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Rapid assessments of amphibian diversity

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15.1 Background: rapid assessment of amphibian diversity

More than 6400 amphibian species are known worldwide, with more than 50 new species being described in just the first half of 2008 (AmphibiaWeb 2008). Many of these species are threatened or declining and more than 150 may have recently become extinct (IUCN 2006). Such rates of species loss are far greater than the historic background extinction rate for amphibians (e.g. McCallum 2007; Roelants *et al.* 2007). Amphibians play diverse roles in natural ecosystems, and their decline may cause other species to become threatened or may undermine aspects of ecosystem function (Matthews *et al.* 2002; Whiles *et al.* 2006). Anthropogenic habitat loss and degradation, disease, introduced species, and pollution or combinations of these factors are at the root of most declines. As awareness of declines has increased, conservation groups, governments, and land managers have become more interested in protecting amphibian diversity. However, the lack of accurate data on amphibian distributions, particularly for tropical regions where diversity and declines are concentrated (IUCN 2006), is often a roadblock to effective conservation and management. Ideally, lack of information on the amphibian fauna for a particular area would result in a thorough inventory. Unfortunately, this is usually not realistic. Exhaustive inventories are costly and may take decades to compile (e.g. Timm 1994). Given the urgency of the current global biodiversity crisis, finite resources, and dynamic socio-economic environments with respect to conservation, an approach for rapidly gathering preliminary data on biodiversity is sometimes required.

Rapid biodiversity-assessment methods were developed in response to this need. A Rapid Assessment (RA) is an accelerated, targeted, and flexible biodiversity survey, often focusing on species associated with particular vegetation types or topographical features (Sayre *et al.* 2000). RAs consist of planning, field sampling, and analytical and writing stages, and are implemented by teams of biologists and resource managers with expertise in the region and taxonomic group(s) of interest. Most RAs aim to be completed, from planning to report, in less than a year. Although a variety of RA strategies have been proposed, two of the better documented are the Rapid Ecological Assessment methodology developed by the Nature Conservancy (Sayre *et al.* 2000) and the Rapid Assessment Program methodology developed by Conservation International (Roberts 1991; www.conservation.org). RA approaches share a number of features in common (modified from Sayre *et al.* 2000).

- *Speed*. Reducing project duration reduces costs and delivers results to decision-makers quickly.
- *Careful initial planning and training*. Effective planning saves time and money and increases the consistency of the information gathered.
- *Use of mapping technologies*. The use of Geographic Information Systems (GIS), remote sensing, and global positioning systems (GPS) can greatly facilitate planning, sampling design, and geo-referencing of data.
- *Careful scientific documentation*. Selecting classification, sampling, and surveying methods that are most effective for the habitat, season, and taxa being sampled can maximize assessment effectiveness.
- *Capacity-building and partnerships*. Developing collaborative relationships among conservation, government, and academic partners in host countries and internationally helps ensure that information generated will have a local impact.

An RA is not an exhaustive faunal inventory, monitoring program, environmental impact assessment, or management plan, nor does it seek to elucidate species interactions or ecological processes, although an RA could serve as an important prelude to any of these activities. Instead, an RA is a conservation planning tool that can provide an efficient initial characterization of diversity in areas for which relatively little is known (Sayre *et al.* 2000). Here we describe in brief the steps involved in RA and discuss sampling methodologies likely to be effective for assessing amphibian diversity. Due to the integrative nature of RA, we often refer the reader to other chapters in this volume that cover material important to the topic.

15.1.1 When is an RA needed?

Determining whether an RA approach is called for depends on how much is already known about the area of interest and the urgency to obtain additional information. The best candidate sites are those that are only marginally surveyed and are highly threatened (Sayre and Roca 2000). It is in these cases that data resulting from an RA, though typically limited in scope, can have important implications for decision-making.

