# INTEGRATED EFFORT
# IN THE
# PRIORITIZATION OF AREAS FOR CONSERVATION IN BORNEO

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## INTRODUCTION

Prioritization of areas has become a crucial aspect of environmental conservation. Prioritization of areas for conservation reviews areas with the best representation of biodiversity so that conservation efforts, and especially the scarce conservation money, can be targeted for effective and feasible environmental conservation. This is even so when human-induced environmental disturbances and threats such as deforestation, logging, pollutions, forest fire, flood, and poaching are intensifying rapidly over the years exerting overwhelming pressure on the environment. For instance, the coverage of undisturbed forest (lowland and highland Dipterocarp forest) in Sabah has dropped 85.25% from 1975 to 1992 (Ministry of Science, Technology and the Environment, Malaysia, 1997). These disturbances and threats have direct link with anthropogenic activities for economic gains like agriculture (Ooi, 1993), industrialization and housing. Consequently, the competition for land between materialistic development and conservation stiffens. Sacrifice of the former for the latter and vice versa are unrealistic. Thus, compromise is inevitable; prioritization of areas for conservation has become important.

Prioritization of areas for conservation requires an analytical tool, biodiversity value, selected site, and selected organism group. On top of that, integrated effort is also imperative in the prioritization of areas for conservation knowing that the process needs large data sets in ensuring the reliability of the outcomes, and covers a vast area as in this research. The integrated effort is practically and conceptually divisible into three strata, namely Stratum 1 (data collections and identification), Stratum 2 (data sharing), and Stratum 3 (outcomes dissemination and utilization).

The analytical tool for the prioritization of areas for conservation has to be able to handle large data sets, and user friendly. WORLDMAP program (version IV), which was used for this research, is most suitable. WORLDMAP is a PC-based and tailor-made analytical tool to map biodiversity. It is an interactive program designed to allow users to directly update the data and select desired analyses (Williams, 1994). It uses a 15' x 15' grid cell system as its smallest representation unit for Borneo. The grid cells show results of various analyses solely based on the data digitalized into WORLDMAP that correspond to the actual localities represented by the grid cells.

Biodiversity needs to be quantified into biodiversity value for the prioritization of areas for conservation. Although there are three measures of biodiversity value, namely through genes, species and higher taxa (Williams & Humphries, 1996), the most popular and logical measure is by using species (e.g., Lombard *et al.*, 1995; Gaston, 1996; Williams & Humphries, 1996; Fjeldsa & Rahbek, 1997, 1998; Humphries *et al.*, 1999; Fjeldsa, 2000; Fjeldsa & De Klerk, 2001). Information of the species and their localities in GPS format become the biogeographical data of the research. However, as some of the data were compiled from other researchers, they were in genera.

The selected site for this research, Borneo, is situated on the Sunda Continental Shelf. Borneo, the world's third largest island (after Greenland and New Guinea), covers 751,929 km$^2$, and comprises of Sabah (74,500 km$^2$) and Sarawak (124,450 km$^2$) in Malaysia, Kalimantan (547,214 km$^2$) belonging to Indonesia, and Brunei Darussalam (5,765 km$^2$). Borneo has a wide variety of habitats spanning from mangrove forests to alpine forest on Gunung Kinabalu, Sabah, northern Borneo. These habitats contribute to various microhabitats which support floral and faunal richness in Borneo. The faunal component of Borneo is unique. The uniqueness can be seen in comparison to Sulawesi and other islands on the Sunda Continental Shelf (Moss & Wilson, 1998).

The selected organism group was anurans (Amphibia: Anura) or tailless amphibians. Anurans have been regarded as one of the best group of environmental health indicators. Anurans have highly permeable skin which contributes to its high vulnerability towards environmental pollutants. Anurans are also habitat specialists. Hence, anurans are gravely affected by environmental deterioration (Payne, 2000) and habitat disappearance. This is exemplified by the dwindling of anuran population sizes, geographical ranges and even extinction in several parts of the world such as North America, Central and South America, Europe, Africa, Australia and Asia (Blaustein & Wake, 1990).

Besides, Borneo is rich in anuran species. The number of species in Borneo was 143 in 1997 (Inger & Tan, 1996; Inger & Stuebing, 1997), and is increasing almost annually with the discovery of new species. Additionally, about 69% of the fauna is endemic to Borneo (Inger & Stuebing, 1997) making anurans politically appealing. This aspect can help to attract public and governmental interest (Mohamed Zakaria, 2000). In the tropics, like Borneo, anurans occupy almost all types of habitats.

## METHODS

### Data collections

For WORLDMAP, data are categorized into level 1 and level 2 data (Kueh, 2000, 2001a, 2001b; Kueh *et al.*, 2002). Level 1 data are assumed presence of anurans based on habitat preference. Data were compiled from the ecological notes of the anuran species in Borneo from *A Field Guide To The Frogs Of Borneo* (Inger & Stuebing, 1997) and *The Systematics And Zoogeography Of The Amphibia Of Borneo* (Inger, 1966).

Level 2 data refer to the actual presence of anurans based on paper in journals and monographs, expedition notes, fieldtrip records, as well as wet specimens, coupled with personal samplings. As Borneo is a vast area, integrated effort in gathering data is required. Integrated effort is defined by collective effort in data collections and identification (Stratum 1) in personal samplings, and data sharing (Stratum 2) of existing data in various forms as mentioned earlier. Due to the integrated effort exercised in this research, biogeographical data (level 2 data) of anurans throughout Borneo were compiled for the very first time in a compact duration of two years.

