Harvest monitoring of snakes in trade

A guide for wildlife managers

D.J.D. Natusch, L. Fitzgerald, J.A. Lyons, A.S.C. Toudonou, P. Micucci and T. Waller

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Preface

Who is this guidance for?

This guidance is written for government wildlife managers, conservationists, professional scientists, and amateurs interested in ensuring the sustainable utilization of wild-caught snakes in commercial trade. It is a practical guide to harvest monitoring; that is, collecting data from harvested snakes and using that information to draw inferences about the status of their populations and the sustainability of their offtake. This guidance is for use by anyone.

The primary purpose of the guidance is to assist those actively engaged in snake harvest and trade situations, who are faced with the need to implement monitoring and management. The guidance itself does not address the impacts of harvest and trade on host ecosystems or local communities, or discuss the drivers, benefits, or social issues linked to trade participation. Although these topics are important and intricately linked to the harvesting of snakes for commercial trade, they are outside the scope of this guidance. The guidance is also not intended for those who wish to create a market, initiate a new trade, or do the work needed to comply with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) beyond monitoring a harvest. That being said, the principles and guidance contained within this document will be valuable for the support of CITES Non-Detriment Findings (NDF), which are required under Article IV of CITES before exports of CITES-listed snakes can occur. Therefore, we envision this guidance being used by CITES Scientific Authorities of Parties to ensure sustainability of offtake of wild snakes and to assist with meeting their obligations to CITES.

Harvest monitoring is only one of several important tools to assess the sustainability of trade in snakes. As such, this guidance is not intended to replace other methods. Rather, harvest-monitoring systems are viewed as an important complement of existing monitoring and assessment programs that provide critically important information on the makeup of the harvest of snake populations over time. This guidance for harvest monitoring may be particularly applicable in situations where implementing other monitoring strategies is not feasible.

What does the guidance contain and how should it be used?

This guidance is meant to be practical. It offers a step-by-step guide to collecting data from wild-harvested snakes that is useful for the assessment of sustainability. We expect managers and scientists to take this guidance document into the field, to use as a reference when collecting data. The guidance should also be used in capacity development activities (e.g., workshops) for those engaged in monitoring and management of snake trade. The guidance offers supporting information on why harvest monitoring is useful, how to design a harvesting monitoring program, basic steps for analysis of data, and interpretation of some important patterns that may emerge from a harvest monitoring system over time. This guidance document also briefly discusses what sorts of management interventions may be required should data reveal trends in need of action.

Photo by Daniel Natusch

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Harvest monitoring systems

an overview

1.1 Introduction to harvest monitoring systems

Monitoring trends in populations of wildlife is fundamental to any wildlife management program, whether it is for sustainable use, managing endangered species, or controlling an exotic invader (Caughley and Sinclair 1994). Many tools and approaches exist for monitoring animal populations. However, whenever and wherever wildlife is managed, it is critical to know how many individual specimens are harvested as well as the makeup of that harvest. Animal populations persist based on the balance between the number of offspring being produced that grow up to reproduce themselves, and the number of individuals that die. Harvest monitoring is crucial for understanding this balance between births and deaths in populations of wild species that are used by people. In all populations, individuals are constantly dying, but in harvested populations we consider the deaths from hunting to be mortality that is in addition to the death rate we would observe in a population that is not harvested . Thus, it is paramount to know if populations of species used by people can persist in the face of this added mortality from hunting. For our purposes, we can define harvest monitoring as:

The accumulation of standardised data taken from harvested animals at key locations over time.

Harvest monitoring is a system that includes institutionalized systems for funding, archiving the data, and for renewing the capacity of leaders and technicians necessary to analyze and interpret the data, and sustain the monitoring system itself.

One of the best ways to know how populations are withstanding the amount of added mortality from hunting is to gather data on the sexes, body sizes and reproductive traits of individuals taken for the harvest and examine the demographic patterns in those data. Harvest monitoring systems, when properly implemented, provide long-term data on these demographic attributes of harvested populations. Data on hunter effort are difficult to obtain in many circumstances, especially in wildlife trades that are transitioning from exploitation to management, but can add a lot to managers' ability to interpret findings. Taken together, data from harvest monitoring can be examined to test for trends over time and across geographical areas. When trends are seen in harvest data, biologists and managers can evaluate how and why the harvest may be changing. Armed with this knowledge, managers can present scientifically defensible justifications for harvest quotas and other regulations and can call for corrective actions if needed.

Photo by Daniel Natusch

[1]Although harvesting is an additional form of mortality in many cases, in other cases harvesting can largely replace natural mortality. This typically occurs when harvests are focused on young specimens that normally have a low probability of natural survival in the wild (e.g., crocodilians; some turtles).

Data from harvest monitoring systems can take us a long way towards answering these sorts of questions:

- Is the number of harvested animals increasing, decreasing, or remaining stable?
- Is the proportion of males and females changing?
- Are the mean, maximum, and minimum sizes of harvested animals changing through time?
- Are the mean, maximum, and minimum sizes at sexual maturity of harvested animals changing through time?
- Is the pattern of hunter effort, or catch-per-unit-effort, changing?
- What geographical and environmental patterns are associated with the harvest data?
- Are conservation policies related to the management system working? For example:
    - Harvest quotas
    - Harvest seasons
    - Size restrictions
    - Restrictions on take of either sex
- Harvest monitoring can also let us know what information may be lacking so that we can modify the monitoring program to collect additional important information.
- Harvest monitoring allows us to obtain large amounts of biological data on life history traits of the species, and understand geographical variation among populations of the same species. As examples:
    - Size at maturity and timing of reproduction
    - Clutch or litter size
    - Diet
    - Disease and parasites

Good harvest monitoring systems share these characteristics:

- The monitoring system must be appropriate for the species that is harvested.
  - The plan for data collection needs to be compatible with the kinds of data that can quickly and easily be collected from harvested animals at locations in the trade chain where large numbers of harvested animals tend to accumulate (check stations, warehouses, processing facilities, tanneries).
- Standardized measurements that are directly related to body size of live animals.
  - The size of skins or other measures need to be calibrated to the size of the harvested animals in life in order to provide better information for assessing impacts on populations.
- Ability to determine sex of harvested animals.
  - If the harvested animals are prepared in a way that does not allow sex to be determined, biologists and managers should work with industry and agencies to find a way for proof-of-sex to be incorporated into the harvest system.
- Ability to obtain large sample sizes that are representative of the total harvest.
- Ability to obtain, preserve, and store samples of whole animals that will serve as specimens needed for studies of life history characteristics (sexual maturity, clutch size, diet, growth, disease, etc.).
- Information on hunter effort.
- Data management system that allows for archiving data sets that are accessible to changing personnel.
- Linkages to museums, universities, non-government and government agencies.
- Systems established to allow funding for harvest monitoring in perpetuity.
- **Accountability to the outside world.** The credibility of harvest monitoring systems depends on transparency and the ability of outside groups to understand and verify findings from the monitoring system.

1.2 Basic principles of harvest theory for dynamic wildlife populations

Before launching into the details of harvesting monitoring systems, it is important to explain some basic principles of harvest theory and how they relate to harvest sustainability. Intuition suggests that harvesting of a species – removal of individuals from a population – makes the population smaller and more vulnerable to threats. However, this is not necessarily the case. In fact, due to the dynamic nature of wildlife populations, harvesting can actually make a population *more productive*. This occurs because most wildlife populations are strongly density dependent. This means that only a finite number of individuals can persist in a population at one point in time and space, owing to limited amounts of resources available for survival, growth and reproduction (for reptiles, this limiting resource is typically 'food'). We consider an unharvested population containing the maximum number of possible individuals to be fluctuating around its *carrying capacity*. When a population is at carrying capacity, its growth is limited by resources, such as food or space. Individuals depend on the available resources within that population. Thus, an individual's ability to procure resources for growth and reproduction becomes limited as numbers increase towards carrying capacity. The result is that population growth slows down, and the demographic structure of the population generally reflects a stable age distribution.

When individuals are removed from a population by harvesting, the population declines to a lower level of abundance, and population growth is stimulated. This occurs because greater amounts of resources become available to the remaining individuals in the population, which are utilized and invested in growth and reproduction. The further a population is reduced below carrying capacity the more resources become available, and so follows that population growth accelerates. In real world examples, 'productivity' typically manifests in females producing more young more frequently, and those young growing to adulthood more rapidly. If this process did not take place, sustainable harvesting of any renewable resource would be impossible – a situation we know is untrue.

There is an optimal level of population reduction, to a new level of abundance in which population growth is maximized. If that new (lower) level of abundance is sustained over time, by management, the annual growth component can remain maximized and be harvested – theoretically forever. This is *sustainable use* producing the *maximum sustainable yield*. If the level of population reduction does not reach the optimum level, but is nevertheless sustained over time, then this remains sustainable use but not generating maximum sustainable yield. Therefore, declines in population abundance (or density) to new levels of abundance should be expected under any harvesting regime. The main issue concerning conservationists and wildlife managers is when neither the decline in abundance nor the harvest can be controlled, and both population abundance and harvest levels are in freefall. This would occur when unrelenting harvest pressure keeps a population too small for it to naturally increase its numbers. This is *unsustainable use*, and is exactly the situation that monitoring and management programs are designed to prevent.

For our purposes here, principles of monitoring and management are used to ensure sustainability – a continuous harvest of biologically safe populations at no risk of extinction – independent of the level of extraction. For more detailed discussion about the relationship between harvest theory, sustainable use, and non-detriment in the context of CITES, please see the CITES Guidelines on Non-detriment Findings for Snakes

1.3 Examples of harvest monitoring of exploited reptiles

Harvest monitoring is carried out for aquatic and marine fisheries and for terrestrial wildlife. A vast scientific literature consists of reporting and analysis of harvest monitoring data, ranging from theoretical models to practical case studies (e.g., Getz and Haight 1989. Population Harvesting: Demographic Models of Fish, Forest, and Animal Resources. Princeton University Press (Monographs in Population Biology 27.).

A number of monitoring systems have been put into place for crocodilians, lizards, and snakes. A monitoring system for lizards of the genera *Tupinambis and Salvator* (tegu lizards) was implemented in Argentina and Paraguay during the height of commercial trade in those lizards in the 1980s and 1990s, which averaged 1.9 million skins entering trade per year from 1980-89 (Fitzgerald et al. 1991, Fitzgerald 1994, Mieres and Fitzgerald 2006). A monitoring system for these commercially exploited species was developed that was financed by a fee collected for every exported skin, the cost of which was passed on to the consumers abroad. The funds were deposited into a foundation account or ear-marked by legislation to be designated for harvest monitoring. Teams of trained observers collected data on the size and sex of dried skins that were held at general stores and warehouses in the field, and also at commercial tanneries. Each month during the harvest season skins were measured, amounting to thousands of skins measured every year. Data were compiled, analysed, and reported. The three shortcomings of this system may have been: 1) Difficulties in sustaining the monitoring program when the market demand for tegu skins (and consequently, the international conservation concern) was low; 2) developing a data management plan for long-term, accessible storage of the raw monitoring data and reports; and 3) it was practically impossible to gather long-term data on hunter effort.

In the Bolivian Chaco, a community-based program was established that allowed harvest of tegu lizards (*Salvator rufescens*). The program was under direct control of Isoceño indigenous parabiologists who proposed quotas and directed hunter self-monitoring (Cuéllar et al. 2010).

In northern Argentina's Formosa Province, a harvest program for yellow anacondas (*Eunectes notaeus*) has been in place since 2002. The program aims to improve the livelihoods of traditional hunters while promoting the conservation value of the species (Micucci et al, 2006; Micucci and Waller, 2007). After an experimental period of two years, a harvest monitoring system was established, which is governed by provincial authorities. Every year, yellow anaconda skin exporters fund an officially approved working plan, with monitoring of the harvest undertaken by an Argentine NGO (Fundación Biodiversidad). Approximately 3,500 skins larger than 2.3 m in length (the minimum size requirement) are produced during a 3-month harvest season each year. Environmental stochasticity (year to year changes in wetland water level and in mean winter temperatures) significantly influences the annual yields. Skins are stockpiled by local traders and tagged before transport to a main collection point (a warehouse). Data on hunting sessions, such as dates, number of hunters, and number of skins produced, are obtained at the local level. At the end of the season all anaconda skins are measured and sexed at the main collection point to monitor year-to-year changes in sex ratios and mean skin sizes. Effort and capture data are used to feed surplus yield models (to estimate maximum sustained yield) and capture and effort trend curves (*sensu* Fitzgerald and Painter, 2000). All the information is compiled and reported to the authorities by Fundación Biodiversidad. The main difficulty identified within the program is that bureaucratic delays result in changes to activity timelines each year, which affects annual harvest yield results and complicates analysis and comparisons of data between years.

Table 1: Examples where harvest monitoring has been used to address conservation issues surrounding species of lizards and snakes (excluding crocodilians) in commercial trade.

Species	Country	Citation	Key Finding
Tegu lizards	Argentina, Paraguay, Bolivia	Fitzgerald et al. 1994; Mieres and Fitzgerald 2006; Cuéllar et al. 2010	Establishment of sustainable use programs for tegu lizards in Argentina and Paraguay. Work in Bolivia was community-based and relied on hunter self-monitoring.
Yellow anacondas	Argentina	Micucci et al. 2006.	Establishment of sustainable use program for yellow anaconda.
Reticulated pythons	Indonesia, Malaysia	Shine et al. 1999; Natusch et al. 2016a; Natusch et al. 2016b	Design of management protocols; monitoring changes in harvest demographics over a 20-year period to inform harvest sustainability.
Water snakes	Cambodia	Brooks et al. 2007; Brooks et al. 2008; Brooks et al. 2010	Monitoring of offtake levels over time, combined with biological data collection from harvested individuals
Rattlesnakes	USA	Fitzgerald and Painter 2000	Monitored harvest to answer questions about trade in rattlesnakes; rattlesnake roundup organizers engaged in self-monitoring.
Nile monitor lizards		Buffrenil and Hemery 2002	Not a long-term monitoring program. This was an analysis of data from different populations.

Harvest monitoring can be carried out by hunters themselves. For example, in the USA, large numbers of western diamondback rattlesnakes are collected for a commercial trade in events called rattlesnake roundups. This use of snakes is controversial because of serious concerns regarding the hunting methods, treatment, and transport of live rattlesnakes. Harvested rattlesnakes are traded alive, not dead, and are killed in public as a form of entertainment. Nonetheless, addressing the challenges of rattlesnake roundups will depend in part on data and analysis of the use of rattlesnakes. Researchers began collecting data from rattlesnake harvests to study the conservation challenges (Fitzgerald and Painter 2000). Soon, organizers of rattlesnake roundups desired to incorporate harvest monitoring into the event's activities. The total harvest of rattlesnakes brought to the rattlesnake roundup in Sweetwater Texas is publicly available, so trends in the total harvest can be identified. The Sweetwater Jaycees, who sponsor the largest of these events, adopted a monitoring system after observing and learning from biologists who studied the rattlesnake roundups and commercial trade in rattlesnakes. The organizers of the roundup events measure the length and weight of a sample of rattlesnakes and report the data to the Texas Parks and Wildlife Department.

Appendix I provides a summary of key considerations for harvest monitoring of reptiles traded for different purposes.

1.4 Limitations of harvest monitoring

Harvest monitoring is one of many tools used by scientists to assess the sustainability of international and domestic wildlife trades. Monitoring the harvest is necessary and useful because it identifies patterns and trends and allows the effectiveness of regulations placed on collectors and traders to be measured (Mieres and Fitzgerald 2006). Harvest monitoring data can help determine if quotas, size restrictions and other management regulations are working. As such, harvest monitoring is also important for enforcement and compliance aspects of sustainable use systems. Despite its importance to managing trades of harvested species, harvest monitoring in itself cannot answer every question about how the added mortality from harvest may affect populations and interactions among species and their environments (Fitzgerald 2012). For example, monitoring can tell managers *what is happening* to a population, but is limited in its ability to explain *how* or *why.*

In general, harvest monitoring is not adequate for answering some important ecological questions:

- **How does population density vary over areas?**
  - e.g., Where are the source populations and sink populations?
- **How does harvest alter the behavior of individuals in a population?**
  - Do individuals change daily activity patterns?
  - Do individuals alter use of microhabitats?
- **How does harvest change interactions among the harvested species and other species?**
- **Harvest monitoring in itself cannot identify direct causes of changes in population demographics and size distributions.**
  - For example, are changes in body size and population structure due to effects of harvest, or other factors like deforestation, agriculture, roadkill or climate change?

1.5 Consistency for repeatability and defensible findings

The overarching objective of harvest monitoring is use of data to understand the effects of harvest on the wild population of animals (snakes, in our case). It is, thefore, critical that monitoring data be interpretable by those analyzing and using the data over long time periods. Because the data from harvest monitoring are the basis for creating and adapting policies, findings based on harvest monitoring data must be scientifically defensible to a broad group of industry stakeholders, politicians, government agencies, and non-government organizations.

Reliable harvest monitoring results depend on the accumulation of long-term datasets. For data to be comparable across time periods, such as years or seasons, data should be collected in a consistent fashion. Differences in how the length of skins are measured, for example, could cause broad variance associated with harvest statistics, and could even obscure important differences. If methods and approaches change during the course of a monitoring program, it becomes difficult to say whether the observed trends are due to harvest or if they are artifacts of methodology. Consistent data allow for simple and robust examination of trends in the harvest, such as changes in sex ratio among places or over time, or changes in the distribution of body sizes. For harvested snake species, long-term time series of the sex ratio and size distribution are the core data for understanding the effects of harvest on snake populations.

1.5.1 What if the harvest monitoring system itself reveals better ways to obtain monitoring data?

In almost all cases, we strongly advise against stopping measurement of one set of variables and taking new kinds of measurements (exceptions are those variables that tell users nothing about the sustainability of harvest; e.g., tail length). Doing so means that before-after comparisons and analyses of the longitudinal data series will become much more complex and more difficult to interpret. In some cases, comparisons may not even be possible. Making changes to the data collection plan in harvest monitoring might not add much to the knowledge-base from harvest monitoring. It is better to plan well before a monitoring program is implemented, and then stick with that program.

Careful consideration should be given to adding more variables to be measured, because more elaborate monitoring protocols increase the cost of the program. Addition of variables to be measured, such as multiple ways to measure size, or taking data at a number of new places, carry costs associated with time, transportation, personnel, training, and relationships between the monitoring teams and collectors or industry. If new approaches are deemed necessary, we suggest that both the old and new measurements be taken together for several years until robust calibrations can be made between the new and old measurements.

1.6 Harvest monitoring data management

Collecting large amounts of data from harvested reptiles is time consuming and costly. There is little point collecting those data if they are not adequately recorded and archived. The results of harvest monitoring need to be adequately recorded and kept in perpetuity so future investigators/managers can easily access and interpret those data, many years after the original data were collected. The first step in this process is to ensure you have adequate hard-copy data collection sheets.

1.6.1 Hard copy data sheets

Data collection sheets should allow the rapid recording of data in the field. They should be designed before a monitoring program commences and should include space for all relevant data to be recorded. Information common to many harvesting monitoring programs are:

- Name of the investigator
- Time and date of data collection
- Premises from which data are collected
- Specimen identification number
- Sex
- Body length (e.g., SVL)
- Mass

However, in many cases (particularly where data are collected at animal processing facilities) it will be possible to record information on reproductive condition, number of offspring, sizes at sexual maturity, diet, fat scores, and a variety of other measurements of interest. A sample data collection form is provided in **Appendix II.**

1.6.2 Electronic data forms

In almost all cases, once data are collected they must be inputted into an electronic format to aid data handling and analysis. This process can be time consuming. In some cases, it may be possible to record data directly into an electronic format, using a smart tablet, iPad™, or laptop computer. It is important to ensure sufficient back-up files are created in the event that electronic data collection forms are corrupted. Considerations for recording directly into an electronic device are included in Table 2.

Table 2: Considerations for recording data into hard-copy data sheets vs. an electronic device.

Hard copy recording	Direct recording into electronic device
Time consuming to later convert to electronic format.	Electronic device may get wet and/or damaged in some situations.
Good to have a back-up hard copy available in the event that electronic device is damaged or corrupted.	Quick to record directly into analysis software; allows for rapid analysis of monitoring data.
Transferring data from hard to soft copy can result in human error.	Design of management protocols; monitoring changes in harvest demographics over a 20-year period to inform harvest sustainability.
Transferring data from hard to soft copy allows mistakes to be identified and corrected.	Monitoring of offtake levels over time, combined with biological data collection from harvested individuals


Photo by Daniel Natusch

1.6.3 Data archiving

The purpose of collecting monitoring data is to examine trends over time, or from one year to the next. There are many possibilities for long-term archiving of monitoring data but keeping them in the office filing cabinet is probably not the best option. Monitoring programs need to be setup to last decades, and likely outlive the positions and careers of individuals charged with operating the monitoring program. We know of specific cases where monitoring data were lost due to changes in personnel, changes in organizational structure of ministries, and cancellation of programs. Thus, it is critical that monitoring data be archived in a suitable data repository so that they can be easily accessed by future researchers and managers no matter where they may be located or employed.

Data archiving systems

- Data may be stored in various formats. In some cases, data may simply be recorded in Microsoft Excel™ files within a dedicated file on a computer.
- It is critical that multiple copies be kept on external drives in different locations.
  - Different locations means keeping a copy of the data in a different building than the main computer. This ensures against problems of theft, flooding, fire, confusion, and vandalism.
- It is critical that data are formatted in a simple manner and appropriately labeled. Where applicable, it is important not to use abbreviations (e.g., HL for head length) unless these abbreviations are appropriately defined in the Excel workbook itself. It is also important to ensure units are presented, such that measurements of body mass, for example, are recorded in grams "(g)" or kilograms "(kg)".
- It is important to develop a logical system of file naming during design of the monitoring program and ensure file names follow this system consistently.
  - Filenames should be easily interpreted and include the type of data collected, and the year of data collection.
  - It is critical to lock original files in read-only mode and label the files with MASTER in the filename. Copies of these files may be used for analysis, sharing, and so forth, and labeled ANALYSIS in the filename.
    - The reason it is critically important to archive MASTER files and use copies for ANALYSIS is because data in a spreadsheet can become scrambled, most typically through mistakes in sorting. If one column is sorted without the others, the data in each row no longer correspond to the same specimen. For example, sorting by body size without mass and tail length will cause the spreadsheet to list mass and tail lengths that were not taken from the specimen. It may be impossible to unscramble the data properly. Hence it is critical to archive a locked MASTER file in case of emergency.
- Databases, such as Microsoft Access, have a number of advantages over Excel in terms of safely recording and keeping large datasets. Databases can be quickly programmed to produce reports and tables (called queries) without manipulating the data-entry spreadsheet. Scrambling of the data cannot occur in a database. As monitoring programs grow, it is worth considering importing Excel spreadsheets into a database.
- Printed hard copies of data serve as a failsafe method for data safekeeping. Hard copies should be printed on good quality paper and filed in an organized system that is easy to interpret by anyone. The question for the long-term is where to archive hard copies of monitoring data.

Where to deposit data

A challenge to long-term data storage in a monitoring program is how to ensure that data are not lost during the inevitable changes that happen in institutions over time. While we never know what may happen, some risks to data archiving are predictable. What happens to data if those charged with conducting monitoring change jobs, government officials change the program, the organisation of the institution changes, the operation moves to a new location, or the monitoring program suffers a hiatus or is cancelled? A consultant charged with monitoring may lose the contract. Where and how will data be stored to minimize these sorts of risks? Below is a list of potential approaches to data archiving. The main lesson here is to do our best to incorporate a data management plan into the monitoring program from the outset and follow through with it. After all, keeping the data is just as important as collecting it, and data management needs to be given high priority.

