Bukit Timah: the History and Significance of a Small Rain-forest Reserve

by

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INTRODUCTION

The threats to tropical rain-forest world-wide are well known and a source of grave concern. In Southeast Asia, we are rapidly approaching a situation where the only surviving primary forest will be the fragments preserved in national parks and Nature reserves (Aiken & Leigh, 1985). Undoubtedly, the preservation of large areas—of the order of thousands of square kilometres—of little-disturbed forest should be the primary goal for conservationists, but many governments are unwilling or unable to set aside large areas of land for a use whose potential economic returns are long-term and largely intangible. Even if large reserves are acquired, there will always be some species or habitats which are not included. Moreover, the educational and recreational functions of a reserve system are best met by areas close to major population centres, where large reserves are seldom possible. Thus, whatever the overall conservation situation, small reserves (tens or hundreds of hectares in area) may have an important role to play in the tropics as they do in other parts of the world.

Doubts have been expressed, however, about the ability of such small rain-forest areas to maintain much of their original diversity (Wilcox, 1980; Frankel & Soule, 1981). There is now a vast literature on the theory of reserve design, but still no agreement on this question—beyond, perhaps, the necessity of study on a case-by-case basis. The ambitious Minimum Critical Size of Ecosystems project in Brazil (Lovejoy *et al.*, 1983; Lewin, 1984) will eventually produce answers to many of the questions about the conservation value of rain-forest reserves of different sizes, but the most important results will not be available for another decade or more. In any case, the purely biological problems of reserves, particularly small ones, are often dwarfed by the influence of social and political factors.

In this paper I trace the history of what is perhaps the oldest small rain-forest reserve in the world, and attempt to assess its past, present, and future, contributions to the conservation of Singapore's rain-forest biota. I hope this case-history will serve as both warning and encouragement to those involved in the management of similar areas.

Bukit Timah Nature Reserve today consists of 71 hectares of forest (a mixture of lowland and coastal hill dipterocarp forest, and secondary forest) on the slopes and summit of Singapore's highest hill, Bukit Timah (162.5 m) (Figs 1 and 2). It is only 8 km from the city centre and a few minutes' walk from three crowded shopping-centres. The main body of the hill is of granite. Mean annual rainfall at the summit is 2,579 mm, more or less evenly spread through the year. The temperature averages 26°C and shows almost no seasonal variation. A general account of Singapore's vegetation is available in Wee & Corlett (1986).

