APPLICATION OF ISLAND BIOGEOGRAPHIC PRINCIPLES TO THE SELECTION AND MANAGEMENT OF TASMANIAN DRY SCLEROPHYLL RESERVES.

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Being a Thesis Submitted in Part Fulfilment of the Requirements for the Degree of Master of Environmental Studies.

Environmental Studies
University of Tasmania

December 1976.

ACKNOWLEDGEMENTS

We would like to thank many people for their assistance during the course of this study, in particular: our supervisors Dr. R. Jones, Mr. R. Rose and Mr. D. Thomas for their criticisms and guidance; Dr. A. Richardson for his suggestions and supervision in the early part of this year; Dr. P.S. Lake who helped initiate the study and whose advice in the planning of the field work programme was invaluable; Mr. R. Wilson for his participation in the census studies; staff of the Forestry Commission, particularly Mr. P. Duckworth, for supplying us with maps and other information; Mr. B.F. Ginn from the Commonwealth Department of Defence for information on property leased by that department; staff of the National Parks and Wildlife Service for the material and time they made available; and Mrs. V. Sykes for her patience and her accurate typing of this manuscript.

SUMMARY

Recent studies have suggested that island biogeographical principles may be applied to the selection and design of nature reserves. In this study, island biogeography provides the basis for the development of a planned approach to the preservation of the flora and fauna of Tasmanian dry sclerophyll forest.

The process of land clearance in eastern Tasmania has resulted in the fragmentation of large areas of dry sclerophyll forest into many smaller areas. These forested areas, surrounded by cleared land, resemble islands from the point of view of forest species. A series of eight such habitat islands is investigated in order to determine those factors which are important in controlling the number of island bird species. The investigation shows that the best predictor of the number of island bird species is the habitat island area. The investigation also shows that the species-area relationships for these islands are similar to those obtained in studies of oceanic and other habitat islands.

In the future, it is conceivable that all nature reserves will be surrounded by modified habitat. In this respect, they too may be regarded as habitat islands. The established similarity between the studied habitat islands and other types of islands provides the justification for the application of island biogeographic principles to the selection and management of Tasmanian dry sclerophyll reserves. The fact that there is a species-area relationship for dry sclerophyll habitat islands allows the prediction of 10,000 ha as the minimum size of a reserve required to preserve the biological diversity of the dry sclerophyll forest.

An examination of existing dry sclerophyll reserves using this size criterion, in conjunction with other design principles developed from island biogeography, emphasizes the inadequacy of the present reserve system. This situation is made even more serious by the modification of dry sclerophyll habitat which is occurring as a result of woodchipping operations in eastern Tasmania.

The desire within the community for an improvement in the present reserve system has recently been highlighted by several public enquiries into various aspects of forestry activities. Unfortunately, the availability of land suitable for reservation has been severely restricted by the extent of woodchip concessions over most of eastern Tasmania. Nevertheless, some areas are suggested which, if set aside as reserves, would reduce the pace of species extinction in dry sclerophyll forest.

If the principles developed in this study are accepted by the relevant agencies then the creation of an additional effective Tasmanian dry sclerophyll reserve should be a relatively straightforward process.

CONTENTS

1. INTRODUCTION

Throughout the world today the areas occupied by many natural habitats are undergoing two types of change. Firstly, the total area occupied by natural habitats is shrinking and secondly, formerly continuous natural habitats are being fragmented into disjunctive pieces. Both these processes have important consequences for the future of the world's plant and animal species. To preserve natural diversity it is critical, therefore, that the present methods of conserving wildlife be reviewed and that careful planning of reserves be undertaken, based on appropriate ecological principles.

A comparison may be drawn between a nature reserve and an oceanic island from the point of view that each is surrounded by a zone of inhospitable habitat which acts as a barrier to dispersal for many species. Considerable progress has been made over the last decade towards an understanding of the functioning of oceanic island systems, particularly as regards the maximum number of species that an island may support without threat of extinction to any species. Application of this knowledge may provide a basis for understanding what to expect from reserves and, most importantly, may offer a method for determining the minimum size of a reserve needed to maintain the diversity of plant and animal species characteristic of that habitat type.

To date, studies in the field of island biogeography have concentrated on natural islands with little attention given to the habitat islands created by man in clearing land for agricultural and commercial activities. The aim of the present study is to investigate the species-area relationship for a series of islands of dry sclerophyll forest on the Tasmanian mainland and to compare the findings of this study with previous studies undertaken on oceanic islands.

The implications of establishing a similarity between the two types of islands are far-reaching. It is hoped that this and other similar studies will serve to emphasize the special features of habitat islands and that, in future, more attention will be given to the planning of reserves in accordance with island biogeographical principles. Thus determination of the most suitable size and shape of a reserve, as well as planning for an integrated system of reserves which functions in the most effective way possible, may be achieved.

Apart from being of general significance the study is also important at the local level. In Tasmania, as in other places of the world, the natural environment is being fragmented as land is cleared to make way for urban and rural development. In the past the dry sclerophyll forest has been the habitat type most heavily exploited for these purposes and, more recently, has been subject to further pressure from the woodchip industry. Furthermore, whilst provision has been made for the conservation of other vegetation types within the State adequate reservation of areas of dry sclerophyll forest has failed to occur. For these reasons it is imperative that the present situation regarding the dry sclerophyll reserve system in Tasmania be examined and the need to establish additional reserves be investigated as soon as possible.

The desirability of having large-sized reserves to ensure maintenance of species diversity has been emphasized by several authors recently (Willis 1974; Diamond 1975; Moore and Hooper 1975; Sullivan and Shaffer 1975; Terborgh 1975). Few authors, however, have actually suggested dimensions. Unfortunately, it is extremely difficult to demonstrate experimentally the concept of minimum reserve size; nevertheless there have been some attempts, using a variety of approaches, to determine the size of a reserve required to maintain a particular taxon or group of species. These studies will be discussed further in the following chapter but it is important to emphasize that none of the authors have adopted the approach of the present study, in making use of the island nature of reserves and applying the corresponding biogeographic principles.

In order to understand why the field study was conducted and how the results of the study could be used to determine the area requirements for a dry sclerophyll reserve, it is necessary to trace the development of the theory of island biogeography and to examine the arguments which have been advanced in applying these principles to the design and management of nature reserves. This review introduces the field study where the planning and executing of the study are described in detail.

To develop a method for determining the size requirements of a reserve it was not necessary to conduct lengthy studies and, accordingly, all field work could be completed within a year by three workers. The apparent brevity of this study sets it apart from other more detailed pieces of scientific work but does not detract from the validity of the methods used or from the results obtained.

The results of this study are analysed and a minimum area, which would preserve the diversity of dry sclerophyll species, is suggested. The exploitation of the forest, both past and present, is then examined and the existing reserve system is also assessed. The need for augmenting this system is emphasized and some areas, which in biological terms may be appropriate for reservation, are discussed. It should be pointed out, however, that there are many other aspects which need to be considered before reserving an area but which are essentially beyond the scope of this report. The responsibility of dealing with these factors lies with those agencies which are involved in the planning of reserves at the government level.

2. THE DEVELOPMENT OF THE THEORY OF ISLAND BIOGEOGRAPHY AND ITS APPLICATION TO NATURE RESERVES

In the last ten years considerable interest has been shown by workers in the field of island biogeography and much has been written either directly on the subject or on its related applications. The studies which have been conducted are diverse and consequently it is convenient to divide the review material into four sections.

The first section reviews the literature relating to the numbers of species on islands and follows the development of the theory of island biogeography from early studies of oceanic and habitat islands through to its recent application to those islands created by man's activities. The second section examines the material which is predominantly mathematical in nature, written on faunal relaxation rates. In recent years many workers have turned their attention to the application of island biogeographic theory to nature reserves and this literature shall be reviewed in the third section.

A fourth section briefly discusses the literature relating to the characteristics of island species. As a minor part of the field study an attempt was made to investigate certain aspects of species feeding behaviour. Although the literature related to this section is important it is not central to the purpose of the review. For this reason, and in order to provide a background to that part of the field study, it is attached as an appendix (Appendix E).