- Data may be kept in an online, public, repository, such that other researchers and general public can access, analyze and assist wildlife managers to draw conclusions from those data.
- Arrangements can be made with scientific institutions for data storage associated with programs. National museums of natural history are good candidates for archiving data. University libraries, national archives, and other kinds of museums may also be good candidates for long-term data storage.
- Publishing data papers-- Data papers are publications of compiled data, published by Global Biodiversity Information Facility (GBIF) and major journals such as Nature.
    - If monitoring data are intended to be publicly available, publishing data papers periodically can go a long way towards getting more recognition for a monitoring project and the scientists who are carrying out the monitoring program.
    - Refer to Global Biodiversity Information Facility (GBIF) about data papers here: https://www.gbif.org/data-papers
- DRYAD is a non-profit organization specifically designed to store data and make it available to scientists. The DRYAD website (https://www.datadryad.org/) includes information on how data packages are stored, and includes information on costs. It is worth considering incorporating costs of long-term data storage into the design of the monitoring program. Data packages could be submitted to DRYAD on a yearly basis, and the costs would be minimal.
- Including raw data as appendices in theses—When students are working in association with monitoring programs, it is good practice to insist that raw data be included in appendices. For example, the monitoring program for tegu lizards in one country fell apart after 9 years of near-perfect monitoring at check stations and tanneries. The data can no longer be found in the government ministries, but hard-copies exist in a student's masters degree thesis.

1.7 How to use harvest-monitoring data

1.7.1 Time series

The essence of biological monitoring lies in the accumulation of comparable data over time. As data from a monitoring system accumulate, we can construct time-series for different variables that have been measured. A time series consists of data points arranged in sequential order. Time series usually are made from data coallected at regular intervals (e.g., weekly, monthly or yearly).

Data from a well-designed harvest-monitoring program would allow a number of time series to be constructed, for example:

- Total harvest over time
- Catch-per-unit-effort (CPUE) over time
- Body sizes over time (SVL, mass, skins)
- Sex ratio, or proportion of females in the harvest over time
- Proportion of adults/juveniles over time
- Natural history variables over time
    - Clutch size and mass
    - Sizes at sexual maturity
    - Frequency of certain prey items

1.7.2 Long-term data

Longer time series from harvest monitoring systems allow more informed interpretations of trends, and allow detection of trends that would not be perceived without many years of data (Fitzgerald 1994b; Gibbons 2012). There is no special number of years that make a dataset qualify as "long-term". Many data points are needed in a time series to allow meaningful trends to be identified. Three or four occasions cannot provide a defensible trend, whether upward or downward. Moreover, without many sampling occasions it is also problematic to judge whether the trend is due to harvesting, or because of natural fluctuations over time (Fig. 1). We usually consider more than 5 years to be the beginning of a long-term dataset, and the most impressive long-term data span multiple decades.

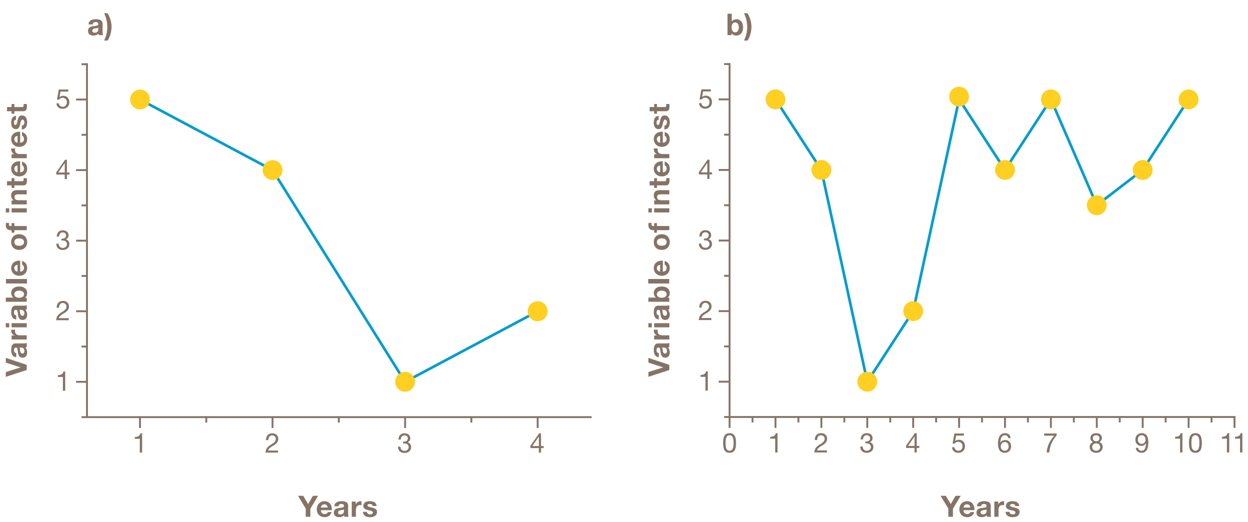


Fig. 1. *Time series showing (a) a declining trend over four years of monitoring and (b) the same four years of monitoring expanded over multiple years revealing that the declining trend at the beginning of the time series was somewhat of an anomaly caused by factors other than harvest.*

Long-term data can allow interpretation of the effect of unpredictable events in a harvest system. For example, suppose that a market collapse occurred during a few years, resulting in decreased demand for a snake species in the trade. We would predict that the total number of snakes harvested would decline, but what changes might occur with hunter effort, size distributions, and sex ratios?

Long-term data are also needed to reveal how well management policies are working. Consider policies intended to reduce the total harvest or to reduce the number of large females in the harvest. Long-term data allow comparisons to be made before the management intervention was implemented, and after it has taken effect. If size restrictions were instituted to protect the largest female pythons because of their importance for producing offspring, then we would hope to see a rapid decline in the number of female pythons above the restricted size.

The graphs below illustrate how events like increased demand, decreased demand, and size restrictions may be observed in long-term harvest data.

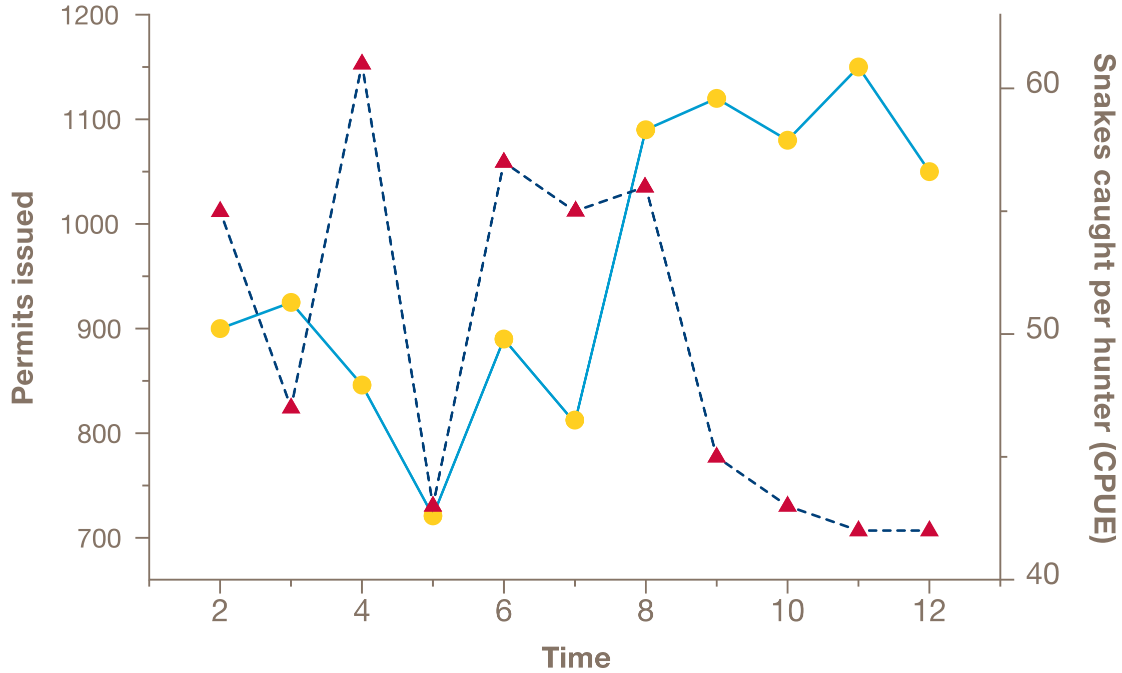


Fig. 2. *A time series showing an increase in the number of permits applied for and issued to hunters (solid line, circular yellow points) due to an increase in demand. This increase in the number of hunters results in fewer snakes being captured per hunter (dashed line, triangular green points) due to increased competition, resulting in a decrease in the catch per unit effort (CPUE). *Note the short lag before CPUE begins to fall.*

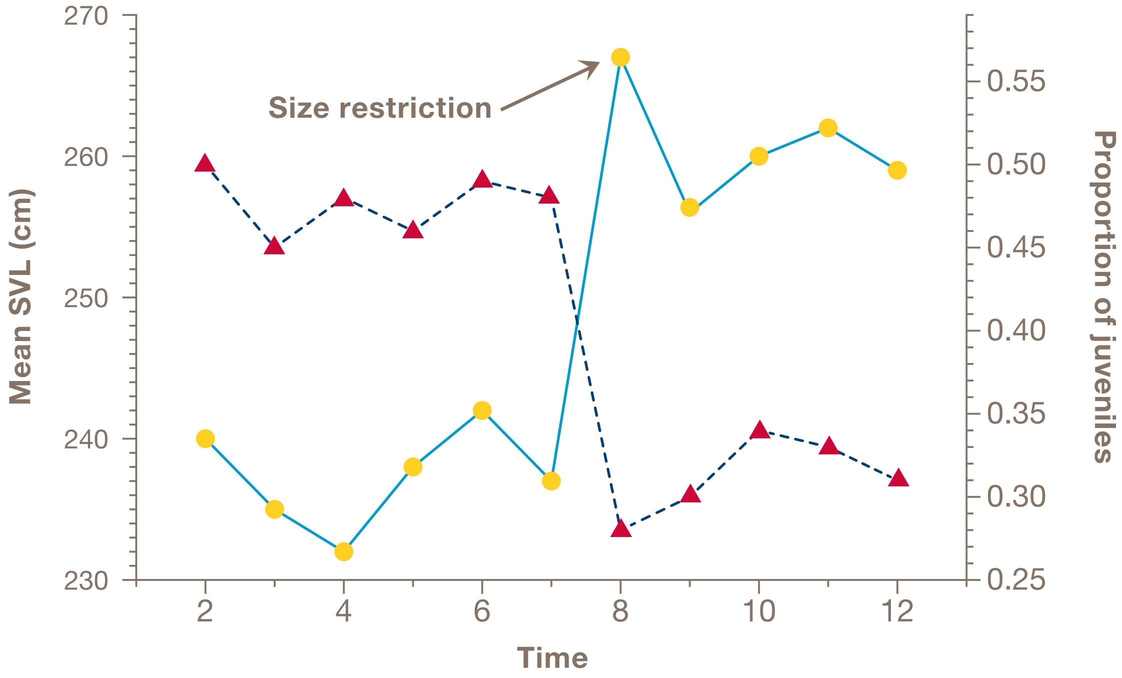


Fig. 3. *A time series showing mean snout-vent length (solid line, circular yellow points) and proportion of juveniles (dashed line, triangular green points) in harvests of a snake species. In order to protect a greater proportion of juveniles from harvesting, a minimum size restriction was implemented after five years of monitoring. The monitoring data clearly display an increase in the mean body size of harvested snakes after the management intervention, and a corresponding decrease in the proportion of juveniles in the harvest.*

1.7.3 Natural history studies

Natural history information is needed to develop population models based on life history traits of harvested species. The size at maturity, fecundity, timing of reproduction, and frequency of reproduction are used to develop sustained yield models, and this information is derived from basic natural history studies of species (Fitzgerald et al. 1993). Important natural history information can be obtained from harvested animals by working with hunters and processing facilities. Large numbers of specimens can be obtained from the harvest monitoring system and used for detailed natural history studies such as:

- Reproductive cycles—Specimens of harvested animals can be examined to provide data on:
  - Timing of reproduction;
  - Size at sexual maturity;
  - Clutch size-body size relationships;
  - Proportion of females in a population that reproduce each year;
  - Other studies related to reproduction.
- Dietary patterns
  - Frequency and occurrence of prey items;
  - Importance of specific prey in the diet;
  - Variation in diet over time;
  - Differences in diet between males and females;
  - Ontogenetic shifts in diet (dietary changes from juveniles to adults).
- Parasites and Disease
  - Identification of parasites;
  - Frequency of parasitism in the harvested population;
  - Seasonal and yearly variation in parasites;
  - Assessment of effects of parasites on individuals and populations;
  - Identification of diseases.

1.8 What is needed to establish a harvest monitoring system?

If monitoring systems are themselves to be sustainable in the long term, then careful planning, design and implementation are needed. There is no simple formula for designing a monitoring and management system, and sometimes even the best planned systems have to be modified over the first few weeks of implementation due to unforeseen logistical complications. Nevertheless, there are a number of considerations and steps managers can take to ensure monitoring is consistent, and runs smoothly over long time periods. This section of the guidance discusses some of the key considerations for establishment and longevity of a successful harvest monitoring program.

1.8.1 Recognition that harvest monitoring is needed

The first step in the establishment of any harvesting monitoring program is to recognize when a harvest monitoring program is needed.

- Is offtake of wild specimens taking place?
- Are protocols needed to ensure offtake is sustainable, and that the species does not decline and/or become endangered?
- Are alternative monitoring protocols (e.g., more traditional field survey methods) providing the types of information necessary to determine harvest sustainability?
- If not, can a harvest monitoring program improve the quality and usefulness of data collected?
- Is it logistically, financially, and technically feasible to implement a harvest monitoring program?
- If a monitoring system is established, what are its objectives?
- What may occur in the absence of a harvest-monitoring program?

If the decision is made that a harvest-monitoring program is needed, then further considerations are required, as discussed below.

1.8.2 Accurate species identification

Correct identification of the species being monitored is the critical first step in any monitoring program. In many cases, this will be straightforward; many reptiles have highly distinctive shapes and patterns. In other cases, this will not be so simple. For example, the closely related short tailed pythons (Python brongersmai and Python curtus) are brought to processing facilities in northern Sumatra to be utilised for their skins and meat (Shine et al. 1999). These species are difficult to tell apart because of similarities in body shape and pattern, but it is critical that they are accurately identified so that data collected is not mixed between species. Problems of identification are complicated when monitoring at sites where a species has already been processed into parts and derivatives (e.g., a snake skin tannery).

Guidebooks and other resources will be important tools for wildlife managers collecting data as part of monitoring systems. Other resources such as groups of experts (e.g., the IUCN SSC Boa and Python Specialist Group) can assist wildlife managers while they become acquainted with the study species. In many cases, the traders and industry representatives will be able to help differentiate species. In other cases, however, traders (for example, those trading snakes for traditional medicines) may not know the differences between certain taxa.

In systems where multiple species are monitored, written criteria for identifying characteristics of each species need to be developed and understood by all participants. Whenever possible the species' key traits should be evident in as many stages of the monitoring system as is practical.

1.8.3 Stakeholder engagement

The international and domestic trade in snakes is an environmental, economic, social and cultural issue. Decisions made about the harvest of snakes will thus have important political and socioeconomic ramifications for the various stakeholders involved. Managers should keep this in mind when designing monitoring and management systems, and ensure different stakeholders understand why the monitoring system is being undertaken and what it involves. It is important that all stakeholders understand how objective data informs all sides. As such, managers should not allow stakeholders with self-interest agendas to undermine the methodology, transparency, or integrity of the science underpinning the monitoring system. However, a clear understanding by stakeholders of the monitoring system and its importance to the trade (and their business) will help to ensure any system that is implemented has an increased chance of success. Therefore, managers should hold workshops or conduct visits to meet with affected stakeholders to explain the system, as well as any changes to the system over time.

1.8.4 Government, NGO, and public awareness

The backing of national and provincial/local government is critical to the success of harvest monitoring programs. If NGOs or private groups are undertaking monitoring, government approval and buy-in is necessary to facilitate access to monitoring sites, ensure cooperation from hunters and traders, and to avoid misunderstanding about program goals and procedures. In many cases, monitoring programs will already be government-run programs undertaken by government staff. Nevertheless, it is important that different institutions within government are aware of (and, where possible, involved in) the design and implementation of monitoring programs. A government's understanding of a harvest monitoring program is critically important if the results of the program are feeding into non-detriment findings undertaken for CITES-listed taxa by the national CITES Scientific Authority.

In the same way, NGOs working in the area should be informed about harvesting monitoring activities. If linkage exists between NGO-run projects and monitoring programs, there may be opportunities to benefit from financial or in-kind support from NGOs. At the very least, knowledge of the activities being undertaken as part of the monitoring system and those being undertaken by NGOs can help to prevent duplication of effort and identify where synergies may exist.

1.8.5 Industry partnerships

The fundamental goal of harvest monitoring programs is to ensure sustainability of the harvest and persistence of the target populations. This is critical not only for species conservation, but also for the people and businesses relying on a sustainable supply of snakes. Industry thus has a strong incentive to be involved with, and contribute to, harvest monitoring. Industry partnerships are one way to achieve this. Industry might provide funding for monitoring activities, or may contribute in-kind support by facilitating access to key monitoring locations within a supply chain. Industry partnerships are also important because buy-in from industry stakeholders is often critical to the ongoing success of a harvest monitoring program. The Python Conservation Partnership (PCP) is an example of a successful industry partnership. It was a partnership between the IUCN/SSC Boa & Python Specialist Group, the UN/WTO International Trade Centre, and Kering, a French company utilizing reptile skins within its products. Funding from this partnership was used to conduct monitoring and improve the sustainability of the python skin trade in Southeast Asia. Similarly, many programs aimed at sustainable use of crocodilians world-wide include partnerships among governments, CITES, IUCN Crocodile Specialist Group, and the industries that use crocodilian skins and meat.

1.8.6 Creation of a sustainable funding mechanism

Harvest monitoring systems need to include a long-term funding plan. There are a variety of different ways to secure funding for monitoring activities. In certain cases, monitoring programs are undertaken using private grants provided by donors. Although monitoring systems reliant on grant funding are workable, they are typically not ideal because of the uncertain nature of future funding. Some grants only provide annual funding, and the time needed to write grant applications and search for new donors can itself be unsustainable. In other cases, government authorities allocate funds to the management of harvested species out of their annual budgets. Such funding mechanisms are generally more sustainable, but can suffer from uncertainty such as changes in political administrations or funding priorities. The sustainability of a monitoring program has been shown to be enhanced when operational costs are transparent and 'internalised', thereby removing ongoing dependency on externally-sourced revenue. This enables unexpended funds to be carried across fiscal years. It also makes sense that the industry that is exploiting snakes as a natural resource be accountable for the costs of conservation and management. There are a number of ways this can be accomplished, and a balance of realistic expectations, wise decision-making, and common sense will help in the creation and institutionalization of long-term funding mechanisms for harvest monitoring (Fitzgerald et al. 1994; Natusch et al. 2016). Here are some examples of what has been developed in our own experiences:

- Financing monitoring of tegu lizards in Argentina (V. Lichtschein pers. comm.):
    - In the early years of decision making a Tupinambis Commission was formed that included industry, government, and rese arch partnerships.
    - In later years, the national wildlife agency worked with provincial administrations and industry to arrive at harvest quotas.
    - An industry group included most traders and exporters of Tupinambis skins and products.
    - The exporters contributed to a fund in proportion to the number of skins they exported, which was confirmed by CITES permits.
    - A Trust Fund for holding the funds was set up in a reputable bank. Later, the trust fund was moved to a private foundation.
- Tegu monitoring in Paraguay (A.L. Aquino, pers. comm):
    - Exporters paid taxes on each skin that was exported, with the number of skins confirmed by CITES permits.
    - The funds went to an NGO - TRAFFIC-USA - in the first year.
        - The NGO made donations to the CITES authorities in Paraguay who directed the monitoring program.
    - In later years, the Ministry of Agriculture created a “wildlife fund” where these taxes were deposited.
    - The funding was used for travel, salaries, communications, and equipment for all monitoring and research.
- Yellow anaconda monitoring in Argentina:
    - A local NGO (Fundación Biodiversidad – Argentina) was engaged as a technical advisor from the beginning of the harvest management program.
    - Every year a budget and a work plan is presented by the NGO to the provincial government and industry for approval.
    - Industry members privately agree their share (%) based on the results of the harvest.
    - Industry members fund the budget presented by the NGO on their agreed share basis.
    - Funding is used for travel, salaries, and equipment for monitoring and research.

1.8.7 Planning and implementation

Making a budget

Undertaking regular and scientifically robust harvest monitoring takes time, and requires ongoing funding to implement year after year. Making a realistic budget is thus critical for ensuring available resources are used wisely, and for attracting future funding to defray the costs of ongoing monitoring activities.

When making a budget it is important to consider:

- How many days are needed to obtain sample sizes large enough for robust statistical analyses?
- How many facilities should be monitored (to appropriately assess spatial variation)?
- How many times should monitoring surveys occur each year (to assess temporal variation)?
- How much will it cost to provide for long-term data storage?
- What is the time period when funds will be available?
    - Will unexpended funds roll-over from one year to the next, or is a new budget required every year?

Once these details are known, for each monitoring occasion you will need to consider:

- Staff/consultant salaries to conduct monitoring (if applicable)
- Transport to monitoring sites (including fuel/vehicle hire)
- Accommodation at monitoring sites
- Food/subsistence at monitoring sites
- Equipment necessary for monitoring
    - Measuring tools, computer, software,office supplies, copy costs
    - Supplies and tools for collection of biological specimens
- Sundry other costs specific to the monitoring system
    - Typically 10-15% of annual budget to cover contingencies.
- Building in costs for external program reviews every 5 years. External assessments of the monitoring system are important to ensure the program is meeting its stated objectives and for identifying areas of improvement.

Training sessions:

The effectiveness of a monitoring system relies heavily on the expertise of the personnel gathering the data, and the consistency of protocols from one monitoring occasion to the next (Hayek 2012). Therefore, regular training of personnel involved in a monitoring system is critical. Training sessions should involve:

- Familiarising and/or reacquainting participants with data collection tools (e.g. how to use calipers and record data in collection sheets)
- Familiarising and/or reacquainting participants with data collection techniques (e.g., how to stretch a snake to take length measurements and how to identify and measure reproductive organs).
- Familiarise and/or reacquaint managers tasked with interpreting data in how to analyse, interpret, and draw conclusions from monitoring data.
- Familiarise and/or reacquaint monitoring and data interpretation personnel of any sources of biases inherent in data collection and/or errors in previous monitoring periods.
- Provide monitoring and management personnel with any updates or changes to the monitoring system (e.g., what's new in the datasheet, new sites to survey, new data collection protocols, etc).