### Data digitalization

Once the biogeographical data were compiled, the coded data were digitalized into WORLDMAP manually. The codes each consists of one digit and five capital letter alphabets that was specially created for anurans of Borneo, and highly distinctive (Kueh, 2000, 2001a, 2001b; Kueh *et al.*, 2002). For WORLDMAP, each datum fills up a grid cell (Fig 1).

## WORLDMAP analyses

WORLDMAP analyses used in this research were: (a) 'species richness': analysis of the number of species or genera (taxa) in every grid cell, (b) 'top ten hotspots by species richness': analysis of ten grid cells with the highest number of taxa, (c) 'range-size rarity': analysis of the total inverse number of grid cells occupied by each taxon in every grid cell, (d) 'top ten hotspots by range-size rarity': analysis of ten grid cells with the highest range-size rarity, (e) 'near-minimum sets': analysis of grid cells to represent all the taxa, and (f) 'GAP analyses': analyses on the feasibility of the conservation priority areas which involve comparison of those areas with the current protected areas network and present human settlements pattern in Borneo.

The intensity of analyses (a) – (d) was denoted with colours ranging from red to light blue. Red is superlative while light blue is the opposite. The colouration is strictly determined by the biogeographical data digitalized into WORLDMAP.

# RESULTS

## Species richness

Overall, species richness of the anurans of Borneo is concentrated at four major grid cells or their aggregations. The four concentrations of species richness are along the Crocker Range at western Sabah, lowland to hilly and lower montane zones at eastern Sabah, lowland zone on northwestern Sarawak, and lower montane zone at southwestern Sarawak. The concentrations encompass grid cells with 60 – 85 taxa out of the 139 taxa of anurans data gathered and digitalized into WORLDMAP (43.17 – 61.15%) (Fig 2).

The species richness concentration along the Crocker Range has 43.17 – 61.15% of species richness with the only red grid cell produced in the species richness analysis. Besides the Crocker Range National Park, prominent localities included in this species richness concentration are Kinabalu Park, Poring Hot Springs, Gunung Alab, Rafflesia Forest Reserve, Tambunan, Bunsit Park, Keningau, Gunung Lumaku Forest Reserve, Tenom, and Mendolong. It includes three of Sabah's divisions, namely Kudat, West Coast and Interior.

The next species richness concentration is at eastern Sabah with 43.17 – 50.36% of species richness. It represents localities like Tabin Wildlife Reserve, Danum Valley Conservation Area, Tawau Hills Park, and Maliau Basin Conservation Area. It covers Sandakan and Tawau Divisions.

Another species richness concentration is at northwestern Sarawak. It has 67 taxa of anurans (48.20%) making it the richest grid cell in Sarawak. Tubau, Bintulu Division, is situated in the concentration.

The fourth species richness concentration is at southwestern Sarawak with 45.32% of species richness. It represents Sungai Mengiong, Kapit Division, which is at the southwestern border of Sarawak and Kalimantan.

Low species richness is clearly projected from the middle of Borneo which covers several mountain ranges at southwestern Sarawak, East Kalimantan, South Kalimantan, Central Kalimantan and West Kalimantan. Each of the grid cells merely accommodates one to seven taxa of anurans and is shown either as blue or light blue.

## Hotspots by species richness

Top ten hotspots by species richness are at western Sabah (Fig 3). Each of the ten hotspots houses 70 or more taxa of anurans. Collectively, hotspots 1, 2, 5, 7 and 9 represent Kinabalu Park. On a similar ground, hotspots 1 – 8 except 5 represent Crocker Range National Park. Hotspot 10 is the most southern hotspot which represents Mendolong and Gunung Lumaku in Sipitang District as well as Belumbang, Tomani, Melutut and Sungai Tomani in Tenom District, Interior Division.

## Range-size rarity

Range-size rarity of the anurans of Borneo peaks at five areas represented by grid cells or their aggregations. The peaks are at montane zone at western Sabah, lowland to hilly and lower montane zones at eastern Sabah, lowland zone at northwestern Sarawak, montane zone at northeastern Sarawak and lower montane zone at southwestern Sarawak (Fig 4). All the grid cells involved have range-size rarity of 10.00 – 22.16% and are shown as red or dark orange.

The range-size rarity peak at western Sabah is in the range of 10.13 – 18.84%. The peak covers localities in Sabah such as the Crocker Range National Park, Kinabalu Park, Gunung Tambuyukon, Poring Hot Springs, Mamut, Gunung Alab, Rafflesia Forest Reserve, Sunsuron, Rompon, Tambunan, Keningau, Tenom, Membakut, Bunsit Park, Mendolong, Tomani, Gunung Lumaku and numerous rivers. It spans across the divisions of Kudat, West Coast and Interior.

The next range-size rarity peak is at eastern Sabah with range-size rarity of 10.08 – 17.19%. It covers three conspicuous protected areas in Sabah, namely Danum Valley Conservation Area, Maliau Basin Conservation Area, and Tawau Hills Park. The areas are in Tawau and Interior Divisions.

Northwestern Sarawak shows the highest range-size rarity of 22.16%. It is the only red grid cell produced in the range-size rarity analysis. The peak includes localities like Tubau and Sungai Pesu in Bintulu Division.

Another range-size rarity peak is at northeastern Sarawak. It shows range-size rarity of 10.08%. It is the northeastern edge of Gunung Mulu National Park, Miri Division. The grid cell houses the pinnacle of Gunung Mulu too.