For example, the Atewa Range Forest Reserve of Ghana contains some of the last remaining upland evergreen forest in the country and is home to endemic plant and insect species (McCullough *et al.* 2007). In 2006, Conservation International initiated a Rapid Assessment Program of amphibians (and other taxa) within the Atewa Range Forest Reserve in response to proposed mineral exploration in the reserve. Sampling sites were selected in areas suspected to support high biodiversity that also had large mineral deposits (McCullough *et al.* 2007). Field surveys were conducted over just 18 days at the beginning of the rainy season. Nearly one-third of the 32 amphibian species observed were listed as threatened on the IUCN Red List. One species was considered Critically Endangered (Kouamé *et al.* 2007). Based in part on the amphibian assessment results, the authors recommended that Atewa Range Forest Reserve be elevated to national park status and that mineral exploitation be prohibited (Kouamé *et al.* 2007; McCullough *et al.* 2007).

15.2 Planning an RA

When an RA is indicated, the next steps involve planning and preparation. Because RAs may involve government and non-government participants from multiple regions, are often conducted in remote, logistically challenging field localities, and investigate unknown or poorly described faunas, substantial advanced planning is necessary for success.

15.2.1 Developing objectives

Establishing clear and realistic objectives is the most important step of the planning process, as the objectives become the yardstick for subsequent activities and resource allocation (Hayek 1994; Sayre and Roca 2000). Often amphibian assessments will be conducted as part of a larger project involving specialized teams looking at a variety of taxonomic groups, and objectives will need to be coordinated (e.g. Kouamé *et al.* 2007). The objectives should define the temporal, spatial, and taxonomic scope of the project, and in doing so determine the sampling methods and intensity required. For example, the objective might be to provide a preliminary species list of stream-associated taxa from a particular watershed based on snapshot sampling of several sites during the rainy season. Or perhaps the goal is to provide an initial inventory of all amphibian species within an area of conservation interest based on sampling effort spread over multiple seasons. Ideally, one's objectives are focused, realistic, and quantifiable (Chapter 2). Initial effort in reviewing and refining objectives is always worth the investment.

15.2.2 Costs and funding

Consideration of the costs and time necessary to successfully complete an RA is important and the decision on whether or not to proceed with an RA is often affected by financial and time investments. Costs will depend upon the scope of the objectives and logistics of field implementation, and can include salary expenditures, field equipment and supplies, landscape imagery purchases, international and in-country travel expenses, collecting and research permits, training expenses, contracts, laboratory equipment, museum supplies, software, digital storage media, and publication costs (Sayre and Roca 2000). Advanced consideration of these costs allows careful evaluation of trade-offs in the use of finite resources. For example, the use of satellite images, aerial photographs, or aerial videography to identify and map different habitat types and topographical features can greatly facilitate selection of sampling localities and is a key feature of some RA approaches (e.g. Rapid Ecological Assessment; Sayre *et al.* 2000). However, acquisition and processing of remote imagery can be very expensive, putting it beyond the scope of projects with more limited resources. Similarly, additional field sampling across seasons may increase the number of species observed, but also increases costs associated with returning to the site or maintaining a team in the field. Once costs have been estimated and a short project proposal developed, potential financial supporters can be approached. Options for securing financial support include development banks, governments, development agencies, conservation organizations, foundations, corporations, military landowners, and private individuals (Sayre *et al.* 2000).

15.2.3 Team selection and training

Depending upon the scope of the project, RA teams range from a few to many people, and may include senior scientists, students, technicians, field assistants, guides, rangers, data managers, cartographers, and administrators from multiple collaborating institutions (Sayre and Roca 2000; McCullough *et al.* 2007). For larger teams, an initial planning workshop is advisable, with the goal of developing a work plan that clearly identifies the roles and responsibilities of participating organizations and individuals. An example outline for a planning workshop and an example working plan for Rapid Ecological Assessment is given in Sayre and Roca (2000). International collaborations are recommended, whenever possible. Foreigners planning an RA should collaborate with local scientists to increase the chances of a successful project, and to make lasting contributions to the host country. Nationals planning an RA should consider involving foreign experts in important methodologies or taxonomic groups, especially from neighboring countries with related faunas.