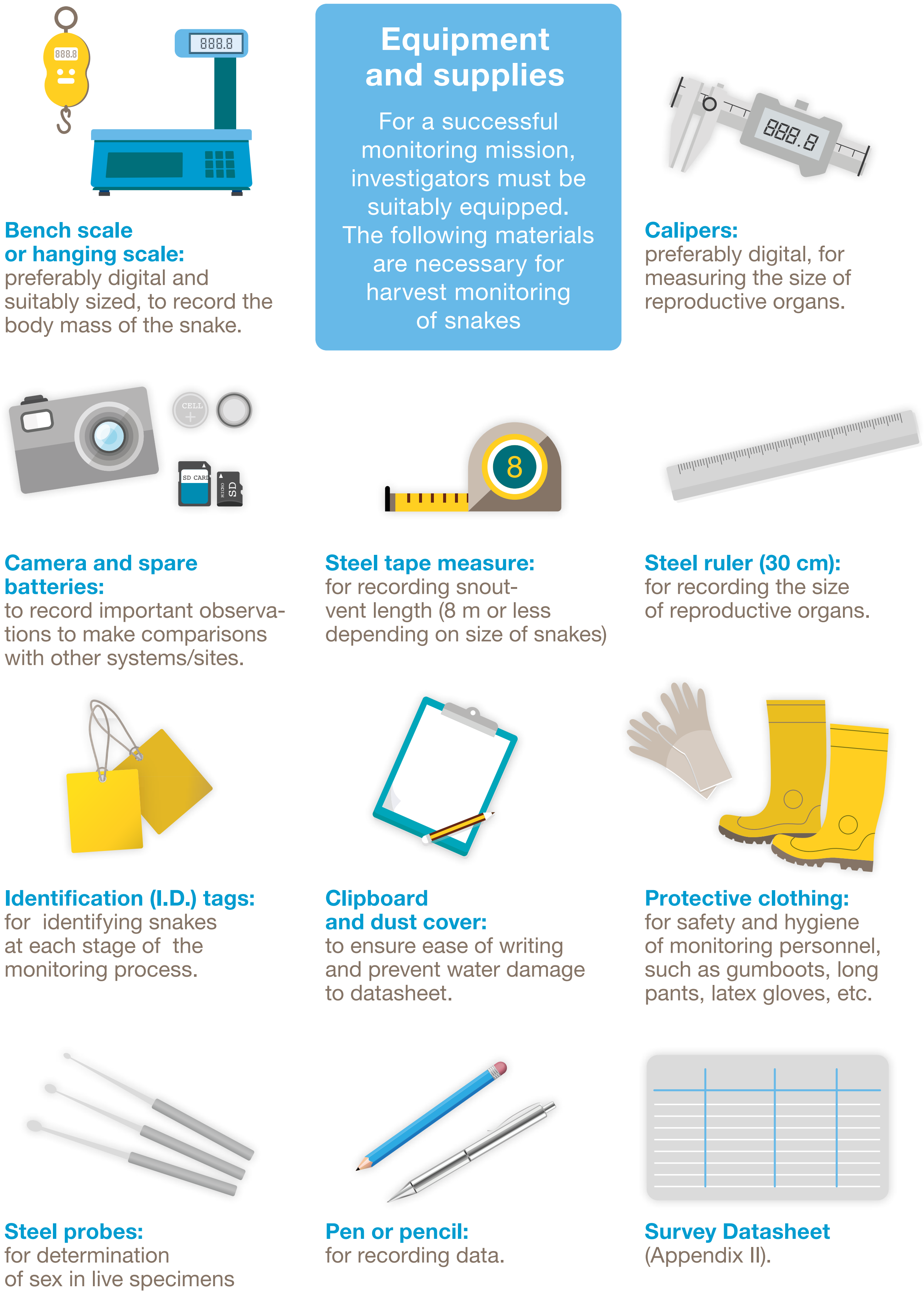


Fig. 4. *Some essential equipment required for examination of snakes at processing facilities.*

Ensuring safety and hygiene

Below are some safety and hygiene considerations to be aware of when conducting monitoring surveys:

- Snakes typically arrive alive at processing facilities, and may be killed there (depending on the purpose of trade). Do not assist with this process.

- Most, if not all, facilities utilize large volumes of water to process snakes and clean facilities after use. Ensure there are no electrical hazards, such as live power cords or outlets in or near water, in the workspace.

- Ensure scissors, scalpels, and other sharp equipment that may be required are handled correctly.

- Be mindful of your body position when moving larger, heavier species, such as boas or pythons. Ensure you lift and carry snakes correctly by keeping them close to the body; bend your knees and lift with the leg muscles. If possible, organise a workspace for data collection that reduces the amount of bending, twisting and stretching required, such as a bench top or table.

- Be careful when working on slippery or uneven surfaces as you may fall and injure yourself. Wear appropriate footwear to prevent this.

- When conducting exanimations of snakes, ensure that you wear disposable gloves to reduce the risk of zoonosis and contamination. Zoonotic diseases are infectious diseases that can pass from animals to humans. There is little risk from direct contact with snakes; however, there may be prey in the gastrointestinal tract (stomach, large and small intestines) that becomes dislodged. This prey may be infected. Dispose of used gloves and always wash your hands and arms thoroughly with anti-bacterial handwash (or at least soap) when finished (or if you need to leave the workspace).

- Do not smoke, eat, or drink while collecting data, or anywhere within the areas where snakes are killed and processed.

- Ensure protective clothing (e.g., gumboots) is clean and in good working condition before conducting surveys. Thoroughly clean protective clothing when finished examining snakes.

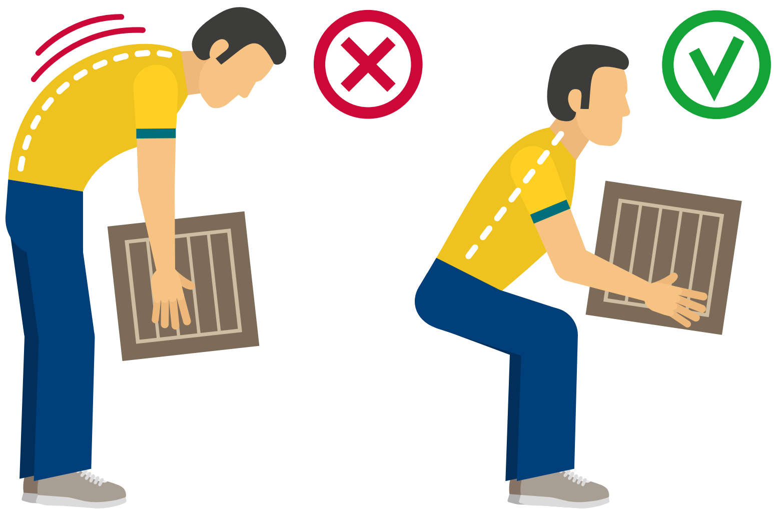


Photo by Daniel Natusch

Photo by Trevor Cole on Unsplash

2

Standardized protocols for data collection

2.1 Selection of sampling sites

2.1.1 Why survey major collecting points?

Gathering data from harvested snakes brought to major collection points is time- and cost-effective, because it yields larger sample sizes than can otherwise be gathered using traditional field-based surveys. Although snakes are often abundant, many species are remarkably cryptic and secretive, resulting in low detection probabilities and thus encounter rates. For example, recent experimental research has demonstrated that the detection rates for some snake species can be lower than 1% - that is, for every one snake found, investigators passed by more than 99 that remained undetected (Dorcas and Willson 2013). Understandably, the costs of gathering a sufficient sample of snakes from which to establish important biological parameters of a wild population (e.g., population demography) can be prohibitively high. When data are needed to establish robust population trends over time, collecting sufficient samples of snakes may be virtually impossible for many taxa (Dorcas and Willson 2009).

By contrast, the ability to consistently examine large samples of snakes at single locations (as they are brought to major collection points) allows managers to build sizeable and robust datasets with which to make management decisions (Shine et al. 1998; Natusch et al. 2016b). The types of collection points at which data can be gathered include:

- Hunters and collectors;
- Check stations;
- Warehouses/holding facilities;
- Processing facilities;
- Tanneries;

2.1.2 Which collection points to survey?

Commercial trades in snakes share characteristics in common with essentially all wildlife trades. Wildlife trades are organized in trade chains, where hunters collect wild animals and sell them to local buyers. Depending on the situation and level of management that has been implemented, a series of middlemen may purchase snakes and re-sell them up the chain. Finally, the harvested snakes arrive at processing facilities where they are prepared for export or domestic markets for skins, meat, pets, or other wildlife products.

Major collection points typically vary in the number of snakes that pass through them over a given period. The amount and types of data that can be gathered also depend on the function of the facility. For example, very large samples can be gathered in a short time from tanneries. However, the only data that can reliably be gathered are the numbers of skins and their sizes. By contrast, snakes are brought to a processing facility for a variety of purposes, such as processing snakes for food, skins, and for medicine. Because entire snakes, often alive, are held at these facilities, data can be gathered on numbers of each sex, body size, reproductive traits, parasites, and a range of morphological and life history attributes of the harvested snakes.

Preferably, surveys should be conducted at large collection facilities that allow data to be gathered from many snakes, from a range of sizes, within short time periods. Ideally, more than one facility should be surveyed in an area to account for spatial variation, as well as variation in purchasing characteristics. For example, in some situations businesses may partition markets or sources of snakes. Large and well-resourced traders may focus on purchasing the largest and most valuable snakes, leaving smaller facilities to purchase small, less valuable, snakes. Alternatively, larger facilities may purchase snakes from longer distances away, while smaller facilities purchase snakes captured locally. It is important, therefore, to have an understanding of these sources of variation, and to survey facilities in a way that includes any possible variation in the attributes of the snakes being captured for trade.

Ultimately, choosing which collection points to survey will depend on the objectives of the monitoring and management system. Table 3 describes some of the advantages and limitations in monitoring the harvest at different levels of the trade chain.

Table 3: Advantages and limitations of harvest monitoring at distinct levels in the commercial trade of a typical snake species (Adapted from Fitzgerald 2012).

Level of Trade	Advantages	Limitations
Hunter and Collector	• Geographic origin of snakes can be traced. • Hunters can help obtain specimens for natural history studies • Methods for measuring hunter effort can be devised. • Potential to develop community-based programs	• Smaller sample sizes • More difficult logistics • Time consuming • Usually more costly
Mid-level Traders	• Trade patterns can be studied • Larger sample sizes and efficient data collection • Relatively reliable information on geographic origin of snakes	• Precise collecting locations may be unknown • More difficult to measure hunter effort • Difficult to study hunting patterns and methods
Final processing facilities	• Large sample sizes and efficient data collection • Able to collect data for assessment of overall harvest levels • Can assess compliance with program-wide regulations on size and sex restrictions • Body size and sex ratios are representative of entire harvest • Builds important relationships with industry	• Little information on hunter effort • Limited information on geographic origin of harvested snakes • Inability to work closely with hunters and local communities

2.2 Survey and sampling considerations

2.2.1 Survey frequency and timing

Ideally, the timing of monitoring surveys should coincide with periods when large amounts of data can be gathered rapidly. Thus, the timing of surveys is constrained to a certain extent by both the species' biology and the traditional harvest systems. Because most management systems report their findings on an annual basis, the surveys can be timed to allow managers to establish trends in harvesting and biological characteristics that are linked to annual management goals.

Major collection points should be surveyed consistently, at an interval capable of revealing trends indicative of population change. In some cases, this may require weekly or monthly monitoring (for example, when undertaking detailed natural history studies, or when species are known to be threatened). However, in most cases less frequent monitoring is also reasonable, occurring only every 1-2 years. That being said, regular, periodic monitoring keeps the monitoring team in practice, including allowing for new participants to learn. More frequent monitoring also builds relationships between industry, collectors, and the monitoring team.

Adaptive or express monitoring may also be required. Sudden spikes in levels of export driven by market demand may require rapid mobilization of a monitoring team to collect baseline data at the beginning of a rapid increase in harvest and trade. These data can then be used to compare to the results of future monitoring to ensure rapid trade-related declines do not occur.

Investigators may also wish to conduct surveys during important periods in a species' life-cycle – for example, during the breeding season. Surveys during the breeding season can allow collection of valuable data on fecundity and the proportion of the population that is reproductive each year. However, these goals are also influenced by the interaction between species' biology and the harvest system. The biology of western diamondback rattlesnakes and their harvest, for example, is very different from that for pythons and other species. The harvest of western diamondback rattlesnakes can only practically be monitored once yearly during three days of traditional rattlesnake roundups, limiting the reproductive data to a brief time of year. Some snakes are more difficult to locate during the breeding season and investigators may obtain fewer samples than during other survey periods. Finally, the level of risk to the species should also inform the frequency of monitoring. For example, harvests of a habitat-specialist endemic to a small island should be monitored more often than a wide-ranging generalist species.

2.2.2 Survey duration and sample sizes

Surveys must be of sufficient duration to obtain sample sizes necessary for robust statistical testing. However, the amount of data that can be collected will depend on the system and species being monitored, and on available resources such as funding and staff. A critical component of any monitoring system is that sample sizes are large enough to draw conclusions with sufficient statistical power. If statistical power is not sufficient, investigators run the risk of not being able to draw conclusions or make robust inferences. In the worst case, biased or inadequate samples can lead to statistical type I errors, such as concluding that a harvest is sustainable when it may be declining (Peterman 1990). To avoid this, investigators can determine the sample sizes needed to draw conclusions from monitoring before the monitoring system has been implemented (Gerrodette 1987).

Statistical power refers to the ability of a test to reject the null hypothesis when it is false (Cohen 1977). In statistical tests, we start with the null hypothesis that samples are not different. The statistical test (e.g., regression, ANOVA, t-tests) calculates the probability that the trend, or differences among groups, is not due to chance. A statistically significant result (usually $P < 0.05$) means there is a 95% probability that the groups are different, on average, or that the trend is showing an important association.

Sample size has a profound effect on the test's ability to reject the null hypothesis of no difference. In general, more data are needed to identify trends and patterns in systems that are highly variable. In a system characterized by large variation in the size of animals harvested, or where the number of animals harvested fluctuates wildly across years, large sample sizes are needed for rigorous statistical testing. For example, if statistical analysis of monitoring data returns a result that average body size differences across years are not statistically significant, is this because the differences in size are not important, or is it because there was not enough statistical power to be able to reject the hypothesis of no difference? We want to design our monitoring systems to provide plenty of data so that we have adequate statistical power to reveal differences. With large samples and high statistical power, we can make informed decisions about whether these results are biologically meaningful and important to consider in terms of sustainable harvests.

The sample sizes required to draw conclusions with sufficient statistical power depends on the size of the effect the investigator is trying to detect. An effect size is the percentage change in an attribute of interest over a defined period (Cohen 1977). The smaller the effect to be detected, the larger the sample size must be (Fig. 5). For example, to detect a 15% decrease in snake body size between two periods, a sample size of 277 individuals is required at both sampling periods (a total sample of 554). However, if managers are interested in detecting a 10% decrease in body sizes, then a sample of 619 specimens is required per sampling period (a total sample of 1,238). Appendix III presents sample sizes required to calculate effect sizes with sufficient statistical power (typically > 0.8; Cohen 1977). The table caption contains specific details of the calculations.

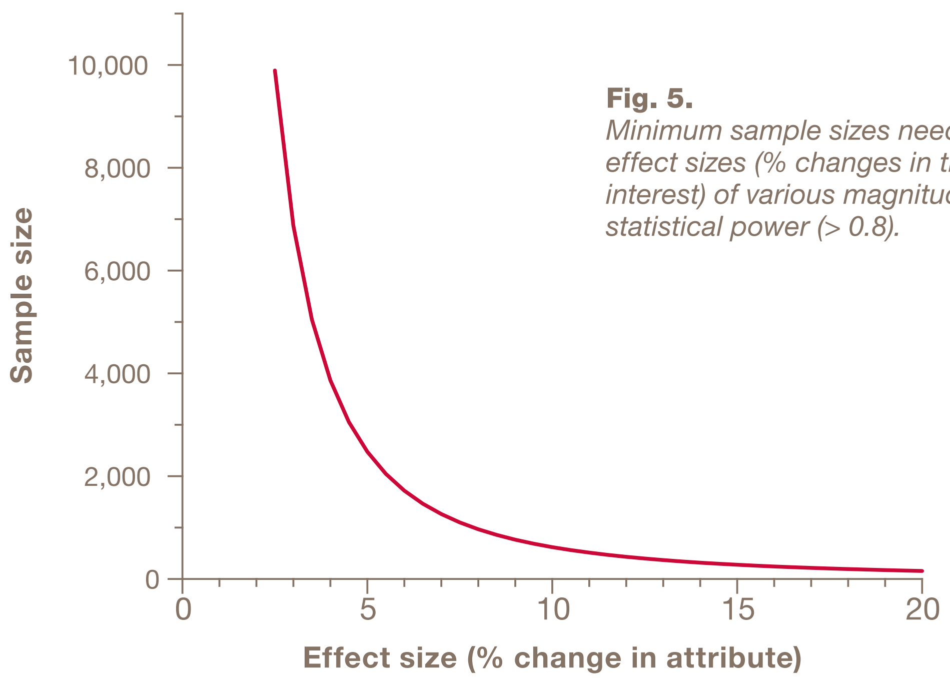


Fig. 5.
Minimum sample sizes needed to detect effect sizes (% changes in the attribute of interest) of various magnitudes with sufficient statistical power (> 0.8).

2.3 Protocols for gathering data

2.3.1 Size distributions and sex ratios

Overharvesting can cause changes to the minimum, mean, and maximum size of harvested individuals, and to the ratio of males and females within populations (Shin et al. 2005; Festa-Bianchet 2017). In many species, males and females differ in body sizes (termed sexual size dimorphism). These differences may result in disproportionate pressure on certain sexes. For example, the largest sex may be preferentially hunted if large skins are more valuable. In many pythons and other boid snakes, females are the largest sex, thus selection for large skins may remove many mature females and impact the sustainability of the harvest. For this reason, obtaining measurements of the sizes and sexes of harvested individuals at regular monitoring intervals allows us to understand how harvesting affects these attributes over time, and whether harvesting may be negatively impacting a wild population.

Body sizes

The two most common measurements of snake body size are length and body mass. Snake body length is measured from the tip of the snout to the cloacal opening (i.e., the vent, or base of the tail). Body mass is the total weight of the live or freshly killed snake. Snout-to-vent length (hereafter, SVL) is typically the most common standard measure of body size in snakes. It is a more reliable measurement than body mass, because body mass can vary based on season, reproductive condition, or how recently a snake has eaten. Nevertheless, body mass can provide a good indication of overall population biomass, and can be used to cross-check against SVL measurements. Measurements of each body size indices can be made as follows:

Snout vent length (SVL; in cm)

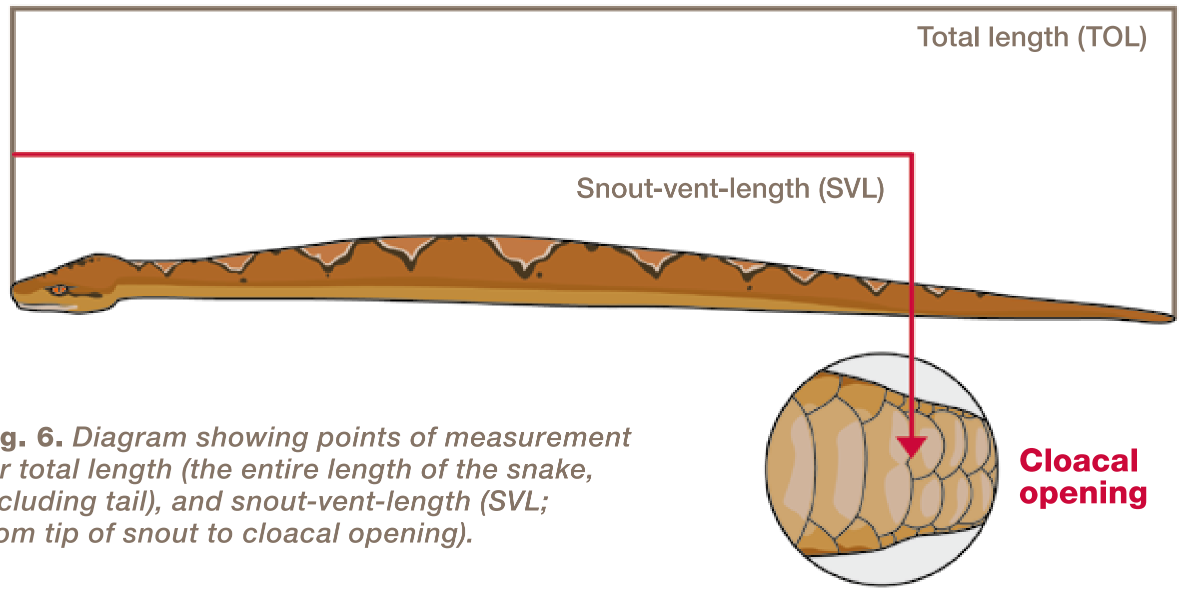
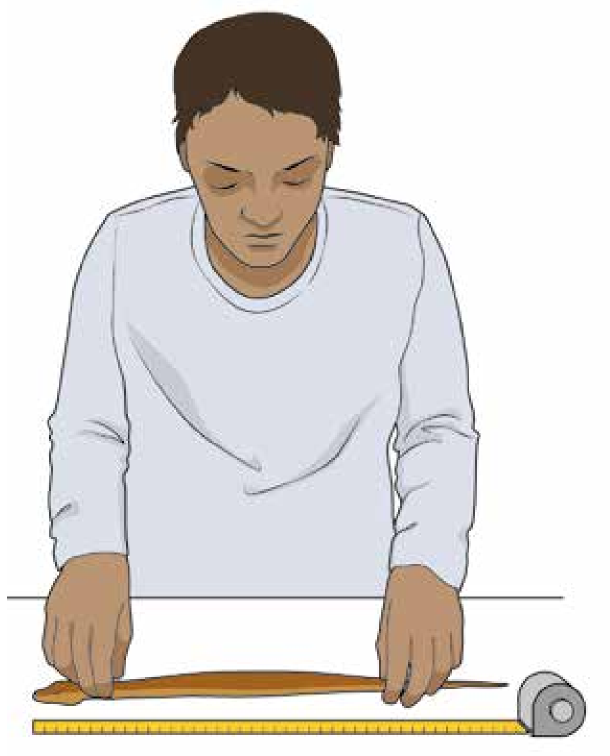


Fig. 6. *Diagram showing points of measurement for total length (the entire length of the snake, including tail), and snout-vent-length (SVL; from tip of snout to cloacal opening).*

- *To measure SVL, a steel tape measure should be placed on the ground or an appropriately sized table. The snake can be laid beside the tape measure (do not attempt to lay the snake on top of the measure; this is unnecessary and typically results in bending of the tape).*
- *Investigators should grasp the snake behind the head, making sure the tip of the snake's nose (snout) is at the 0-point on the steel tape measure. Grasp the tail and pull the snake to its maximum length.*

Fig. 7. ***Small snakes (up to approximately 60 cm SVL) can be accurately measured by a single observer. Care should be taken to ensure to the snake's snout is in line with the 0-point before the length measurement is taken at the cloacal opening.***



• *In the case of large snakes (typically snakes longer than 60 cm), two investigators may be required to measure SVL. One investigator should grasp the snake behind the head, making sure the tip of the snake's nose (snout) is at the 0-point on the steel tape measure, while the second person grasps the tail and pulls the snake to its maximum length.*

• *Record SVL in centimetres (cm) from the tip of the snout to the cloacal opening (vent, or base of the tail).*

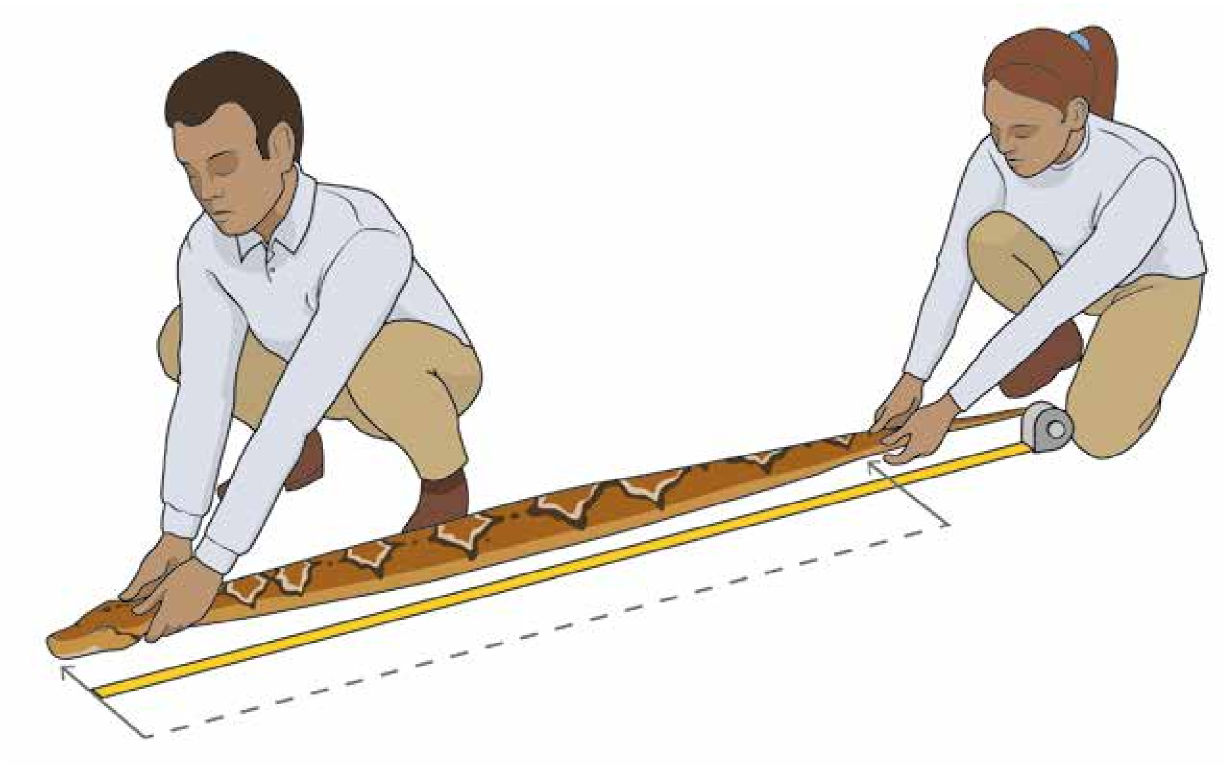


Fig. 8. ***Larger snakes need to be measured by two people. One person should control the snake's head and ensure the snout is in line with the 0-point when the second person records the SVL measurement at the cloacal opening.***

IMPORTANT TIP:

The most consistent way to measure a snake (to minimize bias between operators) is to ensure the snake's body is fully stretched when the SVL measurement is taken. In the case of live snakes, or large, recently killed snakes with significant musculature (e.g., pythons and boas), this can achieved by gently pulling the snake, releasing slightly, and pulling again until the snake's body is fully straight (no kinks or bends). For larger snakes, more than one person may be required to pull the snake. It may be easier if someone who is reasonably strong pulls the snake. Other methods, such as using string to measure coiled snakes, are typically unreliable, and introduce significant bias into body length comparisons. They should be avoided where possible.

