Assessment of Biodiversity Among Southeast Asian Amphibians and Reptiles

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Introduction

The 2005 Biodiversity Research and Training Program meetings featured biodiversity as a theme throughout the presentations. Since Thailand is a major center of biodiversity in Southeast Asia and is renowned for the range of its latitudes, elevations, land forms, soils, geological ages, and plant and animal communities, this was particularly appropriate.

In this paper, which is based on my presentation at those meetings, I wish to explore three important aspects of assessing biodiversity:

1. Methods and considerations in sampling biodiversity, including the roles of time and space;
2. Use of traditional and modern methods to recognize species, the units of biodiversity;
3. Ways of estimating the value of biodiversity.

Methods and Considerations in sampling Biodiversity

My work focuses on amphibians and reptiles, thus my examples are drawn from studies done on these groups. However, the issues raised, as I hope to make clear, are generally applicable to the study of other groups and the assessment of their biodiversity.

Valid estimates of the biodiversity of amphibians and reptiles are highly dependent on the sampling methodology used. Although there is an extensive literature on the subject (see Heyer et al., 1994), sampling remains the single weakest link in the process of estimating biodiversity because it takes considerable effort to plan it thoughtfully and hard work to execute it well.

As discussed in detail by Inger and Voris (1993), Voris and Inger (1995), and summarized by Inger (2003), effective sampling surveys of amphibians and reptiles must include the following:

- Use of a variety of techniques to access the breadth of the microhabitats within each locality;
- Study of multiple localities to detect spatial diversity;
- Taking of multiple samples through time to detect seasonal variation and population oscillations.

To be specific, this means that effective surveys of amphibians and reptiles in tropical rain forests must include sampling along transects during both day and night, both in the forest and along streams, since very different species lists result from sampling these different areas at different times and in different dimensions. Microhabitats that must be sampled include tree buttresses, leaf litter, and rotting logs on the forest floor, as well as shrubs, tree trunks and vines in the vertical dimension.

Inger and Voris (1995) have documented that even streams within a few kilometers of one another that appear to be similar in topography and microhabitat composition, have distinctly different assemblages of species. These results clearly illustrate that if sampling is done at only one or two localities within an area, the species composition and/or relative abundance--the biodiversity--in the area will be underestimated.

Perhaps the most neglected aspect of sampling amphibians and reptiles in the tropics is the need to sample through time. The perceived lack of seasons in tropical rainforests has led to the belief that it is redundant to sample through time, but this is not the case. For example, in the area of Nanga Tekalit, in the lowland tropical rainforests of Sarawak Borneo, temperatures and rainfall are relatively constant throughout the year and there is no marked annual dry season. Yet, when Inger, in 1962, conducted a continuous full year of sampling on several hill forest streams in this setting, the resulting data clearly confirm the following assertions regarding sampling of amphibians in seemingly aseasonal tropical rainforest (Inger, 1969).

First, the level of overall activity of frogs along a stream (the Serbong) varies from night to night (Fig. 1, from Inger, 2003). Thus, several nights of collecting are required to insure that samples are obtained on nights when frogs are active.

Second, different species of frogs differ in terms of their activity patterns. For example, Figure 2 (from Inger, 2003), illustrates the activity pattern for one species, *Limnonectes leporinus*, on the Serbong. Note that this species was observed on every night over 36 nights of collecting, although not in the same numbers.

The activity pattern for a second species, *Pedostibes hosii*, taken from the same stream, the Serbong, is shown in Figure 3 (from Inger, 2003). It is clear that there are many periods when this species is not active, sometimes for as long as eight consecutive nights. However on a few nights it was very active. Thus we see the necessity of making observations over a longer period of time on a single stream to insure that we detect those species that have sporadic activity patterns.

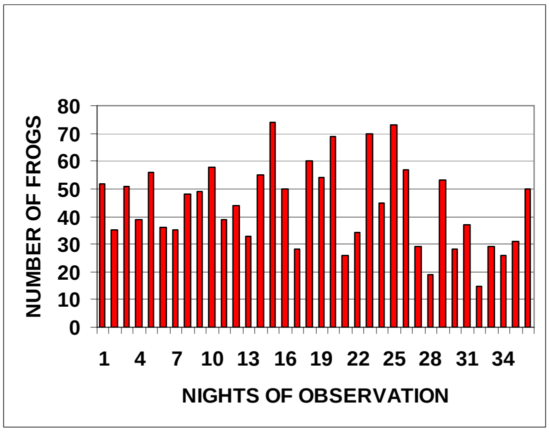

Figure 1. Graph showing the numbers of all frogs observed on 36 nights on the same stream (the Serbong) in Sarawak (Borneo) over a 12-month period in 1962-1963. (From Inger, 2003)

These examples illustrate and support the assertion that sampling of anurans in tropical rainforests is not a simple task but one that requires planning and effort over a period of time.