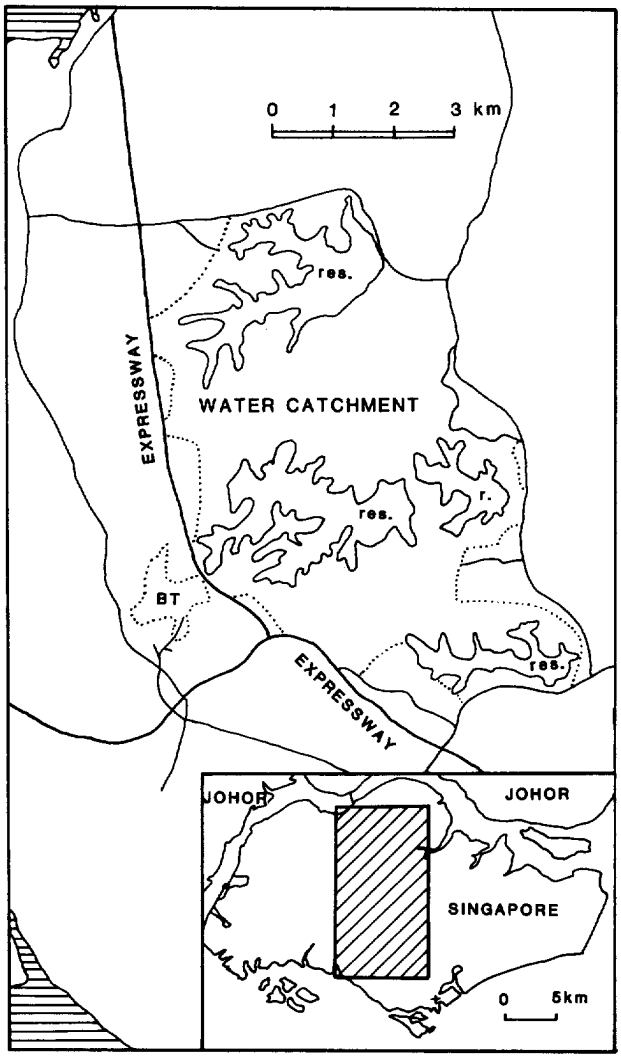

FIG. 1. *Sketch-map showing the location of Bukit Timah Nature Reserve. (Dotted line = boundaries of Bukit Timah Nature Reserve* [BT] *and the water catchment area;* res. = *reservoir.) Inset maplet of Singapore and adjacent parts of Peninsular Malaysia. The site of the original British settlement is indicated by the small cross to the south-south-east of the lower right-hand corner of the hatched vertical oblong in the inset maplet.*

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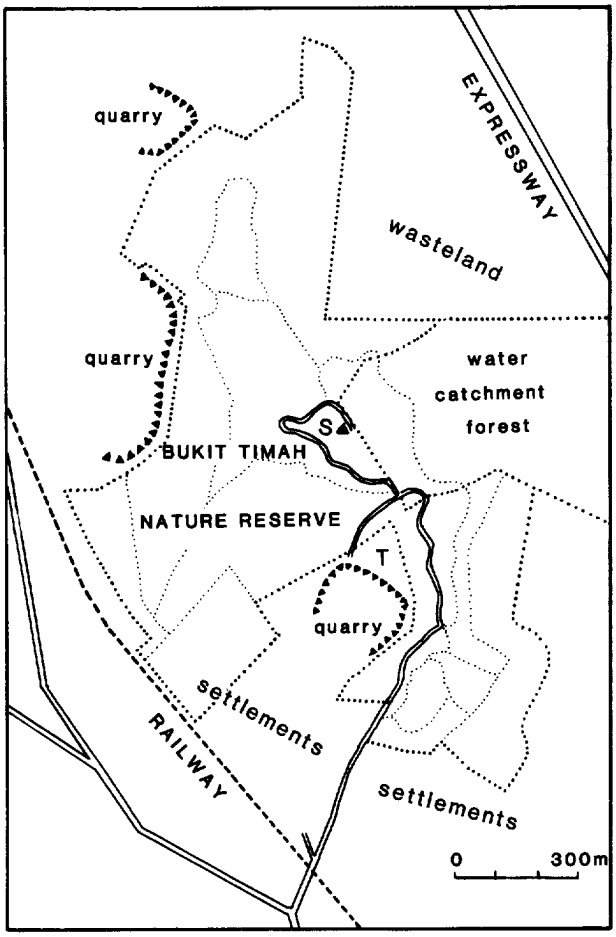

FIG. 2. *Sketch-map of Bukit Timah Nature Reserve. (Large-dotted line = boundary of the Reserve and the contiguous part of the water catchment; small-dotted lines = major footpaths; double lines = roads; S = summit; T = Telecom tower.)*

For a brief earlier account of Bukit Timah Nature Reserve, *see* Polunin (1981).

HISTORY

The modern history of Singapore* started with the foundation of a British colony at the mouth of the Singapore River in 1819. This colony later developed into the town. Any previous settlement appears to have been entirely coastal, and the interior of the island to have been trackless rain-forest. Although Bukit Timah hill was clearly visible from the sea, it was separated from the new town by 8 kilometres of dense forest. *The Singapore Chronicle* reported in 1825 that 'Bukit Timah... has never been visited by a European resident, seldom by a native' (Moore, 1975). However, the expansion of gambier and pepper cultivation into the interior rapidly reduced the width of the barrier. Thus already in 1827, when a Mr Prince reached the top of Bukit Timah hill—apparently the first European to do so—three-quarters of his route from the town lay through gambier and pepper plantations (Buckley, 1984).

* Singapore is the name used to refer to the City, the main Island, and the Republic—which last consists of the main island and several smaller islands.

There is no record of when the forest on Bukit Timah Hill first became isolated but, after a road to the summit made Bukit Timah easily accessible in 1843, a visitor remarked that 'dark masses of primeval forest stretch away from Bukit Timah on every side' (Buckley, 1984). As late as 1848, more than sixty per cent of the island was still under forest (Thomson, 1850).