Body mass *(in g or kg)*

- To measure body mass, weigh the snake using bench or hanging scales appropriate for the size of the snake; larger snakes will require larger scales. Record the mass in grams (g).

- If the snake is weighed within a bag, then the weight of each bag should be recorded and subtracted from the weight of the snake. Alternatively, if all snakes are weighed in bags, then the weight of the bag does not need to be subtracted. As long as all snakes weighed as part of the monitoring program are weighed within bags, then this minor bias will not be a problem. The key here is consistency. Subtracting the mass of any receptacle used to weigh snakes will be more important for small snakes than for large snakes, because of the overall mass of the receptacle relative to the snake's body.

Sex ratios

Sex ratios are the ratio of males to females within a population. A sex ratio is calculated by dividing the number of males by the number of females. The resulting figure will be the proportion of males within the population, which can be monitored over time.

Typically, in most natural populations of animals we should expect a 50:50 sex ratio (that is, 50% male and 50% female). However, in some cases the sex ratio in harvest data may be consistently different than 50:50. In some harvests biased sex ratios are due to the differences in vulnerability of males or females to harvest. For example, in many snake species, and reptiles in general, more males are often collected during the mating period because males are more active than females. Harvest monitoring over time can help understand these sorts of differences between males and females, which can be useful for developing management strategies. Continued monitoring can reveal if the sex ratio in the harvest is constant, if it changes during the year, or if the sex ratio in the harvest meets predictions from the management program.

2.3.2 Diet

Monitoring the diet of snakes can reveal important changes in prey items over time, and can provide information on the habitats and regions from which snakes were harvested. For example, we are able to elucidate regional differences in the proportion of reticulated pythons captured in oil palm plantations vs forests based on the proportion of commensal rodents in their gut compared to other (forest restricted) prey types (Shine et al. 1999). Snake diets can be monitored in two main ways:

→ Direct observation of prey items regurgitated by live snakes, or prey items found within the gut of dead snakes.

→ Faecal analysis of samples collected and sent to a laboratory for comparison against a database of known prey types.

In both cases, additional information about the specimen (e.g., body size, sex) should be collected to accompany dietary information.

2.3.3 Reproductive condition

Intense harvesting pressure can result in evolutionary effects that impact the life-history traits of individuals within a population (e.g., declining sizes at sexual maturity; Trippel 1995; Sharpe and Hendry 2009). Examining the reproductive condition of snakes over long time periods can thus reveal important data useful for the assessment of sustainability, as well for natural history studies. This includes:

- Timing of reproduction
- Size specific fecundity
- Sizes at sexual maturity
- Proportion of juveniles vs adults in the harvest

In addition, examining reproductive organs is the simplest way to determine sex (via direct inspection) and can be useful for management (e.g., protecting immature life stages). The anatomy of a snake's reproductive system can appear complicated and daunting. The following section provides photographs of dissected snakes to assist in identifying anatomical structures during examination, especially females. Additional photographs are provided in Appendix IV.

When examining the reproductive system, aim to identify the:

Female	Male
☐ *Oviduct*	☐ *Vas deferens*
☐ *Primary follicles*	☐ *Testes*
☐ *Secondary follicles*	
☐ *Corpora luteum*	
☐ *Corpora albicans*	
☐ *Eggs/embryos*	
☐ *Oviducal scars*	

IMPORTANT:

In females, not all structures will be present at the same time.

Female ovulation

Ovaries are generally covered with primary follicles. As the breeding season approaches, primary follicles begin to mature into secondary follicles. This process is termed vitellogenesis, and results in the follicles turning from brittle and white, to soft, vascularized and yellow, (due to yolking). Following follicular maturation, the infundibulum surrounds the ovary and the secondary follicles rupture to release their ova. The ova make their way into the oviducts. This is the process of ovulation.

In oviparous (egg-laying) species, the albumen, shell membranes, and shell, are formed in the oviducts prior to laying. In viviparous (live-bearing) species, the foetuses are retained in the oviduct for the duration of gravidity. After ovulation, the ruptured secondary follicles reduce in size and become corpus luteum. When corpus luteum completely regress they become little red/black specks or scars on the surface of the ovary. These scars of the corpus luteum are called corpus albicantia.

In some species (e.g., *Python reticulatus*), the oviduct also reduces in size and can become clear when the female is no longer reproductive. However, unlike immature non-virgin females, those that have reproduced previously will retain corpora albicans (regressed scars) on the ovary. In other species (particularly those that breed annually, as well as viviparous species) the oviduct remains thick and muscular for the duration of the snake's life.

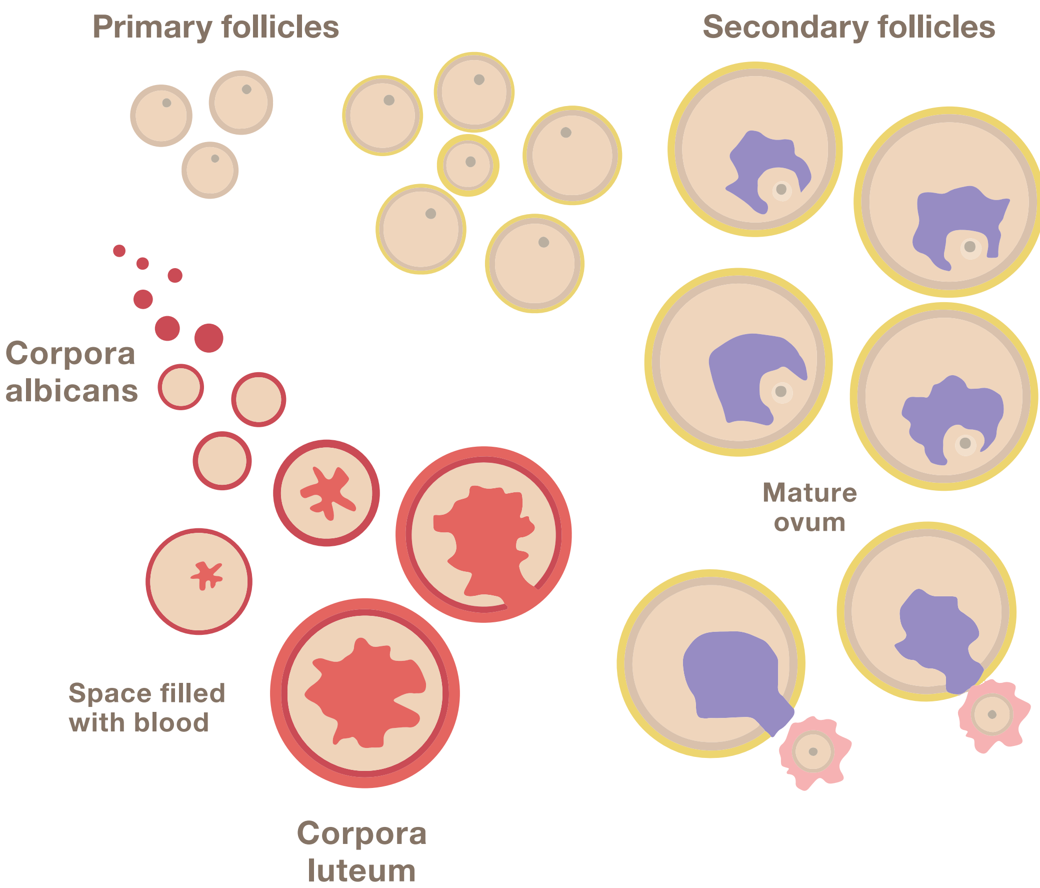


Fig. 9. *Basic stages of female ovulation.*

Guide to identify anatomical structures of the reproductive system

Photos by Daniel Natusch

Male reproductive anatomy

The images below depict the vas deferens and testes of male snakes. Examination of these organs, and their sizes, can reveal information on a specimen's sex, maturity, and stage of reproduction.

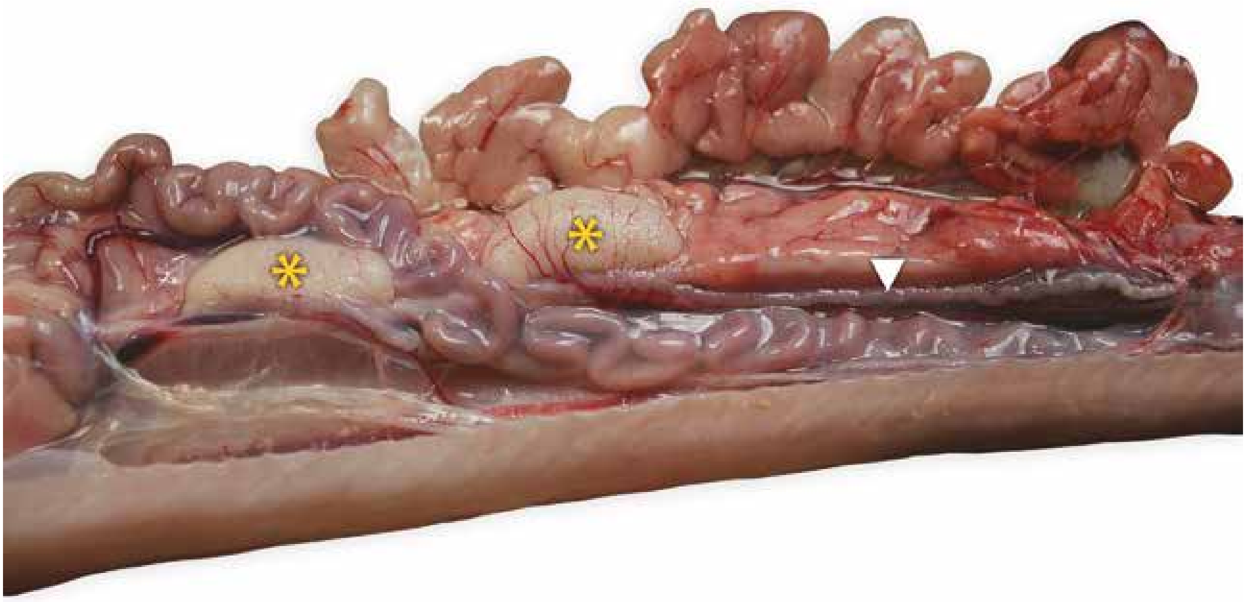


Fig. 10. *Mature, turgid testes (asterisks) and convoluted vas deferens (white triangle) in a masked water snake (**Homalopsis buccata**).*

Fig. 11. *A mature male short-tailed python (**Python breitensteini**). Vas deferens is convoluted (white triangle). Testes can clearly be seen (asterisks).*

▶ *cont.*

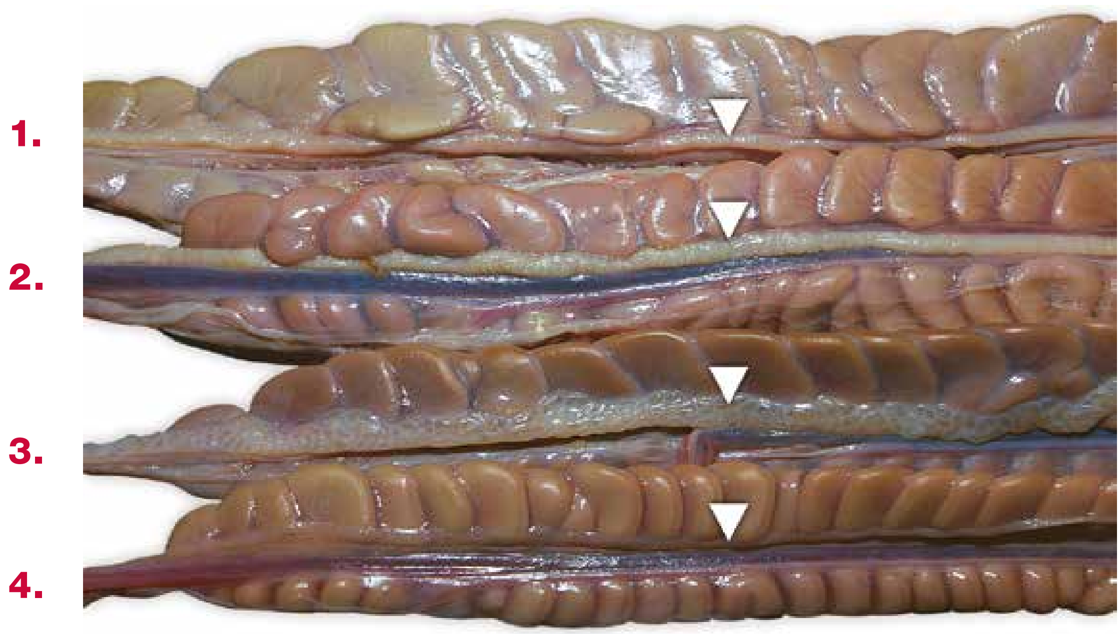


Fig. 12. *Convoluted (top, 1-3) and non-convoluted (bottom, 4) vas deferens (white triangles) in reticulated pythons (Python reticulatus).*

Fig. 13 *Hemipenes of Python reticulatus (left) and Acrochordus javanicus (right). Males have two penises that if seen, can be used to determine sex. The hemipenes varies in shape, structure and colour depending on the species.*

Guide to identify anatomical structures of the reproductive system

Photos by Daniel Natusch

Female reproductive anatomy

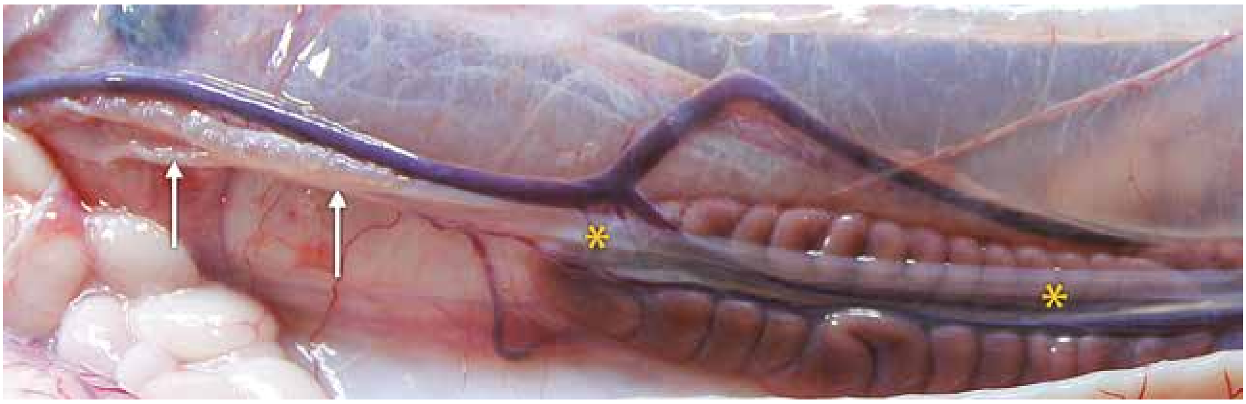


Fig. 14. *An immature, virgin female reticulated python (**Python reticulatus**). Oviduct is clear (asterisks). Note the kidney can be seen through the oviduct. Primary follicles are present (arrows). Corpora albicans are absent.*

IMPORTANT | The oviduct is classified as thick if the kidney cannot be seen through the oviduct.

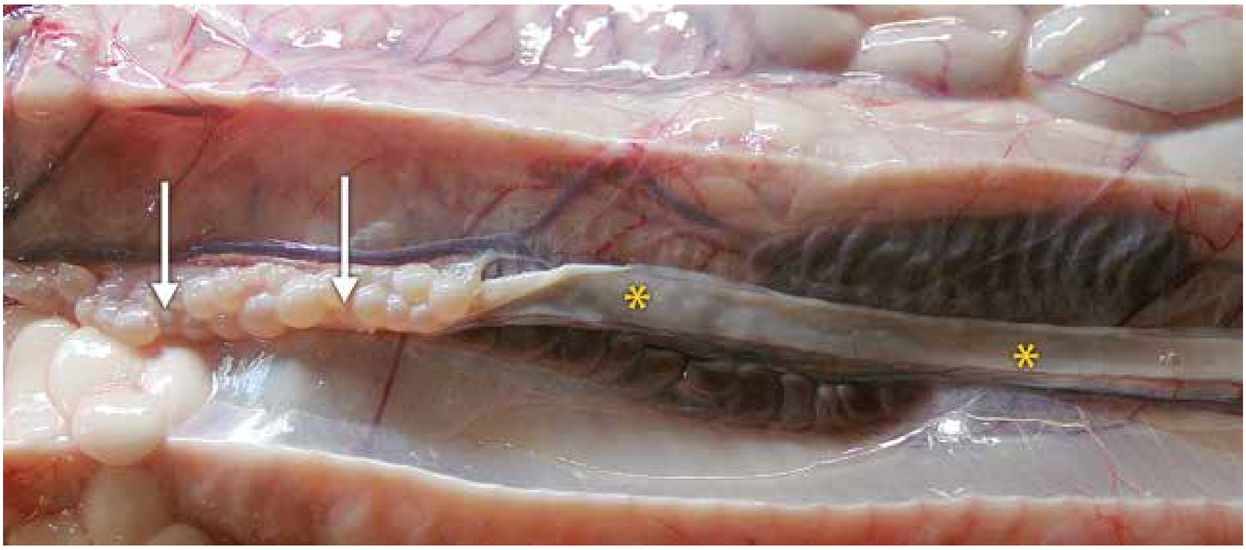


Fig. 15 *A mature, virgin female reticulated python. Oviduct is in the process of thickening (asterisks). Note the kidney cannot be seen through the oviduct. Primary follicles are present, and are relatively large (arrows). Corpora albicans are absent.*

▶ *cont.*

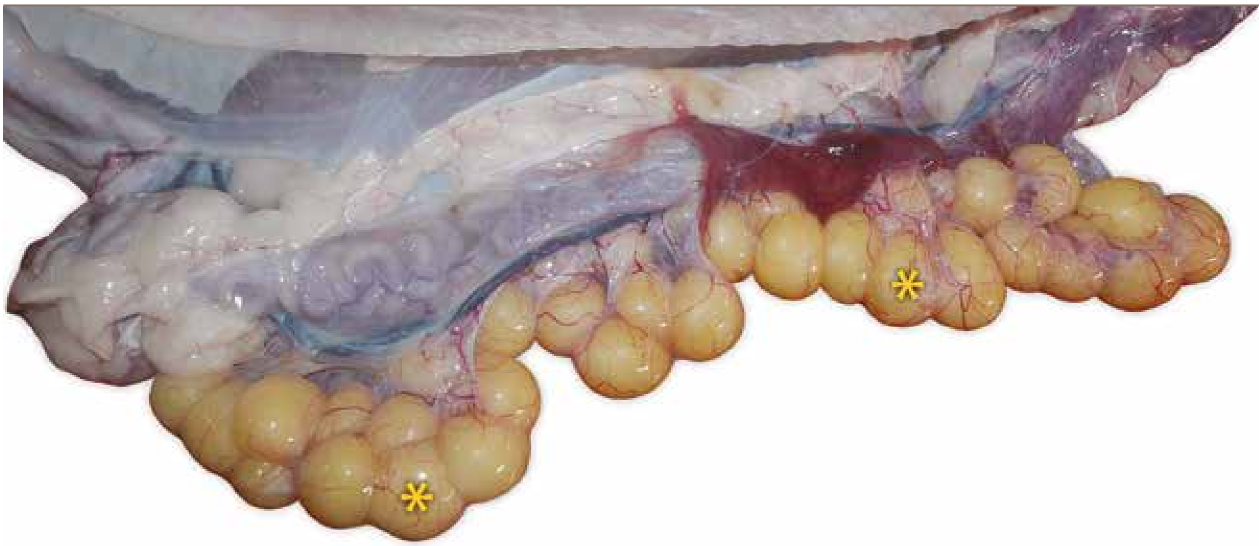


Fig. 16. *Secondary follicles in the ovary of the viviparous water snake* ***Homalopsis buccata*** *(asterisks). These follicles are very close to ovulation (bursting, with the ova migrating into the oviduct).*

