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CONSERVATION OF RAIN FOREST MAMMALS IN SABAH: LONG TERM PERSPECTIVES

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ABSTRACT. — The two authors of this paper commenced their careers under the guidance of the Earl of Cranbrook, in Sabah in 1979, when the timber boom was under way, and when knowledge of the mammal fauna was rudimentary. A faunal survey of Sabah conducted in 1979–1982 provided a baseline and recommendations on forest conservation relevant especially to the large mammal species reckoned to be threatened by logging and forest loss at that time. This paper traces some of the major changes in forestry in Sabah, the establishment of the forest estate, and the replacement of a long-cycle selective logging system by over-logging and conversion of forest to plantations. The visionary Sabah Forestry Department has tried to maximise the extent of forest retained and its value to species conservation in the face of inevitable political, social, and economic pressures, and has largely succeeded. The situation regarding Sumatran rhinoceros, Bornean elephant and Bornean orang-utan in Sabah is described, along with the surprising changes in our perception of the conservation needs of these iconic species since 1982.

KEY WORDS. — Borneo, conservation, elephant, Malaysia, mammals, orang-utan, rain forest, rhinoceros, Sabah

INTRODUCTION

Sabah (7.36 million hectares) represents the northern 10% of the island of Borneo and is the second largest State in the Federation of Malaysia. This supplementary volume of the Raffles Bulletin of Zoology presents an opportunity to reflect on the changing perceptions and understanding of Sabah's mammal fauna since the Second World War, and to look at the conservation approaches that have been proposed as our understanding has changed. We examine how ecological studies have informed mammal conservation and how this is affected by state conservation, forestry, and development policies. In 1979–1982, midway through the period in question, a state-wide survey was conducted to inform conservation thinking in a systematic way. That *Faunal Survey of Sabah* (Davies & Payne, 1982) is therefore taken as a reference point for discussion about the changes that have occurred in recent times.

The chronology of zoological expeditions to Borneo, including Sabah, is well documented in the second edition of Medway's Mammals of Borneo (Medway, 1977, following an earlier edition in 1965). This was a foundation text, widely used in the 1970s and 1980s to provide a clear and systematic description of mammal names and their distribution within Borneo, which guided ecological and conservation research. As noted in the preface to that volume, much of our understanding of mammals in northern Borneo stemmed from the work of the Museum officials and collaborators in the adjacent state of Sarawak, especially in the 1920s and 1930s. Expeditions to Sabah in the post war years, including a number that focused on the flora and fauna of Mount Kinabalu (4,095 m), further clarified our understanding (Medway, 1977). An excellent monograph produced in the 1960s, and published in the Bulletin of the National Museum of Singapore, is by D. Dwight Davis of the Chicago Field Museum, in which he records most of Sabah's lowland mammal species with excellent notes on ecology and relative abundance (Davis, 1962).

Both the Sabah mammal fauna and their habitats can be divided for convenience into various categories (Davis, 1962; Davies & Payne, 1982; Payne et al., 1985). In this chapter we focus on the large mammal fauna of the lowland dipterocarp forest, epitomised by orang-utans *Pongo pygmaeus*, gibbons *Hylobates* spp., red and grey leaf-

monkeys *Presbytis rubicunda* and *P. hosei*, and a wealth of squirrel, ungulate, and small carnivore species. Population densities of these species generally decline with increasing altitude, and another faunal assemblage emerges as the vegetation changes to montane forests, dominated by oaks, laurels, myrtles, and conifers. There are distinctly different riverine habitats, along the lower reaches of major rivers—typified by the association of proboscis monkeys *Nasalis larvatus*, silver leaf-monkeys *Trachypithecus cristata*, and long-tailed macaques *Macaca fascicularis*, and nearer the coast mangroves and nipah palm predominate. In this paper, we consider conservation of lowland forests, taking orang-utans as a recognisable icon of this habitat. The Sumatran rhinoceros *Dicerorhinus sumatrensis* represents a species on the brink of extinction primarily through long-term hunting pressure for its horn. The rhino is therefore discussed to focus attention on a species which needs urgent and bold conservation attention beyond just habitat maintenance, while the elephant *Elephas maximus* in Borneo is discussed as a large mammal species that may have recovered from a uniquely extreme population bottleneck.

To complete this introduction, we record that both authors began their Borneo careers in Sabah in 1979, as employees of WWF-Malaysia when Ken Scriven was the Director, and David Wells and the Earl of Cranbrook (then Lord Medway) were scientific advisers to the Faunal Survey of Sabah (WWF/IUCN Project 1692)—and we acknowledge the guidance we received in those early years. Furthermore, Cranbrook was the external examiner for both authors' PhDs, and we can vouch for his incisive questions and great knowledge. This was, however, combined with a sense of humour, a passion for field work, and a concern to share, teach, and encourage—without rank or side. A particular feature of Cranbrook's published papers is their characteristic combination of narrative style, quantitative data, and ideas that are not necessarily backed by other published papers. This way of thinking and writing is not only very rare, but may result in rejection by the majority of journals. We respectfully dedicate this chapter to the independent thinking which Gathorne called for and exemplified.

NEW TECHNOLOGIES, NEW ECOLOGIES

For early studies of mammals in Borneo, which include Wallace's now rather distressing reports of how animals were slaughtered to secure good specimens to send to private collectors and museums in Europe, our understanding depended on skins and skeletons, with labels often lacking or inaccurate (Wallace, 1869; Medway, 1977). These were supplemented with fossil studies, again dependent on skeletal material (Hooijer, 1960; Medway, 1977). This pattern began to change in the 1960s, with the beginning of a surge of ecological field studies, pioneering in making direct observations of wild animals in the dimly lit, dense old-growth rainforest vegetation which dominated Sabah at the time, and these included early descriptions of the ecology and social behaviour of orang-utans (e.g., Davenport, 1967; Horr, 1972; MacKinnon, 1974). This required that the guns and traps of previous expeditions be replaced with binoculars, tape-recorders and (when the foliage allowed) cameras. Researchers walked through the forest—very occasionally climbing trees or using small boats—straining to extract data from glimpses of elusive study animals. Detailed understanding of the ranging and feeding patterns, and social behaviour, gradually built up through these surveys and studies as the sightings, sounds, and signs (e.g., footprints and nests) of living specimens were recorded, analysed, and interpreted. These data, in turn, informed conservation policy and planning.

In the mid 1980s, the first major technical innovation which moved research from walking transects to glean information from largely ad hoc observations of animals in the trees, with a few systematic studies of diurnal, arboreal species, was the use of helicopter surveys to count orang-utan nests from above the forest canopy. This technique, stumbled on by chance during a preliminary survey of the Lanjak Entimau Wildlife Sanctuary in Sarawak by the Sarawak Forestry Department, WWF-Malaysia, and Royal Malaysian Air Force (Kavanagh, 1982), transformed our understanding of the species' distribution and abundance when applied in Sabah through a similar collaborative effort (Payne, 1988). By the mid 1990s, another technological step was taken with the arrival of camera trap technology (i.e., setting of many cameras in the forest, to "trap" pictures of wild animals that otherwise are very rarely seen) that could withstand the humidity that had undone many electronic gadgets previously. The wealth of "camtrap" images, of diurnal, crepuscular, and nocturnal species, has substantially increased our understanding of the distribution and abundance of ungulates and carnivores on the forest floor (e.g., Azlan et al., 2009). Similarly, satellite tracking devices embedded in collars and transponders became more reliable and economical for monitoring both large and small mammals (e.g., Heydon & Bulloh, 1997; Emmons, 2000; Wells et al., 2006).

The most recent technological progress has been genetic analyses using DNA from blood, skin tissues, hairs, and even faecal matter, which can allow detailed understanding of taxonomy and, potentially, be used to investigate population size. Pioneering work in Sabah on molecular phylogenetics commenced with Frederick Sheldon and collaborators (e.g., Sheldon, 1987) and this has been developed in the past decade for mammals (Goosens & Ambu, 2012), leading to knowledge and insights that would have been unimaginable 40 years ago. And in the context of ex situ conservation, improved understanding of the physiology and reproductive biology of rare large mammals has provided key tools for captive management of species (e.g., Schaffer et al., 1994; Hildebrandt et al., 2011).