However, in 1854, the great British naturalist, Alfred Russel Wallace, lived for several weeks with a Jesuit missionary near the foot of the hill, and his description of the area, although making no explicit reference to Bukit Timah itself, implies that forest was now reduced to isolated patches, mostly on hill-tops (Wallace, 1869). Forest that was not cleared for agriculture was subject to harvesting of timber, firewood, and minor forest products—such as rattans, resins, and gums. Oxley (1847) reported that in only four years the Gutta Percha tree (*Palaquium gutta*) had been almost eliminated from Singapore by the destructive extraction of its latex, which contains a thermoplastic polymer that is used for coating submarine telegraph cables. Other trees with valuable timber were probably also selectively harvested from the remaining forest, including that on Bukit Timah, and Wallace attributed the number and diversity of the beetles which he collected to the activities of Chinese wood-cutters.

Early Protection of Bukit Timah

There seems to have been little attempt to regulate the exploitation of forest resources although, from time to time, concern was expressed about forest clearance. Logan (1848), in a paper warning of the possible effects of the clearance of hill forest on the climate of Penang, contrasted the situation there with that in Singapore, where 'the present zealous Governor has absolutely prohibited the further destruction of forests on the summits of hills'—including, presumably, Bukit Timah. Concern for the climatic effects of deforestation, particularly of hill-tops, continued. Accordingly when the Colonial Engineer, J.F.A. McNair, described the state of the forests of the Malay peninsula in 1879, he stated that, in Singapore, 'a reserve is kept round the principle hill [Bukit Timah] for climatic purposes'.

Thus in 1882, when Nathaniel Cantley, the Superintendent of the Singapore Botanic Gardens, was commissioned to prepare a report on the forests of the Straits Settlements, Bukit Timah hill had apparently already been under some kind of protection for more than three decades. Cantley, noting that only seven per cent of Singapore's forest remained, and that there were 'absolutely no Forest Rules or Regulations, or Forest Law of any kind', recommended the establishment of forest reserves and the reafforestation of wasteland (Cantley, 1884). The proposed reserves were to supply timber and firewood, prevent soil erosion, protect the water-supply, and improve the climate. Cantley admitted, however, that most areas contained very little timber of any value.

Cantley's proposals were accepted. Bukit Timah had the greatest extent of good forest of all the reserves on Singapore Island, and demarcation of its boundaries received priority. A fire-break, ten kilometres long and five metres wide, was cut around the margin of the reserve in 1884. However, according to the first Annual Report of the newly-created Forest Department, not much more than a third

FIG. 3. *'Original' Lowlan Timah Nature Reserve. foreground, rooted outsi ence are visible.*

(totalling 122 hectare 'under timber'. The la pied by 'grass and fern' 'brushwood'.

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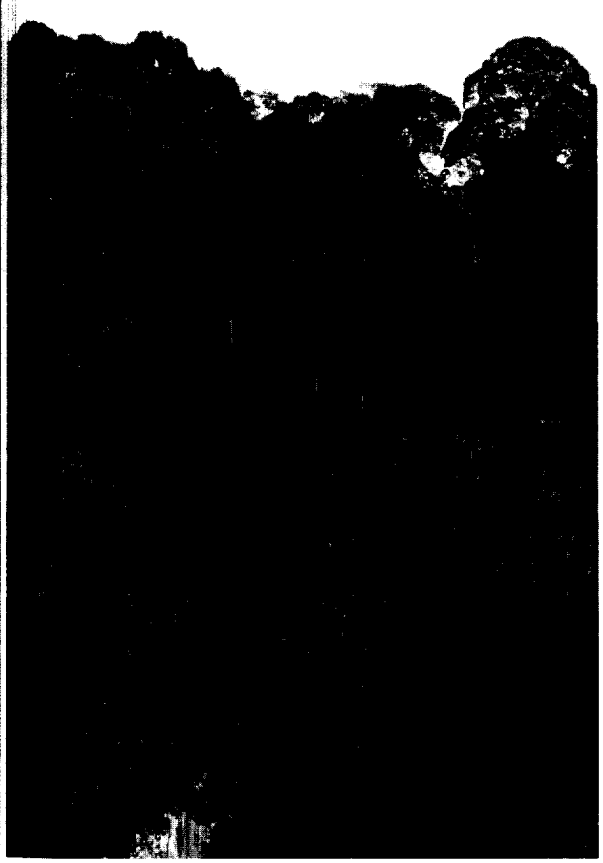

FIG. 3. *'Original' Lowland Evergreen Tropical Rain-forest in Bukit Timah Nature Reserve. Except for the tops of exotic trees in the foreground, rooted outside the Reserve, no signs of human interference are visible. Photo: Dr Ivan Polunin, 1984.*

(totalling 122 hectares) of the 343-hectares' reserve was 'under timber'. The largest area (133 hectares) was occupied by 'grass and fern', and the rest (88 hectares) was under 'brushwood'.