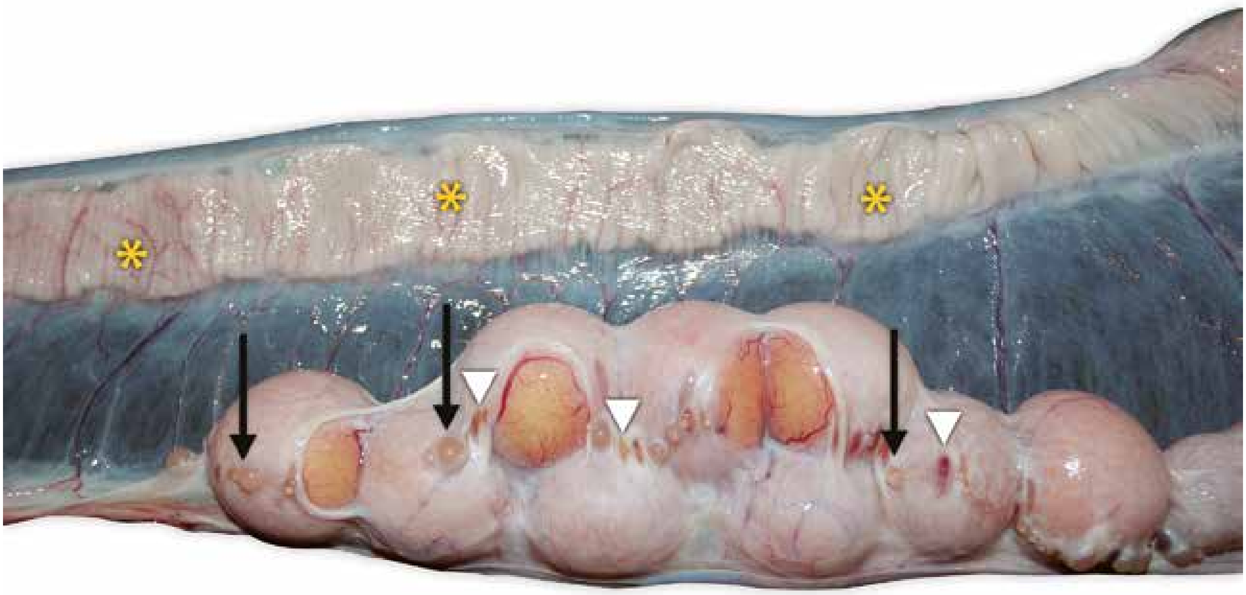


Fig. 17. *A mature, non-virgin female reticulated python (****Python reticulatus****). The oviduct has thickened ready for ovulation (asterisks). Primary follicles are present (arrows). Large yellow secondary follicles are present. Corpora albicans from previous reproductive events are also present (white triangles).*

Guide to identify anatomical structures of the reproductive system

Photos by Daniel Natusch

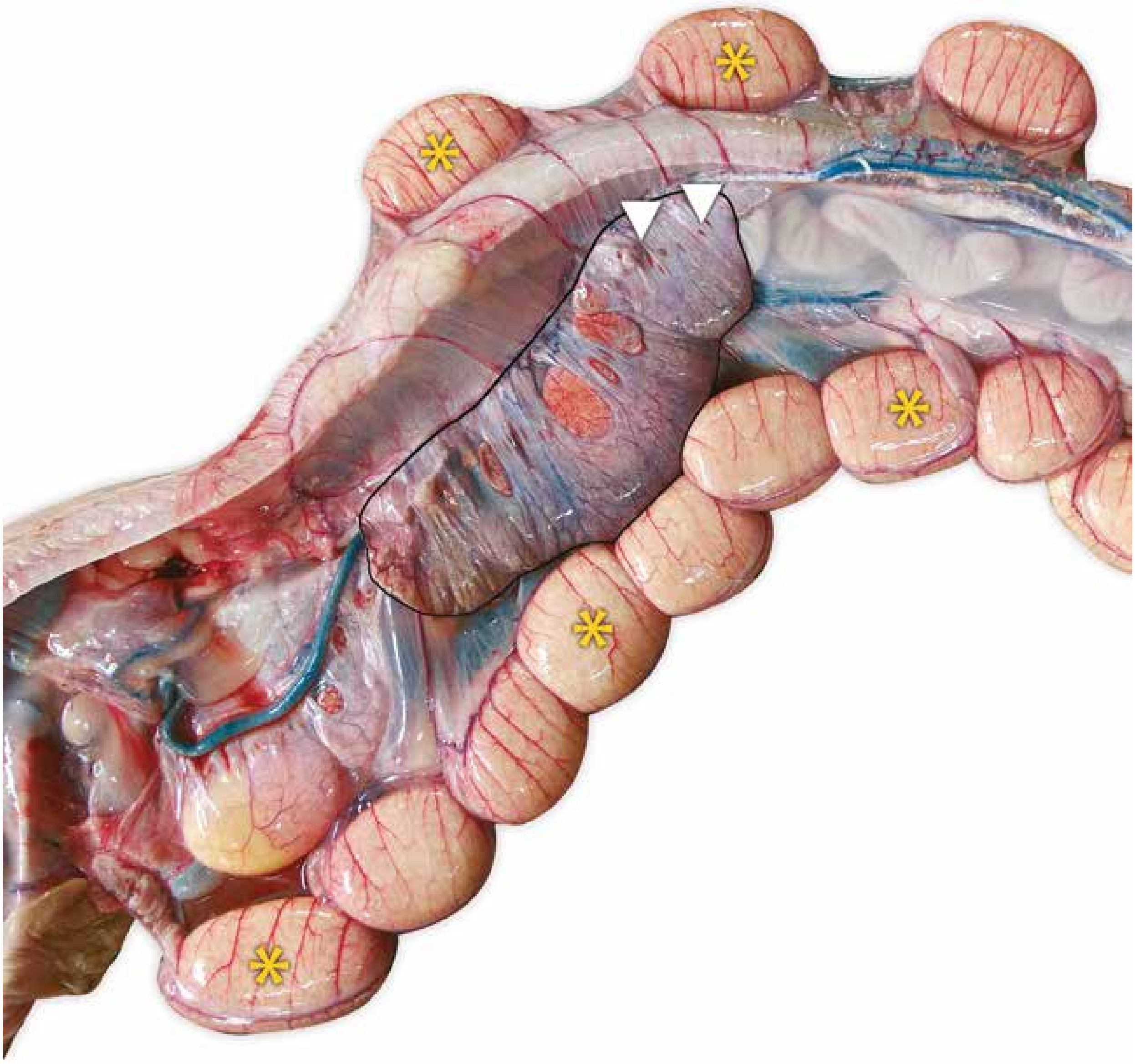


Fig. 18. *A mature, non-virgin female reticulated python (**Python reticulatus**). Oviduct is thick and contains eggs (asterisks). Corpora albicans are present (white triangles). One very large yellow secondary follicle is present indicating she is in the final stage of ovulation. Corpora luteum are present (enclosed black area).*

▸ *cont.*

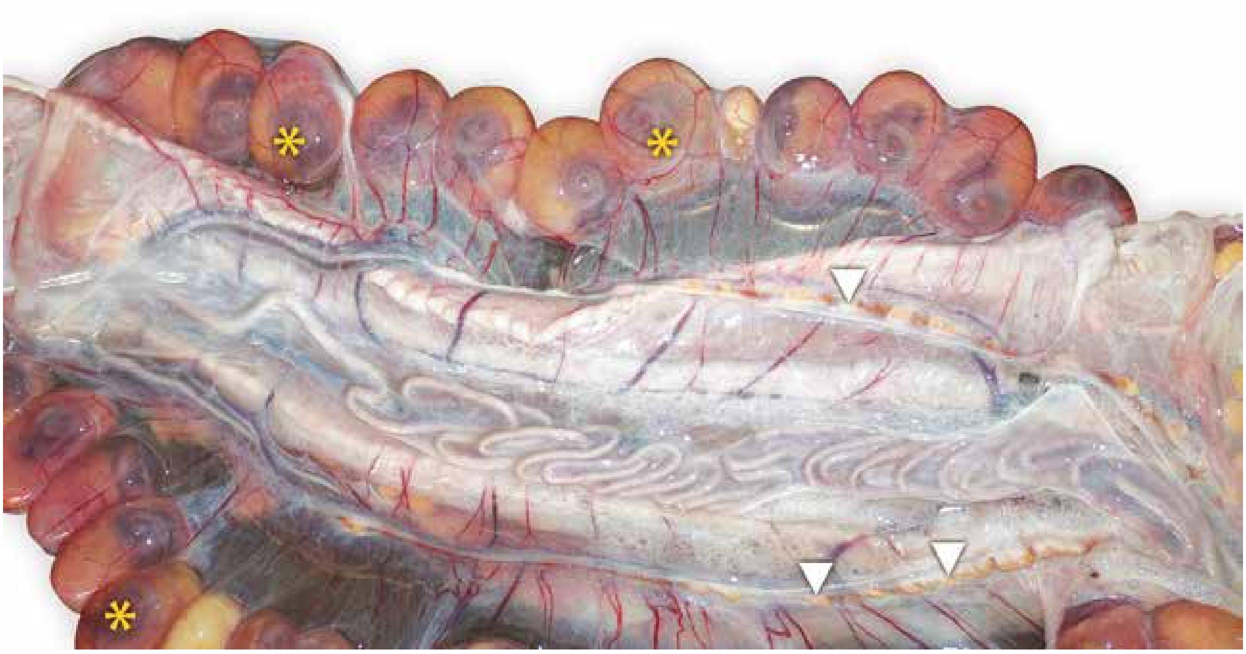


Fig. 19. *Developing embryos in the oviduct of the viviparous acrochordid snake, Acrochordus javanicus (asterisks). Regressed corpora lutea can be seen in the ovary of the snake (white triangles).*

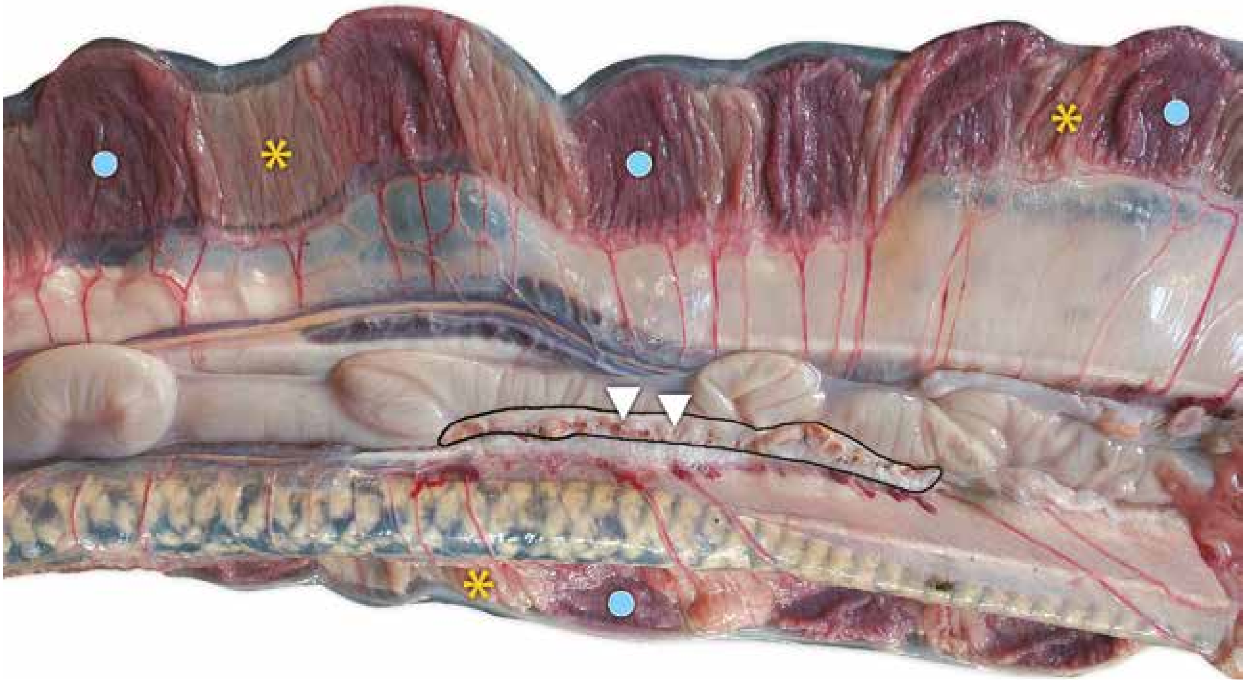


Fig. 20. *A mature, non-virgin female reticulated python (Python reticulatus). Oviduct is thick (asterisks) and oviducal scars are visible (circles) indicating she has recently laid eggs. Regressed corpora luteum (enclosed black area) and corpora albicans are present (white triangles) in the ovary.*

Guide to identify anatomical structures of the reproductive system

Photos by Daniel Natusch

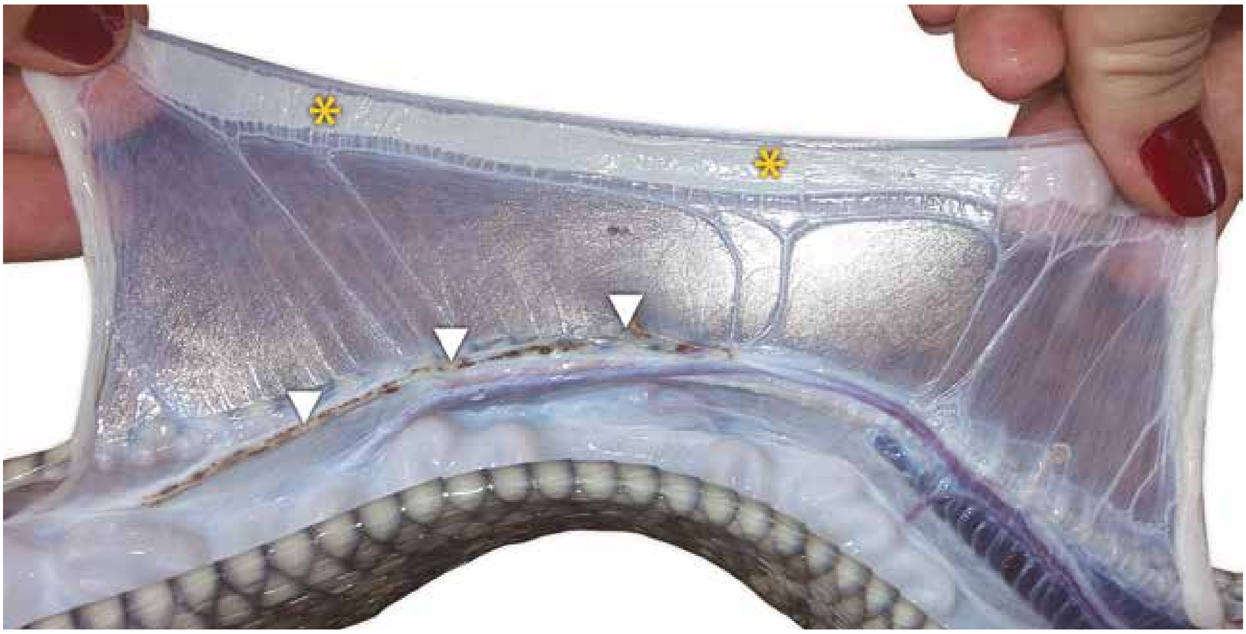


Fig. 21. *A thickened oviduct (asterisks) and corpora albicans (white triangles) in the regressed ovary of an oviparous scrub python (**Simalia amethistina**).*

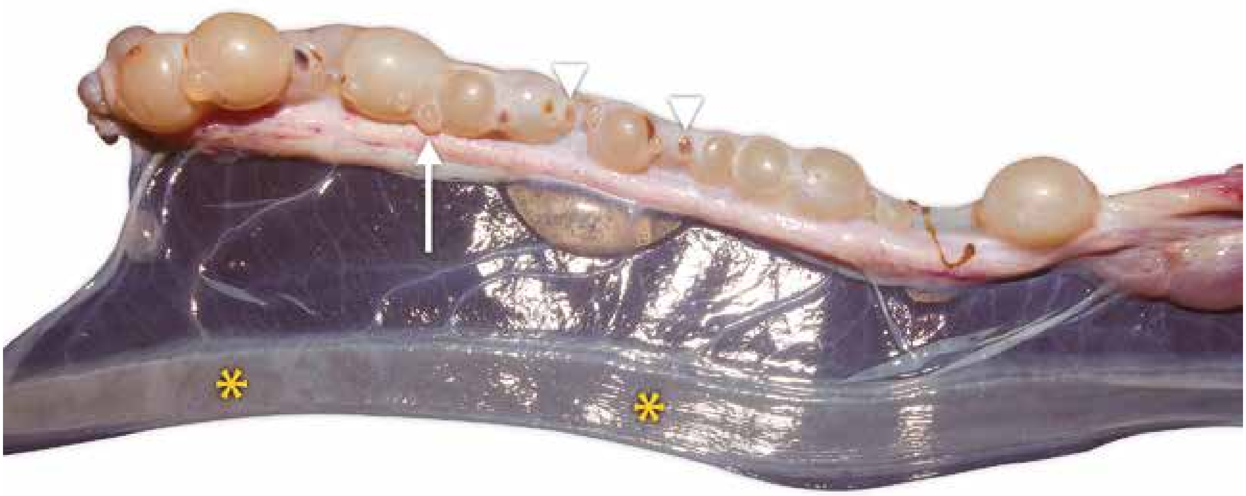


Fig. 22. *A clear oviduct (asterisks) of a non-virgin short tailed python (**Python brongersmai**). Primary follicles are present (arrow). Corpora albicans on the ovary indicate a previous reproductive event (white triangles).*

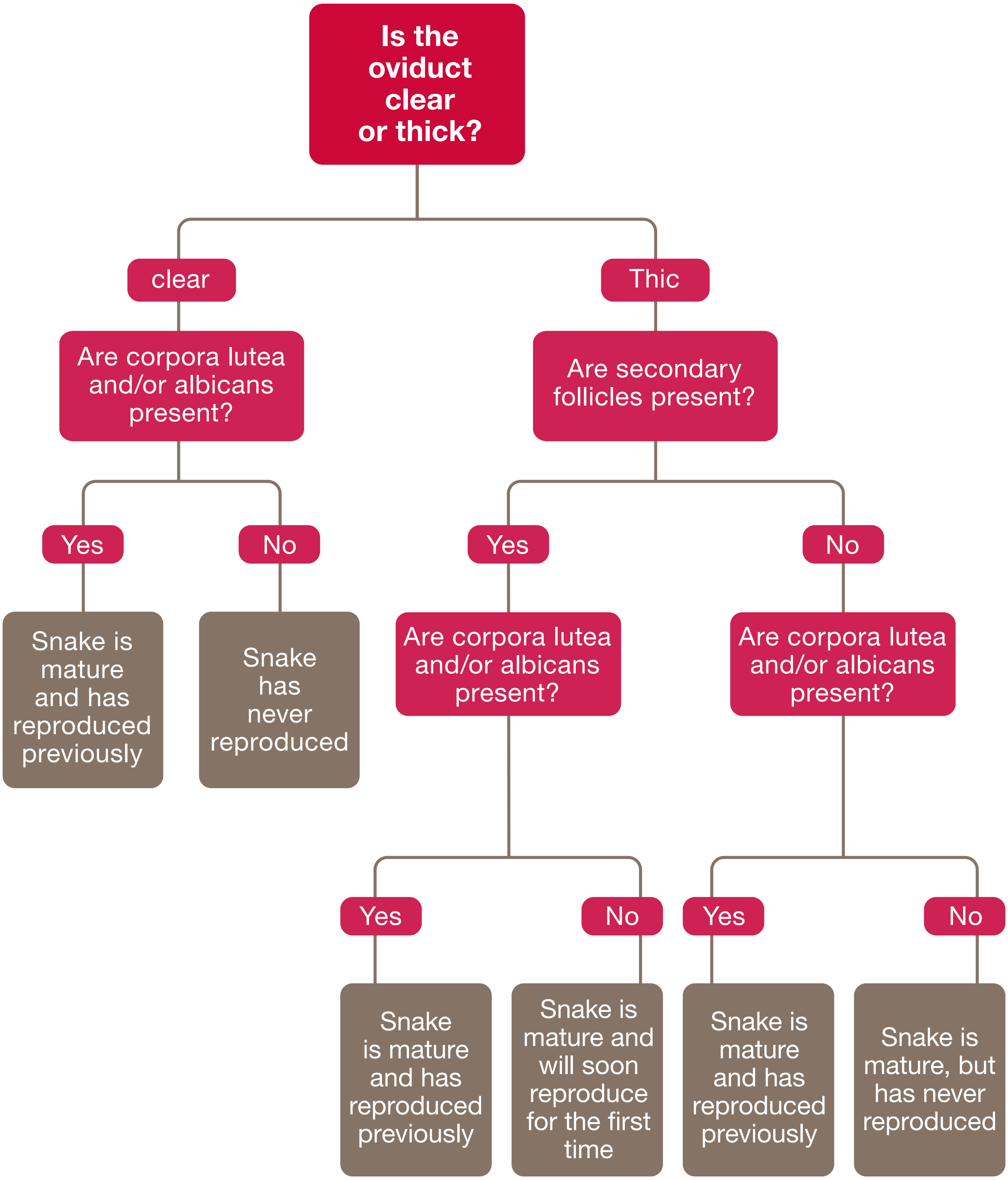


Fig. 23. *A flow-diagram showing the process for determining reproductive stage and condition of female snakes.*

2.3.4 Preparation and storage of reference samples and specimens

As seen above, a tremendous investment in time and effort is needed to properly carry out rigorous natural history studies of snakes that have been collected for harvest. Moreover, the availability to obtain large samples of snakes is a rare opportunity. If whole specimens, or reproductive tracts, stomach contents, tissue samples, and other types of samples are saved during the course of natural history data collection, more studies can be conducted in the future using the same material. The preservation of samples also allows studies to be revisited and replicated – an important part of the scientific method. Therefore, it is strongly recommended that specimens be collected, prepared, and accessioned into natural history museums or other repositories. In this section we briefly outline how to prepare and store reference samples and specimens obtained from the harvest.

Items needed for specimen storage:

- Rubber gloves, safety glasses;
- Large syringes (e.g., 60 cc) and hypodermic needles (18 gauge needles work well and tend not to clog as much as finer gauge needles);
- Large forceps or tongs;
- Gauze, linen, or other cotton cloth for wrapping specimens;
- Labels and pens: It is absolutely critical that the thread, labels, and ink used in making specimens are adequate for long-term storage in liquids. If labels detach from specimens, the paper disintegrates, or labels fade, all of the work collecting the data is at risk and likely to be lost and irretrievable.
    - Label paper should be at least 50% rag content, 100% rag content preferred. Rag paper should be available at good stationary shops.
        - High quality paper for labels is paramount. Common-use paper will disintegrate over time in storage. It is mandatory that paper with high rag content be used for making specimen tags and labels.
    - Waterproof pens
        - It is important to use high quality pens with indelible ink. Cheap ballpoint pens and felt-tip markers do not work for specimen labeling because the ink will not last in preservative. Perform tests with any pens that are going to be used for making specimen labels by making a label, let the ink dry, and placing it in alcohol solution. Rub the writing with your fingers and confirm there is no smudging or bleeding of the ink. If there is, discard the pen and try a different brand.
- 100% cotton string, or thick carpet thread;
- 20L buckets with sealing lids or equivalent containers;
- 10% formalin solution:
    - Formalin is a fixative that binds proteins and effectively pickles the tissues being preserved. It is important to use a fixative such as formalin to ensure the specimens will last. Specimens properly fixed in 10% formalin can last centuries in properly curated collections. Alcohol is an inferior fixative, and does not substitute for formalin. If formalin is not available, preserving the specimen in alcohol is better than nothing.
    - Mixing formalin: Specimens are fixed in 10% formalin solution. In specimen preparation we start with a concentrated formalin solution ("pure formalin"). To make the 10%

formalin solution that is needed for specimen preparation, mix 1 part concentrated formalin with 9 parts water. For the purposes of specimen preparation described here, it is okay to use any source of clean water.