A training workshop specifically for field personnel can also be an important tool, by providing training related to animal identification, field sampling techniques and data collection, use of GPS for geolocation, mapping and navigation, and safety protocols. All team members in charge of data collection should have at least a basic appreciation of the sampling design and statistical analyses planned (Magnusson and Mourão 2004; Chapter 18). In addition, amphibian pathogens and parasites can be carried between habitats on hands, footwear, or field equipment, and could be spread to new localities. Thus, it is important that initial training for those involved in RA include how to minimize the spread of disease and parasites between study sites (Declining Amphibians Population Task Force (DAPTF) code of practice, Chapter 26; Aguirre and Lampo 2006). Typically, this training occurs at the study area at the commencement of fieldwork. An overview of basic qualifications for field biologists, training tips, project supervision, and quality assurance are given in Fellers and Freel (1995).

15.2.4 Permits

Conducting an RA may require permits from local, regional, national, and international governing agencies. Most national governments, and many state and local governments, require permits to study amphibians within their boundaries and public lands. Many protected areas (e.g. national parks) require additional permission. National agencies and international treaties (e.g. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), U.S. Fish and Wildlife Service, Convention on Biological Diversity) also regulate export and import of specimens and tissue samples. There is considerable variation among regions in permit fees and the times required to process and receive permits, ranging from weeks to well over a year. Thus, the permitting process should be initiated well in advance of the planned fieldwork.

15.2.5 Data management

Although short in duration, RA projects can produce large amounts of data of different types, include *quantitative* data that can be represented as numbers, *qualitative* data that are not easily represented in numerical form, *spatial* data that are linked to geographic coordinates, *metadata* documentation that accompanies other data sets, and images or video or audio clips. Data management is the process that helps ensure that diverse data sets can be efficiently collected, integrated and analyzed, and archived so that they can be easily retrieved in the future (Gotelli and Ellison 2004). Planning for good data management begins early in project development by making a table of the types of data to be produced in the field; for example habitat variables (Chapter 17), conditions, counts, specimens, and other media such as photos, audio (Chapter 16), or video. This information can be used to design protocols (e.g. field forms, labels, code numbers) for collection and management of disparate types of data. Once data are being generated it is important to review data in the field, and verify that team members are using identical protocols. Data should be transcribed regularly and transferred to a database as soon as possible. If a portable computer is brought to the field, raw data should still be maintained on paper in case of damage to the computer. Widely used software for data management include Microsoft Access and the non-proprietary OpenOffice BASE. Protocols need to be established for reviewing, cleaning, and backing up data on a regular basis. Museum specimen data should be stored in a manner compliant with the Distributed Generic Information Retrieval (DiGIR) protocols, such as the database management software, Specify (http://www.specifysoftware.org).

15.2.6 Developing the sampling plan

The sampling plan is a document that identifies areas to be sampled during field work, the time that each area is to be sampled, the sampling techniques to be used and designate the individuals or teams responsible for conducting the field work. The sampling plan lays out the strategy for obtaining data that are representative of the target area of interest (Sayre 2000).

15.2.6.1 Selecting sampling sites

RA, at its most basic level, involves the collection and characterization of taxonomic and spatial information about biodiversity (Sayre *et al.* 2000). Although identifying sampling localities is one of the first steps in developing a sampling plan for any RA, protocols differ in their emphasis of initial landscape characterization. In some cases, sampling sites may be identified based upon perceived high biodiversity potential (e.g. perhaps as indicated by previous sampling of other taxa), specific conservation threats, or access logistics (e.g. Kouamé *et al.* 2007). In other cases, sites may be selected to capture clines in important abiotic features (e.g. elevation, rainfall, vegetation) that may determine the boundaries of particular amphibian assemblages (e.g. Menegon and Salvidio 2005). Some projects use remote sensing imagery to visually identify specific habitats of interest prior to sampling. Finally, GIS (Chapter 19) coupled with ecological niche modeling provide a new tool for remotely identifying potential habitat for species of concern or biodiversity hotspots in general (e.g. Raxworthy *et al.* 2003; Pawar *et al.* 2007).