A start was made on planting the wasteland areas in 1883, and by 1886 a total of 118 hectares had been planted with a mixture of native species and exotics, such as Teak (*Tectona grandis*) and Mahogany (*Swietenia macrophylla*). Planting of waste areas continued under Cantley's successor, Henry Nicholas Ridley*, until a great reduction in the Forest Department vote in 1893 made anything but minimal protection of the reserves impossible. Fires and timber thefts had been problems from the beginning, but Bukit Timah seems to have been better protected than most of the other reserves on Singapore Island. Fig. 3 is a recent photograph of an area of little-disturbed lowland evergreen tropical rain-forest on a margin of Bukit Timah Nature Reserve, and Fig. 4 is taken in an area of dipterocarp-dominated forest in the Reserve.

The forest reserve system eventually incorporated 11% of Singapore's land area, although only part of this was actually forested, and much of the forest was mangrove. In 1894, the Annual Report of the Forest Department commented that, because of the small extent and poor quality of the reserves, 'their utility as a source of revenue was subordinated to their climatic and hygienic uses'.

In the following year, 1895, the reserves were transferred to the control of the Collector of Land Revenue at the Land Office. There was never any legal extraction of timber from Bukit Timah, but illicit felling continued to be a major problem, despite the presence of forest guards. The only income derived from the reserve was from a plantation of Gutta Percha trees, later mixed with rubber, which was started on an area that had been cleared of scrub on the lower slopes of the hill in 1898 and eventually covered 40 hectares.

Of the Reserve's original area of 343 hectares, 52 hectares—including much forest—were transferred to the control of the Municipality of Singapore in 1909 as part of an extended water-catchment area to the east and north-east of Bukit Timah (cf. Fig. 1). Although most of the rest of the catchment area had previously been under cultivation, succession back to forest proceeded rapidly after protection. Small areas were also excised for granite quarries, for realignment of the railway, and for a rifle range. Despite all this, Bukit Timah survived, whereas most of the other reserves were worked for timber, handed over to squatters for growing vegetables, or otherwise 'developed'. Of Cantley's original reserves, only one other, Chan Chu Kang (Nee Soon), was saved from total clearance by incorporation into the extended water catchment in 1909.

More Recent Developments

In 1930, Bukit Timah Forest Reserve was 'revoked' and so reconstituted as to include only forest land (72 hectares). The following year a proposal was made to revoke all the reserves on Singapore Island except Bukit Timah, which was to be retained 'on grounds of amenity and its botanic interest'. This proposal was finally carried out in 1936. All the reserves were then revoked, but Bukit Timah and parts of the mangrove reserves at Pandan and Kranji were taken over by the Gardens' Department, to be held as Nature reserves. There was apparently a great deal of illegal felling of timber at Bukit Timah, particularly in the north-west, between revocation and the start of regular patrols by Gardens staff in July 1937. Finally, in 1939, these three areas were re-gazetted as forest reserves (there being no Nature reserve legislation) and the Director of the Botanic Gardens was gazetted as Conservator of Forests. The area of Bukit Timah Reserve was now only 66 hectares.*

During Bukit Timah's 53 years as a forest reserve, the major concern of the Department of Forests was the protection of the timber resources. The Department's annual reports, not surprisingly, make no mention of animal life apart from pest species. The fauna was not unprotected, however—at least in theory. The Wild Birds Protection

*The celebrated botanist, sometimes referred to as 'founder of the rubber industry', whom we had the privilege of knowing in his later years of retirement at Kew near London, and whose devoted wife and lively interest in plants enabled him to pass the century.—Ed.

* Down from some of the areas indicated earlier but subsequently increased to 71 ha as confirmed by the Author.—Ed.