    - Formalin versus formaldehyde: Understanding the differences between formaldehyde and formalin solution can be a bit confusing. However, it is important to keep the differences clear to be sure the formalin solution for fixing specimens is correct. Formalin is formaldehyde gas in solution. One hundred per cent formalin is a saturated solution of formaldehyde. Forty per cent formaldehyde solution is 100% concentrated formalin! In other words, the concentration of formaldehyde in solution is 40%, but this solution is fully concentrated formalin. When mixing formalin, always mix 10% a formalin solution (1 part concentrated formalin: 9 parts water).
- Tissue vials of various sizes with leak-proof lids and able to be frozen
- 95% Ethanol (ETOH)
    - Ethanol is used for storing tissue samples for genetic analyses and other purposes.
    - Any samples that should be prepared in ethanol should not come into contact with formalin at any time; formalin damages DNA.

Storage of reproductive tracts, viscera, gut contents, or other animal parts.

- To properly fix and store entire animal parts, such as reproductive tracts, wrap the parts in a gauze package with the label inside the package. Tie the cloth with a string securely so the package does not open during transport.
- Place the packages in a bucket with 10% formalin solution. There should be at least 3 cm of liquid above the level of the gauze packages.
- Only use buckets or other containers with sealing lids that will not leak when tipped over.
- Transfer of these materials into 70% ethanol for long-term preservation in a natural history collection can take place in the laboratory of the receiving institution. It is fine if the materials remain in 10% formalin for up to several months if they are kept in a dark, relatively cool place.
- Specimen samples can be stored individually or together, depending on the purpose of collection.

Preparing whole specimens

- Whole specimens must be injected with 10% formalin then completely submerged in a container of 10% formalin. If snake specimens are not injected from head to tip of tail, the entire specimen or parts of it will rot, even if submerged in formalin. Formalin does not penetrate reptile skin well, so it is necessary to inject the specimens and fill them with formalin.
- Using a large syringe and needle, inject copious amounts of formalin into the specimen's body cavity every few centimeters. This can become tedious on a long snake, but it is necessary to properly fix the internal organs and keep them from decomposing.

- **Preparation of hemipenes of male snakes:**

    - Approximately halfway down the length of the tail on one side, make a small incision with scissors.
    - Using small forceps, locate the strap-like muscle that retracts the hemipenes and cut it.
    - Wearing gloves and safety glasses, hold the tail with forceps and with the other hand inject the tail every 1-3 centimetres. The tail is dense, so not much formalin may go in. Nonetheless these perforations are necessary to keep the tail from rotting.
    - As the tail fills with formalin, the hemipenes of male snakes will become everted. Try to keep one side from everting by applying pressure with thumb and fingers on that side of the cloaca, while allowing the other side to fully evert. The hemipenes should evert fully if the retractor muscle was cut as explained above.
    - Use cotton thread to tie off the base of the everted hemipene.

- **Positioning the specimen:**

    - Proper positioning is important because properly positioned specimens are easy to use and take up less storage space than specimens that are allowed to become fixed in a chaotic position. Poorly positioned specimens are difficult to examine, dissect, and measure.
    - Whole specimens of snakes can be positioned coiled in a round container, like a plastic jar, or drum.
    - Multiple specimens can be stacked in the same container.
    - Once positioned, the container should be flooded with 10% formalin to a level that keeps all specimens covered.

- **Storage of specimens:**

    - If large numbers of specimens are to be collected as part of a monitoring system, sufficient physical storage space is required.
    - Managers should have access to this storage space before specimen collection commences. A guarantee that this space is capable of housing the specimens over extended periods (many years) is required, depending on the purpose of the collection.
    - Museum or university specimen repositories are useful places to store specimens collected as part of monitoring activities.

2.4 The data collection procedure – a walkthrough

This section of the guidance offers a step-by-step guide to undertaking surveys and collecting data from snakes brought to centralised locations for trade. Here, we provide a walkthrough data collection from snakes that are taken to processing facilities to be killed for trade. Note that only part of this data collection procedure will be possible if data are taken from facilities where only live animals or skins can be observed (e.g., holding facilities, tanneries).

At least two persons should conduct surveys; one person to examine the snakes and the other to record information. A template Survey Datasheet has been included in these guidelines to assist with record collection (see **Appendix II**).

IMPORTANT: Be aware that surveys will be carried out during normal working hours at the facility. Processing staff may or may not assist with the surveys, but investigators should be conscious of working around processing staff without disrupting their normal activities. The procedure to follow when completing the Survey Datasheet is described below. Required equipment is underlined at each step.

Data collection from snakes is divided broadly into three steps. These are as follows:

Step 1: Preparing for data collection:

- Ensure all equipment is ready to begin data collection. This may involve ensuring batteries are in cameras and digital calipers, there are sufficient numbers of data collection forms, and there are sufficient identification tags available for the number of snakes from which data will be collected that day.
- Record the date, processing facility being surveyed, and the data collector, at the top of the <u>Survey Datasheet.</u>
- Wear <u>closed shoes</u> and <u>disposable gloves</u> before conducting examinations of snakes.

Step 2: Initial data collection from intact snakes:

At this point, processing facility staff will humanely kill the snake.

- Attach an identification tag to the snake (usually using a rubber band around the snake's neck). Explain to the processing facility staff that the tag MUST stay on the carcass at all times (it may need to be removed and replaced on the carcass so it is identifiable).
- Weigh the snake using bench or hanging scales appropriate for size of the snake. For example, larger snakes will require larger scales. Record the mass in grams (g). ▸

▸ cont.

**Note:* In some cases, it may be simpler to weigh the snake while it is still alive (e.g., if snakes are kept securely in bags prior to killing). In this case, measurement of mass can be performed immediately before the snake is killed.*

- Once the snake has been killed, measure the snout-to-vent length (SVL) using a steel tape measure (8 m or less depending on size of snake). See section 3.0 in Chapter II for a detailed explanation of how to properly and consistently measure a snake.

Step 3: Examining the snake's carcass

At this point, processing staff will usually remove the skin (depending on the purpose; some snakes traded for food and traditional medicine are sold with skins intact). It is critical to ensure the tag accompanying the snake is attached to the snake's carcass after the skin is removed. Accidental switching of tags between snakes should be avoided at all costs. If switching does occur, and cannot be easily rectified, then data from those snakes should not be recorded. Steps should be taken to ensure this does not happen again.

- Move the snake's carcass to a bench workspace or table for examination.
- Turn the snake's carcass belly side up and part the fat and tissue of the lower half of the body with fingers (approximately 30% of SVL anterior from the cloacal opening).
- Locate the kidney. If female (♀), the oviduct is adhered to the surface of the kidney and the ovaries are located directly anterior to the kidneys. If male (♂), the vas deferens is adhered to the surface of the kidney, and the testes are located immediately anterior to the kidney.
- If male (♂), examine the vas deferens and determine if they are convoluted or not. Also record testes length and width (at the widest point). Record in the data sheet.

Fig. 24. *Convoluted vas deferensin a reticulated python (Python reticulatus); the testes are large and turgid.*

▸

▶ *cont.*

- If female (♀), examine the oviduct and determine if it is clear or thick. Measure the oviduct width using calipers and record in millimetres (mm). Record if oviducal scars are present and the number (if possible). Record if eggs are present and the number. *Note: remember that snakes have two ovaries and two oviducts on each side of the body. Examining the number of egg scars in a single oviduct will therefore underestimate the total clutch size.*

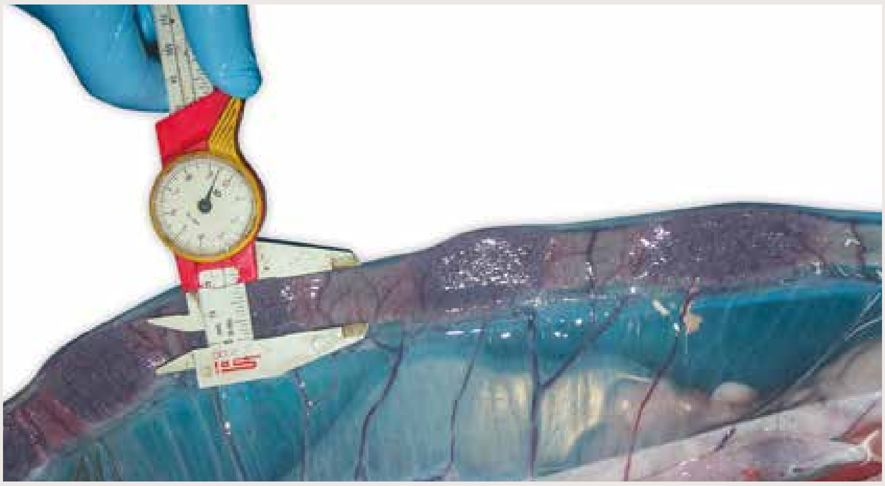


Fig. 25. *Measuring the oviduct width with calipers. The oviduct is thick and oviducal scars are present.*

- If female (♀), examine the ovaries and locate the primary follicle(s). If present, measure the size of the largest primary follicle using calipers and record in millimetres (mm). Locate secondary follicle(s). If present, record their presence in the data collection sheet.

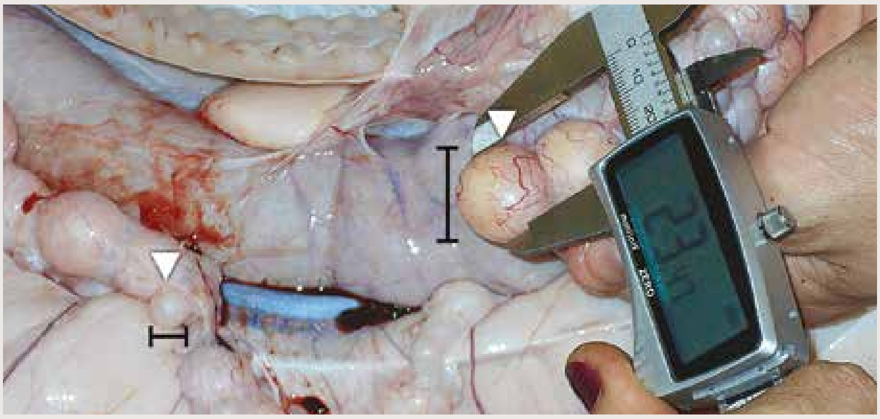


Fig. 26. *White arrows show the measurement of length in the largest primary (left) and secondary (right) follicles in a reticulated python (Python reticulatus).*

- If female (♀), examine the ovaries and record if corpora lutea and/or corpora albicans are present.

- Ensure all data rows in the record sheet are completed.

- Examination of the snake is finished. The next snake can now be examined.

2.5 Self-collection of data by traders

Data useful for harvest monitoring can be gathered directly by the industry itself. Such datasets are invariably large, and can provide information on the impacts of harvesting at larger spatial scales than targeted monitoring at a smaller number of facilities. Traders can also collect data unavailable to independent monitors, such as how hunter catches (to estimate CPUE) vary over time when monitors are not present. Traders can also keep records of capture locations that aid in understanding habitat and site-specific harvest intensity. In reality, national-level monitoring systems all depend in some part on cooperation among hunters, buyers, traders, and exporters. The CITES system of permits and certificates for wildlife trade transactions is one example of how data are provided by exporters and importers, archived into the World Conservation Monitoring Centre, and made available to anyone who wishes to examine the data and conduct analyses. As mentioned above, although the hunting and trade of live rattlesnakes at the rattlesnake roundup in Sweetwater, Texas, USA is rightly controversial, it is a case where the organizers of the event measure samples of snakes and provide the data and the harvest total to the Texas Parks and Wildlife Department. Biologists are aware of what is going on and advise the organizers on data collection, and if desired can conduct inspections. This works because the event organizers are eager to participate and provide data.

Another classic example is the data provided by commercial fishing vessels, who routinely have an accredited inspector on board to verify adherence to catch quotas and minimum fish sizes. Therefore, where possible, governments and managers tasked with monitoring harvests and ensuring sustainability should make it compulsory for traders to collect and accumulate such data. In reality, this will take relatively little effort, because most snakes are measured or weighed when they are sold to determine purchase price. Recording basic snake morphometric data (length, mass), along with basic details about the hunter and the snake's capture location, yields massive amounts of data useful for monitoring purposes.

Community-based conservation efforts are another way that hunters and managers at the local level can become deeply involved in harvest monitoring (Fitzgerald 2012). In community-based programs, members of communities work together to establish quotas and harvest regulations, and keep track of the number of animals hunted and hunter effort (Cuéllar et al. 2010). Hunters in community-based programs can provide important traditional ecological knowledge about the natural history of species, and collect specimens for examination. A number of community-based programs also have been developed where community members conduct population surveys in the field using a variety of methods ranging from transect counts to radio-tracking studies (Noss et al. 2004, Painter et al. 2003).

2.5.1 Establishment of industry monitoring programs and data to be gathered

In many situations where snakes are harvested, we anticipate monitoring programs would begin and run for a relatively long time without reliance on traders collecting important data. However, established programs may eventually include participation from traders in the data collection process. Scientists who are managing the monitoring system would engage in training of personnel, and include procedures for inspection and validation of data provided. The industry trading partners would need to be voluntary and willing participants, and protocols must be in place to ensure any data collected are verifiable. Nevertheless, it is important that data collection by traders does not substitute independent monitoring undertaken by regulators or scientists. Industry-led monitoring should ideally complement independent monitoring, such that it helps to verify (and possibly strengthen) independent findings.

In programs that are running smoothly and are easily verified by managers, commercial traders can provide the following types of basic data:

- Total number of snakes purchased per time interval
- Catch-per-unit-effort based on hunter records kept by traders
- Locations and habitats in which snakes are captured
- Body sizes (SVL, mass) of live snakes sold to traders
- Lengths and widths of skins

Tables 4 and 5 offer a data collection template that traders can use to collect important data for monitoring purposes. Table 4 includes data obtainable from processing facilities/traders purchasing snakes directly from hunters. Number of snakes captured, capture locations and habitats, catch per unit effort, and body size trends can be determined from this simple trader monitoring form. Table 5 includes information that can be gathered from traders or tanneries further up the supply chain. Numbers of snakes harvested and trends in body size can be determined using these data, which can also be used to cross-reference against data collected at other points within the supply chain. These sheets can also be provided to agents and middlemen, so that data can be collected if hunters are not selling directly to processing facilities.

Table 4: Example data collection sheet for snake processing facilities purchasing snakes directly from hunters.

Date	Hunter name and address	Snake species	Capture location	Habitat of capture	Snake SVL (cm)	Snake Mass (g)
15/02/2019	John Citizen, OK Village, Australia	Cobra	Astra Oil Palm Estate	Oil palm	112	350
15/02/2019	John Citizen, OK Village, Australia	Cobra	OK Village	Secondary forest	150	1750
15/02/2019	John Citizen, OK Village, Australia	Cobra	Astra Oil Palm Estate	Oil palm	200	2500
16/02/2019	Jane Doe, Greentown, Australia	Python	Red Swamp	Secondary forest	132	2400
16/02/2019	Jane Doe, Greentown, Australia	Python	Red Swamp	Oil palm	134	2350

Table 5: Example data collection sheet for a trader or tannery selling snake skins.

Date	Species	Transaction	Skin length (cm)	Skin width (cm)
15/02/2019	Water snake	Sale	112	14
15/02/2019	Water snake	Sale	100	12
15/02/2019	Water snake	Sale	110	13
16/02/2019	Water snake	Sale	120	15
16/02/2019	Water snake	Sale	105	13


Photo by Tomas Waller

Photo by Alfonso Castro on Unsplash

3

Standardized protocols for data analysis and interpretation

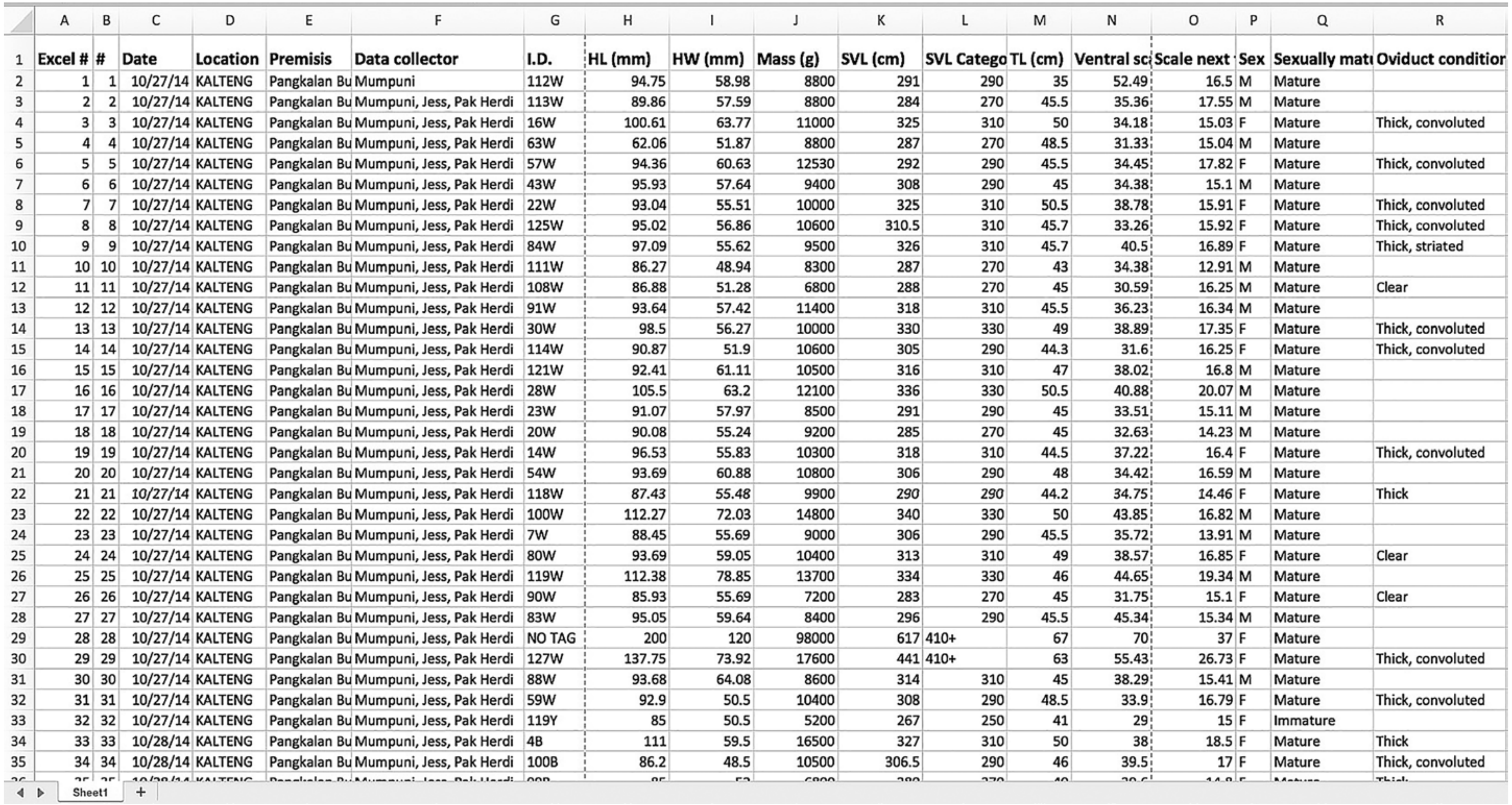
3.1 Basic analyses and data presentation

3.1.1 Excel spreadsheet analyses

Computerized spreadsheets, such as Microsoft Excel™, are powerful tools for collecting, managing, and analyzing data from harvest monitoring systems. The basic use of spreadsheets is widely known, so here we will focus on specific uses of Excel for the purposes of keeping monitoring data organized and conducting basic analyses.

Basic data organization

- Excel files are called **Workbooks**. A workbook can have many independent Worksheets that are identified by tabs.
- Each row in the spreadsheet should correspond to one unit that is being measured. In most cases, each row corresponds to a specimen or skin.
- Each column corresponds to one variable being noted or measured for each specimen. There can be as many columns for variables as needed.
  - The variables to be included should be identified during the planning stage of the harvest monitoring system.
    - As a reminder, it is important to have very detailed and specific protocols in place before the initiation of data collection!
- In most cases, the columns will list:
  - Species
  - Date
  - Location where data are collected
  - Origin of specimens (if known)
  - Sex
  - Size measurements in separate columns (snout-vent length, skin width, skin length, mass, etc)
  - Note that during a single measurement session, the species date and location will be repeated for each specimen. This redundancy is fine, and actually becomes important for data analysis and archiving long-term data.
- Each sampling occasion should maintain the exact same arrangement of columns. This will greatly facilitate summarizing and analyzing data as they accumulate over time.



	Excel #	#	Date	Location	Premisis	Data collector	I.D.	HL (mm)	HW (mm)	Mass (g)	SVL (cm)	SVL Catego	TL (cm)	Ventral sc	Scale next	Sex	Sexually mat	Oviduct conditior
2	1	1	10/27/14	KALTENG	Pangkalan Bu	Mumpuni	112W	94.75	58.98	8800	291	290	35	52.49	16.5	M	Mature	
3	2	2	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	113W	89.86	57.59	8800	284	270	45.5	35.36	17.55	M	Mature	
4	3	3	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	16W	100.61	63.77	11000	325	310	50	34.18	15.03	F	Mature	Thick, convoluted
5	4	4	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	63W	62.06	51.87	8800	287	270	48.5	31.33	15.04	M	Mature	
6	5	5	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	57W	94.36	60.63	12530	292	290	45.5	34.45	17.82	F	Mature	Thick, convoluted
7	6	6	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	43W	95.93	57.64	9400	308	290	45	34.38	15.1	M	Mature	
8	7	7	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	22W	93.04	55.51	10000	325	310	50.5	38.78	15.91	F	Mature	Thick, convoluted
9	8	8	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	125W	95.02	56.86	10600	310.5	310	45.7	33.26	15.92	F	Mature	Thick, convoluted
10	9	9	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	84W	97.09	55.62	9500	326	310	45.7	40.5	16.89	F	Mature	Thick, striated
11	10	10	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	111W	86.27	48.94	8300	287	270	43	34.38	12.91	M	Mature	
12	11	11	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	108W	86.88	51.28	6800	288	270	45	30.59	16.25	M	Mature	Clear
13	12	12	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	91W	93.64	57.42	11400	318	310	45.5	36.23	16.34	M	Mature	
14	13	13	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	30W	98.5	56.27	10000	330	330	49	38.89	17.35	F	Mature	Thick, convoluted
15	14	14	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	114W	90.87	51.9	10600	305	290	44.3	31.6	16.25	F	Mature	Thick, convoluted
16	15	15	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	121W	92.41	61.11	10500	316	310	47	38.02	16.8	M	Mature	
17	16	16	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	28W	105.5	63.2	12100	336	330	50.5	40.88	20.07	M	Mature	
18	17	17	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	23W	91.07	57.97	8500	291	290	45	33.51	15.11	M	Mature	
19	18	18	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	20W	90.08	55.24	9200	285	270	45	32.63	14.23	M	Mature	
20	19	19	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	14W	96.53	55.83	10300	318	310	44.5	37.22	16.4	F	Mature	Thick, convoluted
21	20	20	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	54W	93.69	60.88	10800	306	290	48	34.42	16.59	M	Mature	
22	21	21	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	118W	87.43	55.48	9900	290	290	44.2	34.75	14.46	F	Mature	Thick
23	22	22	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	100W	112.27	72.03	14800	340	330	50	43.85	16.82	M	Mature	
24	23	23	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	7W	88.45	55.69	9000	306	290	45.5	35.72	13.91	M	Mature	
25	24	24	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	80W	93.69	59.05	10400	313	310	49	38.57	16.85	F	Mature	Clear
26	25	25	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	119W	112.38	78.85	13700	334	330	46	44.65	19.34	M	Mature	
27	26	26	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	90W	85.93	55.69	7200	283	270	45	31.75	15.1	F	Mature	Clear
28	27	27	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	83W	95.05	59.64	8400	296	290	45.5	45.34	15.34	M	Mature	
29	28	28	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	NO TAG	200	120	98000	617	410+	67	70	37	F	Mature	
30	29	29	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	127W	137.75	73.92	17600	441	410+	63	55.43	26.73	F	Mature	Thick, convoluted
31	30	30	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	88W	93.68	64.08	8600	314	310	45	38.29	15.41	M	Mature	
32	31	31	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	59W	92.9	50.5	10400	308	290	48.5	33.9	16.79	F	Mature	Thick, convoluted
33	32	32	10/27/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	119Y	85	50.5	5200	267	250	41	29	15	F	Immature	
34	33	33	10/28/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	4B	111	59.5	16500	327	310	50	38	18.5	F	Mature	Thick
35	34	34	10/28/14	KALTENG	Pangkalan Bu	Mumpuni, Jess, Pak Herdi	100B	86.2	48.5	10500	306.5	290	46	39.5	17	F	Mature	Thick, convoluted

Sheet1

Fig. 27. *This example worksheet in Excel shows a typical layout for measurements of reticulated pythons (**Python reticulatus**) that are hunted and brought to processing facilities for meat and skins.*

Entering raw data directly into a spreadsheet when monitoring

When working in teams for harvest monitoring, it can be practical to measure specimens and enter data directly into the spreadsheet. However, there are some simple best practices that greatly reduce errors during data entry. We recommend following this procedure to ensure efficient data collection directly into an Excel spreadsheet:

- Prepare a table and chair where the laptop can be used in the area where samples are being measured. A proper setting for data collection reduces errors in large data sets.