2.1 Number of Species on Islands

Biologists have long been fascinated by island biotas and have found islands capable of providing insights into the nature of complex biological phenomena. These well-defined areas have fewer species than do continental areas of the same size, therefore species interactions are simpler to follow. Early interest in island biotas provided much information of a taxonomic nature concerning island inhabitants and their distributions. Only recently has attention focussed on a quantitative rather than a qualitative approach, leading to formulation of biogeographic theories at the species level.

The original studies in this field were undertaken on oceanic islands. In recent years however, many workers have extended the scope of study to include situations other than those involving aquatic barriers. Thus for alpine species, a mountain top may be interpreted as an island surrounded by a sea of lowland; for an aquatic species, a lake is a distributional island surrounded by a sea of land; and for a forest species, a forest is an island surrounded by a sea of non-forest habitat.

2.1.1 Oceanic Islands

Early workers (Darlington 1957; Wilson 1961; Preston 1962; MacArthur and Wilson 1963, 1967) compared the floral and faunal diversity of different oceanic islands with similar habitats and in the same archipelago. They found that the number of species (S) of a particular taxon increased with island area (A), according to the relationship $S = CA^Z$. The value of the parameter C depended upon the taxon and the biogeographic region studied whilst the value of Z remained remarkably constant. The comparisons also revealed that the number of species present on an island decreased with distance from the nearest colonizing source.

More recent studies (Wilson and Taylor 1967; Lack 1969, 1971; Power 1972; Abbott 1973; Johnson and Raven 1973; Terborgh 1974; Thomas 1974) have confirmed the findings of the early workers. More detailed studies (Hamilton *et al.* 1963, 1964; Hamilton and Armstrong 1965; Hamilton and Rubinoff 1967; Johnson *et al.* 1968; Diamond 1972, 1973, 1974, 1976; Lack 1973; Case 1975; Power 1975; Amerson 1976) using sophisticated multiple regression techniques have shown that species number can be predicted more accurately if other ecological variables are included with area and isolation in the statistical analyses. For islands in the West Indies, Hamilton *et al.* (1964) and Hamilton and Rubinoff (1967) found that area alone accounted for 93% of the variation amongst islands, whilst for the islands of the East Indies, area accounted for only 72% and elevation for an additional 15%.

Preston (1962) and MacArthur and Wilson (1963, 1967) independently interpreted the island pattern, of species increasing with area but decreasing with isolation, to mean that insular species diversities represent an equilibrium between immigration and extinction rates. In the equilibrium model proposed by MacArthur and Wilson the rate of immigration decreases monotonically with the distance of the island from a source of colonizers. Thus, all else being constant, distant islands will theoretically reach equilibrium with fewer species than an island closer to the source. MacArthur and Wilson further argued that the rate of extinction decreases monotonically as the area of the island increases. Thus, all else being constant, a small island will reach equilibrium with fewer species than a larger island. MacArthur and Wilson also pointed out that this equilibrium should be of a dynamic nature; that is, the composition of equilibrium species may change over time but the number of equilibrium species should remain fairly constant.

In a study of the avifauna of the Channel Islands off the coast of California, Diamond (1969) found that 17 to 62 percent of the species recorded on these islands in a survey conducted 50 years previously had disappeared and that an almost equal number of new species had established themselves. Diamond interpreted the results to mean that an equilibrium number of species had been reached on these islands. The study also showed that no island supported as many species of birds as it would have if it were part of the mainland and that the species turnover rate on any particular island was inversely proportional to the species richness of that island.

The same properties of island species have been demonstrated by Simberloff and Wilson (1969, 1970) and by Wilson and Simberloff (1969). They studied six very small mangrove islands in Florida Bay. The arthopod fauna of these islands was firstly recorded then each island was enclosed with plastic sheets and fumigated. This killed the fauna of the islands while leaving the flora undamaged. The subsequent recolonization of each island by arthropods was closely monitored. The islands acquired a fauna of the original number of species within six months but many of the species differed from the original ones. After the first 6 to 9 months the number of species stabilized but new species continued to replace old ones. In addition, the number of species present on each island varied inversely with the island's distance from the nearest source of colonists.

The equilibrium theory has been further established by the more recent work of Diamond (1971, 1973, 1974) and Terborgh and Faaborg (1973).

Shortcomings in the equilibrium theory have been discussed by Pianka (1967), Preston (1968), Simberloff (1969), Whitehead and Jones (1969), Diamond (1976), and Schoener (1976). Criticism has mainly centred on the non-interactive assumption of the equilibrium theory (Simberloff 1969; Schoener 1976) from which follows the general rule that the slope of the species-area relation should increase with increasing isolation (Diamond 1976; Schoener 1976).

In a study of the Solomon Archipelago avifauna, Diamond (1976) found that the relationship between species and area was best explained by an exponential rather than a power function. He also found that the value of the slope of the species-area relation, when considered as a power function, was considerably lower than would be expected from equilibrium theory for such an isolated archipelago. Diamond explained this anomaly by assuming that intra-archipelago immigration contributes far more colonists than inter-archipelago immigration for an island in a remote archipelago and concluded that the slope of an archipelago's species-area relation decreases with isolation.

In a more detailed analysis, Schoener (1976) estimated Z separately for the principal archipelagos of the south-west Pacific and also found that it showed a strikingly regular decrease with increasing distance from a source. He interpreted this apparent contradiction in the context of MacArthur-Wilson equilibrium type models as follows.

By assuming that species abundances are complementary and modelling average population sizes he was able to show that the slope (Z) of the species-area relation depended only on how close an island was to the maximum number of equilibrium species and not additionally on area, density, immigration, or extinction. A further consequence was that Z decreased monotonically with area A and was not constant as the power function $S = CA^Z$ implied.

However, these shortcomings are relatively minor and do not affect the general applicability of the equilibrium theory of island biogeography.

In fact MacArthur and Wilson (1967) acknowledged some of these weaknesses but pointed to the theory's virtues of making testable predictions which were not immediately obvious and of placing less emphasis on historical factors in order to explain the diversity of island species.

Wilson and Taylor (1967), Simberloff and Wilson (1969), and Diamond (1973, 1974) have added an evolutionary twist to the equilibrium model. They describe the first species to arrive and equilibriate as the "supertramp" species, which are good immigrants but inappropriate to the vegetation of the island. However, the equilibrium established is unstable and these species are vulnerable to gradual replacement by more specialized native species.

2.1.2 Habitat Islands

In several of the early studies carried out on oceanic islands and in the development of the equilibrium theory frequent mention was made of habitat islands (Preston 1962; MacArthur and Wilson 1967). MacArthur and Wilson pointed out the effect that differences in barriers between oceanic and habitat islands could have on species composition. As compared with oceanic islands, species already present on the habitat islands are faced with constant pressure of high immigration of less well-adapted species drawn from the surrounding habitat. Simultaneously, species attempting to colonize a habitat island should find it harder to do so because of the greater diversity of competition facing them at any given moment.

Results similar to those for oceanic islands were obtained when habitat islands within a large continent or large island were considered. Vuilleumier (1970) studied the bird species of paramo islands (islands of alpine vegetation) in the northern Andes and found that the number of species present on an island was directly proportional to its area and inversely proportional to the distance from the nearest colonizing source of alpine species. A recent reanalysis of Vuilleumier's data by Mauriello and Roskoski (1974), using multiple regression techniques, confirmed the finding that the best predictors of an island's avifaunal species richness are its area and distance from the nearest colonizing source.

Simpson (1974) studied essentially the same paramo islands but concentrated on the plant species. She found that the modern plant species diversity has a greater significant correlation with the area and isolation of these islands during the last glacial period than with similar measures of their present form.

Brown (1971) studied small mammal species which inhabit mountain vegetation in the Great Basin region of the western United States. He concluded two things from these studies. Firstly, that the species-area curve is considerably steeper than the curves usually obtained for insular biotas and secondly, that there was no correlation between the number of species and degree of isolation. Thence he implied that the rate of immigration was low and that the mammalian faunas of the mountain tops were relict populations, distinct from the equilibrium population predicted by island biogeography.