FIG. 4. *A grove of giant* Shorea curtisii *(Dipterocarpaceae) on a ridge in Bukit Timah Nature Reserve. Much of the bare ground to the right of centre marks the course of a footpath alongside the plank-buttresses of the dominant trees. The tallish human figures indicate the scale. Photo: Dr Ivan Polunin, 1986.*

Ordinance of 1884 made it illegal to kill any birds in Singapore without a licence, except for pests and legitimate game birds (including snipe, duck, pigeon, jungle fowl, and pheasant). In 1904, this was replaced by the Wild Animal and Birds Ordinance which, while retaining the same protection for birds, gave the Governor powers to prohibit the killing of any specified bird or animal in any specified area. Sambar Deer (*Cervus unicolor*) and Barking Deer (*Muntiacus muntjak*) were given absolute protection in 1923, followed by the Pig-tailed Macaque (*Macaca nemestrina*), Banded Leaf-monkey (*Presbytis femoralis*), Slow Loris (*Nycticebus coucang*), Pangolin (*Manis javanica*), and both species of Mouse Deer (*Tragulus javanicus* and *T. napu*), in 1947. All this legislation, however, seems to have done virtually nothing to curb the depradations of weekend hunters and trappers (Chasen, 1923).

Under the Gardens' Department, the changed role of the reconstituted Reserve became immediately obvious. New paths were cut and signposted, trees were labelled, timber thefts were stopped, devastated areas were planted, and a thorough botanical survey was started. However, these changes were interrupted by the coming of World War II and the Japanese occupation of Singapore from 1942 to 1945. Bukit Timah Hill was itself on the front line of the battle for Singapore in February 1942, and must have suffered considerable damage. Corner (1981), on his first visit to Bukit Timah during the occupation, was 'astonished and appalled at the quantity of unexploded mortar shells which had fallen on the paths and among the trees'. During the occupation, the Japanese felled some trees and carried ou some excavations for defensive purposes but, on the whole the reserves were protected (Corner, 1981). This was largely due to the efforts of Professor Kwan Koriba, who was sen out from Kyoto University to have charge of the Singapor Botanic Gardens.

After the war's end the most obvious threat to Buki Timah Reserve was from the continued activities of th granite quarries, five of which now removed vast quantitie of rock from the sides of the hill and, in places, encroache into the Reserve. The Government appointed a Sele Committee to investigate the granite quarries and th reserves. The final report of the committee, in 195 recommended the gradual closure of the quarries at Buki Timah, and the enactment of new legislation to protect th reserves (Burkill, 1961). As a result, the Nature Reserv Act of 1951 was passed to provide for the dedication an administration of Nature reserves 'for the purposes of pr pagation, protection and preservation of the indigenou fauna and flora of Singapore and for the preservation o objects and places of aesthetic, historical or scientific inte est'. A secondary purpose was to provide 'facilities for th study of and research into matters relating to the flora an fauna of Singapore and the physical conditions in whic they live'. A Board of Management was created to admi ister the reserves.

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Labrador, on the south coast, and two areas of mangrove forest, respectively at Pandan (219 ha) and Kranji (20 ha). The two mangrove reserves were subsequently reduced in area and finally deleted, Pandan in 1962 and Kranji in 1973.

Current Legislation and Administration

The Nature Reserves Act gives explicit protection only to plants and vertebrates, although invertebrates are probably impicitly protected under the more general provisions of the Act. Birds receive triple protection, as they are covered also by the Wild Animals and Birds Act (which protects all birds but the House Crow anywhere in Singapore) and the Bird Sanctuaries Order (which protects birds in designated sanctuaries, including Bukit Timah Nature Reserve). Subsequent changes in the legislation applying to the Reserve have been minor. The reserves, including Bukit Timah, are currently administered by a Board of Management consisting of a Chairman and nine Trustees, two appointed by the President of the Republic of Singapore and the others by the Minister of National Development. In practise, Bukit Timah is run by the Parks and Recreations Department for the Board. Five 'permanent' rangers supervise the Reserve.

Despite the recommendations of the Select Committee, two quarries are still active, although they are no longer being expanded horizontally. An additional five hectares have been added to the Reserve in the south-west corner, but more than half of this extra area is occupied by two Malay villages. With other minor adjustments, the area of the reserve is now 71 hectares (cf. Fig. 2). The adjacent water catchment area is now largely covered by tall secondary forest but, unfortunately, a new six-lane expressway provides an effective barrier between most of the catchment forest and Bukit Timah (cf. Fig. 1).