- One person calls out each datum in a clear voice, one variable at a time, always in the same sequence. For example:
  a. Data collector calls out the data: "ID# A307"; "Mass 862.5"; "SVL 388"; "Tail 67".
  b. Data entry person: The person entering data repeats the measurement back to the data collector as s/he is entering it into the keyboard. Reading the data back is important.
    i. This way, the data entry person keeps up with the data collection and if a number is mixed up, the data collector can correct it.
    ii. With a brief amount of practice and consistency, data collection can proceed very quickly and efficiently.

Saving original data sheets and saving spreadsheets as Master Files

Our worst nightmare is losing data. Data are expensive to obtain in every way - from the time and money invested to collect the data, to the integrity of the monitoring program, to the loss of life of an animal that was killed for harvest. Therefore, we need to institute policies to protect original data gathered as part of harvest monitoring programs.

- Hard copy datasheets need to be organized into high quality notebooks and archived. Refer to Data Archiving in Chapter I, Section 5.0, of this document.

- During data collection, it is critical to save electronic data often onto the computer's internal drive and also to at least one external drive.
  a. The original spreadsheet should be saved independently for each session, and NEVER altered. A copy of the file will be renamed for data analysis.
    i. Use logical filenames to identify the monitoring session and that this is the master spreadsheet.
    ii. e.g., filename: [date]_[place]_MASTER.xlsx
    (18March2019_Sweetwater_MASTER.xlsx)
    iii. Archive MASTER files in multiple, separate, locations.

- Create a duplicate file, renamed for ANALYSIS.
  a. This file will be proofed, corrected, and then used for analyses.
  b. Below we will discuss adding worksheet tabs in the ANALYSIS files.

Entering raw data into a spreadsheet from printed data forms

- When entering data into spreadsheets from data forms, it is most convenient if data forms were designed with rows and columns like the spreadsheet. This will make data entry easier and minimize errors.
  - When making data collection forms made up of rows and columns, make them large enough so the data collectors can write legibly.
  - It seems remedial, but we have actually examined data collectors' handwriting and even given instructions on how letters and numbers need to be written on data forms.
    - Many errors occur during data entry when letters and numbers are not legible. These errors are avoidable through use of best practices for data collection, which include instruction on proper writing.

- It is best, and faster, to enter data with two people; one to read the data to the data entry person who enters it into a spreadsheet.
  Follow the protocol above to read the data back-and-forth during data entry.

- If only one person will enter data from hard copies, use a straight edge on each row of the data form to minimize errors.

- ***Scanning data sheets into Excel***- If data collectors are properly trained in how to write letters and numbers in clear and consistent fashion, it is feasible to scan data sheets, which can be converted to spreadsheets with Optical Character Resolution software. However, there will be errors and time will have to be spent carefully proofreading the spreadsheets.

Proofing Excel spreadsheets for errors through sorting and graphing.

It is important to check electronic data for errors before analysis. It is common for errors to occur during entry that involve transposition of numbers or entering decimal points in the wrong place. There are several handy ways to quickly identify likely errors:

- Identifying outliers by using ratios or differences among variables.

- ***Add a column and compute the ratio of SVL to mass and SVL to tail length***

- The ratios between snout-vent length and tail length and mass are reliably consistent. By computing these ratios in a column on the spreadsheet for ANALYSIS, then sorting the data, one can quickly find the data entries that do not make sense.
- In the worksheet, Insert Column, then compute ratios by dividing SVL by mass, or tail length, or another variable of interest.
  - To calculate ratio in Excel type: =[cell]/[cell] then copy and paste down the column.

- Sort the **entire** worksheet based on the ratio (e.g., SVL/tail)

- Identify outliers in the dataset. Outliers will have values for ratios that do not make sense. This is almost always because one of the values was entered in error. The mistake can be corrected in the ANALYIS file, or the erroneous entry can be deleted.

3.1.2 Producing descriptive statistics, graphs and tables

Graphs and tables form much of the basis for presenting monitoring results. Tables can be easily made in Excel and imported into word processing documents.

Descriptive statistics can easily be calculated from spreadsheets in Excel. If all spreadsheets are constructed the same way, compiling the statistics can be replicated for each sampling period very quickly. These statistics are typically the most useful:

- Count (the sample size, or N, in the sample)
- Mean (the average of the sample)
- Standard deviation (a measure of dispersion around the mean)
- Minimum
- Maximum
- Range (difference between maximum and minimum value)
- Number of males (=COUNTIF (cell:cell, “m”)
- Number of females (=COUNTIF (cell:cell, “f”)

Many add-in packages are available that will calculate descriptive statistics and conduct statistical analyses. Add rows and calculate the above statistics in dedicated rows either above or below the sample data as shown below in Figure 28.

D2 =AVERAGE(D10:D333)

	A	B	C	D	E	F	G	H	I
1	Sample Size (n)	298		SVL (mm)	Tail (mm)	Total (mm)	Mass (g)	Formula	
2	MEAN			1,050.03	85.89	1,135.92	957.78	=AVERAGE(range)	
3	Standard Deviation			222.93	26.40	245.73	650.47	=STDEV(range)	
4	Minimum			508.00	32.00	542.00	62.00	=MIN(range)	
5	Maximum			1,632.00	149.00	1,753.00	3,084.00	=MAX(range)	
6	number of males		213					=COUNTIF(C10:C307, "m")	
7	number of females		85					=COUNTIF(C10:C307, "f")	
8									
9	No.	SP	Sx	SVL (mm)	Tail (mm)	Total (mm)	Mass (g)	Comments	Locality
10	1	ca	m	1122	96	1218	1037	viscera # 99-1	SE NM
11	2	ca	m	1182	135	1317	1629	viscera # 99-2	SE NM
12	3	ca	m	955	86	1041	702	viscera # 99-3	SE NM
13	4	ca	f	942	79	1021	613	viscera # 99-4	SE NM
14	5	ca	m	1236	124	1360	1387	viscera # 99-5; small fresh wound, dorsal, ca. 10 cm posterior of head	SE NM
15	6	ca	m	1180	111	1291	1258	viscera # 99-6	SE NM
16	7	ca	m	1150	106	1256	1165	viscera # 99-7	SE NM
17	8	ca	m	1112	96	1208	1073	viscera # 99-8	SE NM
18	9	ca	f	1075	68	1143	865	viscera # 99-9; fresh wound left lateral ca. 20 cm behind head	SE NM
19	10	ca	m	1305	121	1426	1801	batch in generally poor condition	Deming
20	11	ca	f	822	51	873	376	batch in generally poor condition; skinny	Deming
21	12	ca	m	758	52	810	219	batch in generally poor condition; skinny	Deming
22	13	ca	f	750	46	796	227	batch in generally poor condition; rib damage mid-body	Deming
23	14	cv	m	910	82	992	474	batch in generally poor condition	Deming
24	15	cv	m	538	62	600	93	batch in generally poor condition	Deming
25	16	ca	f	790	56	846	370	batch in generally poor condition	Deming
26	17	ca	m	770	68	838	286	batch in generally poor condition	Deming
27	18	ca	f	910	53	963	476	batch in generally poor condition; emaciated	Deming
28	19	ca	m	945	69	1014	360	batch in generally poor condition	Deming
29	20	ca	m	980	82	1062	648	batch in generally poor condition	Deming
30	21	ca	m	1120	120	1240	1173	batch in generally poor condition	Deming
31	22	ca	f	650	49	699	188	batch in generally poor condition	Deming

Fig. 28. *An example of using Excel spreadsheets to show summary statistics for variables of interest. If all spreadsheets are set up the same way, the formulas will automatically calculate these statistics as data are collected.*

Trend charts

The most common use of monitoring data is to create figures that reveal trends over time. Line charts and scatter plots are thus the most common figures in an investigator's tool kit. Time (or monitoring occasion) is typically represented on the x-axis, while the variable of interest (typically the mean of numerous data records from a single variable) is represented on the y-axis. Each value on the y-axis must correspond to a time on the x-axis. In Excel, the time data and variable of interest should be recorded in two separate columns. A figure can be created using the following procedure:

1. Highlight both columns together
2. Click on "charts" in the toolbar (see Fig. 29)
3. Select "Scatter" from the chart menu

The resulting chart depicts a time-series, and addition of a regression line (by right-clicking on a data-point and selecting "***add trend line***"; Fig. 29) reveals the prevailing trend.

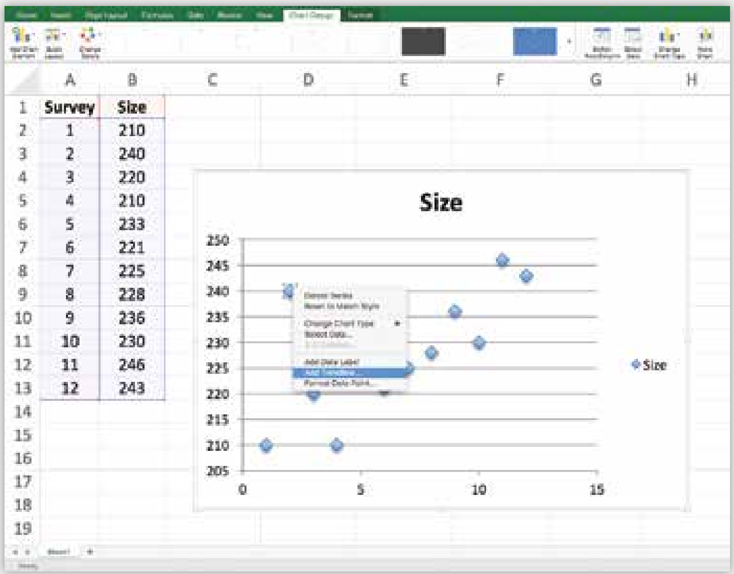


Fig. 29. *Screen shot of Microsoft Excel™ worksheet showing highlighted columns of interest and a scatter plot created using the "scatter" tool in the Charts menu. A trend line can be added by right clicking on a data point in the resulting scatter plot and clicking "Add Trendline".*

3.1.3 Determining if a trend is meaningful

When data are collated and analyzed, managers may observe a trend over time in the variable of interest. But how do we know whether an observed trend is statistically meaningful? For example, if data points fluctuate strongly between monitoring occasions, then it may not be possible to conclude with certainty that the trend is due to a decrease or increase in the variable of interest or whether it is simply due to natural stochasticity in the data. In those cases, an observed trend may not be considered statistically meaningful. To illustrate this, Figure 30a depicts a highly variable dataset with a steep trend suggesting a decrease in the variable of interest. Figure 30b shows a dataset with low variability, with what appears to be a weak trend suggesting a decrease in the variable of interest. Contrary to intuition, the trend in Figure 30a is not statistically meaningful, while the trend in Figure 30b is statistically meaningful.

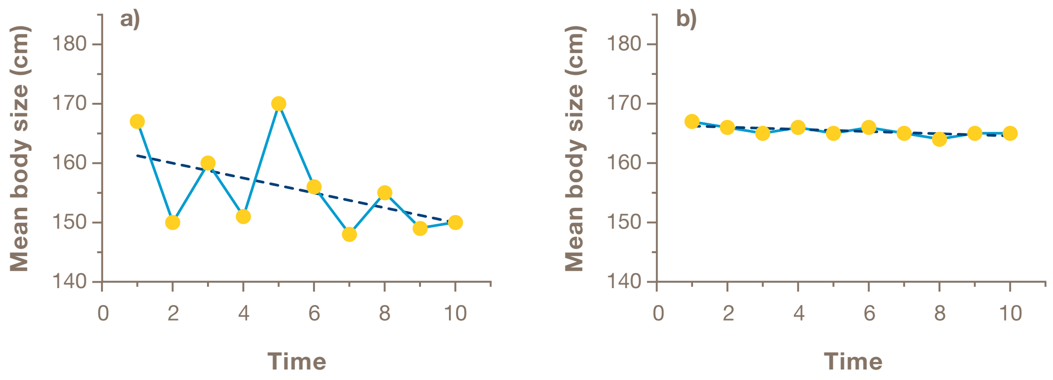


Fig. 30. *Time-series of snake mean body size showing a trend that is (a) not statistically meaningful and a trend that (b) is statistically meaningful.*

To determine whether a trend is statistically meaningful, investigators can calculate an indicator of statistical meaningfulness. A score based on the r^2 value and statistical significance of the trend (the p-value) is calculated. The r^2 value is commonly known as the coefficient of determination and may be used for measuring the correlation between two variables. An r^2 value at or near 0 means low correlation between variable x and variable y, and a value near 1 indicates a high correlation. The p-value is used for describing the probability (from 0 to 1) in statistical significance tests in which a null hypothesis is rejected when the p-value is low.

Bryhn and Dinberg (2011) provide a simple, Microsoft Excel based, tool for testing the statistical meaningfulness of a trend. This tool can be downloaded from here:

https://doi.org/10.1371/journal.pone.0019241.s001

Guidelines on how to setup the tool and input data are provided here:

https://doi.org/10.1371/journal.pone.0019241.s002

3.2 Data interpretation

3.2.1 How to interpret data to infer sustainability

Once the data collected from an ongoing monitoring program have been compiled and statistically analysed, they should be correctly interpreted to help inform management. Interpreting trend data is relatively straightforward; in most cases it can be done visually. A regression, or line of best fit, can be assigned to the data to assist visual interpretation. Managers are primarily interested in whether the trend in a variable of interest is increasing, decreasing, or remaining stable over time. Figure 31 offers examples of the types of trends monitoring data may reveal. Below we offer interpretation of these trends.

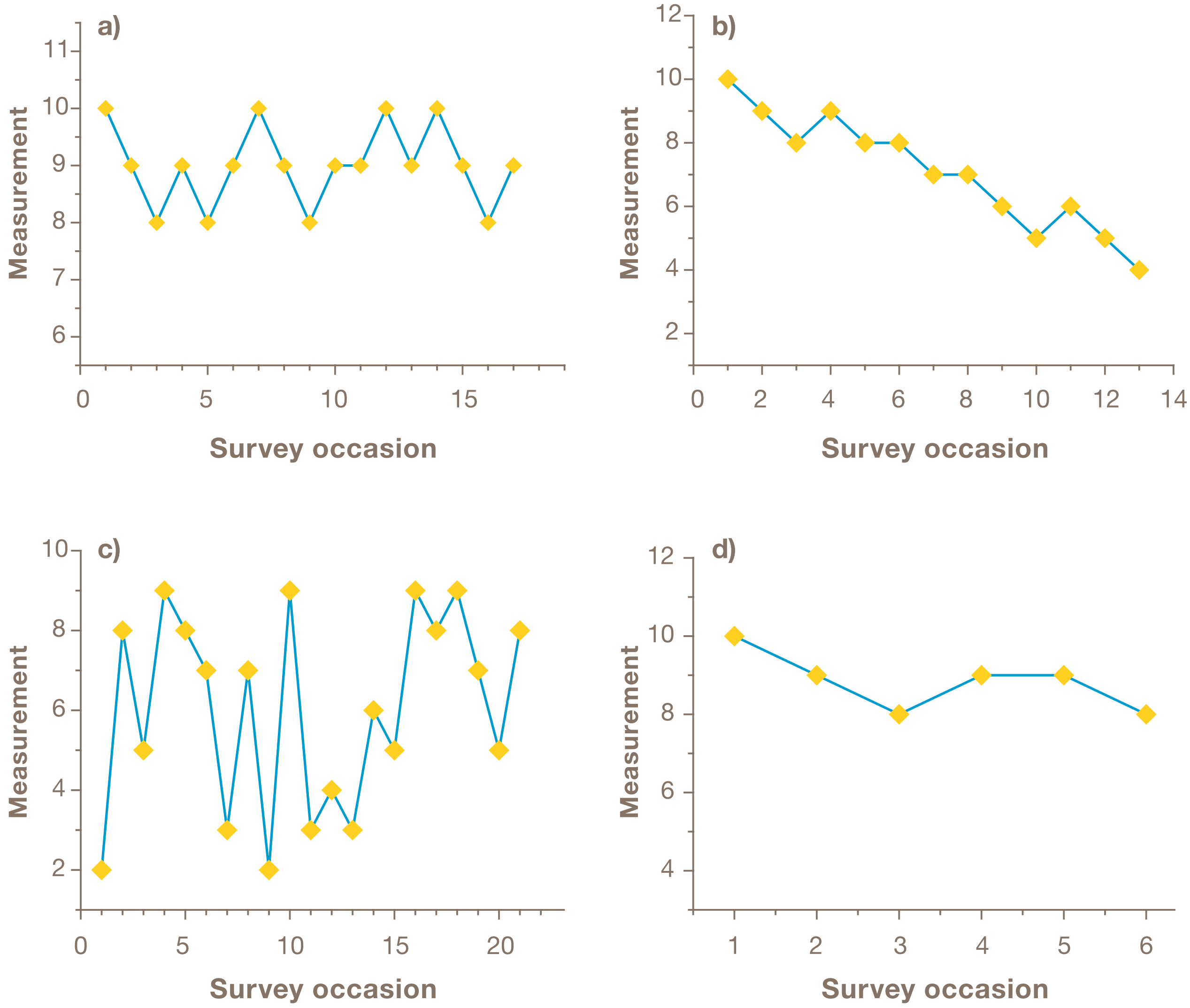


Fig. 31. *Examples of trends in attributes of snakes collected using harvest monitoring data. Interpretations provided below.*

a) Figure 31a depicts a stable trend. Fluctuations in the variable of interest should be expected in any natural wildlife population under harvest. Regular monitoring should continue. No management interventions are required at this time.

b) Figure 31b depicts a declining trend. Many years of monitoring data have been gathered, and the downward trend is robust, which may indicate that the population is suffering from the effects of overharvesting. The cause of this trend should be investigated, and a management intervention should be implemented to reverse the trend.

c) Figure 31c depicts a stable but highly fluctuating trend. The trend does not suggest the harvest is unsustainable. However, it is important that research is undertaken to understand why the harvest exhibits such fluctuations. Managers may or may not wish to implement a management intervention.

d) Figure 31d depicts a small dataset with a slightly declining trend. The trend is not alarming at this stage; so further monitoring should be undertaken before conclusions are drawn. Managers may wish to take a precautionary approach for the time being by implementing a management intervention.

3.2.2 Does a declining trend indicate an unsustainable harvest?

Dramatic patterns such as the decline shown in Figure 31b (above) may be relatively easy to explain. Either demand for snakes plummeted or the pattern reveals something wrong may be happening in the population. However, many patterns are not so dramatic. How would one interpret the slight decline in Figure 31d? If monitoring data reveal a declining trend, it does not automatically follow that a harvest is unsustainable. The market may be in flux and low prices are causing fewer snakes to be harvested. Or naturally occurring "bad years" for snakes in the wild, such as drought or severe weather, may result in snakes moving less and being less available for harvest. These are stochastic events that cannot be predicted, but which can cause harvest levels to fluctuate unpredictably.

In the rare cases where a population has never been subjected to harvest, we may observe the mean body size of specimens to decrease after harvesting commences because fewer individuals are growing to large sizes before they are harvested. In this example, the population abundance and demography has simply reached a new equilibrium, even if the harvest itself is at sustainable levels. The issue concerning wildlife managers is when harvest attributes continue to decline below this point of equilibrium. Determining whether or not a recorded decline is indicative of actual population decline is challenging, because there is no perfect formula or level at which all species' harvests suddenly become "unsustainable" – in many cases, this threshold will change as other variables influencing the population also change. Managers should focus attention on the following attributes of the trend:

- Has the decline begun to plateau?
- How sharp is the decline (how rapid, or how steep)?
- What are the patterns related to hunter effort?
- Is market demand being met, or is the industry constantly harvesting at or above historical levels?
- Have several independent experts been approached who are not invested in this monitoring system that may be able to offer insights?

In situations where a decline has begun to plateau, or where the decline is only moderate (not fast), it may be possible to continue monitoring to collect more data to establish a trend's cause. However, in cases where no plateau has been reached or where the decline is steep, there is greater risk that the harvest is indeed unsustainable. In cases where uncertainty is high, a precautionary approach is warranted. For example, moderate management interventions could be implemented while the harvest continues to be monitored. If further monitoring suggests the harvest was sustainable, then management interventions can be relaxed, or changed altogether. This is the process of adaptive management.

3.2.3 Limitations and biases in data interpretation

Wildlife populations are dynamic by nature, which introduces bias and confounding variables into any biological dataset. Coupled with the human element of harvest and trade, confounding variables can strongly influence the results of monitoring systems. Therefore, it is important that Scientific Authorities and wildlife managers consider how factors independent of harvesting pressure can influence key indices derived from snake monitoring data. For example, a decrease in the number of snakes harvested may be caused by a decline in the market rather than by overexploitation. Alternatively, unsustainable offtake and population declines may be masked by an increase in hunter effort, resulting in constant numbers of snakes entering trade. Understanding these sources of bias is critical for correct interpretation of data; both to prevent inappropriate or unnecessary management interventions, and to prevent unwanted population declines. Managers should endeavor to gain a holistic knowledge of harvest and trade to complement monitoring data. Examples of factors independent of population-level harvesting effects may include:

- A new hunting technique may be implemented that reduces hunter effort while increasing numbers of snakes harvested.
- The trade may switch demand from large adults to small juveniles, resulting in a shift in the harvest size demographic.
- Increased prices for snakes may stimulate more hunting, resulting in stable numbers of snakes being collected despite overall population declines.
- End users may begin to request snake skins above a certain length, resulting in a change of harvest demographic in the exporting country.
- Many snakes are commonly encountered only in the wet season. Monitoring the population or harvest in the dry season may suggest that declines have occurred, when this may not be the case.
- New operators collecting monitoring data may be inadequately trained, resulting in a perceived shift in the attributes (e.g., body size, reproductive condition) of harvested snakes due to observer bias.
- Increased employment opportunities in other industries, or a rise in social or unemployment subsidies, may result in fewer people capturing snakes. The consequence is that fewer snakes will be harvested, which could be erroneously attributed to population declines.
- Recruitment of a new generation of hunters without experience in detecting snakes may result in differences in capture vs. effort data, erroneously suggesting the snake population is decreasing.
- Sudden changes in price structure (like a change in the pricing policy for different snake lengths) may introduce distortions

over the size structure of the harvested snakes.