The montane islands of the Great Basin were also used by Johnson (1975) who studied the avifauna. In particular, she found that island area alone was not a good predictor of bird species number but that an index of habitat diversity, which includes area of forest, width of barrier, elevation, and latitude, explained 91% of the variation in total bird species. Furthermore, only a minor isolational effect was shown. Johnson concluded that the resident birds on the montane islands may also represent a non-equilibrium situation. Thus her conclusions are similar to those of Brown (1971).

However, these conclusions have been criticized by Diamond (1976) and Schoener (1976). Schoener (1976) suggested that the high value of Z obtained by Brown was, by itself, consistent with an equilibrium model in which rates of immigration and extinction are very low.

Other studies of habitat islands have considered arthopods in caves (Culver 1970; Vuilleumier 1973), insects in trees (Strong 1974), fish species in lakes (Barbour and Brown 1974), freshwater mussels in coastal rivers (Sepkoski and Rex 1974), insects on host plants (Janzen 1968, 1973; Opler 1974), small mammals of locally isolated rock piles in the Sierra Nevada (Smith 1974), mites using host rodents

(Dritschilo *et al.* 1975), plant species associations on badger disturbances in a tall-grass prairie (Platt 1975), cattle droppings as ecological units (Mohr 1943), insects on *Heliconia inflorescences* (Seiffert 1975), the bird species on mountain tepuis of southern Venezuela (Cook 1974), and the colonization of isolated bodies of water by small aquatic organisms (Maguire 1963).

2.1.3 Man-Created Islands

Apart from these natural examples of islands (both oceanic and habitat) there are islands which are created by man. In the past when natural communities formed a continuum the characteristics of insular populations were probably not of importance. With modern development vast areas of unsuitable habitat have been created, leaving the natural species to inhabit pockets of undisturbed vegetation. In the last few years there has been an increasing feeling among ecologists that island biogeography can be applied to such islands (Preston 1962; Diamond 1972, 1974, 1975, 1976; Terborgh 1974; Willis 1974).

The fragmentation of formerly continuous areas of natural vegetation into ecological islands has been demonstrated by Curtis (1956). He showed that a continuous area of woodland in the township of Cadiz, Wisconsin, of 21,528 acres in 1831, was reduced to 786 acres in 55 islands by 1950. Similarly Moore *et al.* (1967) showed that the mechanization of farming in Britain had led to the loss of hedgerows and the formation of islands of hedgerow habitat.

Most of the natural habitat islands reviewed earlier have followed the MacArthur-Wilson equilibrium theory in that the number of species an island can hold at equilibrium is a function of its area and isolation. Similar findings were obtained when man-made habitat islands were investigated. Cairns *et al.* (1969) submerged artificial substrates in Douglas Lake, Michigan, and studied their subsequent colonization by species of freshwater protozoans. Their results suggested that the formation and composition of protozoan communities on artificial substrates were the result of an equilibrium, comparable to that proposed by MacArthur and Wilson.

Similarly, Schoener (1974) considered plastic mesh sponges as islands for a variety of marine invertebrates and used them to explore island colonization in the marine environment. Colonization of small and large sponges simultaneously submerged either near or far from an algal bed, thought to be a source of colonists, was studied. She concluded that the results agreed with the equilibrium model of MacArthur and Wilson in that more species were present at equilibrium on larger than on smaller sponges equidistant from their source and that extinction rates were higher on smaller sponges. However, contrary to other predictions of the equilibrium theory, she found that larger islands had higher turnover rates than small ones the same distance from their source.

The biogeography of laboratory islands was studied by Wallace (1975) who considered the colonization of artificial islands by species of flies. He found that the equilibrium number of species was set by a balance betweem immigration and extinction.

Usher (1973) showed that the number of species of higher plants growing in twelve nature reserves in Yorkshire fitted the species-area relationship, $S = CA^Z$. However, the degree of correlation obtained by Usher was not as marked as that obtained in studies of natural islands since the nature reserves selected for study were in areas of high biological diversity.

Moore and Hooper (1975) studied 433 woods in Great Britain and recorded the breeding bird species in each wood. Although different types of woods were considered, the number of species present was found to be related to the area of the wood. The best correlation between species and area was given by the relationship, $S = CA^Z$. Because geographical isolation was usually compounded with ecological differences in the woods its effect on the number of species could not be ascertained.

An interesting study of the effect of geographical isolation on a man-made island was carried out by Willis (1974). Barro Colorado Island was formerly a mountain top until the building of the Panama Canal when the creation of Lake Gatun surrounded it by water. The island was set aside as a nature reserve in 1923. Since that time 45 species of birds, out of an original 200, have become extinct. Surprisingly no new species have taken their place. While many of the species that disappeared lived in second growth or at the forest edge and were presumably pushed out by forest growth, at least 13 of the lost species were forest types. Willis therefore presumed that their loss was an island effect. Since 1960, the three largest of the seven original ant-following bird species had become extinct and at least one more species is facing extinction. Willis concluded that Barro Colorado was approaching a new and lower equilibrium number of bird species because of its insularization.

2.2 Faunal Relaxation Rates

Most island biogeographic studies have concentrated either on the number of species as a function of certain physical parameters of the island or on the characteristics of island species. However, MacArthur and Wilson (1963, 1967), Simberloff (1969), Diamond (1972, 1973) and Gilroy (1975) have considered methods for estimating the time taken by an area that has been insularized, or an island whose fauna and flora has been disturbed, to attain its new equilibrium species number.

Diamond (1972) described the re-equilibriation of islands as the resultant of the extinction rate (species per year) exceeding the immigration rate (species per year) until an equilibrium number of species is established. He then derived the length of time required for the departure of the species excess at a certain time to relax to $\frac{1}{e}$ or 36.8% of the initial excess. This he called relaxation time.

In his derivation, Diamond acknowledged that his model was highly simplified in that the process of island equilibriation is treated as a non-interacting one, whereby the species are assumed to be independent.

MacArthur and Wilson (1963, 1967) obtained a similar result by considering the interaction of the immigration and extinction rates as functions of the number of species. Simberloff also derived a similar equation but again the non-interactive assumption is implicit in his treatment. Gilroy (1975) has proposed a more sophisticated molecular model whilst acknowledging that the Diamond model is quite appropriate for describing the early stages of colonization.

Diamond (1972) used the formula (described previously) to calculate the relaxation times for the total avifauna of land-bridge islands formerly connected to New Guinea; for the land-bridge relict avifauna of these islands; for islands formerly connected to some other larger satellite island but not to New Guinea itself; and for islands that lie on a shallow-water shelf and that formerly must have been much larger in area, although without connection to a larger island.

A similar analysis in a continental situation was made by Brown (1971) in his study of small mammals isolated on forest mountain tops in the Great Basin. During the cooler climates of the Pleistocene age these populations were not isolated as the forests formed a continuous belt. Terborgh (1974) made a similar analysis of the avifaunas of Caribbean Islands and dramatically confirmed the accuracy of his calculation by showing that they correctly predict the extinction rates observed within the present century on Barro Colorado Island by Willis (1974).

Both Diamond's analysis of New Guinea birds and Terborgh's analysis of Caribbean birds show that relaxation times increase with increasing island area. Diamond (1972) also suggested that relaxation times increase with increasing isolation but did not test this hypothesis.

2.3 Application of Island Biogeographic Theory to Nature Reserves

Up until this point consideration has been given to the development of the theory of island biogeography from initial studies of oceanic islands through to studies of man-created islands. As land clearance continues throughout the world and the fragmentation of continuous areas of natural habitat increases, the results of island biogeographic studies become increasingly relevant to the development of an understanding of the functioning of nature reserves. Whilst Preston, in 1962, pointed to the implications of his work on the canonical distribution of commonness and rarity for nature reserves, it has only been in the last few years that workers have begun to apply the knowledge gained from biogeographical studies to nature reserves.