To explore how such changes in technology have changed our understanding, we consider below studies of ecology and surveys of populations of three of Sabah's rarest large mammals, and track how new knowledge has led to different recommendations for conservation. They are: Sumatran rhinoceros, Bornean elephant and Bornean orang-utan—all flagship species for conservation in Sabah.

It is, of course, salutary to remember that other technologies have fast evolved over the past 80 years. We have come a long way since the 1950s, when Iban tribesmen walked from Sarawak to fell trees for logging licence-holders, using hand-axes. The introduction into Sabah in the 1950s of the chain-saw and bulldozer tractors allowed access far beyond large waterways for transporting logs and with it felling on scales never imagined in the 1950s. Helicopter logging added to the scale of potential exploitation from the 1990s, by allowing logs to be taken from very steep lands where even bulldozers cannot reach.

SUMATRAN RHINOCEROS *DICERORHINUS SUMATRENSIS*

The Sumatran rhinoceros is the most ancient line amongst the five living rhinoceros species, now on the brink of extinction. A few centuries ago found throughout Southeast Asia, all literature on this species shows that its distribution and numbers were severely depleted by the mid 20th century. The species was already regarded as very rare and endangered in Sabah by 1961 (Burgess, 1961), yet less than a century before rhinos had been reported as "not infrequent" and were sometimes found even in Sandakan gardens (Pryer, 1881). Payne (1990) showed that isolated ones or twos of rhinos occurred in many parts of eastern Sabah as recently as the 1970s, but the species quickly became extinct at most sites during the 1980s.

Pressure from hunting of rhinos for their horns (a mainstay of ancient Chinese medicine) has likely been on-going for over a millenium. Rabinowitz's (1995) polemic on "helping a species go extinct" identified hunting and habitat loss as the causes of the Sumatran rhino's decline. Cranbrook (2009) points to the long inter-birth interval of these taxa, and refers to Brook & Johnson's (2006) modelling of different levels of off-take applied to large mammals, whereby a small increase in juvenile mortality can hold recruitment rates below a level needed to replace breeding adults. The idea that hunting by humans, whether using traps, spears or blowpipes, could have been the sole or main factor that caused the extermination of the ecologically-similar Javan rhino and (non horn-bearing) Malayan tapir from Borneo is difficult to imagine, however, especially while the Sumatran rhino, also persecuted for its horns, survived. The extinction of these two related species from Borneo when the human population was tiny and scattered, and before the advent of firearms, suggests that natural factors may have played a role in the low population density of rhinos. Disease might also have played a role, although this is likewise difficult to imagine for a sparsely-distributed solitary animal in a high-rainfall environment.

More plausibly, poor food quality might contribute to poor breeding of rhinos in rain forests, and the less fertile the soil, the poorer quality rhino food is likely to be. An anecdotal comparison may be relevant. Sumatran rhinos kept in captivity at Tabin Wildlife Reserve (which has clay-rich soils, sloping land, and year-round rainfall) select leaves from pioneer tree and liana species as food, and normally reject leaves from woody plant species characteristics of closed-canopy forest; these rhinos are given daily supplements of horse pellets, to help maintain body weight, which tends to decline in the absence of this supplementary food. In contrast, Sumatran rhinos kept in captivity at Way Kambas in Sumatra (with sandy soils, flat terrain, and seasonal rainfall) willingly take a much wider array of plant species and do not need supplementary food to maintain body weight.

Davies & Payne (1982) noted that all Sabah rhino records compiled in 1981 showed that a natural salt source or mud volcano was present within a maximum of 14 km for all records, suggesting that the species distribution may be limited by access to certain minerals (most likely sodium and/or kaolin clays). Widodo Ramono (pers. comm.) who has over many periods since 1964 visited Ujung Kulon National Park, the location of the last remaining Javan rhinos, where plant composition is still changing through natural succession, believes that closed canopy rainforest is not ideal habitat for this species. Leaving aside the clearly very negative impact of hunting on this species, perhaps the Sumatran rhino is now found only in very marginal habitats in Sabah, lacking the right combination of soil, leaf productivity, and forest successional stage to allow regular breeding to occur.

The Faunal Survey of Sabah estimated that between 15–30 rhinos remained in Sabah in 1982, with the only evidence of breeding at that time found in and around the Tabin river catchment in the Dent Peninsula. A recommendation to establish a conservation area, Tabin Wildlife Reserve, was approved by the Government of Sabah in 1984, and a plan to capture and utilise the scattered rhinos outside that area as part of a globally managed captive population was pursued by the Sabah Forestry Department and WWF-Malaysia with the American Association of Zoo Parks and Aquariums. In 1984, the IUCN Species Survival Commission Captive Breeding Specialist Group, on behalf of the IUCN, convened a three-day meeting in Singapore to "formulate an acceptable plan for a captive propagation project as part of the overall strategy for the conservation of the Sumatran rhino". Twenty participants representing governments of the three main Sumatran rhino regions (Indonesia, Peninsular Malaysia, and Sabah), zoos and others, agreed to a plan to, firstly, prioritise conservation of wild Sumatran rhino populations and, secondly, form a loosely-coordinated global captive population drawn from rhinos outside protected areas.

Eight natural forest habitats containing Sumatran rhinos were protected in the three main Sumatran rhino regions, and 40 rhinos were captured for the captive breeding programme between 1985 and 1995, from areas converted to plantations. Subsequently, the wild populations in the eight areas have mostly stagnated, declined or gone extinct. The captive breeding was a failure, except in Cincinnati Zoo (in collaboration with several other US zoos), where three young were born at intervals of two years and 10 months between 2001 and 2007. Contrary to the adverse assessment of some observers (notably Rabinowitz, 1995), the failure of breeding in captivity was due to a combination of bad

luck (many of the rhinos caught were either old, injured by snare traps prior to capture, infertile or sub-fertile) and bad decision-making by the various parties involved (not mixing rhinos from the different regions of capture, poor sharing of information, and poor management and veterinary care in some of the facilities involved).

By the 1980s, the very few remaining wild rhinos may not necessarily have been in contact with each other. Humans look at maps of large forest areas, and see scattered records of rhinos, and may make the assumption that all the rhinos (and "all" may mean perhaps less than five) are in regular contact. Female rhinos have individual home ranges of probably less than about 2,000 ha, so they will be available for mating only if any remaining males, which have larger home ranges, actively seek the females. Females cycle at intervals of about 22–27 days, and are receptive to mating for only one or two days per cycle. Thus, the prospects for successful natural mating are very small when rhino numbers are very low. Important lessons need to be learnt from the 1984–1995 captures of 40 Sumatran rhinos. At least half the female rhinos caught between 1984 and 1995 had reproductive tract pathology (Schaffer, 2001), a phenomenon associated with lack of either breeding or carrying of foetuses to successful birth that appears to particularly afflict rhinos (Hermes et al., 2006). The fact that at least some wild female Sumatran rhinos have exhibited this pathology at time of capture indicates that not all wild female rhinos are breeding, presumably due to insufficient fertile males to meet and mate. This point is compounded by the slow breeding rate. For wild Sumatran rhinos, actual overall birth frequency is likely to have been much less in recent decades than achieved in Cincinnati Zoo, because of the paucity of sites with fertile females and males present, further limiting prospects of population recovery of wild Sumatran rhinos in Sabah.

Rookmaaker et al. (1998) report that Skafte (1964) caught nine rhinos within the Siak River area, Riau, Sumatra, in 1959, of which only one was a male. No similar story has been reported before or since. In retrospect, it seems most plausible that Skafte happened to locate one of the very last places where the Sumatran rhino existed in a relatively non-depleted state, with a higher population density than has been otherwise recorded. The skewed sex ratio might have reflected a reality of more females than males in one locality. A severe bias in sex ratio in the opposite direction was observed in Sabah where, between Mar.1987–Nov.1995, a total of 10 rhinos were captured. Of those, nine were caught within an area of about 100,000 hectares which would, up to around 1980, have been contiguous forest cover. Of the nine, one was a mature female and eight were mature males. There are unlikely to have been many, if any, rhinos not located during the conversion of this 100,000 ha of forest. Thus, the remnant rhinos in this small population were almost all mature males. The only rhino caught outside that zone, in Apr.1989, was a young female that had arrived near a major road and which may have come from Tabin Wildlife Reserve, the nearest large block of forest some 25 km away in a straight line.