Development and accessibility of new mapping technologies over the past two decades have had important impacts on the way RAs are conducted. Spatial technologies, including GIS, remote sensing, and GPS are commonly used in defining project scope and establishing sampling localities. The Rapid Ecological Assessment approach developed by Conservation International places strong emphasis on using satellite and aerial imagery to classify landscapes of interest into vegetation or land-use cover categories (Sayre *et al.* 2000). Sampling sites are spread across these vegetation categories to establish the framework within which field sampling is conducted and to facilitate linkages between fine-scale sampling by field teams with landscape-level assessment of biodiversity (Nagendra and Gadgil 1999; Sayre *et al.* 2000). Sayre *et al.* (2000) provide a detailed example of how natural-colour and colour-infrared satellite and aerial fly-over imagery were used to develop an initial landscape characterization of Parque Nacional del Este, Dominican Republic, which was subsequently used to identify specific sampling sites and generate detailed site maps. While the utility of remote sensing imagery when planning an RA is readily apparent, costs can be considerable. Commercial satellite imagery may cost US$3000–5000 per scene and an aerial photo acquisition mission may cost between $20 000 and 120 000 (Sayre *et al.* 2000). For projects with limited resources, Google Earth™ maps integrate data from satellite imagery, aerial photography, and a GIS 3D globe to provide resolution of at least 15 m for most terrestrial areas.

We draw a distinction between the ways sampling sites are determined in most RA studies compared to traditional ecological inventory methods. Traditional ecological inventories emphasized objective field sampling based on randomized selection of replicated samples and substantial effort may be given to issues such as defining sampling coverage and determining detection probabilities (e.g. Buckland *et al.* 1993; 2001, 2004; Heyer *et al.* 1994; Williams *et al.* 2002). This emphasis on randomization, replication, and estimating detection functions greatly increases the kinds of inferences that can be made. However, for many RAs, sampling may be opportunistic, or determined by issues such as logistics, access, efficiency, and *a priori* perceptions of areas likely to be highest in diversity or under the greatest threat. Although replicate units may be sampled in some cases, the resulting data may not be rigorously applied to all questions of interest to the ecologist or biogeographer (Sayre 2000). As a result, the results from many RAs are best viewed as qualitative or semi-quantitative (e.g. Kouamé *et al.* 2007).

15.2.6.2 Selecting sampling time

Scheduling sampling times will depend on latitude, elevation, seasonal patterns of rainfall, and knowledge of species breeding phenology. For example, in Kibale National Park, Uganda, pond-breeding *Hyperolius* reed frogs are most active and breed during the two rainy seasons (Vonesh 2000). In contrast, *Leptopelis* treefrogs breed during the dry seasons (J.R. Vonesh, unpublished results). Successfully sampling both of these taxa might require fieldwork during wet and dry seasons. However, when resources limit sampling to a single season, more amphibians are likely to be sampled during wet months.

15.2.6.3 Selecting sampling techniques

A variety of techniques can be used to assess amphibian diversity, including drift fences, pitfall traps, and cover boards (Chapter 13; Menegon and Salvidio 2005), quadrat sampling (aquatic: Chapter 4; terrestrial: Chapter 14), call surveys (Chapter 16), road and trail censuses (Pearman *et al.* 1995; Rödel and Ernst 2004), aquatic sweep-net sampling (Chapter 4), bottle or minnow traps, and visual surveys (e.g. Crump and Scott 1994). References on amphibian sampling include Campbell and Christman (1982), Corn and Bury (1990), Heyer *et al.* (1994), Olson *et al.* (1997), Lips *et al.* (2001), Howell (2002), Rueda-Almonacid *et al.* (2006), and Williams *et al.* (2002).