Diamond (1972, 1973, 1974, 1975), Willis (1974), Terborgh (1974), May (1975), Slatyer (1975) and Sullivan and Shaffer (1975) have employed island biogeographic arguments to demonstrate that the ultimate number of species a nature reserve will maintain is likely to be an increasing function of its area and that the rate at which species become extinct in a reserve is likely to decrease with the reserve area. Hence the number of species that a reserve can hold at equilibrium will probably be set by a balance between immigration and extinction rates. The equilibrium will be at a larger number of species the greater the reserve is in size or the closer it is to a source of colonists.

Diamond (1975) and Sullivan and Shaffer (1975) have drawn attention to the fact that different species have very different area requirements for survival. Dispersal ability obviously differs enormously amongst species and conservation problems will be most acute for slowly dispersing species in normally stable habitats, such as rainforests. Diamond also pointed out that low colonization rates may mean that a species cannot cross unsuitable habitats or that for certain reasons it will not cross unsuitable habitats (Willis 1974).

Natural experiments in differential extinction studied by Diamond (1972, 1975) demonstrated that those species most in need of protection are generally those that are differentially lost. That is, the species with the highest extinction rates are those whose initial populations must have numbered few individuals, either because the species is a carnivore rather than a herbivore, or because it has specialized habitat requirements, or because it is a large mammal.

The importance of boundary effects has been discussed by Duffey (1974) and Williamson (1975). Williamson noted that species-area relationships similar to those obtained for islands have been obtained for quadrats of different sizes and in other studies of continuous ecosystems (Hopkins 1955; Preston 1962; Kilburn 1966). He argued that when a boundary was created around a natural reserve in a larger area of the same habitat the area of the reserve is, in effect, reduced and the number of species the reserve could support in equilibrium would be less than in the region as a whole. Williamson also noted that the species at the boundary would frequently be different from those suited to the centre of the reserve, especially if the habitat which lay outside the boundary was cleared away.

The authors mentioned above have examined how the eventual number of species that a reserve can hold is primarily related to its area, the variation in survival prospects between species, and the effect of boundaries on the species content of nature reserves. Diamond (1975) collated this background information and suggested six geometric design principles which could be expected to optimize the function of natural reserves, thereby ensuring the long term preservation of natural species. Diamond's principles, identified as A, B, C, D, E and F, are summarized diagramatically in Figure 1.

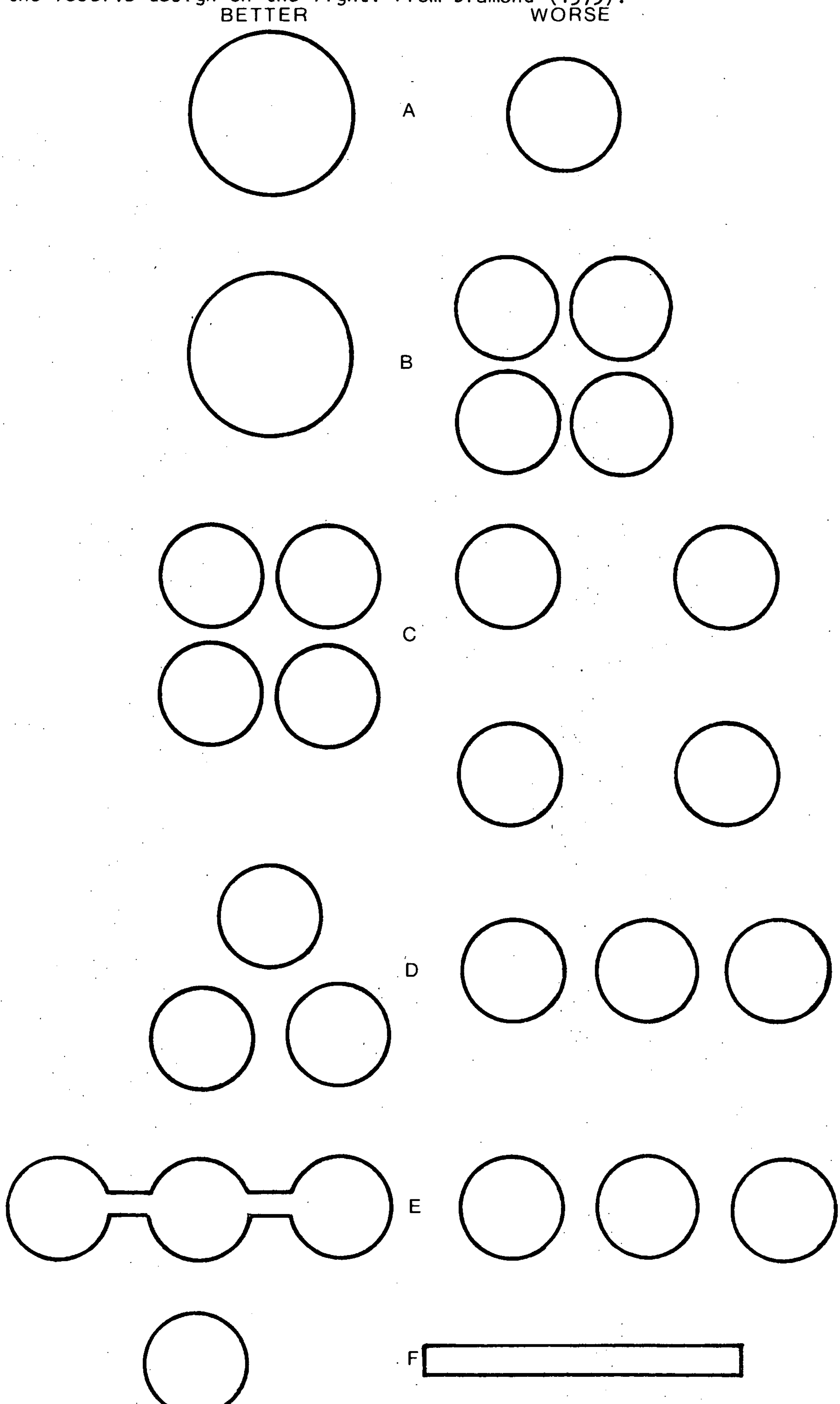
Principle A states that a large reserve is better than a small reserve. This is because the large reserve will hold more species at equilibrium and it will experience lower extinction rates.

Principle B states that given a certain total area available for reserves in a homogeneous habitat, the reserve should generally be divided into as few disjunctive pieces as possible. Many species that have a good chance of surviving in a single large reserve would be less likely to survive if the same area was apportioned among several smaller reserves. Additional credence is given to the principle by the work of several authors (Diamond 1974; Oxley *et al*. 1974; Willis 1974; May 1975) who have shown that some species are stopped by narrow barriers which could have the effect of converting one large reserve into two smaller reserves. Oxley *et al*. (1974) found that roadways inhibit the movement of small forest mammals. The effect was not necessarily dependent on traffic volume or road surface but appeared to be mainly related to the width of clearing made for the road.

Principle C states that if the available area must be broken into several disjunctive reserves, then these reserves should be as close to each other as possible if the habitat is homogeneous. Proximity will increase the probability of colonization where the population of the colonist species has become extinct.

FIGURE 1

Suggested geometric design principles, derived from island biogeographical studies, for nature reserves. In each case labelled A to F species extinction rates will be lower for the reserve design on the left than for the reserve design on the right. From Diamond (1975).



Principle D states that if there are several disjunctive reserves, these should be grouped equidistant from each other rather than grouped linearly. Equidistant grouping means that populations from each reserve can readily recolonize, or be recolonized from, another reserve.

Principle E states that if there are several disjunctive reserves, connecting them by strips of the protected habitat may significantly improve their conservation function at little further cost in land withdrawn from development (Preston 1962; Willis 1974).

Principle F states that any reserve should be as nearly circular in shape as other considerations allow in order to minimize boundary effects (Duffey 1974; May 1975; Williamson 1975). If the reserve is elongated or has dead-end peninsulas, dispersal rates to outlying parts of the reserve from more central parts may be sufficiently low as to perpetuate local extinctions by island-like effects.

Criticism of some of these principles as expressed by Diamond (1975) have come from May (1975) and Sullivan and Shaffer (1975). May (1975) pointed out that some of the principles ignore the fact that in certain cases several scattered reserves may have an advantage over a single large reserve or several clustered reserves. Thus, for example, a system of scattered reserves would probably provide better protection in the case of a disastrous event such as a bushfire.