The fifth area with high range-size rarity is at southwestern Sarawak with range-size rarity of 13.48 – 13.54%. The peak represents Sungai Mengiong, Kapit Division.

Low range-size rarity is concentrated at the middle of Borneo which covers mountain ranges at southwestern Sarawak, East Kalimantan, South Kalimantan, Central Kalimantan and West Kalimantan, especially at western Schwaner Range. Another low range-size rarity concentration is at the focul point of the interior of Sibu Division, eastern Sarikei Division, and western Kapit Division in Sarawak. It includes localities such as Sibu, Julau and Kanowit.

## Hotspots by range-size rarity

Top ten hotspots by range-size rarity are scattered in Sabah and Sarawak (Fig 5). Each of the ten hotspots has range-size rarity of 15.65% or above. Collectively, hotspots 2 – 5 and 7 represent Kinabalu Park. Hotspot 8 stands for localities like Tambunan, Sunsuron and Rompon in Tambunan District, Interior Division. Hotspots 6, 9 and 10 represent Danum Valley Conservation Area. Hotspots 2 – 10 are all in Sabah. Hotspot 1 is the only top ten hotspot by range-size rarity in Sarawak. It represents Tubau and Sungai Pesu in Bintulu Division. It is the only grid cell with range-size rarity above 20.00%.

## Near-minimum sets

A total of 16 near-minimum sets are identified out of the 1,057 grid cells utilized (Fig 6). The near-minimum sets are in Sabah, Sarawak and Kalimantan.

There are nine near-minimum sets in Sabah. Six of these grid cells are at western Sabah and three are at the eastern region. In Sarawak, there are five near-minimum sets.

The remaining two near-minimum sets are in Kalimantan. Both grid cells are at the lowland of West Kalimantan.

Out of the 16 near-minimum sets, four are irreplaceable grid cells (red) while the rest are flexible grid cells (orange). One irreplaceable grid cell is at western Sabah representing localities like Dalit, Kalampon, lower Sungai Dalit, Sungai Sook, Sungai Punti and lower Sungai Keramatoi in Keningau District, Interior Division. Three irreplaceable grid cells are in Sarawak representing northeastern Gunung Mulu National Park and Long Napir in Limbang Division, Tubau and Sungai Pesu in Bintulu Division as well as Batang Ai National Park, Bukit Lanjak and Bukit Tinteng Putar in Sri Aman Division.

## Combinations among hotspots by species richness, hotspots by range-size rarity and near-minimum sets

Combinations among hotspots by species richness, hotspots by range-size rarity and near-minimum sets produced 26 grid cells throughout Borneo (Fig 7). Nineteen grid cells are in Sabah, five are in Sarawak and two are in Kalimantan. Throughout Borneo, there is merely one grid cell that combines a hotspot by species richness, hotspot by range-size rarity and near-minimum set representing Marak Parak and northern Kinabalu Park. On the other hand, combination of a hotspot by range-size rarity and near-minimum set produced three grid cells with two in Sabah and one in Sarawak. Combination of a hotspot by species richness and near-minimum set is observed at one grid cell throughout Borneo; in Sabah. Combination of two types of hotspots, namely hotspot by species richness and hotspot by range-size rarity is at four grid cells in Sabah. Other than the mentioned combinations, there are 11 grid cells which are just near-minimum sets with five in Sabah, four in Sarawak and two in Kalimantan. Grid cells that are just hotspots by range-size rarity are both in Sabah. Lastly, all the four grid cells which are hotspots by species richness are in Sabah.

## GAP analyses

GAP analyses see overlapping of the grid cells produced by the combinations among hotspots by species richness, hotspots by range-size rarity and near-minimum sets with the current protected areas, as well as present human settlements in 22 corresponding grid cells each.

All of the 19 grid cells produced by the combinations among hotspots by species richness, hotspots by range-size rarity and near-minimum sets in Sabah overlap with protected areas or parts of them. A total of 32 protected areas: parks, forest reserves, conservation areas and wildlife reserves, are involved. In Sarawak, only three out of the five grid cells produced by the combinations overlap with protected areas or parts of them. Four protected areas are involved. However, unlike Sabah and Sarawak, both the grid cells produced by the combinations do not overlap with any protected area in Kalimantan.

Except for three, all the grid cells produced by the combinations among hotspots by species richness, hotspots by range-size rarity and near-minimum sets in Sabah overlap with human settlements. In Sarawak, three out of the five grid cells produced by the combinations coincide with human settlements. As for Kalimantan, both the grid cells produced by the combinations coincide with human settlements.

## DISCUSSION

Under the status quo of increasing human-induced disturbances and threats to the environment, having just the know-hows of conservation is not sufficient anymore without owning the ‘know-where’ of conservation. The ‘know-where’ of conservation is acquired through the application of biogeographical data of anurans to prioritize areas for conservation by using WORLDMAP program.

The application of biogeographical data of anurans to prioritize areas for conservation in Borneo by using WORLDMAP program has never been done before. In Borneo, only butterflies (Mahadimenakbar, 1999; Bakhtiar Effendi, 2000), birds (Stabell, unpublished) and palms (Andersen, unpublished) data have been used by other researchers to prioritize areas for conservation.

Species richness analysis of the anurans of Borneo derived from the utilization of 139 taxa from 124 species and 15 groups that have been identified up to their genera. The 15 groups are level 2 data from other herpetologists and institutions. The 124 species represent 86.71% of the total taxonomically described species of anurans in Borneo (Inger & Tan, 1996; Inger & Stuebing, 1997).