The integrity of the Reserve depends on the continued protection of that portion of the catchment area lying between the expressway and the summit of Bukit Timah Hill. The rest of the margins are mostly marked either by a precipitous drop into a quarry or by villages and small farms. Some villagers harvest firewood within the Reserve, and domestic chickens, cats, and dogs, enter its margins. There is a Police radio station on the summit and a Telecom V.H.F. transmitter on a 2 hectares' plot of land overlooking the southernmost quarry. These are served by tarmac roads which are not open to use by private vehicles. An additional area of about one hectare on the summit, cleared last century, is grassed and planted with exotics. There are smaller cleared areas around some of the shelters provided for visitors, and several views have been 'improved' by felling trees.

Numerous walking trails provide access to all parts of the Reserve. Some of these trails have steps reinforced with concrete and metal. All these non-forest areas serve to subdivide the forest into smaller blocks and bring the drying effects of the external environment into the heart of the Reserve. Only about 60% of the Reserve is under primary forest (in the sense of having never been cleared): the rest is secondary forest or scrub.

The reserve was visited by 78,000 people in the last year reported (Anon., 1987), including walkers, joggers, Nature lovers, school groups, and tourists. In addition, many Singapore-based and visiting scientists carry out research there. Current research projects include studies of angiosperms, ferns, bryophytes, Algae, mycorrhizal Fungi, the macaques, birds, insects, and freshwater crabs.

Changes in the Flora and Fauna

Changes in the biota of the Reserve area since isolation could potentially result from either immigration or extinction. Immigration, however, except of weedy non-forest species, will have become increasingly difficult as the surrounding rain-forest was cleared. Rain-forest plants and animals are notoriously poor at crossing non-forest areas. Today, a few small patches of disturbed primary forest, scattered in the water catchment area, provide the only local source of potential rain-forest immigrants. The nearest substantial remnants of the rapidly disappearing rain-forest of Johor, West Malaysia, are more than 30 km away. A few rain-forest bird species apparently travel between Johor and Singapore (C.J. Hails, pers. comm.) and, of these, the Thick-billed Green Pigeon (*Treron olax*), Little Green Pigeon (*T. curvirostra*), and Jambu Fruit Dove (*Ptilinopus jambu*), are frugivores. The green pigeons are apparently seed-destroyers (Leighton & Leighton, 1983), but the Fruit Doves can pass large seeds intact through their digestive systems (Pratt & Stiles, 1985). However, it is doubtful if large seeds are retained in the gut during migratory flights. Fern spores and the tiny seeds of epiphytic orchids could theoretically be blown many kilometres, and some invertebrate species may be able to cross the intervening area in the same way.

Extinction the Principal Determinant of Change

Whether the immigration rate of rain-forest species is actually zero or just very low, it is clear that the major determinant of the present and future biota of the Reserve is extinction. An accurate assessment of species loss from the Reserve since its isolation is hindered by the incompleteness and uncertain localities of early records and the incompleteness of present-day species lists. The birds and mammals are the best-known groups, and reasonable pre-isolation species lists of them can be constructed on the assumption that all native forest species recorded in Singapore inhabited (or, in the case of widely-ranging species, visited) the Reserve area.

For the birds, a list of species present at Bukit Timah recently has been published by Hails (1985). Comparison with the forest birds listed in Gibson-Hill (1949), who also included species known to have become extinct earlier, suggests that more than half of the Reserve's bird fauna has been lost, including all the trogons, hornbills, and broadbills, all but one barbet, more than half of the babblers and woodpeckers, and a variety of other species. Although large species are over-represented in the extinction list, it includes species from the full range of sizes, habitats, and diets, represented in the rain-forest.

For the mammals (excluding bats), a list of species that were probably present before isolation can be compiled from Harrison (1974) and Medway (1978). Unfortunately, our present knowledge of the mammalian fauna is incomplete, particularly as regards nocturnal species. Certainly extinct are the Tiger (*Panthera tigris*) (last shot at Bukit

Timah in 1924), Leopard (*Panthera pardus*), Clouded Leopard (*Neofelis nebulosa*), Pig-tailed Macaque (*Macaca nemestrina*), Sambar Deer (*Cervus unicolor*), Barking Deer (*Muntiacus muntjak*), and Wild Pig (*Sus scrofa*).