Sullivan and Shaffer (1975) have emphasized that corridors between reserves may not be as effective in helping to preserve species as originally thought. They argued that the corridor would act as a filter permitting greater interchanges between taxa such as large mammals, for which the corridor is functional, and that propagules dispersing randomly would rapidly reach low densities along a corridor.

As regards the actual selection of nature reserves, several authors have emphasized that reserves should be large (Terborgh 1974; Willis 1974; Diamond 1975) but only a few have actually suggested dimensions (Main and Yadav 1971; Slatyer 1975; Moore and Hooper 1975; Sullivan and Shaffer 1975; Tyndale-Biscoe and Calaby 1975). Sullivan and Shaffer (1975) considered that there may be some transition size below which an area acts as an island and above which it acts as a continent. Above the transition size there would be no acceleration in the rate of species extinction and the full complement of species present in the original habitat area would be retained. Accordingly, Sullivan and Shaffer proposed that, for any given habitat type, it should be sufficient to set aside an area at least as large as the theoretical continental minimum. However, Sullivan and Shaffer did note that very much larger areas have shown a loss of species (Diamond 1972, 1973) and concluded that a real continental minimum has not been demonstrated in studies undertaken to date.

Alternatively, it has been proposed by Main and Yadav (1971) and Sullivan and Shaffer (1975) that the theoretical difficulties of minimum size might be avoided by considering the range requirement of certain range-sensitive species. If these were properly provided for then there would be sufficient room for organisms that demanded less space. They suggested that the space requirement of rare (not necessarily endangered) species such as large bodied carnivores be initially considered. Being of large size and high on the trophic structure these animals have fairly large range requirements. Sullivan and Shaffer considered that they may also be appropriate for analysis because they are often quite sensitive to human development and are, therefore, very susceptible to man-induced extinctions.

The size of a reserve required to protect a particular species has been considered from the standpoint of effective population number by Crow and Kimura (1970) and Tyndale-Biscoe and Calaby (1975). Effective population number is the population size that will retain the original genetic diversity of the species, or a large fraction of it, in perpetuity and provide the genetic means for continued evolution (Tyndale-Biscoe and Calaby 1975). Crow and Kimura (1970) have examined this concept theoretically and using population genetics have shown that an effective population of 1,000 individuals is near to the minimum to ensure the continuance of genetic variability. This has been supported by analysis of actual situations (Main and Yadav 1971; Tyndale-Biscoe and Calaby 1975).

The three approaches discussed above summarize the studies which have been undertaken in attempting to develop a method for determining reserve size requirements. Such investigations are still in the early stages and a considerable amount of work needs to be done before an effective or convenient method for determining minimum reserve size can be guaranteed.

One feature common to these approaches is that they involve fairly intensive field work or require a reasonable understanding of the community or species which is to be investigated. However, application of studies of the type undertaken on oceanic islands to habitat islands of a particular vegetation type may provide an alternative method for determining reserve size requirements which, in contrast to the previous methods, does not rely on detailed field work or prior knowledge of the organisms on which the study is based.

3. INVESTIGATION OF HABITAT ISLANDS OF DRY SCLEROPHYLL FOREST IN TASMANIA

Studies which have been conducted in the field of island biogeography have been varied, involving a diversity of island types emphasizing different aspects of island communities. However, there have been no studies undertaken to date to investigate habitat islands of natural vegetation created by land clearance and to determine the factors (for example, island area) which are important in controlling the number of species present. If such a series of habitat islands were studied and the similarity in functioning between this and other types of islands established, this would justify the application of the present body of biogeographic theory to the design of nature reserves. Hence a method could be developed, which is based on sound ecological principles, for determining the minimum reserve size required to maintain the diversity of species for a particular vegetation type.

In Tasmania, the dry sclerophyll forest has been heavily exploited in the past for agricultural activities resulting in the formation of isolated patches of forest in rural districts which provide an ideal opportunity for such an investigation. In recent years the pressure on the dry sclerophyll forest has further increased with intensification of forestry activities in the eastern part of the State. The setting aside of areas of dry sclerophyll forest for conservation purposes has been neglected due to past emphasis on the scenic value of reserves and the abundance of this habitat type elsewhere in Australia. Therefore, in view of the escalating demands on this forest and the failure to reserve representative areas,there is an urgent need for developing guidelines to help in assessing the adequacy of the present reserve system and in the planning of future reserves, if the diversity of the dry sclerophyll forest is to be preserved.

The present study was planned as a short term investigation in order to acquire confirmatory data to support the application of island biogeographic theory to the design of nature reserves and to provide a method for determining the size of a reserve of dry sclerophyll forest required for effective functioning. Thus a major advantage of the study lies in its ability to produce, relatively quickly, such information which could henceforth be adopted by those involved in the long term planning of a dry sclerophyll reserve system for Tasmania.

The description of the field investigation undertaken is necessarily brief and selected experimental work only is reported. Additional data concerning the feeding behaviour of species on the different islands was also collected during the course of the field work. This information is, however, peripheral to the main purpose of the study and for this reason is attached as an appendix (Appendix E).

3.1 Planning Field Investigations

3.1.1 Selection of Community Type

The study involved determining the number of bird species present in a series of islands of dry sclerophyll forest located in south-eastern Tasmania.

Bird species were chosen in preference to other taxonomic groups as it was felt that census studies based on this group would be the least difficult to perform. Most bird species can be observed directly, in contrast with amphibian and reptile species, and do not require the use of traps necessary for studies on mammal species. Furthermore, mammals were not considered suitable for this study because of the existence of only a few Tasmanian species which increases the probability of sampling errors associated with census work. Studies based on insects, plants, microorganisms and similar groups were considered impractical and beyond the capabilities of the team in view of the time and experience needed in classifying these organisms.

The importance of conducting studies on the dry sclerophyll forest in Tasmania has been emphasized. However, the decision to concentrate on this habitat type was automatic owing to travel requirements which restricted the study to the south-east quarter of Tasmania where it is the dominant vegetation type. There are several features of the dry sclerophyll forest which make it the preferred one for this type of study. These include the higher diversity of bird species, as compared with Tasmanian rainforest and wet sclerophyll forest, and the lesser amount of undergrowth which facilitates field work in such areas.

3.1.2 Selection of Island Sites

In eastern Tasmania, clearfelling operations have been employed in harvesting the dry sclerophyll forest for woodchip production. It was originally thought that these activities would have led to the formation of habitat islands of natural vegetation. Further investigations, however, revealed that the present method of coup distribution was producing the reverse situation, in creating islands of cleared land within a "sea" of natural vegetation. Thus it was not appropriate to proceed further on this basis and attention was focussed on other land use activities which might lead to the formation of habitat islands.

Land clearing as carried out on private property in rural districts was then investigated. Aerial photographs showing patterns of land clearance in the Midlands and south-eastern districts were examined at the offices of the Lands Department, Hobart. Approximately 80 possible island sites, ranging in size up to 200 ha were located from these photographs. Larger sized islands were detected using topographical maps which displayed the larger areas of uncleared forests in the State. Two islands, approximately 350 hectares and 1,200 ha in size were thus located.

These sites were then examined and certain features such as isolation, extent of logging or burning, as well as the general vegetation of the island, were noted. Sites which had been substantially affected by logging or burning or which were considered to be inadequately isolated were eliminated, leaving approximately 15 sites for further consideration.

As the equations presented in the literature describe the relationship between the number of species and island area in terms of a logarithmic value for island area, it was necessary to select a number of islands which followed a logarithmic series. In view of the time and labour available for this study a series of six sites, ranging in size from a minimum of 10 ha to a maximum of 10,000 ha, were to be investigated.

In practice this size range was limited by the availability of large islands. Whereas there were many islands in the smaller size range (less than 200 ha), only two suitable large islands existed. These were automatically selected for study and a choice was then made between the smaller islands to complete the logarithmic series. In choosing between these islands, features such as accessibility, similarity in vegetation type and distance from Hobart, were considered. The location of the island sites used in the census studies are given in Figure 2. Photographs of three of the sites taken from a light aircraft are presented overleaf (Figures 3 to 5).