Lowland which covers forests from 5 – 800 m above sea level provides a handful of habitats for the anurans of Borneo (Wong, 1994; Inger & Tan, 1996). These habitats are exemplified by sluggish streams with turbid and muddy bottoms as well as muddy banks due to low elevation. There are also streams with clear and rocky bottoms which are rather popular among anurans. Another diagnostic characteristic of lowland is its abundance of rain-filled depressions and temporary puddles, pools and ponds (Abdul Hamid & Wong, 1998). Further away from streams are shallow marshes and grassy fields.

Although Sabah and Sarawak each has 67,994.47 km$^2$ and 114,047.94 km$^2$ of lowland (Perumal, 2001), high species richness is observed only at northern Tabin Wildlife Reserve, northeastern Danum Valley Conservation Area and southern Tawau Hills Park towards the coastal zone of Tawau, all of which are at eastern Sabah, as well as Tubau at northwestern Sarawak.

On the other hand, hilly and lower montane zones from above 800 – 1,200 m above sea level is a haven for anurans despite general postulation that anurans show negative correlation with altitude. Where the topography is hilly with gentle or steep slopes, there is a large variety of streams available. The spectrum ranges from seepages, trickles, slow flowing creeks, tributaries to major streams with sandy or rocky bottoms. There are also still some small rain-filled depressions at flatter areas providing temporary puddles and ponds. Surrounding the streams and rain-filled depressions are trees with strategic overhanging leaves and branches. Each of the habitats further provides a variety of microhabitats to support the greatest diversity of anurans (Inger & Tan, 1996). It is the availability of habitats and microhabitats that plays major role in determining the species richness of anurans (Inger *et al.*, 2000). Therefore, it is justifiable that species richness of anurans is more concentrated at hilly to lower montane zones than lowland, and montane zones in Borneo.

However, species richness of anurans forms a large patch on western Sabah from Kinabalu Park to the tip of Crocker Range National Park. This species richness patch is also the top ten hotspots by species richness for Borneo. The phenomenon is highly attributed to the 'Refugia Hypothesis'. The glaciers from the Second Ice Age have retreated northwards and the cool climate has retreated up the mountains with species that have adapted to the climate (Inger & Tan, 1996; Plummer & McGeary, 1996; Cox & Moore, 2000; McNeely, 2000). Therefore, an assemblage of 'montane species' is grouped at the mountains like Gunung Kinabalu and Crocker Range. These become the refugia where organisms isolated by the habitat changes resulting from the periodic cold and dry periods of ice ages were able to survive until conditions returned to their former state and the organisms could then move out once again (McNeely, 2000). This explanation is also valid to elucidate the distributions of 'montane species' of anurans among Bornean mountains and mountain ranges across lowland gaps (Inger & Tan, 1996).

High range-size rarity is obvious at montane zones in Borneo. Anurans that live at high elevation have restricted distribution because they have adapted to the montane climate which does not exist throughout Borneo. Montane zones merely represent 6,007.22

$km^2$ of Sabah and 9,869.56 $km^2$ of Sarawak (Perumal, 2001). Hence, the total inverse range sizes covered by each species or the range-size rarity is high at montane zones.

Low species richness and range-size rarity of anurans are at the mountainous central Borneo. The reason behind this could be a mixture of the actual distribution, and paucity of biogeographical data of anurans from Kalimantan. As stated earlier on, montane zone is not favourable to most anurans. At the same time, relatively limited anuran inventories have been done in Kalimantan as a result of political as well as geographical causes (e.g., Das, 1995, 2002; Inger & Stuebing, 1997; Sutton, pers. comm.).

For all 139 taxa of anurans to be represented at least once in the 1,057 grid cells for Borneo, it takes 16 near-minimum sets. The near-minimum sets correspond to a mere 1.51% of the total land mass of Borneo. Smaller coverage of near-minimum sets reflects better efficiency in the prioritization of conservation areas.

The near-minimum sets proffer a complete representation of the anurans diversity of Borneo and thus, hotspots by species richness can be ignored at this stage in order to avoid redundancy in representation. It is so unless the hotspots by species richness exist in combination with hotspots by range-size rarity and/or near-minimum sets.

Therefore, 22 conservation priority areas (grid cells) in Borneo were identified by using WORLDMAP on the biogeographical data of anurans. The conservation priority areas cover the montane zones of Kinabalu Park, Crocker Range and Gunung Lumaku Forest Reserve, lowland to lower montane zones of Danum Valley Conservation Area, northwestern Maliau Basin Conservation Area and northwestern Tawau Hills Park in Sabah, montane zone of northeastern Gunung Mulu National Park, lower montane zone of Sungai Mengiong as well as lowland zones of Tubau, Batang Ai National Park and Kuching in Sarawak, as well as Sanggau and Kubu in West Kalimantan.

Eighteen of the conservation priority areas are already in the current protected areas network. The other four conservation priority areas: Tubau and Sungai Mengiong in Sarawak, as well as Sanggau and Kubu in West Kalimantan, are to be suggested as new protected areas in Borneo in order to achieve complete representation of the diversity and high range-size rarity of the anurans of Borneo.

Out of the four suggested new protected areas in Borneo, Tubau (Sarawak), Sanggau and Kubu (West Kalimantan) coincide with human settlements. The gazettment of protected areas at present cannot dismiss local communities, so they have to be involved and more importantly, made an active part of conservation efforts. As articulated by Fjeldsa & Rahbek (1998) and Fjeldsa (2000), the management of these suggested new protected areas needs to encompass political processes which include establishing and promoting new kinds of land use that are more environmentally sustainable.