Selecting the sampling methodologies for an RA requires careful thought. Above all an RA must be rapid, yet our objective of a complete species list would suggest that we employ multiple techniques because techniques differ in the set of species they sample successfully. Often the strengths of different techniques are readily apparent, for example litter quadrat sampling will be more effective at sampling direct-developing species than visual encounter surveys (VESs) around aquatic habitats (Vonesh 2000, 2001a, 2001b; J.R. Vonesh, unpublished results). In other cases the trade-offs among techniques are more subtle and may change seasonally (K. Howell, unpublished results). Techniques also vary in terms of cost, effort, and other logistical requirements. Drift-fence arrays can be effective at sampling amphibians in a variety of situations (Chapter 13; K. Howell, unpublished results) but they are relatively expensive and labor-intensive to set up and maintain. Therefore, each potential field method should be evaluated for its relative capture success, speed, bias, and the extent to which it can facilitate the objectives of the RA (e.g. see Chapter 6, Table 4 in Heyer *et al.* 1994).

15.2.6.3.1 Visual encounter surveys (VESs)

VESs involves field personnel searching the focal habitat systematically for a known period of time. The clock is stopped when not actively searching (e.g. animals are being processed). The number of animals observed can then be expressed in terms of animals observed per area (or distance) per person searching, or per unit time per person. VES is an effective technique for building species lists rapidly (Crump and Scott, 1994; Rodda *et al.* 2007), requires little equipment (e.g. minimally a headlamp and field notebook), and can be implemented in a variety of habitat types. For these reasons it is perhaps the most widely employed sampling method in RA of amphibian diversity, so we provide a brief overview of the method here. For additional information see Crump and Scott (1994), Corn and Bury (1990), Campbell and Christman (1982), Rödel and Ernst (2004), and Rueda-Almonacid *et al.* (2006).

There is considerable variation among past studies in how VES is conducted. In some instances (e.g. Mitchell 2006; Kouamé *et al.* 2007) experienced herpetologists selectively search areas and microhabitats determined most likely to yield amphibians. This approach has the benefit of potentially yielding more animals and species per effort than randomized sampling approaches. However, it is most subject to variation in the skill levels of the field personnel and is limited in its ability to generalize about relative abundances and habitat associations because (micro-)habitats are searched in a biased manner. Alternatively, an area may be searched via VES using a randomized-walk design (Crump and Scott 1994). In this case, prior to going to the field site the researcher generates a random sequence of compass headings as well as a random distance to be searched along each heading. A starting heading and distance is selected at random and field personnel simply work through the list of headings and distances, searching for animals, for a specified time. Since the path to be sampled is determined randomly, this approach has the advantage that replicated random walks from different areas could be compared statistically. However, it is important to appreciate that differences in the observed number of animals among sites may be as much due to differences in detection among sites as much as differences in true abundance. If the sampling design requires greater effort per area, VES can be conducted using a quadrat design (Crump and Scott 1994). In this case, quadrats of a known area are established and each is then sampled systematically by searching parallel transects across the plot (e.g. Hairston 1980; Aichinger 1987; Donnelly 1989). Crump and Scott (1994) recommend plot sizes of 10 m × 10 m or 25 m × 25 m, depending upon amphibian densities. To statistically compare areas of interest (e.g. different habitats) plots must be replicated and randomly located within areas to be compared (e.g. using GPS coordinates or a trail grid system). Finally, transect designs are often used in coordination with VES for sampling across habitat gradients that may affect amphibian diversity and abundance (e.g. moisture, elevation). Although these considerations may determine transect direction, distances to be sampled and starting points are best determined *a priori* and multiple randomly located replicate transects will be needed if areas are to be compared statistically.