Further studies of the six selected sites were undertaken in order to compare the vegetation in greater detail. The dominant *Eucalyptus* species and shrub species were identified and structural features such as the amount of undergrowth and development of the canopy layer were also noted.

Whilst undertaking the first census study it became obvious that one of the selected sites (site 2a) was unique in containing a large proportion of plants in flower. Another site (site 2) slightly smaller in size was included in the census studies in addition to this site. Figures 7 to 10 show examples of the vegetation present in some of the sites, including site 2a.

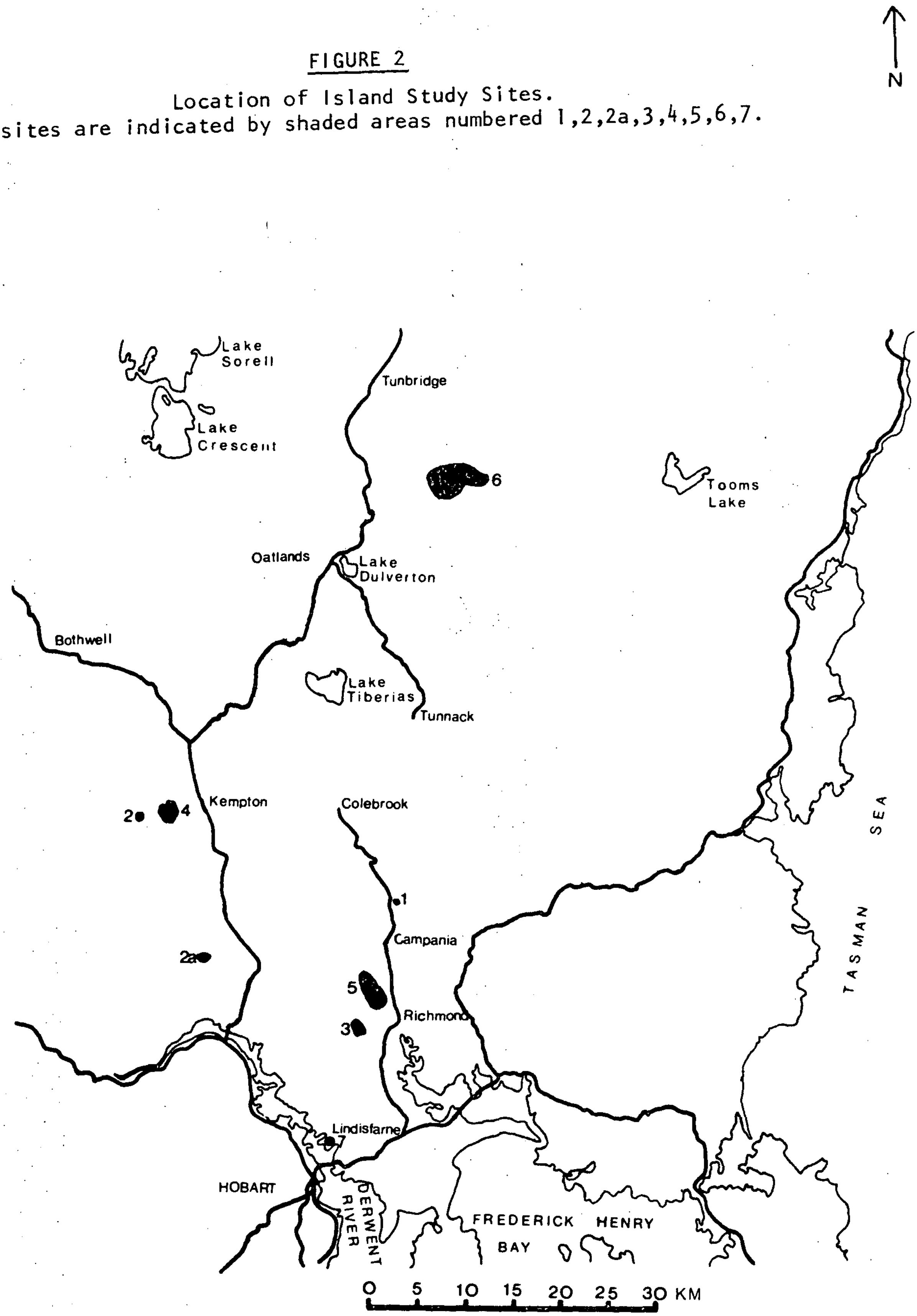
Aerial photographs and a full description of each of the sites including the plant species present, size and other features, are contained in Appendix A, pages 100 to 106 and 107 to 108, respectively.

Reference to topographical maps revealed the existence of two islands, approximately 50 hectares in size, located in a Hobart residential suburb. One site (site 7) was well isolated by a zone of dwellings and it was decided to census this site, not as part of the main study but to allow a comparison with similarly sized rural sites. The location of this site is given in Figure 2. Figure 6 illustrates the positioning of site 7 within the residential zone.

With the exception of the city site, all sites were located on private property and field work was undertaken with the permission of the landowner.

FIGURE 2

Location of Island Study Sites.
Eight sites are indicated by shaded areas numbered 1,2,2a,3,4,5,6,7.



FIGURES 3 TO 5

Photographs of some of the sites taken from a light aircraft.

FIGURE 3

Site 1. This was the smallest island studied (9 ha) and is an example of a well isolated island.

FIGURE 4

Site 2a (in distance). This island is 28 ha in area and is located on top of a low hill. The photograph also shows another island (in foreground) which was not included in the study.

FIGURE 5

Site 5. This island is located on the side of a steep hill and was the second largest island studied (341 ha).

FIGURE 6

Site 7. The photograph shows the location of this site within the residential suburb of Lindisfarne, Hobart.

FIGURES 7 TO 10

Photographs of some sites showing the vegetation present.

FIGURE 7

Site 2

FIGURE 8

Site 2a. This island differed from the other islands studied in containing a large amount of plant material which was in flower at the time of each census study.

FIGURE 9
Site 3

FIGURE 10
Site 6

3.2 Conducting Field Investigations

The field work associated with this project was carried out between the months of March and October, 1976.

Studies using bird species are usually carried out in the breeding season thereby ensuring that the species enumerated (the breeding pairs) are the true "residents" of the area, as opposed to nomads or migrants. Studies conducted out of the breeding season, particularly in the winter months, may still be of value since it is during this period that the species are most likely to suffer a food shortage and are forced into depending on the area for their food supply. In the case of Tasmanian dry sclerophyll species, the breeding season is from August to February with most species breeding in September, October and November. Three separate census studies were undertaken throughout the year. Two of these were in the autumn and winter months (late May and early August) and the third in the breeding season (late September).

3.2.1 Recording Times for the Island Sites

The amount of time spent recording in a site, in order to determine the bird species present, varied in relation to the size of the site. It was necessary to spend more time in the larger sites to allow a full coverage of the area, thereby increasing the probability of encountering all or most of the species present.

A series of recording times, proportional to the area of the sites, was estimated. In deciding upon such a series it was necessary to select a time period for the smallest site which would allow adequate coverage of that area but not result in an excessive amount of time spent in the largest site. For the smallest site one half-hour period was considered sufficient to record the species present and the recording times for the other sites were calculated on this basis.

As mentioned previously, this study was of a short term nature and involved only three workers. Each observer was to work independently and the total time spent in a site was shared amongst the observers. This procedure was followed when recording in each site and repeated for each of the three separate studies undertaken throughout the year.

The maximum length of a recording period was four hours and all census work was carried out in the daytime. No attempt was made to include nocturnal species in the study. Approximately 10 days were needed to complete each census study. The recording times calculated for each of the sites are contained in Appendix B, page 112. Information concerning the dates of the census studies, the times and the lengths of the recording periods are on pages 113 to 115.

3.2.2 Census of an Island Site

Before beginning the census of a site some attempt was made to divide up the area to ensure maximum coverage in the time available.