The new kind of land use that is more environmentally sustainable is none other than nature tourism. Promoting the environment for paying tourists to admire and enjoy, not only help to create more environmental awareness among the people: local and international, but also generate more revenues to propel conservation efforts. The outcomes from the prioritization of areas by using WORLDMAP can also be utilized for tourism prospecting in locating touristic sites with full information of the existing diversity of an organism group within the identified sites. For example, locating sites for a new nature tourism product, namely ‘Anurans Tourism’.

Indeed, prioritization of areas is a powerful process in conservation whether for locating new protected areas or/and touristic sites. In order to ensure that the impacts reach far and wide, therefore, integrated effort is needed too in the dissemination and utilization of outcomes from the prioritization of areas (Stratum 3).

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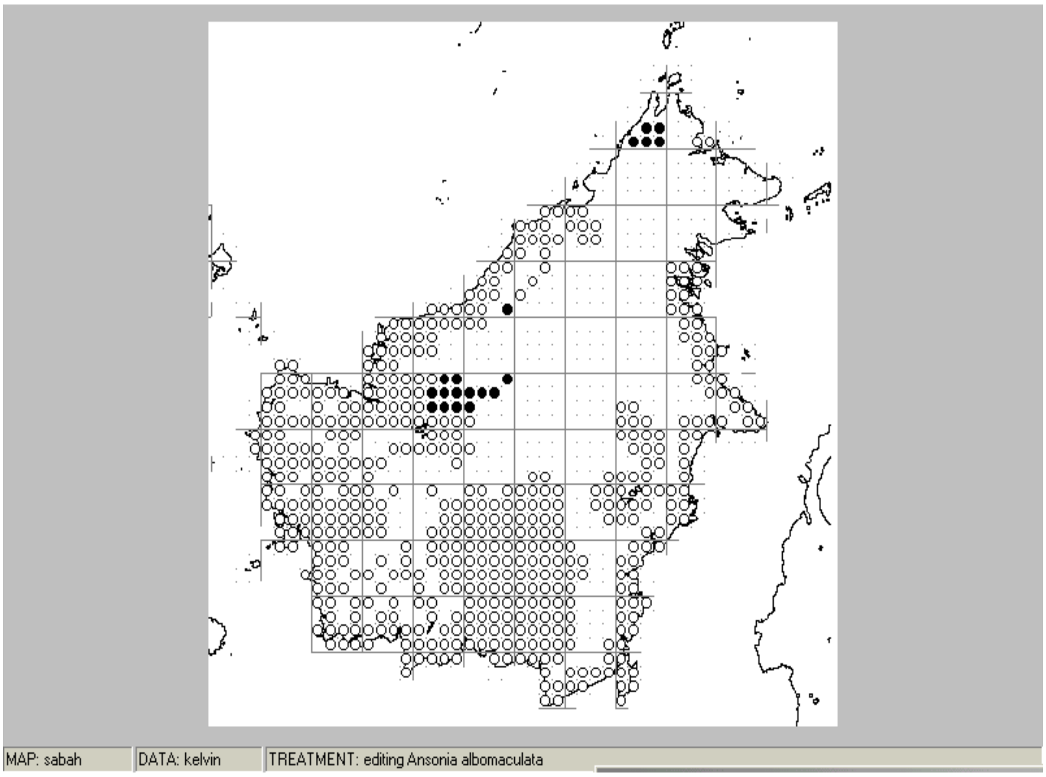