Probably extinct are Horsfield's Flying Squirrel (*Iomys horsfieldii*), Prevost's Squirrel (*Callosciurus prevostii*), the Three-striped Ground Squirrel (*Lariscus insignis*), the Slow Loris (*Nycticebus coucang*), the Porcupine (*Hystrix brachyura*), and the Large Mouse-deer (*Tragulus napu*). The Leopard Cat (*Felix bengalensis*), the Cream Giant Squirrel (*Ratufa affinis*), and the Red Giant Flying Squirrel (*Petaurista petaurista*), have been seen in the water catchment area in recent years and may also survive at Bukit Timah. At least one individual Leaf Monkey (*Presbytis femoralis femoralis*) still occurred at this writing* in Bukit Timah—a survivor of the troupe which persisted until the late nineteen-sixties.

Of the four or more viverrids that have been recorded in Singapore in the past, there have been recent definite sightings of only the Common Palm Civet (*Paradoxurus hermaphroditus*) at Bukit Timah, though the others may still occur. In contrast, the Common Tree-shrew (*Tupaia glis*), Long-tailed Macaque (*Macaca fascicularis*), Plantain Squirrel (*Callosciurus notatus*), and Slender Squirrel (*Sundasciurus tenuis*), are still abundant, while the Flying Lemur (*Cynocephalus variegatus*), Pangolin (*Manis javanica*), Shrew-faced Ground Squirrel (*Rhinosciurus laticaudatus*), and the Lesser Mouse-deer (*Tragulus javanicus*), are still occasionally seen.

The mammalian extinctions are mostly large and/or primary forest specialists, while most of the known survivors can also thrive in secondary habitats. Despite this, it seems probable that the immediate cause of extinction for the majority of bird and mammal species was not isolation or habitat modification but the direct effects of hunting and trapping. At Lima Belas, Perak, Malaysia, a similar 70 ha area of rain-forest has been left largely undisturbed while the surrounding area was cleared and planted with oil palm. Sixty years after isolation, this reserve still contains many of the mammalian species that have been lost at Bukit Timah, including the Pig-tailed Macaque, the Slow Loris, and the Large Mouse-deer, as well as species which were never found in Singapore, such as the White-handed Gibbon (*Hylobates lar*) and Dusky Leaf-monkey (*Presbytis obscura*) (Bennet & Caldecott, 1981).

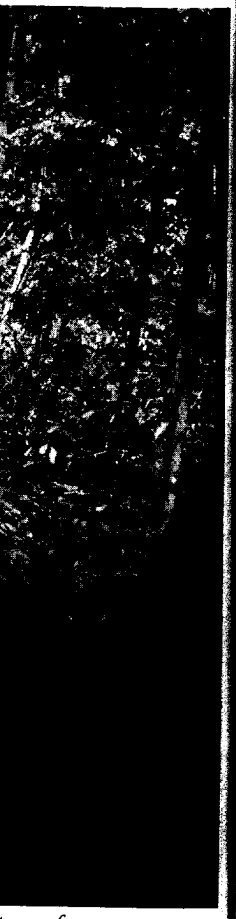
Invertebrate Animals and Plants

For the invertebrates, there is no group for which there are sufficiently complete early and recent records for changes to be identified. The butterflies—which were both conspicuous and well-collected in the nineteenth century—would be the easiest group to study, but unfortunately there is no recent lepidopteran list for the Reserve. All that can be said with certainty for the invertebrate fauna is that it is still incredibly diverse and there is no evidence of significant invasion by exotic or non-forest species (D.H. Murphy, pers. comm.).

FIG. 5. *Below on right a typical plank-buttress of an emergent tree and, on left, a large fallen tree in the Bukit Timah Nature Reserve. The long, gaping slit in the trunk of the fallen tree suggests that its death was due to lightning strike, and, with further deaths from other causes, helps to give the impression that tree-fall is commoner in the Reserve than is usual in similar forests elsewhere. Photo: Dr Ivan Polunin, 1986.*

More than 850 species of vascular plants have been recorded from Bukit Timah during the last century (R.T. Corlett, unpublished list). I have seen nearly 300 of these during a year-long phenological study, covering no more than a small proportion of the Reserve. Only a complete survey of the Reserve—a difficult, if not impossible, task—would establish how many others survive. There is, anyway, no evidence of a general floristic collapse. Except along the margins of the road and other artificial openings, the Reserve has not been invaded by either native or exotic weedy species. Woody pioneers are dominant in the younger areas of secondary forest, and are scattered as mature individuals in the areas of primary forest—perhaps a reflection of wartime disturbance—but are regenerating only around the margins and in large tree-fall gaps. The only obvious negative signs are the unnatural abundance of several small tree species, particularly *Pellacalyx saccardianus* (Rhizophoraceae) and *Gironniera parviflora* (Ulmaceae), which have apparently benefited from disturbance, and a high mortality rate among emergent trees—tree-fall being from old age, lightning strike (cf. apparently Fig. 5), and doubtless other causes. Subjectively, the core areas of the Reserve appear little different from undisturbed rain-forest in Malaysia.