It is also important to determine and carefully define the intensity of field sampling in advance. Crump and Scott (1994) suggest three levels of sampling intensity for sampling amphibians. The least intensive surveys are counts of animals that are active on the surface (Hairston 1980; Vonesh 2000). This approach is minimally invasive and thus is suitable for search areas with sensitive faunas and also requires the least amount of time, increasing the amount of area that can be covered. Intermediate-level searches count exposed animals but also turn over surface cover objects (note that cover objects must be returned to their original position to minimize disturbance). This level of VES can yield species often overlooked by low-intensity VES because of their secretive and semi-fossorial life histories (e.g. many salamanders and caecilians). When the most complete inventory possible is desired, all possible microhabitats are searched; surface objects are turned, decaying logs are torn apart, the leaf litter is systematically raked, epiphytes and tree holes are searched (Crump and Scott 1994), and aquatic habitats are searched for adults and larvae (Chapter 4). Such intensity requires considerable labor per unit area and causes the greatest disturbance to the habitat but may be more effective at sampling some rare species.

15.2.6.3.2 Assumptions and limitations of VESs

The analysis of VES data is based on the following assumptions: (1) all individuals are equally detectable; (2) individuals are recorded once during a survey; and (3) there are no observer-related biases in sampling (Crump and Scott 1994). In most instances, one or more of these assumptions will be violated. Amphibians of different species, sizes, or life stages are generally not equally conspicuous. Even the probability of detecting the same individual may vary due to temporal (e.g. diel, seasonal) variation in behavior (Bailey *et al.* 2004; Schmidt 2005). Similarly, differences in observer experience can often result in differences in detection. Thus, the assumption of equal detection probability across time, space, and individuals is unlikely to hold for most amphibian taxa or studies (Mazerolle *et al.* 2007). This has important implications for simple count-based methods like VES. Consider that the expected number of individuals or taxa counted (C) in a survey area is $\mathrm{E}(C) = PN$, where P is the probably of detection and N is the true number in the population (Williams *et al.* 2002). Without an estimate of P, for any count of animals sampled, there is an infinite number of possible true population sizes. Mazerolle *et al.* (2007) and Schmidt (2004, 2005) provide lucid reviews of these issues and specifically focus on their application to herpetological studies. Given these limitations, VES is best viewed as a qualitative or semi-quantitative approach and should be used only when qualitative results are acceptable (e.g. threatened species were observed; Kouamé *et al.* 2007). VES may be a suitable sampling approach given the objectives of many RA projects. However, when resources and objectives allow, other more powerful study designs (e.g. distance sampling methods; Thomas *et al.* 2002; Funk *et al.* 2003; Fogarty and Viletta 2001; Viletta and Fogarty 2005) should be considered.

15.2.6.4 Determining what data to collect

Generating lists of observed species is usually the principle type of data-collection method used during an RA. In some cases, animals encountered in the field may be identified in the field. In other cases, it may not be possible to identify all species, requiring that specimens be held temporarily for identification (e.g. to consult a key) before being released at the site of collection, or it may be necessary to preserve voucher specimens that can be identified by taxonomic specialists (Jacobs and Heyer 1994; McDiarmid 1994). Voucher specimens are what ultimately define the identity and distribution of any amphibian species. Depending on collecting permits obtained, a series of one or more voucher specimens per sex, life stage, and species should be collected during any give RA, especially for remote geographic locations, and deposited in a recognized natural history museum. Voucher specimens allow independent researchers to confirm specimen identification at a later date, a very important consideration given the highly unstable state of amphibian taxonomy. The systematic value of a voucher specimen increases as more ancillary data are included.

Depending upon the project's goals, it may be important to collect additional data for animals observed or collected. GPS can be used to provide a geo-reference for each sample. Basic size measurements (snout–vent length, mass), sex, reproductive status based on secondary sexual characteristics, notes or photographs indicating coloration, and basic activity (e.g. calling, resting, moving, etc.) may be recorded. Tissue samples for DNA analyses may be obtained from a toe clip, liver sample, or a buccal swab preserved in 95% ethanol or other buffer (Seutin *et al.* 1991; Gonser and Collura 1996; Goldberg *et al.* 2003). The benefits of integrating RA data with the DNA barcode of life campaign are potentially enormous but so far have been under-utilized (Vences *et al.* 2005; Fouquet *et al.* 2007; Ficetola *et al.* 2008; Smith *et al.* 2008). Additional types of sample, such as skin swabs, may be required for disease detection (Chapter 26). It is also important to record environmental characteristics, such as weather conditions, lunar cycle, and vegetation or habitat characteristics (Chapter 17).