**Fig 1** An example of the data of *Ansonia albomaculata* digitalized into WORLDMAP program.

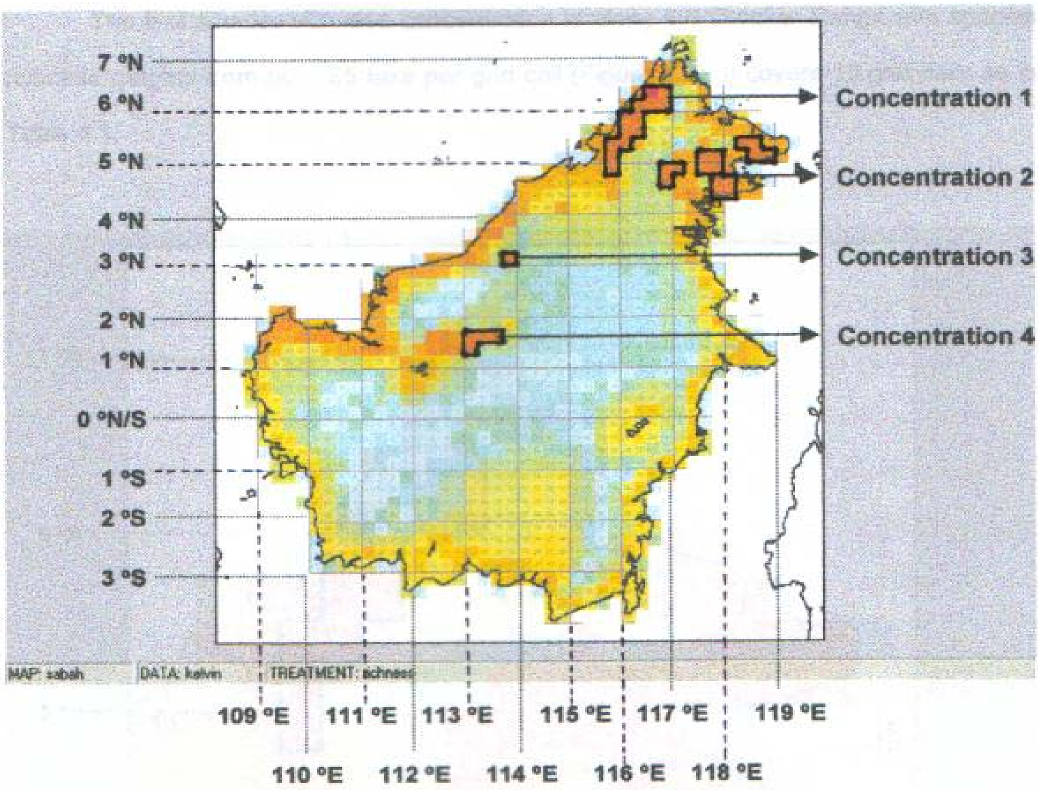


**Fig 2** Species richness of the anurans of Borneo.

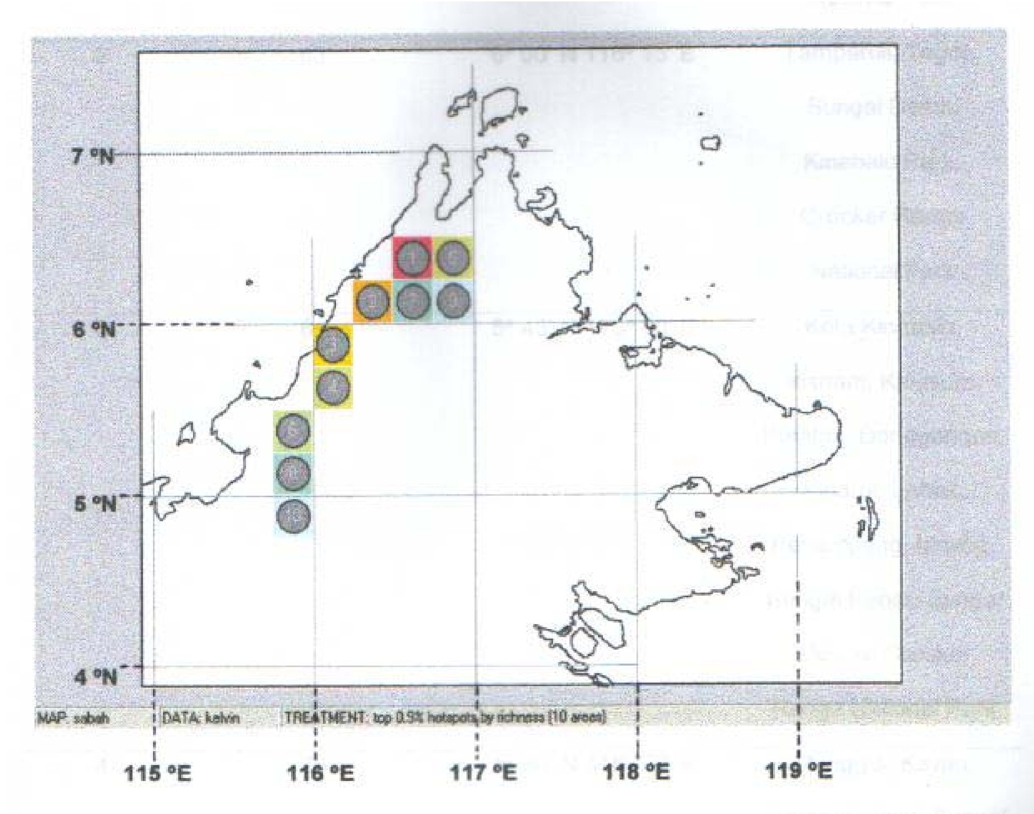