For the very small sites (site 1 and site 2) this was not necessary as it was possible for each observer to cover the area in the allotted time. For the larger sites the island was firstly divided into a number of "segments" corresponding to the number of recording periods set aside for that site. At the beginning of a recording period each observer was then allotted a third of a segment to census.

Having been assigned part of a site each observer walked at random through the area noting the different bird species either seen or heard. Only a record of the presence of a species was required, no estimate of abundance was necessary. Additionally, if a species was observed feeding, the vegetation zone in which it was feeding was recorded. Flocks of birds observed feeding were listed as such. Vegetation zones were defined as follows:

Zone 1 - ground layer (grasses and small shrubs)
Zone 2 - middle layer (taller shrubs, juvenile trees, trunks of larger trees)
Zone 3 - canopy layer (canopy of larger trees)

For the census study conducted in September, a record was also kept of those species which exhibited certain behavioural characteristics (such as nest-building, vocal displays), indicating that they were breeding.

The recording sheet used in this study was based on one used by workers (Dawson and Bull 1975) who conducted census studies on bird species in New Zealand forests. Information relating to physical conditions such as weather, amount of sun, wind and noise encountered whilst recording in each site was also noted. This was done as it was thought that adverse physical conditions might affect the species counts and thus it was advisable to have access to any information which might account for otherwise inexplicable results. An example of this sheet and explanation of the methods used to record the physical data is contained in Appendix B page 110. Records of the conditions encountered for each of the census studies are on pages 113 and 115.

3.3 Environmental Controls of Species Numbers in Tasmanian Dry Sclerophyll Habitat Islands

The main purpose of the study was to investigate the relationship between the number of bird species recorded in the dry sclerophyll habitat islands and various ecological parameters, particularly area, of the islands. This is based on an expectation derived mainly from studies of archipelagos that assumed measures of environmental diversity may be important in regulating the number of species.

3.3.1 Selection of Variables

The dependent variable in the relationship is the number of species resident in each of the dry sclerophyll habitat islands. With regard to the present study, the problem is to determine those species actually resident in each area. Most biogeographic studies of birds on oceanic islands use the number of breeding land and fresh-water species as the dependent variable. This distinction excludes seabirds or "edge" species which are not entirely dependent on the island habitat for survival and food. The analogy with the present study would be to use the number of breeding dry sclerophyll species as the dependent variable and to disregard the "edge" species (for example the noisy miner and the starling). These "edge" species may use dry sclerophyll habitat for nesting but obtain most of their food from surrounding clear areas and are not entirely dependent on it.

However, there is evidence from previous studies of habitat islands (Johnson *et al.* 1968; Vuilleumier 1970; Brown 1971; Cook 1974) that the total number of species resident in the habitat should be considered as the dependent variable.

With regard to Tasmanian birds, winter is the time when food resources are at a minimum. Accordingly Thomas (personal communication) has suggested that those species resident in an area during the winter months are those truly dependent on the area.

The number of species resident in an area the year round could also be used as the dependent variable. For the present study, the residents would be those birds recorded in each of the three census studies (that is, over a period of five months). However, nomadic movements of birds are important in Australia (Keast 1961, Rowley 1974, Thomas 1974). Keast (1961), for example, considered 531 species of land birds breeding in Australia and showed 26% to be nomadic.

The dry sclerophyll islands chosen for study share similar climate and vegetation, therefore, inter-island variation in species numbers should mainly be correlated with island area, isolation (spatial and temporal), and elevation. Unfortunately, temporal isolation could not be accurately estimated. However, all other variables are easily obtained from aerial photographs and maps.

With these points in mind, the following variables were chosen for the present study.

Dependent Variables

Total number of breeding species, S_1
Number of breeding dry sclerophyll species, S_1'
Total number of winter resident species, S_2
Number of winter resident dry sclerophyll species, S_2'

Independent Variables

Island area, A. This is the total area (in ha) of each dry sclerophyll forest habitat island.
Relative isolation, I. This is the relative spatial isolation of each island, measured as the straight line

distance (in km) between the island and the nearest major block of dry sclerophyll habitat. One problem with this variable is the difficulty, in some cases, of identifying which is the nearest major section of dry sclerophyll habitat.

Elevation, E. This is the average elevation (in m) of each island and is used as an indirect assessment of topographic and general environmental diversity.

The data collected in the three census studies conducted on habitat islands of dry sclerophyll forest is tabulated in Appendix C.

A species-habitat list compiled by David Thomas (Appendix D) was used as an aid to classifying the dry sclerophyll bird species. Species not listed but included as dry sclerophyll birds for the purposes of the study were the kookaburra and goldfinch. Although introduced species, they occur mainly in dry sclerophyll forest habitat and therefore must affect the community structure by using food or habitat resources that the native species would normally have used.

At the bottom of the list of species recorded in each island (Appendix C), the number of dry sclerophyll species (excluding migrants), and the total number of species (excluding migrants) are noted. The number of breeding dry sclerophyll species (excluding migrants) and the total number of breeding species (excluding migrants) are also noted at the bottom of the list of species recorded in the third census study.

Eight islands were available for inclusion in the investigation of the environmental controls of species numbers. Of these, site 2a differed from the other sites in containing a large proportion of plant material which was in flower at the time of each census study. For this reason it was decided not to consider this island when investigating the relationship between species and ecological variables. However, the significantly larger number of bird species recorded in the area than would be expected on comparison with the other islands indicates the important effect that a ground and shrub layer of plants in flower can have on species numbers.

The city island, (site 7) which is situated between Lindisfarne and Geilston Bay, represents a completely different type of habitat island to all the others studied being bounded on one side by the Derwent River and on the other three sides by suburbia. For this reason it was also not included when investigating the relationship between species and ecological variables.

Table 1 lists for each island the selected dependent and independent variables.

TABLE 1

Dependent and independent variables used to investigate environmental controls of species numbers.

	VARIABLES		ISLAND 1	2	3	4	5	6
INDEPENDENT	A	AREA (HA)	9	20	74	189	341	1232
	I	ISOLATION (KM)	1.0	1.1	0.9	0.6	1.0	3.5
	E	ELEVATION (M)	100	200	340	100	200	500
DEPENDENT	S_1	TOTAL NUMBER OF BREEDING SPECIES	4	8	11	16	20	27
	S_1'	NUMBER OF BREEDING D.S. SPECIES	2	6	9	15	19	25
	S_2	TOTAL NUMBER OF SPECIES IN WINTER	4	10	17	19	24	27
	S_2'	NUMBER OF D.S. SPECIES IN WINTER	3	7	15	16	22	26

3.3.2 Modelling Species Numbers

The relationship between the dependent variable S and the independent variables A, I and E was determined by regression analyses according to the following five models.

(a) Linear Model

Under this simple model there is a linear relation between species S and each of the independent variables A, I and E such that:

$$S = a_o + a_1A + a_2I + a_3E$$

For this model the independent variable A, together with I and E, accounted very accurately for the variation in the number of species.

The equations obtained by multiple regression together with the multiple correlation coefficients are listed below.

$$S_1 = 15.0675 + 0.0366A - 11.2008\ I + 0.0126\ E;\ r = 0.9754*$$

$$S_1' = 14.4466 + 0.0394A - 12.3852\ I + 0.0113\ E;\ r = 0.9729*$$

$$S_2 = 18.6320 + 0.0409A - 16.8065\ I + 0.0340\ E;\ r = 0.9696*$$

$$S_2' = 15.8230 + 0.0400A - 15.7950\ I + 0.0329\ E;\ r = 0.9816*$$

Note: For the prece ding regressions and for all subsequent regressions * denotes significant at the 5% level and ** denotes significant at the 1% level.