- Environmental changes (exceptional droughts or floods) in a given year may affect the ability of hunters to reach snakes or even produce temporary reductions in snake populations that may be erroneously interpreted as a population decline due to harvest.

- Changes in fashion may reduce or increase the demand from the fashion or manufacture industry.

- What is going on in the entire region? Land use change in traditional hunting areas, such as forest conversion or urbanization, may have altered the availability of snakes to be harvested or reduced the snake populations due to factors that have nothing to do with the harvest itself.

3.3 Using data to adapt management protocols

3.3.1 Adaptive management principles

How data are interpreted to inform management depends on the management goals of the authorities dealing with the species. For example, some authorities may simply aim to ensure a given level of harvest is sustainable, while others may wish to increase the harvest so it is close to the maximum sustainable yield. Regardless of the overall goal, successful management of wildlife populations must accept the reality that perfect knowledge of all variables impacting populations will never be available (especially for cryptic taxa such as snakes). Thus, effective management requires the flexibility to amend protocols when potentially adverse changes become apparent (Walters and Hilborn 1986). Adaptive management is a common strategy in wildlife harvests, essentially treating management decisions as large-scale experiments. Hence, an optimal management system is achieved via a constant process of experimentation and monitoring that is used to inform modifications fed back into the management system. The ability to adapt management or implement specific management interventions based on the results of monitoring data should be a fundamental part of any harvest management system.

3.3.2 Specific tools for snake harvest management

If the results of a harvest-monitoring program reveal trends that require a management intervention to modify, then a number of tools are available to assist with this task. Here we provide examples of the major management tools that are useful for snakes. Further discussion of the positives and negatives of each management tool is provided in the CITES Non-detriment findings guidance for snakes.

Restricting harvest numbers (quotas)

- Restricting export volumes

- Restricting harvest volumes

- Restricting the numbers of each sex captured

Restricting harvest size

- Restricting harvest to specific life stages (e.g., adults, juveniles)

- Restriction on minimum or maximum sizes of harvested specimens

- Restricting harvest to exclude both the largest and the smallest snakes. In fisheries, this is called a “slot size restriction”.

Restricting harvest seasons

- Only allowing harvest during the dry season, or wet season
- Restricting hunting during a snake species' reproductive season

Restricting harvest effort

- Restricting the number of hunting permits issued
- Restriction of harvesting to certain areas (e.g., land use types; or rotating hunting areas)
- Restriction of hunting to daylight hours, or night time
- Restrictions on the tools that can be used to capture snakes

Trade suspensions

In the event that harvest monitoring reveals rapid unsustainable declines in measures of interest, temporary (or in extreme cases, permanent) trade suspension may be warranted. Temporary trade suspensions can be used to halt unsustainable harvesting while more appropriate management tools are implemented to ensure harvest sustainability.

Wildlife managers and policy makers should be aware that trade suspensions can have unintended consequences such as driving legal trade underground (i.e., making it illegal). This is particularly true in cases where poor people rely on trade to improve their livelihoods (Weber et al. 2015). It is critical, therefore, that the outcomes of trade suspensions are well understood, and that a clear plan of action is in place to ensure trade can be resumed at sustainable levels (Natusch et al. 2016). It is important that stakeholders are engaged and remained informed throughout the trade suspension process. In summary, trade suspensions should always be carefully considered and implemented as a last resort.

Combining management tools

Perhaps the most common (and effective) approach to management is to implement multiple management tools in unison. For example, many countries exporting snakes implement quotas, but also impose size restrictions and/or effort restrictions on the harvest. Introducing multiple management measures allows managers to better manipulate and fine-tune a management approach based on the results of monitoring.

Photo by Mohan Moolepetlu on Unsplash

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Appendices

Appendix I – Summary of key monitoring locations for different trade purposes

Purpose of harvest	Key monitoring locations	Key data collected	Example taxa
Pets	Collectors and/or collection points (e.g., warehouses); exporters	Numbers; collection localities; body sizes, sexes; CPUE	Pythons, boas, colubrids, vipers
Meat	Processing facilities where live snakes are brought to be killed; landing sites for aquatic snakes	Numbers; collection localities; body sizes; sexes; reproductive status; CPUE	Pythons, cobras, rat snakes, water snakes
Medicines	Processing facilities where live snakes are brought to be killed; landing sites for aquatic snakes	Numbers; collection localities; body sizes; sexes; reproductive status; CPUE	Numerous
Skins	Processing facilities where live snakes are brought to be killed; landing sites for aquatic snakes; skin tanneries	Numbers, collection localities; body sizes; sexes; reproductive status; CPUE; numbers and sizes of skins	Pythons, boas, rat snakes, cobras, water snakes
Entertainment	Centralised holding facilities	Numbers; collection localities; body sizes; sexes; reproductive status; CPUE	Rattlesnakes
Traditional/local use	Hunters; villages; bushmeat traders; markets	Numbers; collection localities; body sizes; sexes; reproductive status; CPUE	Various

Photo by Daniel Natusch

Appendix II – Example data collection form

An example form for data collection and recording from snakes brought to processing facilities to be killed for trade.

DATE: PREMESIS: DATA COLLECTOR:

I.D.	Mass (g)	SVL (cm)	Sex - M - F	♀ Oviduct - CLEAR or THICK (striated / convoluted), ♂ Vas deferens convoluted (yes/no)	Oviduct width (mm)	1° follicle (mm)	Corpora lutea and/or albicans?	2° follicles or eggs (mm)	Notes - Locality, diet, tail cut, meat mass, number of 2° follicles or eggs, etc

Appendix III – Samples sizes for desired effect sizes

Sample sizes needed to detect effect sizes with sufficient statistical power. Calculations are based on a minimum statistical power of 0.8, with an alpha value (α - error probability) of 0.05. Figures are based on a one-tailed t-test (a one tailed test was chosen because wildlife managers are typically interested in detecting declines – hence all tests are in one direction; Cohen 1977).

Effect size (%)	Sample size	Effect size (%)	Sample size
2	15458	11.5	469
2.5	9893	12	431
3	6870	12.5	398
3.5	5048	13	368
4	3865	13.5	341
4.5	3054	14	317
5	2475	14.5	296
5.5	2045	15	277
6	1718	15.5	259
6.5	1464	16	243
7	1263	16.5	229
7.5	1100	17	216
8	967	17.5	204
8.5	857	18	193
9	764	18.5	183
9.5	686	19	173
10	619	19.5	164
10.5	562	20	156
11	513		

Appendix IV – Additional photographs of female reproductive condition

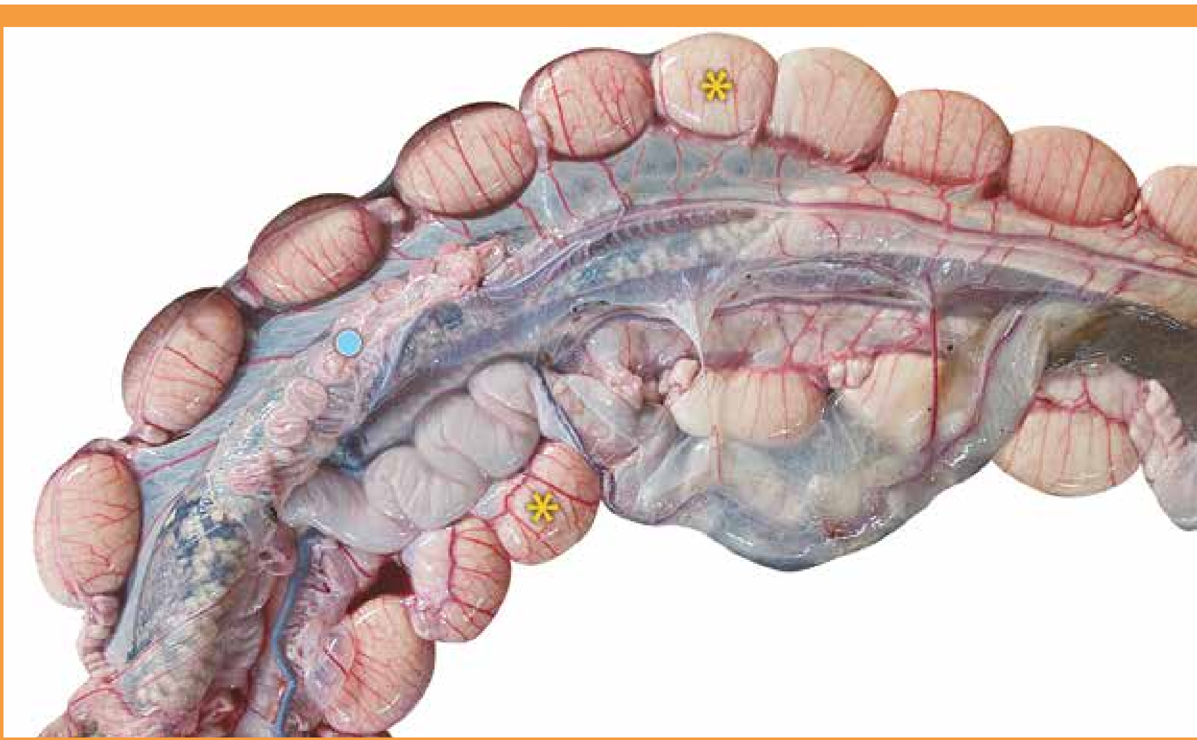
This appendix provides additional photographs of the complicated reproductive anatomy of female snakes, to assist examination and interpretation by data collectors. Features of note include primary and secondary follicle size and colour, thickness of oviducts, and the presence of corpora lutea and/or corpora albicantia.

A1. *Secondary follicles in the ovary (enclosed in black) of a masked water snake (**Homalopsis buccata**). Primary follicles can also be seen (arrow). The oviduct is thick (asterisks) and contains some faint scars (circles). These scars indicate that this individual has reproduced in previous years.*

Photo by Daniel Natusch

A2. *A mature, non-virgin female reticulated python (**Python reticulatus**). Oviduct is thick (asterisks). Very large yellow secondary follicles are present and some have ruptured (yellow yolk can be seen). Corpora albicans are present (white triangle).*

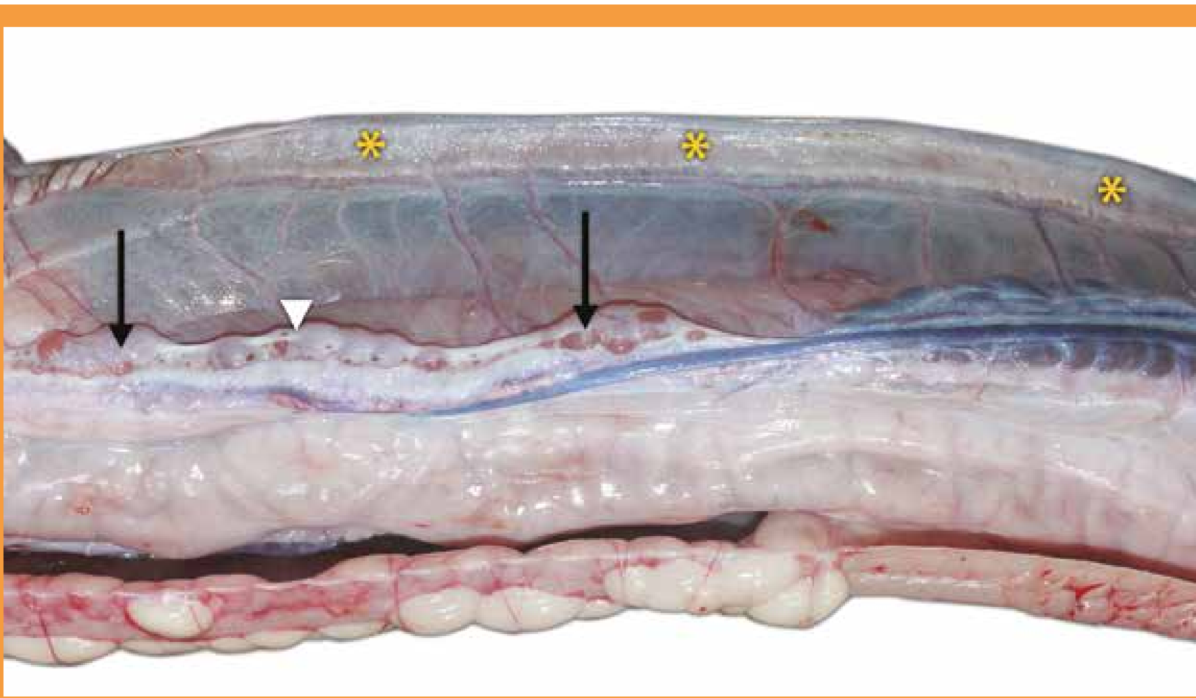
Photo by Daniel Natusch



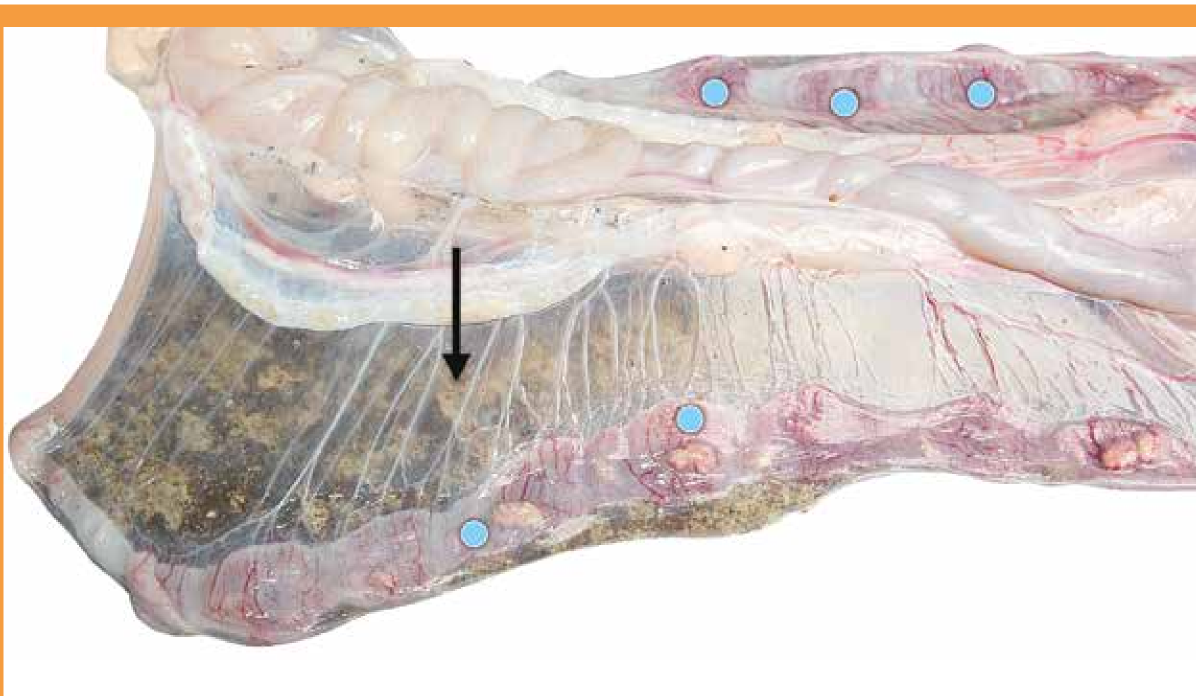
A3. *A mature, non-virgin female reticulated python (**Python reticulatus**). Oviduct is thick and contains eggs (asterisks). Regressed corpus luteum are present (circle).*

A4. *A mature, non-virgin female reticulated python (**P. reticulatus**). Oviduct is thick (asterisks) and oviducal scars are clearly visible (circles) but beginning to fade.*

Photos by Daniel Natusch

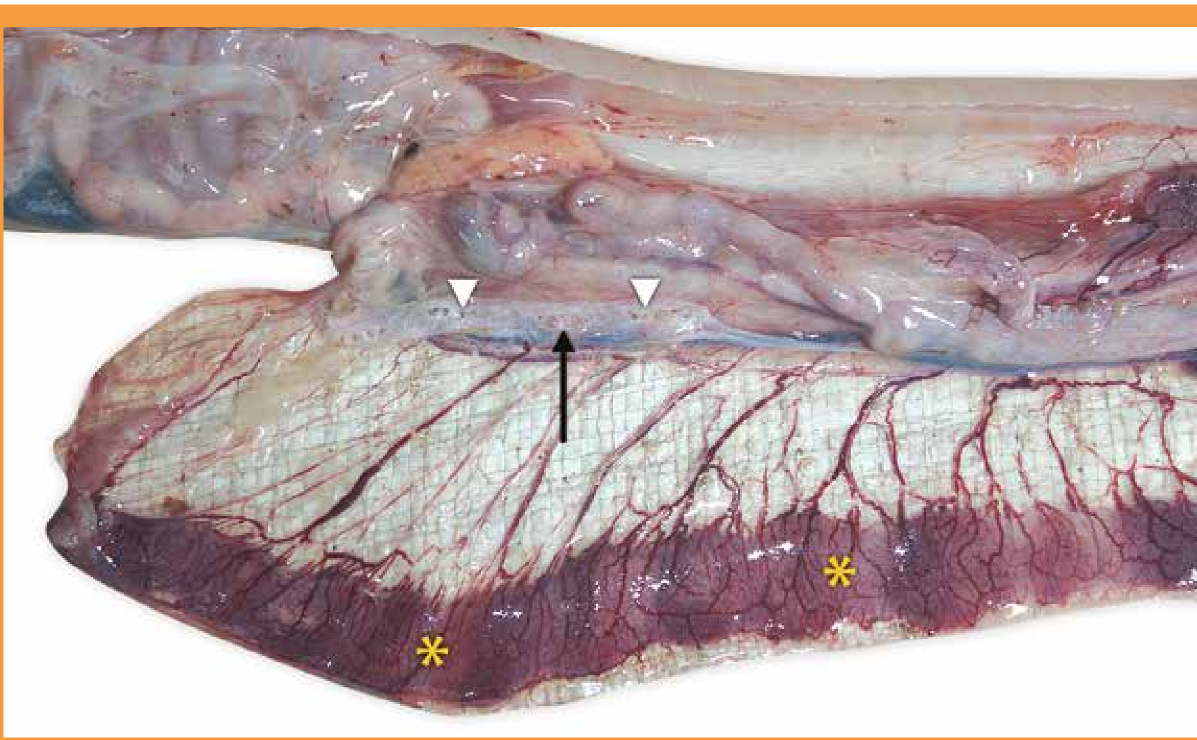


A5. *A mature, non-virgin female reticulated python. Oviduct is thick (asterisks) and oviducal scars have faded completely. Primary follicles are present (arrows) and surrounded by white scar tissue. Corpora albicans are present (white triangle).*



A6. *Scars left in the oviduct by the embryos of the water snake* ***H. bucccata*** *(circles). Scarred ovaries can be seen, together with corpora luteum in the processes of regressing to become corpora albicantia (black arrow).*

Photos by Daniel Natusch



A7. *A thick oviduct in the viviparous snake H. buccata (asterisks). Primary follicles (arrow) and corpora albicans (white triangles) can be seen in the ovary.*

A8. *Almost fully formed embryos in the oviduct of the viviparous water snake, H. buccata. Primary follicles surrounded by white scar tissue can be seen in the ovary (arrows).*

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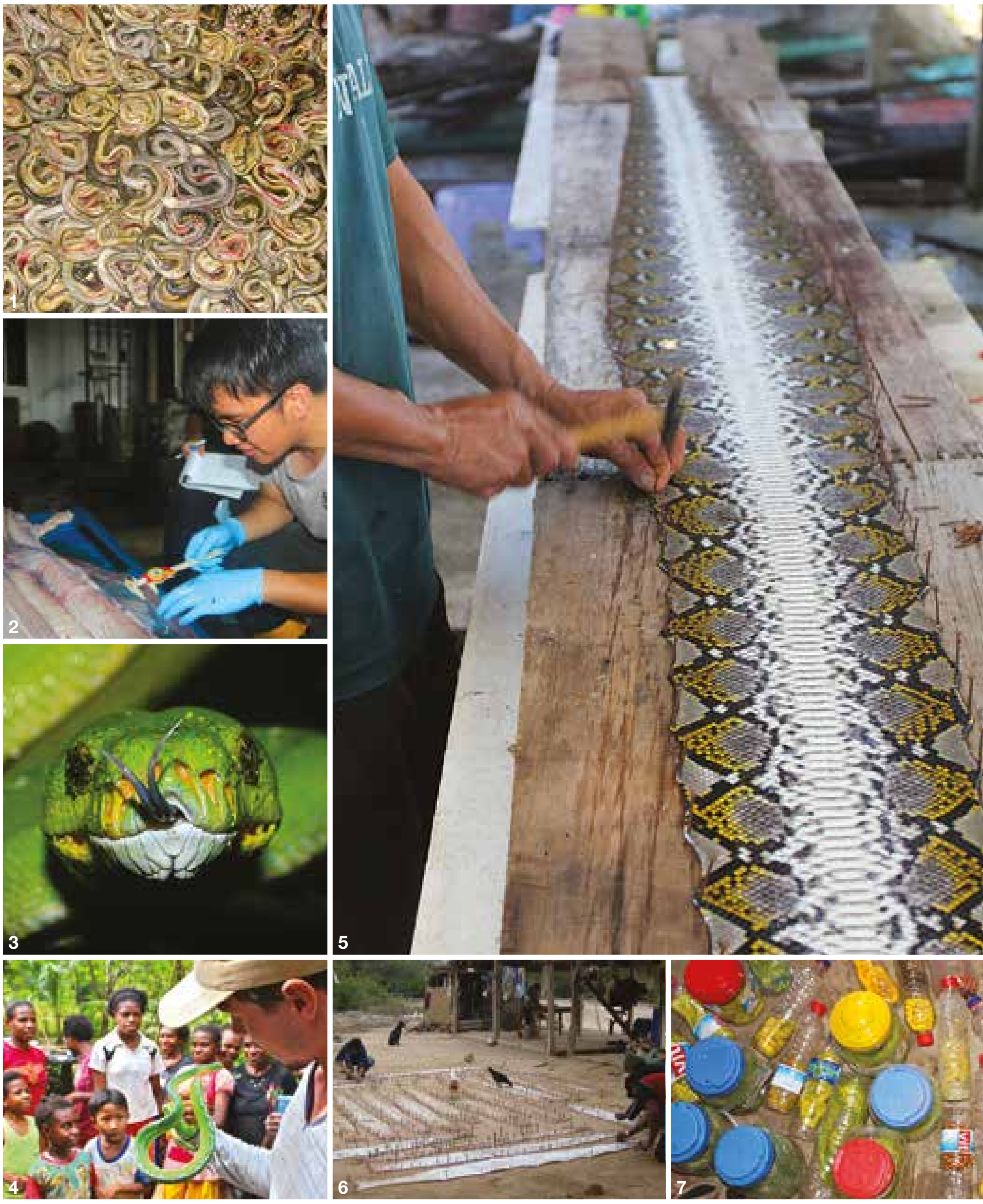

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