**Fig 3** Top ten hotspots by species richness of the anurans of Borneo.

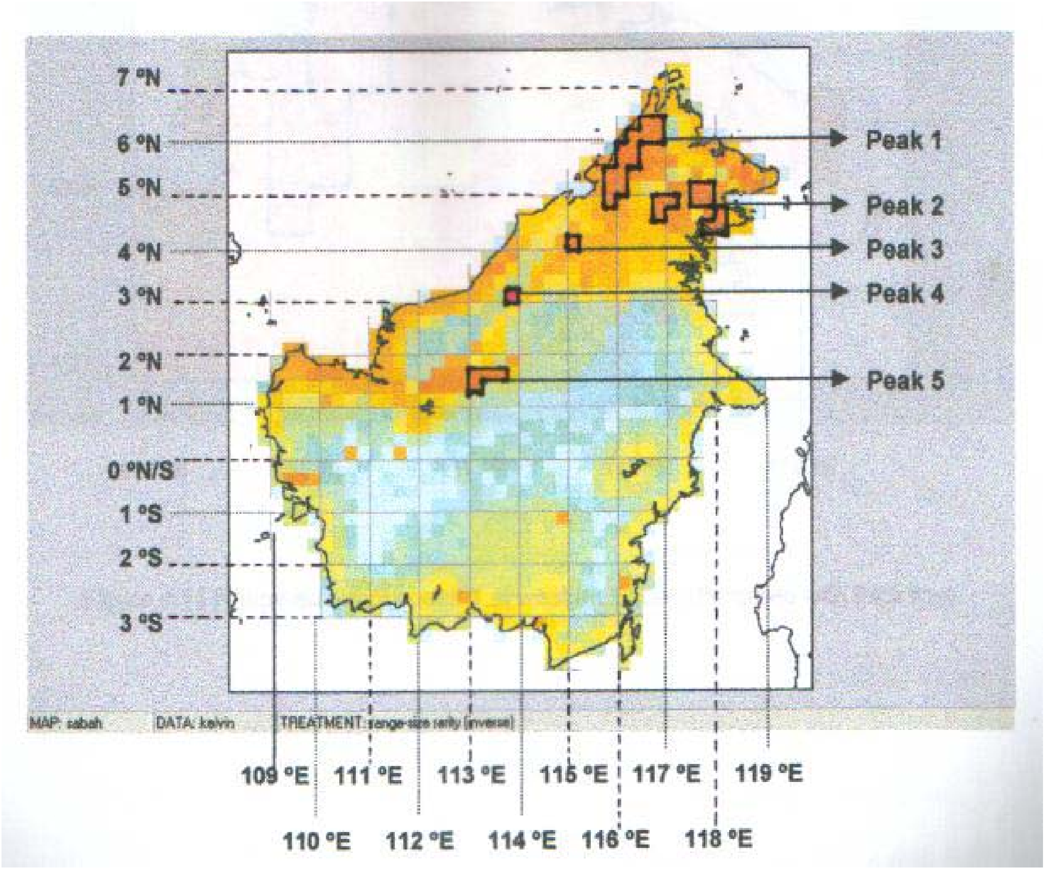


**Fig 4** Range-size rarity of the anurans of Borneo.

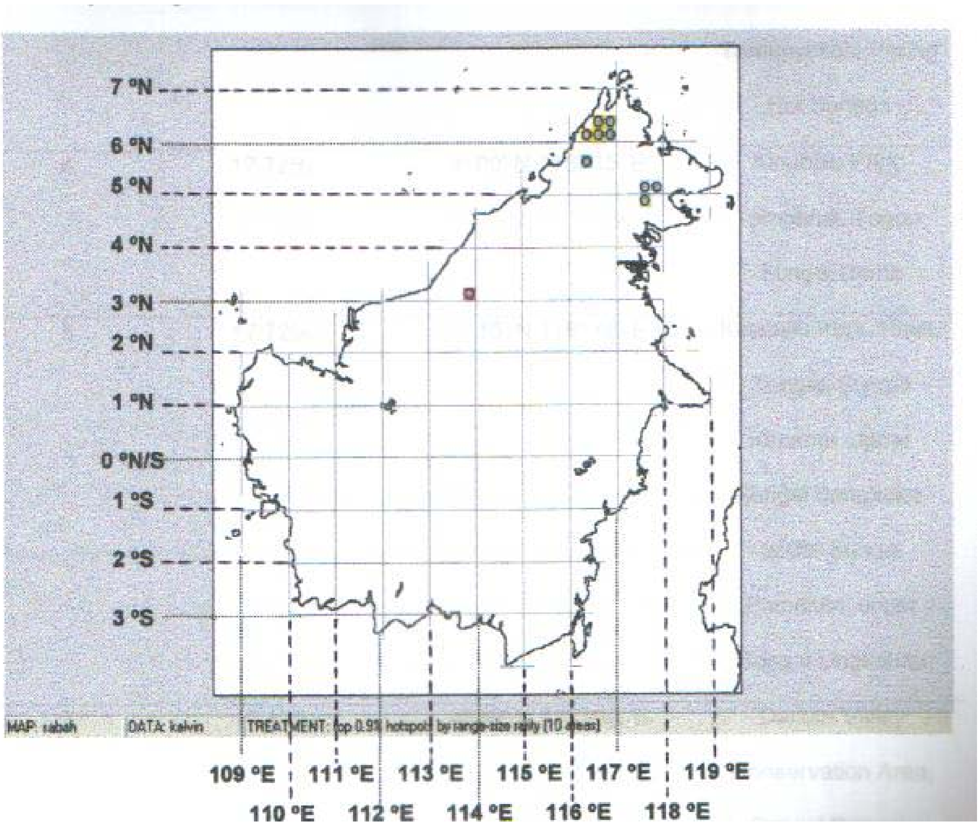


**Fig 5** Top ten hotspots by range-size rarity of the anurans of Borneo.

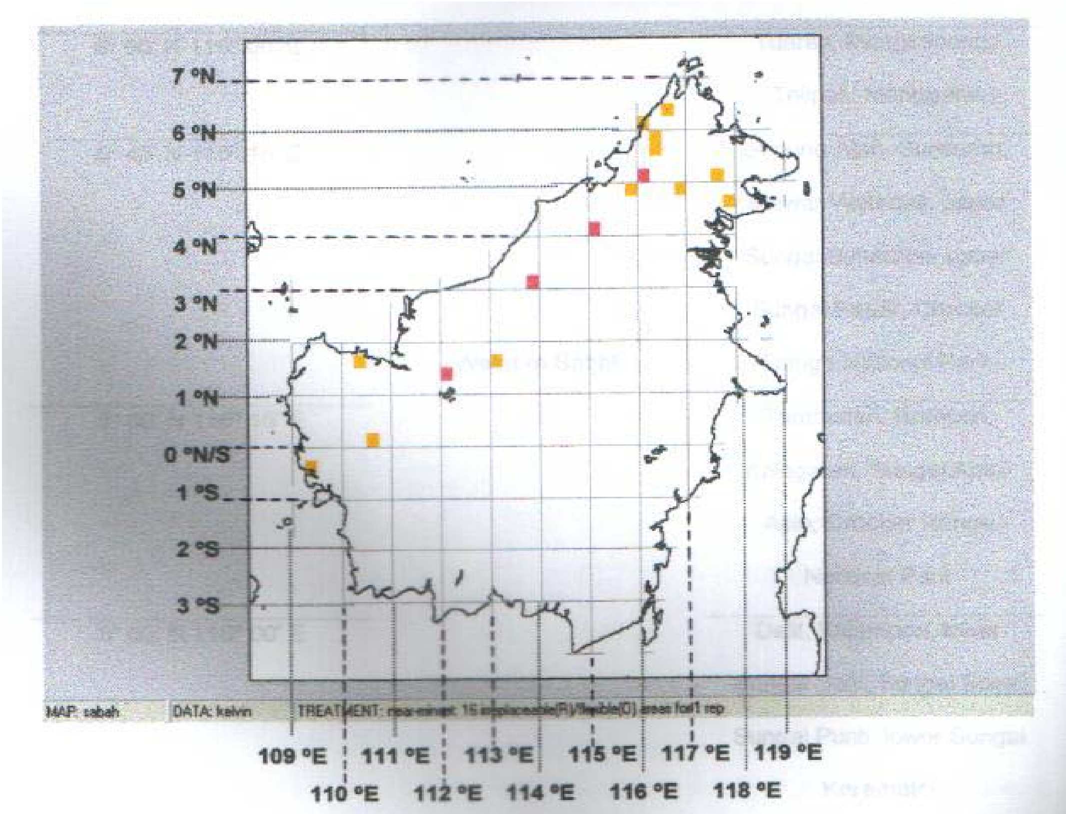