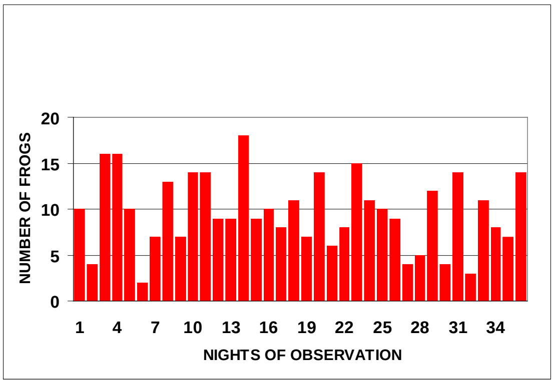

Figure 2. Graph showing the variation in the number of individuals of one species of frog (*Limnonectes leporinus*) observed on 36 nights on the same stream (the Serbong) in Sarawak (Borneo) over a 12-month period in 1962-1963. (From Inger, 2003)

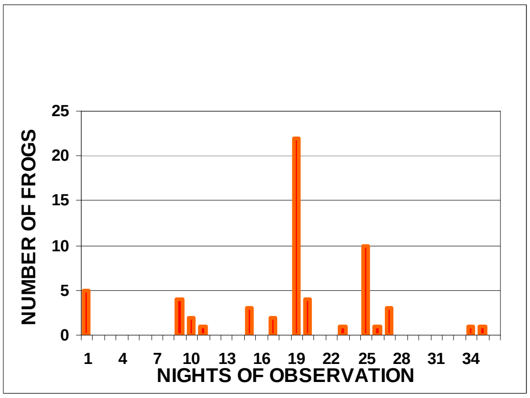

Figure 3. Graph showing the variation in the number of individuals of one species of frog (*Pedostibes hosii*) observed on 36 nights on the same stream (the Serbong) in Sarawak (Borneo) over a 12-month period in 1962-1963. (From Inger, 2003)

Recognizing Biodiversity

Extensive sampling over multiple localities through time and space, as described above, is the crucial first step in being able to recognize individual species, the units of biodiversity.

For over 300 years, the use of traditional methods which emphasize the external morphology of amphibians and reptiles has resulted in a steady increase in the total number of species (Kohler et al., 2005; Sodhi et al., 2004). However, in only the last 40 years, the rate of discovery of new species has escalated due to the application of new techniques and use of additional types of data obtained from behavior, ecology, karyotypes, and various molecular analyses.

Kohler et al. (2005) have carefully documented these trends for amphibians, beginning in 1758. Additional support for the strong up tick in species numbers is given in recent papers by

Hanken (1999) and Bossuyt et al. (2004), which emphasize the use of molecular data to assist in the recognition of species.

Studies which I and my colleagues, Daryl Karns of Hanover College, and his students, Heather Andrews, Elizabeth Phipps, and Jerry Suddeth, have conducted on semi-aquatic snakes from within and near the Khorat Basin in northeastern Thailand, also support the notion that there are many more new snake species than previously thought.

The Khorat Basin is a prominent geographic feature of Indochina, potentially important in the ecology and evolution of semi-aquatic snake communities. We were originally interested in how different populations within known species (*E. enhydris* and *E. plumbea*), might differ at two different but nearby geographical sites, within and outside of the Khorat Basin. We began our work using the existing definitions of species which were based on traditional morphology.

We compared community structure and population characteristics of semi-aquatic snakes (focusing on the homalopsine snakes) from a total of 11 localities located in the Khorat Basin, on the mountainous rim of the Khorat Basin, and at lower elevation sites located outside the Basin. We found that species richness (that is, numbers of species) of semi-aquatic snake assemblages was comparable in and outside of the Khorat Basin (Table 1), and there was a high degree of species overlap between assemblages found in and outside the Basin. However, species diversity was higher in the Khorat Basin (evenness = 0.694), and *Enhydris enhydris* was the strong dominant at sites located outside of the Basin (evenness = 0.334).

Table 1 shows that Homalopsine snakes were absent from the Khorat Basin rim sites, and they were over twice as abundant at sites located outside of the Basin compared to sites inside it. We found size sexual dimorphism for *E. enhydris* outside of the Khorat Basin, but not inside it. Female snakes (*E. enhydris* and *E. plumbea*) from outside the Khorat Basin were larger and heavier compared to populations in the Basin. Historical, biogeographical, biotic, and abiotic factors that may contribute to these observed differences are discussed in Karns et al., 2005.