However, collecting additional data on individuals is time-consuming and thus additional data on individuals may involve trading-off the amount of area that can be searched. Field forms are useful to remind the field team what data are to be collected and can help ensure consistency of data collection among team members. Crump and Scott (1994) provide an example data sheet for VES that includes some basic individual-level data. If designed with foresight, forms can also expedite data entry.

15.2.6.5 Field logistics

Poorly organized trips typically result in poor-quality data collection. Careful advance planning for the transportation of the team, sampling equipment, and basic supplies will be required, particularly for large teams and remote localities. Logistics also includes coordinating the safety of the team. Injuries and illness in remote locations can be dangerous and hinder project progress. In advance of fieldwork the field team should prepare a well-stocked medical kit, review vaccines and allergies of each participant, and plan for various possible medical emergencies that could arise.

15.3 In the field

After the planning and preparation has been completed, the team goes to the field and begins sampling in the manner indicated by the sampling plan. Situations will naturally arise that prevent the sampling protocols from being followed exactly. RAs are intended to be flexible enough to allow field teams to respond to unforeseen roadblocks as they arise. The field team should keep the primary objectives of the project in mind if they are required to alter plans in the field (Young *et al.* 2000).

15.4 Compiling data and interpreting results

Producing information that is useful to conservation biologists, land managers, and policy-makers requires skillful synthesis of the large volume of field data generated. If data-management strategies were developed and the data and metadata have been entered into the database, work can now focus on analysis and interpretation. RA data summaries typically focus on species lists (Kouamé *et al.* 2007). Species lists may be organized to highlight species sampled in different primary sampling localities, particular habitat types (e.g. stream, pond, litter), points along environmental gradients (e.g. elevation; Menegon and Salvidio 2005), indicator taxa (e.g. disturbance-tolerant versus -intolerant; Kerr *et al.* 2000), endemicity or conservation status (e.g. IUCN Red List status). The best summary approach will depend on the goals of the RA. Because sampling effort often varies among sites and may have relied to some degree on opportunistic sampling, it is often difficult to make direct comparisons between species lists among sites across or even within RA studies. In some cases, species accumulation or rarefaction curves can be used to show how rapidly the number of species sampled at a specific site or habitat increased with sampling effort (e.g. Chapter 18; Gotelli and Colwell 2001; Magurran 2003) to facilitate comparison at a given sampling effort. Similarly, in some cases it may be possible to use total diversity estimators to extrapolate from incidence sampling data to estimate the total number of amphibian species at a site (e.g. Chapter 18; Chao *et al.* 2005). When using VES data, however, investigators should clearly define their sampling unit and be aware how their choice could influence the diversity analyses.

15.5 Recommendations and reporting

Because RAs are typically motivated from a conservation or management perspective, recommendations will focus on how the information generated in the RA can be used to maintain long-term faunal diversity of the study sites. However, recommendations should be firmly based on the study results, not on preconceived ideas about the sites importance, and should consider the target audience and their ability to follow through on the recommendations. Little benefit comes from recommendations for which the target audience has no ability to implement (Young *et al.* 2000). Ways in which RA results are typically used to guide decision-making include providing direction for future land acquisition, identifying monitoring needs, establishing priorities for future research, suggestions for how to zone for multiple use, and for identifying potential threats to species of interest (Young *et al.* 2000).

15.6 Summary

Rapid assessment is an approach that can be useful for conservation planning because it can provide an efficient preliminary characterization of the amphibian fauna. However, because the methods are often qualitative or semi-quantitative, the RA approach is of most value when the fauna of the study areas is unknown and when even qualitative information is needed urgently to help decision-making. When resources, time, and project objectives allow, researchers should consider more quantitative approaches.

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