In Sep.2005, two immature female rhinos were caught in Sumatra, each having apparently moved into inhabited semi-forest areas from Bukit Barisan Selatan and Way Kambas National Park. Not much can be gleaned from these records, and as rhino numbers continue to decline, similar records will never be made again. It is clear, however, that a biased sex ratio may occur in very small populations of Sumatran rhino. The observations from Sabah also suggest that female rhinos, potentially easier to locate than males because of their smaller home ranges (van Strien, 1985), had already been selectively taken by hunters before the start of trapping for the global captive breeding programme. Also, despite the very small sample size, the three cases of young female rhinos moving out of forest into areas inhabited by humans suggests that young adult rhinos may tend to move far from their natal area.

In retrospect, biologists concerned with the species should by the 1980s have considered the relevance of the Allee effect (Allee, 1931), which refers to a phenomenon whereby a positive correlation exists between individual fitness (survival probability, fertility, reproductive rate) and population density of the species (Courchamp et al., 2008). As numbers of individuals decline, the various factors associated with very low numbers (e.g., narrow genetic base, locally skewed sex ratio, difficulty in finding a fertile mate, reproductive pathology associated with long non-reproductive periods) conspire to drive numbers even lower, to the extent that death rate eventually exceeds birth rate, even with adequate habitat and zero poaching. Wild populations may have been "doomed" to extinction before the 1980s. Members of voluntary societies, academics in fields other than biology, politicians, and journalists became attracted the to the plight of the Sumatran rhino in Sabah in 1984, but this had the unfortunate effect that public debate on some emotive but unproductive issues (such as the definition of "doomed") took precedence over rational decision-making.

Based on examination of the skulls of a total of only 13 rhinos from Borneo, Sumatra, Malaya, and Burma, Groves (1965) concluded that the Borneo form is "markedly smaller" with a forward-sloping occiput (back end of skull), and therefore ranks as a distinct sub-species (*D. r. harrissoni*), with *D. r. sumatrensis* regarded as a single form occurring in Sumatra and Peninsula Malaysia. Despite the small sample size and subjective nature of the judgement, this publication was used amongst various reasons for Indonesia, Peninsular Malaysia and Sabah to not exchange rhinos in the 1984 IUCN agreed global captive breeding programme. Zainal Zahari Zainuddin (pers. comm.), however, noted that of the 12 Sumatran rhinos captured in Peninsular Malaysia between 1984 and 1994, there was considerable difference in body size, with adult rhinos from the peat swamp of northern Selangor being generally smaller than those from mineral soils elsewhere. Cranbrook (1986) indicated not only that the Sumatran rhino in both Sumatra and Borneo has diminished in size by between 10% and 20% since the Pleistocene but, in numerous papers and discussions, that Borneo, Sumatra, and Peninsular Malaysia would have been linked by land traversable to large mammals until around 20,000 years BP.

Based on mitochondrial DNA, Amato et al. (1995) concluded that all Sumatran rhinos in Indonesia and Malaysia should be regarded as a single conservation unit. These results are of great significance: the Sumatran rhinoceros is so highly endangered that mixing of Bornean and Sumatran forms in captive situations represents a potentially significant means to increase the number of births. Unfortunately, Groves' 1965 paper successfully kept rhino "experts" squabbling for 48 years on whether to mix rhinos from different regions for captive breeding purposes, until Goossens et al. (2013), using only a review of old data, concluded that the basis for sub-specific separation is weak. But in the meantime, 39 of the 40 rhinos caught between 1984 and 1994 had died and only one pair had bred, in Cincinnati Zoo.

Without bold new actions, it is clear that the species will go extinct. In order to prevent extinction, governmental policies, and actions to be taken, need to focus on maximising births of Sumatran rhinos. Every rhino counts, including the sub-fertile females which produce ovarian follicles, but which have too much endometrial cyst growth to allow fertilisation and implantation of embryos. By 2013, however, the number of wild Sumatran rhinos remaining is too small for a reliable estimate to be made of numbers at any one area. The low number suggests that not all will have access to fertile mates. Thus, even if not poached, wild Sumatran rhinos are likely to die of old age without breeding. Wild rhinos with reproductive tract pathologies may be potentially fertile, but need special treatment in managed conditions to allow successful pregnancies to occur. The only way now open to preventing the species' extinction is by a truly collaborative global programme of captive breeding. The situation of the Sumatran rhino is approaching that of the European bison, which almost went extinct during the First World War, but was saved by the lucky fact that a few tens remained in zoos (all descended from 12 individuals) and that in 1923 an International Society for Protection of European Bison was founded in Germany to promote international collaboration on captive breeding for re-introduction to forest areas (Pucek et al., 2004).

In 2009, the Government of Sabah approved the Borneo Rhino Sanctuary programme, involving capture of wild rhinos for translocation to fenced breeding facilities in Tabin Wildlife Reserve. This is in many ways modelled on the pioneering Sumatran Rhino Sanctuary, established in Lampung province, Sumatra, Indonesia in the late 1990s. The pace of the Sabah programme has been slow, for several reasons, including the local extinction in recent years of rhinos from the targeted capture areas, including inside Tabin, from where the last known wild rhino was caught in 2011. At time of writing, captive rhinos in Sabah consist of one mature male, one post-reproductive old female, and one sub-fertile female with reproductive tract pathology. The non-availability of governmental funds between 2009 and 2012 for building permanent facilities to hold rhinos also acted to slow progress of the programme. The programme has survived and been operational only through grants, collaborative discussion and technical assistance from Sime Darby Foundation, WWF-Germany and the Leibniz Institute for Zoo and Wildlife Research (Berlin).

By 2012, the only known location containing wild Sumatran rhinos in Sabah (and Malaysia) was Danum Valley Conservation Area. Government approval was given in 2013 to build holding facilities for rhinos at Danum Valley, and to capture wild rhinos from Danum Valley. Government also endorsed the idea to develop rhino reproductive laboratory facilities in Sabah, and the exchange of gametes (sperm, eggs and other reproductive materials) between Sabah and other countries. In essence, the Government of Sabah has agreed to not be concerned exactly where rhinos are managed, or by whom, but instead that all rhinos should be managed to maximise their contribution to preventing extinction. Such rational thinking is essential when a species reaches very small numbers, and when emotion and national pride may dominate decision-making.

An international meeting on Sumatran rhinos held in Singapore Zoo, 31 Mar.–4 Apr.2013, named the Sumatran Rhino Crisis Summit, involving about 100 participants from governments, NGOs, zoos and various relevant institutions, repeated the 1984 calls, but emphasised Indonesia-Malaysia collaboration, a need for detailed information on wild populations in Indonesia, and use of advanced reproductive technologies for rhinos in fenced, managed facilities.

As an interesting additional note, Cranbrook & Piper (2013) have alluded to the potential of large forest or plantation areas for the secure reintroduction of Borneo's lost 'megafauna', the most obvious of which is the Malayan tapir. It is clear that the tapir went extinct in Borneo in recent times, possibly as recently as the early twentieth century (Cranbrook, pers. comm.). Thus, bringing Malayan tapirs to Borneo from Peninsular Malaysia or Sumatra via a managed programme can be viewed as re-introduction. If tapirs are to be brought back to become a member of the Bornean fauna, the potentially ideal habitats are now available in abundance: heavily logged forests with pioneer regrowth, and plantations. The idea of having large mammals living wild in plantations is one that is confined more by mind-set than by rational thought. If left without weeding, woody undergrowth can become abundant under both oil palm and industrial wood plantations, thereby providing a potentially suitable tapir diet.

BORNEAN ELEPHANT
ELEPHAS MAXIMUS

Both authors of this paper, on arrival in Sabah in 1979, quickly became aware of a prevailing idea amongst many Sabahans that the elephant had been introduced into Borneo by humans. A common notion that the wild elephants were the offspring of tame elephants used for logging before the advent of bulldozers could be quickly rejected for many reasons, not least that fact that there were an estimated 2,000 wild elephants in Sabah by the mid-20th century. The older view was that Sabah's elephants had been left on the

eastern tip of the State by the Sultan of Sulu some centuries previously. Occam's razor at that time tended to favour the view that the elephant would be a native species. How could it be possible that humans had brought elephants to Borneo, presumably in considerable numbers on sailing ships – there was, in fact, an apparently substantial and long distance seaborne trade in elephants from Kedah to India; elephants were definitely on regional shipping in the relevant era—and that from just a few individuals the species could have thrived till the present day as a wild population?