**Fig 6** Near-minimum sets of the anurans of Borneo.

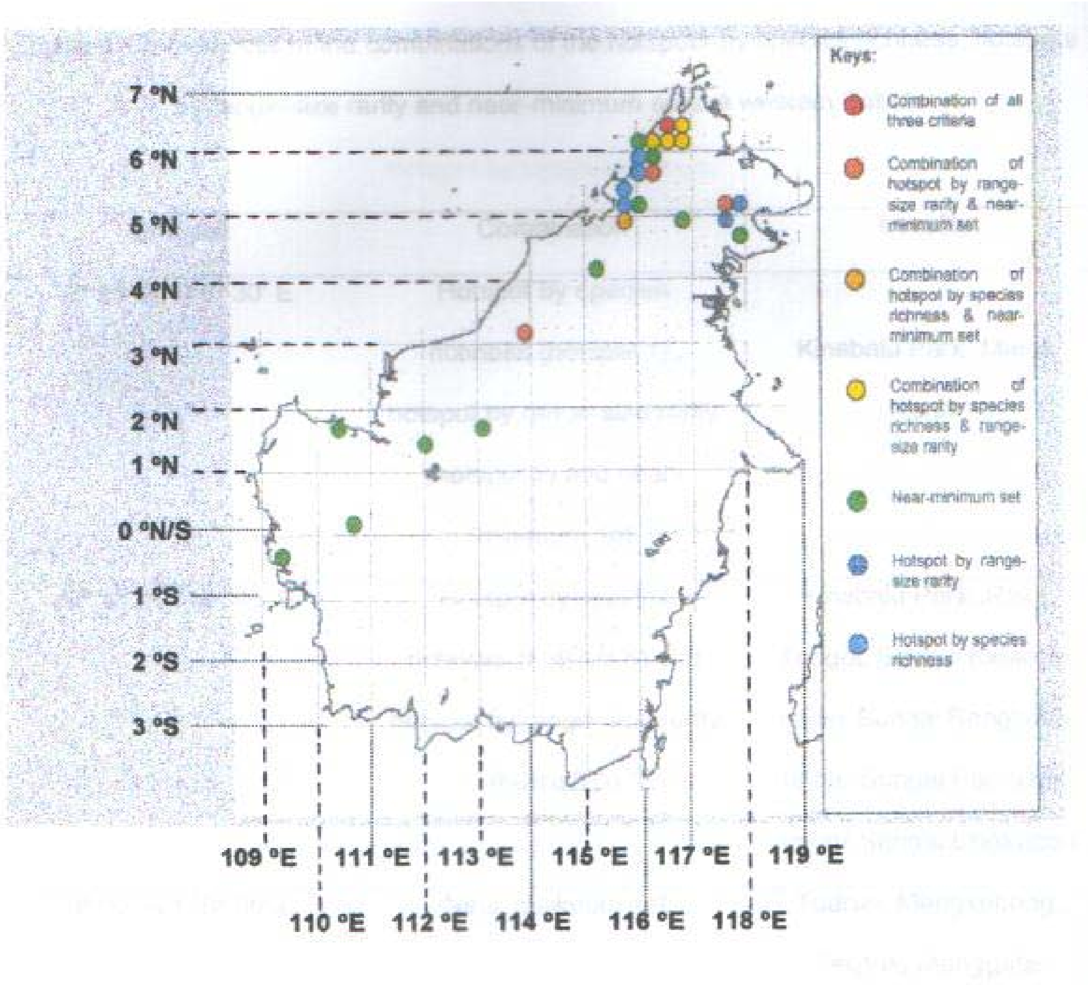


**Fig 7** Combinations of the top ten hotspots by species richness, top ten hotspots by range-size rarity, and near-minimum sets.