After collecting a total of 668 specimens throughout the course of these studies, we found some slight morphological differences between populations, and we also observed geographical differences in the distribution of the species in and out of the Basin. However, by themselves these were insufficient to justify redefinitions of the species. It was when we conducted molecular analyses (not yet published) that significant differences among the populations were revealed, indicating that that there are probably more than the initial two species we thought we were studying. Further support for the multiplication of species among these semi-aquatic snakes is provided in several recent papers describing new species in other parts of the range of this small family (Murphy and Voris, 2005; Murphy et al., 2005; Ziffer, 1999).

These kinds of studies and results clearly increase our estimates of the species richness and diversity present, and are an example of why the rate of discovery of new species of amphibians and reptiles has escalated in recent years.

Estimating the Value of Biodiversity

Such careful, extensive surveys as these document the existence of even more species than previously thought, a richness of biodiversity way beyond our previous expectations. Why is this important? Why should we care? What is the value of having biodiversity and making sure it is maintained? These questions have been answered in a variety of ways.

From a biological point of view, the stability of ecosystems that results from the complexity of the food chains is a very important reason to value and preserve biodiversity.

There are definitely commercial reasons to value biodiversity as well, such as maintaining sustainable harvests for the various purposes of the wildlife trade.

There is an important medical value to sustaining biodiversity both in terms of preserving sources of traditional medicines, and the potential for discovery of sources of new drugs through bio-prospecting.

There are also significant aesthetic, historic, and recreational reasons for maintaining natural areas with their full complements of biodiversity.

But there is also another factor that is often overlooked, which we might call “the cost of construction or creation.” This is based on what was required to produce these great, complex natural systems.

Two primary elements were involved: vast amounts of space (landscape), and vast amounts of time. Plate tectonic events over the last hundreds of millions of years and episodes of glaciation over the past two million years have greatly influenced the earth’s surface, gradually developing a wide range of elevations and geological formations which, coupled with elements of latitude, drove climate changes and created abundant opportunities for the formation of species and the resultant high biodiversity that characterize complex ecosystems.

To illustrate some of these events in what is now Southeast Asia, we will look at three perspectives, through different spans of time.

From the late Permian period, 255 million years before the present, to the Middle Eocene epoch, some 50 million years before the present, the earth experienced the major breakup of the supercontinent, Pangea. Christopher Scotese, at the University of Texas at Arlington, has developed a website (http://www.scotese.com) which depicts, through a series of illustrations, the phenomenal movement of the earth’s plates through this period of time. One example taken from his work is given in Figure 4.

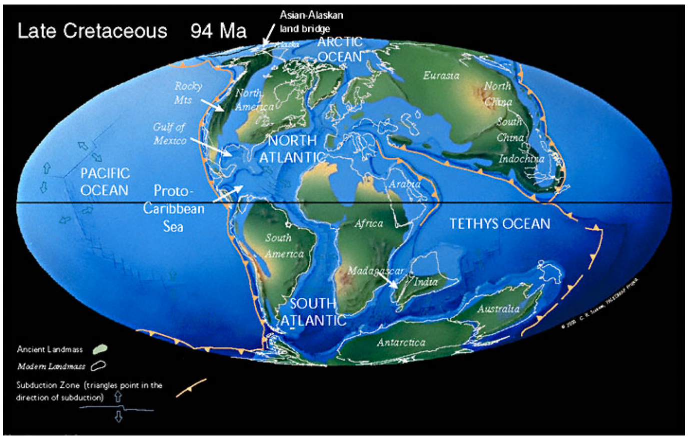

Figure 4. An illustration showing one stage in the breakup of the supercontinent, Pangea. From a website (http://www.scotese.com) developed by Christopher Scotese, at the University of Texas at Arlington.

Hall and Holloway (1998) have looked at plate tectonic shifts somewhat closer in time, from the early Eocene epoch, 55 million years before the present, to the present day, in the Austral-Asia region. A compact disc which accompanies their paper gives an impressive animated portrayal of these events. Figure 5 illustrates one view from their work.

The third perspective, given by Wallace (1881), Molengraaff and Weber (1919), Darlington (1957), Voris (2000), Sathiamurthy and Voris (in press, 2006), focuses on the sea level and climate changes between the period from 250,000 years ago, to the present day. Changes in sea levels over geological time have long been considered crucial to understanding the distribution of both aquatic and terrestrial organisms that we see today.

Figure 6 from Voris (2000), gives a map of present day Austral-Asia, along with a depiction of the extent of the Sunda and Sahul shelves when sea levels were 75 meters below present day levels, showing the magnitude of change in the land mass between two points in time. The publication gives numerous maps of the region at other sea levels.