Two papers were published in 2003, with glaringly different interpretations of available data. Based on mitochondrial DNA, Fernando et al. (2003) demonstrated that the Sabah elephant was more similar to elephants in Sumatra and Peninsular Malaysia than those elsewhere, but that the Sabah elephant was distinctly different from both, with a very long period of separation between the Borneo and other populations. The paper concluded (understandably on the basis of the molecular evidence alone, though on balance erroneously in the light of subsequent evidence) that "Asian elephants are native to Borneo". Malaysian polymath Mr Shim Phyau Soon (Shim, 2003) suggested that the feral elephants reported on Jolo island (southern Philippines) in the 18th and early 19th century and the Sabah population might have descended from the now extinct Javan elephant, based on the absence of convincing archaeological evidence of the presence of elephants in Borneo, on folklore and on the fact that elephants have not occupied the entire island of Borneo.

Subsequently, Cranbrook et al. (2007) reviewed all available information on the elephant in Borneo, writing that "in such cases, a combination of historical and palaeozoological records may provide evidence to resolve contemporary biogeographical uncertainties... In this note, accordingly, we review the history of trade and transportation of elephant in the region. We list all instances of fossil elephant remains discovered in Borneo, both within and outside the present range of the wild population, including two previously unreported discoveries: a molar said to have been found in Niah caves, Sarawak; and parts of the appendicular skeleton found in alluvial soil at Banjarmasin, South Kalimantan (which, based on femoral length must have been a bull Indian elephant). Archaeological records from Java confirmed that the elephants existed on that island well into the historical period of postulated introduction to Sulu. … In our view, on present evidence, the conclusion that the population of north-eastern Borneo consists of remnant survivors of the extinct Javan elephant—implausible though it may seem at first—is the more likely. If correct, this ancestry does not detract from the significance of the elephant population now found wild (or feral) in the rainforests of Borneo. On the contrary, such a conclusion adds to their conservation significance. If proven, this fascinating story would demonstrate that very small populations of large mammals can be saved from the brink of extinction, despite concerns over inbreeding, by the simple expedient of moving a few individuals, from a seemingly doomed population, to a different and safer habitat." Unpublished mitochondrial DNA indicates that all the elephants in Sabah derive from a single female (B. Goossens, pers. comm.) thereby providing further evidence to support this theory.

The elephant in Sabah was in 2003 dubbed by WWF-Malaysia as Borneo Pygmy Elephant. Since Cranbrook et al. (2007) and Nurzahafarina et al. (2008) have shown that the average adult body dimension of the Sabah, Sumatra, and Peninsular Malaysia are the same, the explanation that "Sabah elephants are small" possibly lies in the fact that when one observes herds of wild elephants in Sabah, there are always a high percentage of immature individuals. This is likely because wild elephant populations in Sabah are subject to low hunting pressure, live in elephant food-rich logged lowland forests, and are either stable in size or increasing in number (e.g., in the lower Kinabatangan area), whereas elephants elsewhere in Southeast Asia tend to be under continuing intense pressure from habitat loss and/or poaching.

Davies and Payne (1982) estimated the Sabah elephant population at that time as between 500–2,000 individuals. The original distribution of the elephant in Sabah was similar to that of the orang-utan, and about half that area was converted to plantations over 1980–2010. Undoubtedly many elephants were killed accidentally or deliberately during that period, linked to their damage to newly-planted oil palms and other crops. Using a line-transect dung-count methodology, with data collected 2007–2008, Alfred et al. (2010a) estimated a Sabah elephant population size of 2,040 (95% CI: 1,184–3,652). These data are open to debate, as many of the transects were done near to logging roads and rivers, thereby favouring above-average elephant use, and possibly contributing to an over-estimate of overall population size. Despite occasional reports of elephant deaths in Sabah from shooting or poisoning, there is little doubt that in recent years, annual birth rate is exceeding death rate in some locations, where habitat (logged natural lowland forest) is rich in elephant foods and relatively stable in extent. In contrast to the case of the Sumatran rhino, the Bornean elephant appears to have declined in numbers with conversion of forest to plantations, and rebounded thereafter as the extent of logged forest stabilised and provided ideal elephant food habitat. The challenge for the future will be to sustain the extent of elephant habitat while allowing for possible natural population increase in some areas.

BORNEAN ORANG-UTAN
PONGO PYGMAEUS

The orang-utan has been a fascinating icon of forest conservation, dating back to Alfred Wallace's observations from Sarawak over 100 years ago (Wallace, 1869). He noted their patchy geographical distribution, preference for closed-canopy high forest in lowland areas, and avoidance of areas with high human use. They appeared to be largely solitary; to prefer fruits of tall trees when abundant, or water-side plants if not; and to avoid travel or feeding on the ground.

A century later in Sabah, studies by Davenport (1967), Horr (1972), and especially MacKinnon (1971, 1974) provided

ground-breaking and in-depth knowledge of orang-utan socio-ecology. In the Ulu Segama region, orang-utans were recorded to feed from 97 plant species, with a preference for succulent fruits (e.g., figs [*Ficus*] and durians [*Durio*]), but also take a wide range of fruits and other foods including young leaves, insects, and even the bark of trees in seasons where its preferred food are scarce (MacKinnon, 1974). This overall picture is supported by subsequent studies of diet, but the range of plant species eaten is greater, and there is evidence that this species is capable of storing fat reserves in times of fruit abundance, which can sustain them in leaner times (Knott, 1998). Overall, we have a species with an adaptable diet and a preference for fruits from large trees, some of which are produced only seasonally.

A more variable quality of orang-utan ecology is the size of their home ranges. Early reports from primary forest in the Lokan area of Sabah showed that females had relatively stable home ranges of about 60 ha, with males ranging over 2.5 to 5.2 km^2 (Horr, cited in MacKinnon, 1974). In the forests of Ulu Segama some females had 'small' home ranges, but most had large home ranges (several square kilometres) and adult males had even larger home ranges and, of most interest, some individuals of both sexes were apparently migrating through the study area probably in response to changing food distribution and/or disturbance from logging operations (MacKinnon, 1974). Over the years, more field data have indicated that different orang-utans adopt a series of ranging strategies, from "sedentary" (several square kilometres), through to visiting regions periodically, to migrating over very large areas of several tens of square kilometres (e.g., Singleton et al., 2009). Large rivers and clearance of forest habitat for agriculture will impact on all these strategies, but this adaptability allows at least some members of a population to cope with variable abundance of food supplies in space (over tens of square kilometres), and time (between seasons and between years), as well as to move away from areas with human disturbance. In this context of moving between areas, Horr's (1972) early observations that orang-utans could commonly travel along the ground have also been confirmed by recent camera-records of animals travelling on the ground to traverse logged forest and plantation areas (Loken et al., 2013).

In the early 1980s, based on these detailed field studies and state-wide surveys (Davies & Payne, 1982) orang-utans were judged to be largely dependent on primary forest in the lowlands—with marked population declines above 150 m asl (Davies, 1986). They also appeared to migrate away from areas with logging operations, and in some cases concentrated in small refuges of primary forest surrounded by logged areas and agricultural lands (Davies, 1986).

By the mid 1980s our understanding had changed, based on orang-utan nest count surveys. Once they are nearly mature, each orang-utan makes a nest of leafy twigs and small branches in the tree canopy, normally one per day. The nests take many months to decay and disappear, and so can be seen from the ground, and from a helicopter, but the helicopter has the advantage that tens of thousands of hectares can be surveyed within a few hours. Helicopter nest counts made from 1985–1987 revealed a much bigger picture of the distribution of orang-utans in Sabah: the species is an extreme lowland specialist, with population densities being high only in the lowest, flattest and moistest parts of Sabah. Within these areas (mainly the flood-plains and adjacent foot-hills of the east coast rivers) orang-utans lived in all forest types, including large tracts of heavily logged forests, and including areas extensively burned during the 1982–1983 El Nino drought (Payne, 1988).