* Found dead in late October 1987 and now preserved in the Zoological Reference Collection at the National University of Singapore.



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Prospects

After more than 130 years of isolation and considerable disturbance, the Reserve still retains much of its original diversity. It has experienced the rapid collapse of vertebrate diversity as predicted by theory and the study of continental islands (Frankel & Soule, 1981), although isolation *per se* was probably not the immediate cause of extinction in most cases. In contrast, there is little evidence *as yet* for the predicted 'domino effect' (Howe, 1984), leading to the general collapse of biotic diversity. The very rich flora and invertebrate fauna show no signs of massive extinction and replacement by widespread weedy species.

It is possible that the apparent resilience of the flora simply reflects the long life-span of the tree species that make up the forest skeleton. If this is so, we should expect a delayed 'collapse' in the next few decades. The opening up of the forest would be expected to affect adversely the regeneration of humidity-sensitive species, while the extinction of most of the larger frugivores may lead to failure of reproduction in some other species. It is noticeable that certain tree species, for instance *Canarium littorale* and *Mezzetia leptopoda*, produce large crops of large fruits which are barely touched by vertebrates. Yet both these species are apparently regenerating well.

The major current threat to the reserve is not, however, internal decay but frequent—and usually avoidable—human disturbance. Within the past year, the laying of underground cables beside the main road has caused considerable damage to the part of the forest which is most visible to visitors. Much more seriously, however, shot-blasting of the Telecom tower has led to the deposition of up to a centimetre of copper slag over several hectares of the Reserve's primary forest. Although mostly composed of relatively harmless (?) iron silicate, this slag contains 0.54% of copper, which is highly toxic to many organisms.

Conclusions

Whatever the ultimate fate of Bukit Timah's biota, it is obvious that the Reserve still has great conservation value. It contains more than 40% of Singapore's native flora, much of which is not found elsewhere on the island, as well as an extremely rich invertebrate fauna. It also serves an important recreational, educational, and scientific, function in a country that is dominated by high-rise buildings and close-mown grass. The challenge for the future is to balance these competing uses for the Reserve with its ultimate conservation function.

Bukit Timah is somewhat of a 'worst case' example for a small rain-forest reserve. A circular area of forest with protected margins and no roads or clearings within it, and with no history of log-poaching, firewood collection, wartime shelling, and spraying with copper slag, would undoubtedly be even more effective as a reserve. The bad press received by small reserves in the tropics seems to reflect, in part, a bias towards large vertebrates among conservation biologists. The long-term conservation of viable populations of such vertebrates will undoubtedly require either very large areas or very active management, including probably captive breeding and movement of animals between reserves.

It has not yet been shown convincingly, however, that the loss of many large vertebrate species from a reserve leads inevitably to a general collapse of biotic diversity. In any case, some of the 'functions' of large vertebrates—such as control of herbivore populations and seed dispersal—could probably be taken over by humans in small reserves if necessary. I suggest that reserves of the order of one square kilometre in area are not just of educational or recreational value but can have an important conservation role in the tropics, as they do in the temperate zone. Moreover, the establishment and management of such reserves should be within the means and abilities of many local conservation organizations.

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Summary

The 71 hectares mainly of rain-forest on Bukit Timah Hill have been isolated for more than 130 years. During most of this period, the forest has received some form of protection: initially for climatic reasons, then as a forest reserve, and finally as a Nature reserve. It has also suffered a great deal of disturbance from illegal logging, firewood collection, hunting, wartime shelling, and recreational activity. Despite this, the Reserve still supports an immensely rich flora and fauna, although many bird and mammal species have been lost.

The example of Bukit Timah suggests that, contrary to most predictions, small rain-forest reserves can play a significant role in biological conservation, as well as satisfying educational and recreational needs.

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