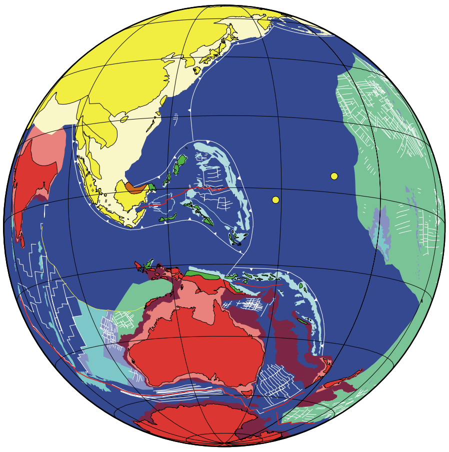

Figure 5. The Austral-Asia region at 40 million years before the present as depicted by Hall and Holloway (1998). A compact disc that accompanies their publication contains this illustration and many others.

Sathiamurthy and Voris (in press, 2006) have further refined and expanded these maps using a comprehensive data base of ocean depths. Figure 7 is one example from their work, again showing a map of present-day Austral-Asia, along with the extent of the Sunda Shelf when sea levels were even lower than in the above example from Voris (2000), some 21 thousand years before the present.

Figure 6. A map of present-day Austral-Asia showing the extent of the Sunda and Sahul shelves when sea levels were 75 meters below present-day levels. (From Voris, 2000)

It is impossible to fully convey in a written paper the awesome impression made by seeing all the visual depictions shown in these studies. However, we can begin to appreciate the magnitude of time and events that have led to the earth's present configuration of geography and ecosystems, by referring to our own experiences of how the powerful forces that result from plate tectonic shifts--volcanic activity, earthquakes, and tsunamis--continue to reshape our environment. We cannot help but be led to a profound appreciation of what the earth has undergone.

We are led to an inescapable conclusion: the enormous amounts of time and spatial diversity on this planet cannot be duplicated, making the biodiversity that has resulted, absolutely unique, irreplaceable, and priceless.

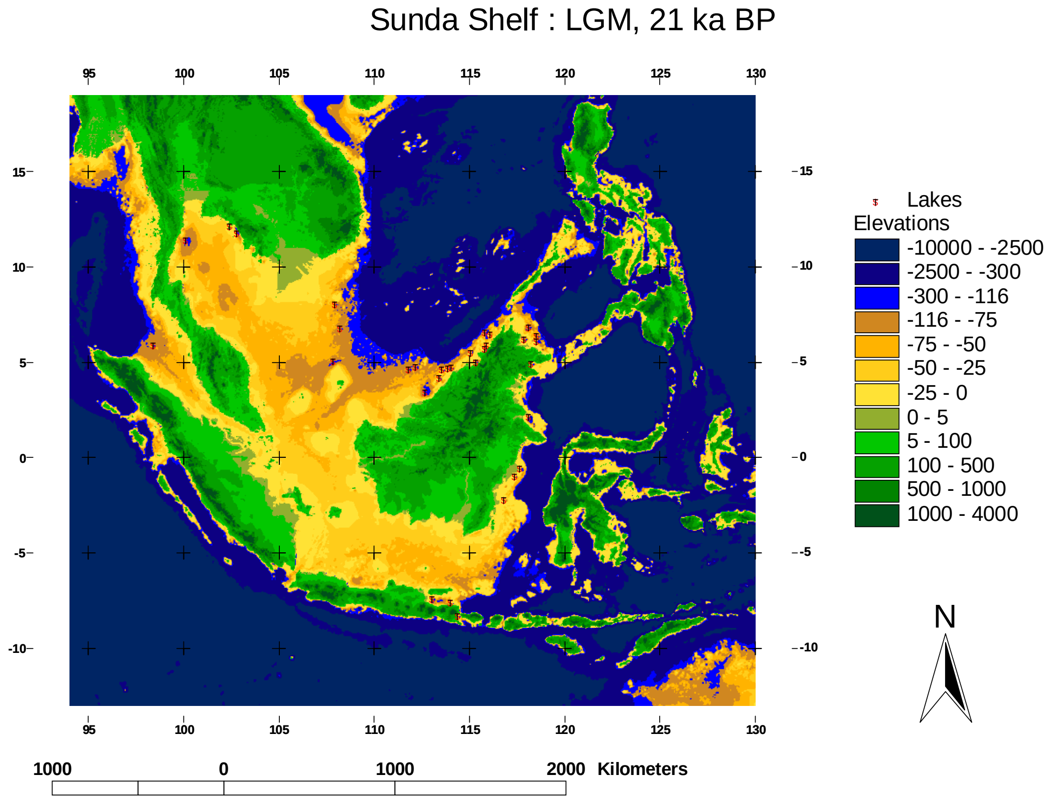

Figure 7. A map of present-day Austral-Asia showing the extent of the exposed Sunda Shelf due to lower sea levels at 21 ka years before present. (From Sathiamurthy and Voris, in press, 2006)

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