Nest counts showed that orang-utans are very sparse, and more usually totally absent, in the extensive regions of old growth (not logged) forest on hills and mountain ranges in the interior of Sabah. Additional and subsequent studies have shown that orang-utans living in the highly degraded extreme lowland forests subsist on a narrow range of plants, and still prefer to range in the better quality patches of forest (Alfred et al., 2010b). And that the extensive tall hill forests are used by wide-ranging males, but in general do not support breeding populations. As with all ecological rules, there are exceptions. There are very small populations of wild orang-utans in the Crocker Range and Kinabalu Park, concentrated around a zone around 900 to 1350 m above sea level. Possibly this is linked to the fact that this is the zone that encompasses the shift from dipterocarp to lower montane forest formations, which have different timings in their peak fruit production. Another exception is that orang-utans do not form breeding populations in mangroves, although some individuals do appear to spend much of their time in the mangrove—freshwater forest interface.

A major programme to examine and monitor a wide range of elements of orang-utan distribution, genetics, ecology, and behaviour was initiated in 1998 by Marc Ancrenaz and Isabelle Lackman, later joined by Benoit Goossens and other collaborators and researchers. What has emerged through these studies is that when the orang-utans' natural and preferred habitat (extreme lowland and freshwater swamp forests) is severely disturbed or lost, a few individuals remain and survive. Both males and females with infants are now being seen in small patches of residual forest in predominantly oil palm landscapes (M. Ancrenaz, pers. comm.). Further research will reveal the situation more clearly, but the current impression is that while most orang-utans die when forest is lost, some individuals may adapt and learn to move through plantations between food sources over a large area. Meijaard et al. (2010) have similarly reported orang-utans in *Acacia* plantations in Kalimantan. These new plantation landscapes will certainly never be able to support orang-utans at their former population densities (averaging about two individuals per square kilometre of original lowland forest), but overall orang-utan numbers could be supplemented, especially if food trees (e.g., *Ficus*) were planted and "corridors" or "stepping stones" of native vegetation could be recreated to link fragmented forest populations. These practical actions in plantation areas, possibly in conjunction with Roundtable on Sustainable Palm Oil (RSPO) certification, are needed in conjunction with monitoring and further research.

So how many orang-utans are there in Sabah? Population estimates from forest survey walks in the 1980s gave figures of one to two individuals per square kilometre in primary forests (<150 m asl) of the eastern lowlands, which tallied with home range estimates from longer term studies (Davies, 1986), although high populations have been recorded at 450 m a.s.l. in one part of the Ulu Segama area over a 40-year period (Ancrenaz et al., 2010). The 1980s surveys found marked declines in population density outside this prime habitat with increasing altitude, logging, and hunting. Based on this assessment, a conservative estimate was made of 'at least 4,000 in 5,000 km^2 of eastern Sabah', noting more surveys were needed in the south and central parts of the country (Davies, 1986). This very cautious estimate proved much lower than figures based on data from helicopter surveys of orang-utan nests in the mid 1980s, noting limitations in generating population estimates from these methods (Mattheson et al., 2008). The helicopter surveys showed substantial orang-utan populations, widespread in lowland logged forests, with an estimate of as many as 20,000 occurring throughout the state (Payne, 1988). As the logged lowland forests were converted to plantations (predominantly oil palm) from the early 1980s to the early 2000s, the estimated population size dropped to about 11,000 (Ancrenaz et al., 2005); most presumably died as their forest was converted to plantations.

In summary, the orang-utan population in Sabah has been through extraordinary change over the past 80 years. In the 1940s and 1950s there appears to have been a dense and widespread population, especially in unlogged forests in the lowlands wherever there was little hunting pressure. As logging intensified in the late 1970s there appears to have been an adaptation in ranging and presumably feeding behaviour. There was emigration from active logging operations, and substantial movement as different areas were logged and left to regenerate, making home range and population estimates highly variable. As areas were logged multiple times, or cleared for plantations, then a mass extirpation of about half the population occurred—a loss of some 10,000 orang-utans in two decades.

The conservation implications of these studies are reviewed by Payne and Prudente (2008). Since the 1970s, the over-riding need for conservation of large areas of lowland forests in eastern Sabah was understood, with an increasing appreciation of the value of some logged forests to supplement populations in unlogged areas and act as a connection between high quality forests that are less damaged. The first step taken to safeguarding viable populations of orang-utans was the recommendation and establishment of Tabin Wildlife Reserve, originally for rhinoceros conservation, and adjacent Kulamba Wildlife Reserve—both in 1984. The next major step was the establishment of a series of forest blocks along the Kinabatangan river as a wildlife sanctuary over the period from 1987–1998. The impetus for this Sanctuary came from the 1988 conclusion (Payne, 1988) that the best orang-utan habitat was the interface between extreme lowland and freshwater swamp forests. It had been hoped that a contiguous broad forest corridor could be established, but at that period Sabah was in the midst of the "land race" for titles to land, for sale or development. Kinabatangan Wildlife Sanctuary therefore ended up as a series of disconnected forest patches, its exact location depending mainly on luck and political concerns. In reality, Government's main interest to approve the establishment of the sanctuary was because of its evident importance as a nature tourism destination. That said, the combined importance of these three wildlife sanctuaries for orang-utan amounts to some 3,000 individuals, albeit largely separated from each other (Ancrenaz et al., 2005).

The most important large block of forest for orang-utans in Sabah is the heavily logged lowland forest in the Ulu Segama-Malua-Kuamut-Kalabakan region, which holds the largest unfragmented population of orang-utans in Malaysia—some 4,500 animals (Ancrenaz et al., 2010). There is agreement that no further logging should occur in the Ulu Segama-Malua, although a number of areas would benefit from restoration management to complement natural regeneration (Reynolds et al., 2011; Goosens & Ambu, 2012; Sabah Forestry Department, 2013). When this forest block is combined with the recent establishment of the Danum-Maliau-Imbak Canyon wildlife conservation areas in 2010 (some 140,000 ha), which made de jure a long-standing policy not to log the Danum Valley and Maliau Basin within the Yayasan Sabah Forest Management area, the combined area of contiguous habitat of these and adjacent Forest Reserves comprises some 7,000 km^2—probably one of the most important areas for forest conservation of most lowland mammals in Borneo (Reynolds et al., 2011; see Fig. 1).

Given that these important orang-utan populations are within existing protected areas, which are not intended to be cleared for agriculture, forest retention within them is critical to sustain the orang-utan populations (Alfred et al., 2010b). A thorough assessment of the impacts of logging on orang-utans in Ulu Segama-Malua region provides clear evidence that repeated and intensive logging of forests has led to local extinctions (Ancrenaz et al., 2010). Moreover, forest patches with active logging disturbance have lower densities of orang-utans, as do 'over-degraded forests', and re-colonisation after logging is affected by the particular pioneer tree and liana species which develop: *Neolamarckia cadamba* may provide a food resource to ward off starvation when no other tree species are fruiting, while *Macaranga* and *Pterospermum* species may provide even less nutrition than *Neolamarckia* for orang-utans, implying that the principal post-logging pioneer vegetation is of poor quality for the species. To maintain orang-utan populations in logged forests, therefore, principles of reduced impact sustainable forest management, maintenance and restoration of food trees, and no hunting, are all required—as prescribed by Forest Stewardship Council (FSC) certification or similar international standards (Ancrenaz et al., 2010). The future of the orang-utan in this region therefore largely relies on Sabah Forestry Department policies and practice. The FSC-certified Dermakot Forest Reserve, with its orang-utan population (about 700 individuals), is an example of how this could proceed positively.

One different, but important contribution to orang-utan conservation has been the Sepilok Orang-utan Rehabilitation Centre. This has been built on the northern edge of the Sepilok-Kabili Virgin Jungle Reserve (4,300 ha) some 23 km from Sandakan town, and was identified following surveys in the early 1960s when there was concern that the trade in orang-utans was leading substantial population declines (Harrisson, 1963). Even at the time there was little evidence to support this claim—Davis (1962) notes substantial populations of orang-utans in Sabah. There was an animal welfare issue, however, as opposed to a population conservation concern, with the need to provide care for orphaned young orang-utans that were kept as pets, often in appalling conditions. The rehabilitation centre has given these individuals a better life, and also served as an important conservation education centre which has grown in importance over the years and is now also an important visitor attraction and tourist destination, of which Sabahans are justly proud.

