the visit rate of most North American surveys, so efforts are currently underway to adapt those protocols to allow even fewer visits per site by combining data across regions. This means that while site-specific indices may not be possible, regional ones will become the goal. Similar efforts to adapt methods for field trips and other opportunistic data are also underway. There are many statisticians and quantitative ecologists who are members of Nab-net and their goals are to take state-of-the-art methods and adapt them to North American Protocols.

Another effort at this time is to determine if death rates can be accounted for during transect counts. A method proposed by Zonneveld (1991) claimed to be able to do this and was even implemented in an online tool, INCA, which has many attractive features (Longcore et al. 2003). However, it turned out that death rate and population size were inseparable using those methods (Calabrese 2012). New methods have been proposed (Matechou et al. 2014) and are being tested using North American data.

Finally, a major goal of nab-net is to continue to track developments in statistical and analytical methods. As these methods evolve, members of nab-net will continually be seeking to adapt them to protocols in North America and make tools available that will make allow these techniques to be used by a variety of stakeholders.

Summary and Key Points

- Monitoring the sizes of butterfly populations is an essential component of conservation efforts
- Various modeling methods measure occupancy or abundance data. Abundance data may sometimes be converted to occupancy data however the converse is not typically true.
- Abundance data are frequently amenable to far more sophisticated modeling than are occupancy data. However occupancy data may be superior in some applications, particularly in cases where populations are small or densities low.
- Pollard walks provide a measure of relative abundance rather than estimating absolute population size. The method is employed by numerous citizen science programs and can generate large quantities of data.
- Mark Release Recapture (MRR) provides the most detailed demographic information, and offers the opportunity for the most robust modeling. MRR is the most labor-intensive of the monitoring methods discussed here and carries a risk of damage to sensitive butterfly species during the marking process.
- Distance sampling, like MRR, produces an estimate of population size rather than relative abundance. It does not involve the same risk of damage to butterflies as MRR. Limitations include the requirement for random transects within areas of uniform butterfly density, as well as key assumptions that may not be met in field studies.
- Count circles and field trips can be used as part of citizen science programs to generate large amount of data which, although collected with less standardization than other methods, provide useful information for trend analysis.
- Sightings databases provide another source of data, but dynamics are difficult to track with these data sources.
- There has been a sharp rise in the number of butterfly monitoring programs in North America and a new organization, The North American Butterfly Monitoring Network, is developing resources to make sure data can be effectively captured, managed, shared and analyzed.
- To date, these monitoring data have been underutilized both for scientific research and conservation decision making, but with the advancement of new programs, systems to support them and more widespread knowledge of the program's existence, data use should increase substantially.

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