INSTITUTIONS AND POLICY FRAMEWORKS FOR CONSERVATION

Conservation impact can only be delivered in the context of the political economy, and the development needs of the state and its citizens. This is where the competing demands for land use are debated and resolved, where political agendas and processes are played out, and where the rule of law and sound governance hold sway. What then are the policy frameworks which have enabled conservation in Sabah, and who are the leaders that have delivered it?

From the colonial era to present day, retention of natural forest on privately-owned land is essentially prohibited, with the policy being that granting of title to land under private ownership is intended for development. Forests and nature conservation are viewed as strictly the prerogative of government. During the 1950s and 1960s, much of Sabah's uninhabited eastern and central regions under natural rain

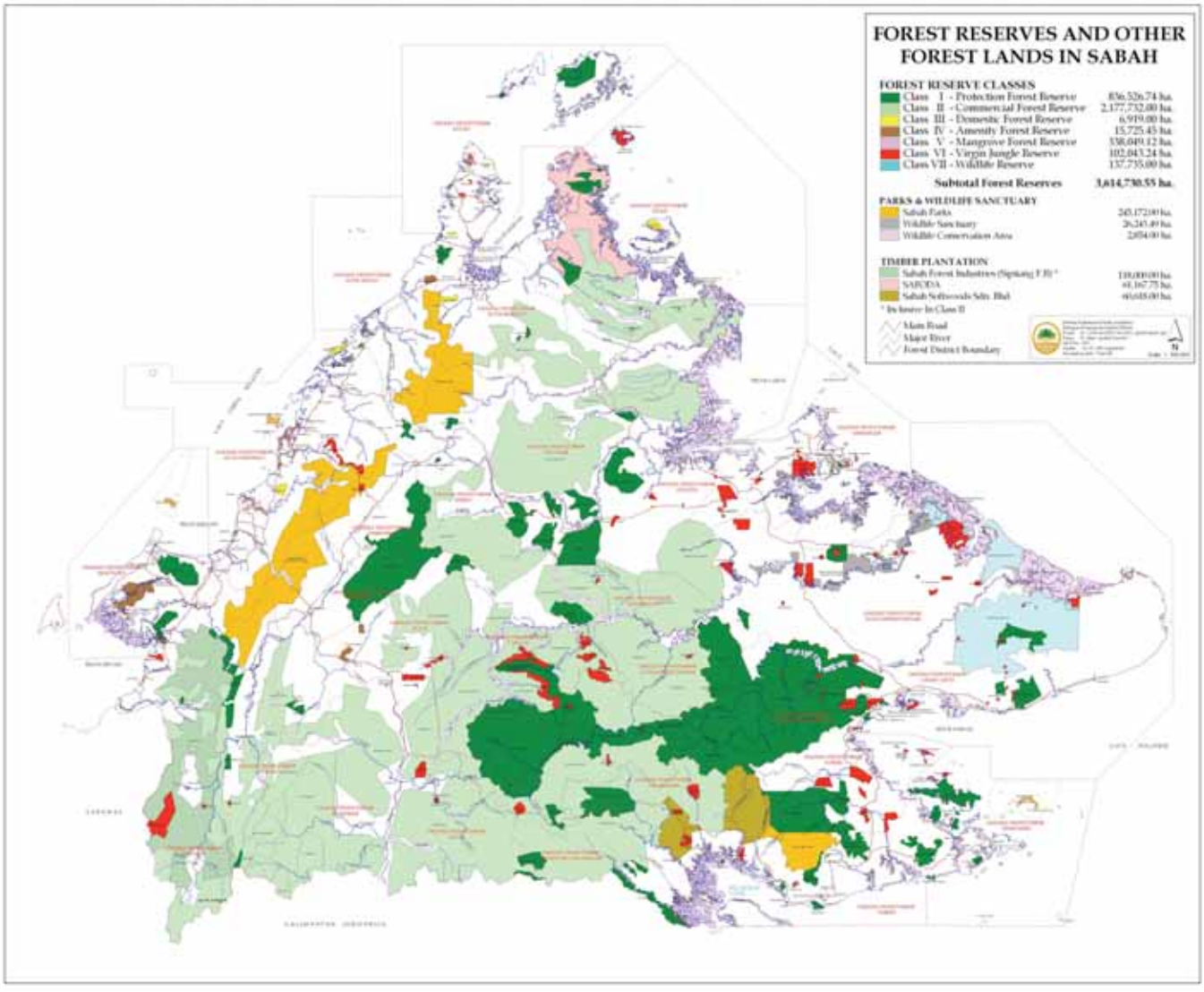

Fig. 1. Map of current Forest Reserves and their classification in Sabah (Sabah Forest Department, 2013).

forest were legislated as commercial Forest Reserves, the intention being for timber production under a permanent selective cutting system. Forest Reserves were and still are managed by the Sabah Forestry Department, but in 1963 a "Game Branch" was established within the Forestry Department, with prime responsibilities relating to culling of elephants entering plantations, protection of marine turtle nesting beaches, and confiscation of orang-utans kept illegally as pets. But 1963 was barely a decade after the introduction into Sabah of tracked bulldozers and chainsaws, two technologies that would subsequently make accessible millions of hectares of previously remote and uninhabited lands, as well as about 100 million massive old growth trees that could be sold as timber. Seemingly no-one fully imagined that most of those lands would be entered and most of those trees cut down within a few decades.

Amongst the few naturalists of the era, special features such as island bird faunas and big mountains seemed to be in need of attention for conservation, but the seemingly limitless dipterocarp forests were too huge to contemplate in terms of specific needs for conservation. Incredibly, only Sepilok Forest Reserve (4,300 ha), representing barely 0.1% of Sabah's dipterocarp forests at that time, had been legislated for protection; and even Sepilok had originally been set aside to become the long-term source of timber for local use in Sandakan town. Thus, the only important step in providing a legal basis for nature conservation in the 1960s was the National Parks Ordinance (1962) which allowed the gazettement of Kinabalu National Park in 1964, adding to some small bird sanctuaries established in the 1930s. Other proposals, such as to reserve upper Tingkayu–Segama for rhinos (1930s) and Danum Valley (1976) came to nothing (Burgess, 1961; Davies & Payne, 1982).

Land use planning. — The Land Capability Classification of Sabah, published in 1976, had been prepared by the United Kingdom Ministry of Overseas Development in collaboration with the Government of Sabah, based largely on topographic, soil, and forest surveys done in the period 1968–1974, together with rainfall records. This study was presented in the form of annotated maps at 1:250,000 scale, whereby all land was classified into five classes: "best" suited to 1) mining; 2) agriculture; 3) agriculture but with at least one constraint limiting crop choice; 4) forestry (at that time implying selective cutting of natural forests on a long cycle); and 5) conservation. The study explicitly stated that land judged suitable for conservation consisted of areas unsuitable for exploitation under the preceding four classes. Neither biological diversity (at that time a term not yet invented) nor water catchment protection were given more than cursory, anecdotal attention. The publication of the Land Capability Classification, with availability largely restricted within government, facilitated a process of de-reservation of Forest Reserves where land had been classified under classes 2 and 3. By the late 1970s, the Sabah Forestry Department was rapidly losing large portions of its Forest Reserves to applicants for land that was to be converted to agriculture. The fact that the Forest Reserves, particularly the lowland parts, supported charismatic mammals such as elephants, rhinos and orang-utans was known to individuals within the Sabah Forestry Department and other interested people, but no process or system existed to account for wildlife conservation in the emerging era of converting forests to agriculture.

Following the faunal survey of Sabah, probably the most important step for nature conservation in Sabah came in 1983, when the Chief Minister of Sabah requested the Sabah Forestry Department to determine a "permanent forest estate" for Sabah. The guidelines evidently provided were that at least 50% of the state should be permanent forest, and that the bulk of the land identified as classes 2 and 3 (together making up about 30% of the State's land area) should be "released" for development. This provided the professionals in the department a small degree of leeway. The Faunal Survey of Sabah results were used as justification to incorporate Tabin and Kulamba Wildlife Reserves into the permanent forest estate. Unfortunately, the significance of extreme lowland forests for orang-utans and elephants, and the fact that both species could adapt to selectively logged forests, had not been fully elucidated by 1983. The mapping of the forest land for inclusion into the permanent forest estate was done swiftly, even though satellite imagery and digital mapping was not available. Essentially, the delineation of the estate was based largely on a combination of the Land Capability Classification maps and identification of forests without any obvious claims to native customary rights (based primarily on absence of signs of cultivation from State-wide aerial photo coverage), plus the Faunal Survey of Sabah recommendations. The permanent forest estate, consisting of Forest Reserves and state parks, was legislated by the Sabah State Assembly in Mar.1984 and, despite excisions and additions in some areas, has remained substantially unchanged to the present time.

In terms of land cover, about 50% of Sabah was forested in 2010 (Reynolds et al., 2011), compared to over 80% in the 1950s (McMorrow & Talip, 2001), and much of this deforestation has been to allow for expansion of plantation agriculture. Between 1990 and 2010 the area under oil palm plantations grew from 3,000 to 14,000 km^2 (Reynolds et al., 2011). This major habitat change, however, was pre-dated by an acceleration of timber production from natural forests from under 6,000,000 m^3 per year in 1965 to 11,100,000 m^3 in 1973 (Reynolds et al., 2011). Thus, over a 40-year period, there was a "timber boom" followed by a "plantation boom", with people in rural villages, junior government staff, housewives, and immigrants from neighbouring countries all realising that they could gain a share by applying for land, ostensibly for development, but typically to be able to sell the timber and land rights.

Bryan et al. (2013) have revealed the extent and intensity of damage to natural forests in Sabah through logging and plantation development, noting that nearly 80% of the land surface of Sabah (and Sarawak) was impacted by high-impact logging or clearing operations from 1990–2009, with only 8% of the state's land area covered by intact forest under designated protected areas by 2009. Nevertheless,

Table 1. Size of Sabah's Forest Estate, broken down by category and extent (km^2) in 1980, 1990 and 2010.

Category of FOREST RESERVE (FR)	**Extent in 1980 (km^2)** Davies & Payne, 1982	**Extent in 1990 (km^2)** Marsh & Greer, 1992	**Extent in 2010 (km^2)** Reynolds et al., 2011
Protection FR	1,886 (recently reduced at that time from 5,060)	1,000	4,668
Commercial FR (estimated unlogged forest within Commercial FR)	33,435 (ca 27,671)	26,746 (ca 5,000)	23,789 (ca 700)
Domestic FR	92	74	70
Amenity FR	150	208	164
Mangrove FR	738	3,164	3,265
Virgin Jungle Reserves	362	883	1,030
Wildlife Reserves	0	1,327	1,371
State Parks and Wildlife Sanctuaries	2,452	2,743	1,136

Notes:
1. Total Sabah land area: 73,631 km^2
2. In Jun.2013, the Sabah Legislative Assembly passed a bill: a, to reclassify 63,769 ha from Class II to Class I (Protected) forests; b, to excise 948 ha of degraded forest from two Forest Reserves Class I; and c, gazetting a Mangrove Reserve of 6,429 ha. The area under Class I protection forests has almost doubled from 4,668 km^2 in 2010 to 8,365 km^2 in Jun.2013 (www.forest.sabah.gov.my)

the combination of established permanent forest estate, governmental commitment to improvement in standards, sound governance and rule of law have together allowed Sabah to achieve a degree and coverage of forest that is high in comparison to most of the Southeast Asian region (Gregory et al., 2012; Mannan, 2012). There are three main current concerns over the extent and management of Sabah's permanent forest estate. Firstly, there are claims of native customary rights. These are relatively small in extent and are dealt with on a case-by-case basis. Secondly, there are a few tens of thousands of hectares lost to illegal encroachment, which have mostly been dealt with by replanting with native trees. Thirdly, there is uncertainty over the location and extent of conversion of forest to monoculture plantations within the "permanent forest estate". Future changes should be the outcome of decisions to balance sustainable development requirements, as the human population needs change, and in the context of Malaysia's international commitments (Mannan, 2012).

Forest management. — Sabah Forestry Department has a duty to manage 3,600,000 km^2, about half of the state's land area, and most of its forests. From a conservation perspective, therefore, the land in the forest estate is central to forest and terrestrial nature conservation in Sabah. A North Borneo Forest Policy was adopted in 1948, modified in 1954, and modified further in a Sabah Forest Seminar in 1980 (Sario & Liew, 1980), setting a framework for sustainable development:

> "*To reserve [the forests] permanently for the benefit of the present and future inhabitants of the land, so as to maintain the climate and physical condition of the country, to prevent damage to water supplies and agricultural land by flooding and erosion, and for the perpetual supply of all forms of forest produce required for agricultural purposes. …the forest estate should be managed with the objective of obtaining the highest revenue compatible with sustained yield, and that technically trained staff should be provided when necessary for forest management, revenue collection and for research into problems that can be investigated locally. ... All appropriate schemes of regional forest research should be supported and co-operated with, and the fact that 'security of tenure and long term planning are essential for successful management of the forest estate' should be accepted. …a real understanding amongst the people of Sabah of the value of the forests, now and in the future, should be fostered, by education and propaganda.*"

This policy clearly was not followed. From the late 1970s until the early 1990s Sabah produced more than 10,000,000 m^3 of timber per annum (Reynolds et al., 2011). By 2011 annual timber production had declined to about 1,500,000 m^3, and from about 2014 annual production will be largely static at 500,000 m^3 (Reynolds et al., 2011). This low level of production is likely to continue for some time, given the severely depleted stocking of the timber reserves, and moderate output from plantation forestry. The impact on State revenues has been dramatic: in 1979, Sabah earned RM 1.1 billion in revenue from timber production, whereas in 2012 revenues were expected to be about RM 100 million (Mannan, 2012), despite the higher timber prices per cubic metre.

A lack of control over selective logging commencing around 1970 led to the abandonment of sustainable natural forest management as the main means to conserve natural forests. From that time, the period between felling cycles (originally 60 years) has been greatly shortened; care has not been taken to reduce impact (through such means as feeder track planning and directional felling); and strict limits on timber species and felling diameters were waived or ignored (Reynolds et al., 2011). The impact of this unsustainable forest management is well demonstrated by figures from Ulu Segama Forest

Reserve, where early timber production was about 120 m^3 per hectare and this declined until salvage logging prior to proposed forest clearance produced a mere 35 m^3 per hectare (Marsh & Greer, 1992; Reynolds et al., 2011)—although ultimately the forest clearance proposed in this case did not proceed. In terms of habitat loss, the disappearance of old growth (unlogged) forest throughout the State's Commercial Forest Reserves has been dramatic: from about 27,000 km^2 in 1980 to only 700 km^2 in 2010—less than one percent of the State (Table 1).

In an effort to bring the State back from the brink of complete loss of a viable forest estate, the Sabah Forestry Department began to introduce major policy changes in 1997, showing strong leadership in the face of prevailing forest exploitation practices and policies at the time. It required a number of actions to be implemented: phasing out short term licences, increasing the use of 'reduced impact logging', compulsory certification of forest management units, increasing the area of totally protected ecosystems in legislation, and adopting a 'no net loss' policy where forest areas that are excised from the forest estate for other purposes must be replaced with new Forest Reserve (Mannan, 2012). A smaller number of long-term (mainly 100 year) licences were then issued, some revoked at later dates for non-compliance, and some areas taken over for management by the Department in an effort at continuous improvement (Sabah Forestry Department).

On-going engagement with political actors in Sabah has been essential to forge a path towards sustainable forest management within the state (Mannan, 2012). Economic realities require a constant search for innovative ways to deliver value from Sabah's forests. Direct state revenue from oil palm (through imposition of a sales tax on export of palm oil) is currently about RM 2,500 per hectare per year, compared with timber revenues from the forest estate of about RM 25 per hectare per year (Mannan, 2012). Furthermore, the benefits of timber production to local communities in the past largely focused on infra-structure provision, but will now need to deliver a broader range of services and benefits.

A pioneering attempt at innovation to increase forest value was to use international standards for sustainable natural forest management in Dermakot FR (55,083 ha), which also became a turning point linked to developing the new forest policy in 1997. The objective was to achieve the highest standards of forest management, and for Forest Stewardship Council (FSC) certification to be given. There is some evidence that the highest value timber species can attract a price premium if it is FSC certified (Kollert & Lagan, 2007), and the presence of orang-utan populations was considered as an element of the certification. However, even with sales of FSC certified timber, income per hectare per year from natural forest is very much lower than from any form of monoculture plantation. A number of constraints have limited further use of this international standard to drive further improvements, in particular the FSC prohibition on certification of any forest management units which involved forest conversion to plantations after Nov.1994. This poses difficulties to Sabah at a time when timber yields from natural forests are so low that further areas will need to be developed for timber plantations.

A second experimental innovation to seek more value for standing natural forests is to see if Sabah can generate revenue through the payment for ecosystem services provided by the forest estate. The development of the Malua Bio-bank has been one approach in this vein, which has generated very modest income. But a much larger frustration has been the prohibition in providing Sabah with international funding through the Reduced Emissions from Deforestation and Degradation (REDD) payments, because Sabah's forests are already being managed and no new (additional) areas are being set aside (Mannan, 2012). This problem is exacerbated by the lack of a strong international trading framework to set a good price for carbon, which could be sequestered through forest regrowth and subsequently traded.

Other forest conservation agencies in Sabah. — Sabah Parks is a statutory body which manages state parks (despite the original name given to Mount Kinabalu in 1964, Sabah has no national parks, as land and forests come under state control according to the Constitution of Malaysia). The parks consist almost entirely of marine ecosystems, offshore islands and forested mountains. Sabah Wildlife Department was established in 1988, primarily as a means to prevent the extinction of the Sumatran rhino. It has under its control one wildlife sanctuary and two wildlife conservation areas, in which no form of natural resource exploitation is allowed. The Department has prepared action plans for Sumatran rhino, elephant and orang-utan.

INTERNATIONAL DIMENSIONS

Sabah is a state within Malaysia, and Malaysia is signatory to the Convention on Biological Diversity, as well as the Kyoto Protocol of the UN Framework Convention on Climate Change. Work towards the fulfilment of the commitments made under these and other multi-lateral environment agreements has received attention from both federal and state governments. This includes safeguarding populations of globally endangered species, as well as making use of the provisions of these conventions to help shape local land-use, forestry and conservation polices, and seeking to raise funds and other support through them where appropriate.

Within the ASEAN region, Sabah has committed to establish some substantial conservation objectives through its plan of action to support the Heart of Borneo initiative, a trilateral agreement between Brunei, Indonesia, and Malaysia, which was signed in 2007. Amongst other things, this agreement shares an objective to establish protected areas and co-ordinate conservation, forest management, and timber trade, as well as ecological research between the three nations. Delivering against these objectives contributes to Sabah's natural heritage and further raises the state's conservation standing in the region.

Related to the Heart of Borneo objectives, Sabah has continued to develop an international profile through conservation research findings. In addition to research that is emerging from Universiti Malaysia Sabah (which has an Institute for Tropical Biology and Conservation and a School of International Tropical Forestry), there is also a long-standing Forest Research Centre at Sepilok, with a substantial herbarium, a tradition of publications, a Rainforest Discovery Centre which is open to the public, as well as the Sabah Museum in Kota Kinabalu. Most prolific as a source of biodiversity and forest research publications has been the Danum Valley Field Centre, which was developed since 1985 as a partnership involving Sabah Forestry Department, Sabah Foundation, local research institutions and agencies in conjunction with the Royal Society (UK) South-east Asian Rainforest Research Programme (Marsh & Greer, 1992). In recent years, Danau Girang Field Centre has been developed by Sabah Wildlife Department, Cardiff University, and several other local partners (Goossens & Ambu, 2012). These have all contributed to our understanding of ecology and conservation in Sabah, and supported conservation policy development to varying extents.

CONCLUSIONS

What does the future hold for rainforest mammals in Sabah?

At species level, the pictures for the Sumatran rhino, elephant, and orang-utan are remarkably different. The rhino is on the verge of extinction, and may go extinct because the single imperative to boost rhino births was not adequately realised and acted upon through global collaboration in the 1980s. The only hope for the species now lies in bringing as many individuals as possible into fenced, closely managed facilities, and to use advanced reproductive technologies. If successful methods for artificial insemination can be developed for the last few fertile females and males, and if embryos can be implanted into surrogate mothers (rhinos of other species in zoos), then hope remains.

Elephants will present an increasing challenge, primarily as some herds and individuals "spill over" into surrounding plantations, gardens, and villages. It is not yet clear if the Sabah elephant population is increasing in number, but this is likely in view of the great increase in favoured elephant food plants (mainly monocotyledonous plants) in heavily logged forests in the permanent forest estate. In any case, further conversion of logged forests to plantations will force some herds to seek food and shelter outside the Forest Reserves. The idea of "elephant corridors" through plantation landscapes is a curiously human foible. Elephants will go more-or-less where they please, limited by a combination of where they are accustomed to be led by the older females, where there is plentiful food, where there is daily plentiful water, and where it is shady during the hot day time hours, where it is not too steep, and where they are not constantly harassed by humans. The main factors preventing them from using established plantations as "corridors" and food sources is that food is patchy and the elephants tend to be harassed.

Following the disastrous loss of about half of Sabah's best orang-utan habitat to plantations, based on the Land Capability study and the 1984 delineation of the permanent forest estate, the pattern of land use within the current distribution of orang-utans has been stabilised, through remarkable vision and leadership shown by the State government at both administrative and political levels. Almost all the areas with high population densities of orang-utans that were included in the 1984 permanent forest estate alignment now have fully protected status, the most recent being the conversion of the 240,000 ha Ulu Segama-Malua forests from production to protection status in 2013. There is cautious optimism that plantations may in the longer term provide supplementary habitat and genetic connectivity between different blocks of forest in the permanent forest estate. This will need buy-in from plantation companies to plant orang-utan food plants along rivers, streams, and on steep sites which are not required for palm oil production, as well as understanding that orang-utans living in plantations do not need to be harassed or translocated to a "rehabilitation centre".

With about 50% of Sabah under permanent forest estate, and all natural forest types well-represented (from mangroves and freshwater swamp forests to mountain tops), albeit in many cases severely degraded by timber extraction, there is no reason to prepare for the extinction of any mammal species other than the Sumatran rhino, although some other species deserve special mention. The banteng *Bos javanicus* is a large terrestrial mammal which is hunted for its meat (and for "machismo"), which does not rely on rain forest habitats (Davies & Payne, 1982), and very little is known other than that it appears to remain rare in a few scattered localities (Goossens & Ambu, 2012). Illegal hunting surely represents the main threat to this wild cattle species. In forest habitats, the elusive clouded leopard *Neofelis nebulosa* occurs at only low population densities and may number 1,500 to 3,000 individuals across Sabah (Wilting et al., 2006) or fewer (http://borneanwildcat.blogspot.com). Sun Bears *Helarctos malayanus* appear to prefer forest habitats, feeding on particular taxa of invertebrates and the fruits of particular trees (Wong et al., 2004, 2005). Although camera trapping and direct observations in recent years have shown that they do travel and feed outside forests, these latter two species probably also depend on well managed forests to provide adequate food to sustain viable breeding populations.

One issue of that great concern has to be emphasised is that the revenue per hectare per year from sustainable logging of natural forests will always be lower than any plantation crop use. More income can be derived overall, both to the private sector and to government in the form of taxes, by having an array of plantations (for wood, oil palms, and other crops) and protected areas (where costs such as road building and maintenance, needed for logging, are not required). The picture that we are likely to see is away from natural wood production forestry, towards plantations and unexploited natural forests (including old growth and abandoned logged forests). This trend will have to be regarded as a new challenge and opportunity, rather than an unmitigated disaster. How can this pattern of land use best be developed and managed

to sustain wild breeding populations of all the mammals? The Earl of Cranbrook has given us insights in his way of thinking and writing. Think big, think paleozoology, think in terms of historical narrative, and think way outside the usual boxes at all times.

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