(b) Log-Log (MacArthur-Wilson or Island Equilibrium) Model

Under this model suggested by MacArthur and Wilson (1963), local areas acquire species by immigration and lose them by extinction. In the absence of historical speciation, the number of species inhabitating an area will represent an equilibrium between the opposing rates of extinction and immigration. The results of various biogeographic studies of islands suggest a relationship of the form:

$$S = CA^{a_1}$$

or

$$\log S = a_o + a_1 \log A$$

The independent variable A accounted for virtually all of the variation in the number of species. The inclusion of the other independent variables I and E in different combinations (log I, log E; log E,I; log I, E; I,E), produced no statistically significant increase in the accuracy of the model. In some cases the accuracy was reduced. The species-area relationships obtained are given below and shown in Figures 11 to 14.

$$\log S_1 = 0.33990 + 0.36956 \log A; \; r = 0.97881^{**}; \text{ Figure 11}$$

$$\log S_1' = 0.01136 + 0.48386 \log A; \; r = 0.95711^{**}; \text{ Figure 12}$$

$$\log S_2 = 0.43318 + 0.35959 \log A; \; r = 0.92314^{**}; \text{ Figure 13}$$

$$\log S_2' = 0.23550 + 0.41971 \log A; \; r = 0.94264^{**}; \text{ Figure 14}$$

A consideration of Figures 11 to 14 indicates that the model is not accurate for small island areas of dry sclerophyll habitat. For this reason a minimum cut-off area of 20 ha was assumed and the regressions performed again. In this case the species-area relationships obtained are given below and shown in Figures 11a to 14a.

$$\log S_1 = 0.49608 + 0.30719 \log A; \; r = 0.99458^{**}; \text{ Figure 11a}$$

$$\log S_1' = 0.30853 + 0.36518 \log A; \; r = 0.98731^{**}; \text{ Figure 12a}$$

$$\log S_2 = 0.73402 + 0.23945 \log A; \; r = 0.96449^{**}; \text{ Figure 13a}$$

$$\log S_2' = 0.50994 + 0.31010 \log A; \; r = 0.95400^{*}; \text{ Figure 14a}$$

Thus the accuracy of the log-log model is increased in all cases by the assumption of a minimum cut-off area of 20 ha.

(c) Semi-log (Uniform Species/Individual Distribution) Model

Under this model, the larger the island the larger will be the number of individuals and hence, the larger the number of species. The islands could, in fact, be regarded as different sized samples from a uniform species/individual distribution. From the work of Gleason (1922), Williams (1964), Pielou (1969), and Diamond (1976), it would seem that in this model:

$$S = a_o + a_1 \log A$$

The independent variable A accounted for virtually all of the variation in the number of species. The inclusion of the other independent variables I and E in differing combinations (log I, log E; log I,E; E, log I; I,E) again produced no statistically significant increase in the accuracy of the model and, in some cases, reduced the accuracy. The species-area relationships obtained are given below and shown in Figures 15 to 18.

$$S_1 = -6.64487 + 10.46790 \log A; \ r = 0.98823^{**}; \text{ Figure 15}$$

$$S_1' = -8.82142 + 10.72233 \log A; \ r = 0.99008^{**}; \text{ Figure 16}$$

$$S_2 = -4.60126 + 10.69564 \log A; \ r = 0.98561^{**}; \text{ Figure 17}$$

$$S_2' = -6.89865 + 10.84403 \log A; \ r = 0.98868^{**}; \text{ Figure 18}$$

Under this model a negative value of a_o implies that, theoretically, there would be no species on a unit area (one ha) dry sclerophyll habitat island.

(d) Perimeter Model

Fundamental to this model is the hypothesis that the greater proportion of the birds inhabiting the forested islands depend upon the edges. If it is assumed that the islands are roughly circular then according to this model:

$$S = a_o + a_1 A^{\frac{1}{2}}$$

For this model, the only independent variable investigated was area (A) and the dependent variable the total number of species (S_1 and S_2). The species-area relationships obtained are given below and shown in Figures 19 and 20.

$$S_1 = 4.80331 + 0.68571 A^{\frac{1}{2}}; \ r = 0.96932^{**}; \text{ Figure 19}$$

$$S_2 = 7.94915 + 0.63924 A^{\frac{1}{2}}; \ r = 0.88207^{*}; \text{ Figure 20}$$

Figures 19 and 20 indicate that the perimeter model is more accurate at smaller areas.

If a maximum cut-off area of 350 ha is assumed under this model then the species-area relationships obtained are given below in Figures 19a and 20a.

$$S_1 = 2.41818 + 0.97144 A^{\frac{1}{2}}; \ r = 0.98894^{**}; \text{ Figure 19a}$$

$$S_2 = 3.63317 + 1.15627 A^{\frac{1}{2}}; \ r = 0.95013^{*}; \text{ Figure 20a}$$

The above equations and Figures 19a, 20a show that the accuracy of this model is increased if a maximum cut-off area of 350 ha is assumed.

Another way of demonstrating the concept of the perimeter model is to consider the ratio of the number of breeding dry sclerophyll species to the total number of breeding species for each habitat island. This ratio (S_1'/S_1) for each island is shown in Table 2.

TABLE 2

Ratio of the number of breeding dry sclerophyll species to the total number of breeding species for each habitat island.

ISLAND	1	2	3	4	5	6
AREA (HA)	9	20	74	189	341	1232
S_1'/S_1	0.50	0.75	0.82	0.94	0.95	0.93

Table 2 shows that for the smallest habitat island (9 ha) edge species comprise 50% of the total number of species. As the area of habitat island increases the proportion of edge species decreases (that is, S_1'/S_1 increases) up to areas of 190 ha. For areas greater than 190 ha the proportion remains reasonably constant.

As might be expected from a consideration of Table 2, the species of the smallest island were of particular interest. Species recorded in this island for all three census studies were the eastern rosella, noisy miner, and forest raven. During each census study a flock of 20 to 30 noisy miners was observed inhabiting this area. The noisy miners appeared to display aggression towards the eastern rosella and several incidents were observed in each census study. The aggressive nature of groups of noisy miners has been mentioned previously by Rowley (1974). He noted that they have a tendency to form groups which forage or attack intruders together. The large numbers of noisy miners and their aggressive group attitude to other species helps explain why no small bird species inhabited this island.

It was also planned to draw a comparison between the species of the city island (site 7) and those of the other islands in order to determine the effect that suburbia may have on species composition. However, when recording species in this island it was found that a large proportion of the island's birds spent the greater part of the day in the surrounding suburban gardens. Consequently, the number of species recorded for this island is very probably a lot lower than the actual number. For this reason comparison between this island and the other islands was not attempted.

(e) Schoener (Species Complementary) Model

This model has only recently been described by Schoener (1976). He assumed that species abundances were complementary, that is, individuals of the species divide some amount of resources that increases directly with area. He then derived a species-area relationship of the form:

$$S = \frac{K_1 A}{2}\left[-1+\sqrt{1+\frac{4P}{K_1 A}}\right]$$

where P is the number of species in the colonizing pool, and K_1 is a constant such that $K_1 = \frac{\lambda_A \rho}{\mu_N}$,

where ρ is the density of individuals,

λ_A is the proportion of unestablished species immigrating per unit time,

μ_N is a proportionality factor which increases with increasing likelihood of an individual dying.

All the dry sclerophyll forest islands studied are not very isolated, relative to most oceanic and habitat islands studied previously, and can easily be colonized. For this reason the number of colonizing species in the source pool (P) can be considered to be the total number of dry sclerophyll bird species (P = 42).

Then the species-area relationship becomes:

$$S = \frac{K_1 A}{2}\left[-1+\sqrt{1+\frac{168}{K_1 A}}\right]$$

Different values of the constant K_1 were then tried in the above equation to determine that value which produced the most accurate estimate of the observed number of breeding dry sclerophyll species for the studied islands.

K_1 = 10.0 was found to be most accurate and the calculated values of the number of breeding dry sclerophyll species (S'_{1C}) are given below in Table 3 together with the observed number of breeding dry sclerophyll species (S_1').

TABLE 3

Calculated (S_{1C}') and observed (S_1') number of breeding dry sclerophyll species for each habitat island studied.

ISLAND	AREA (HA)	S_1'	S_{1C}'
1	9	2	3.6
2	20	6	5.3
3	74	9	9.6
4	189	15	14.2
5	341	19	17.8
6	1232	25	26.4

The species-area relationship obtained from the Schoener equation using P = 42 and K_1 = 10 is shown in Figure 21 along with the observed dry sclerophyll data.

The correlation between the results calculated from the Schoener equation and the observed results is very good (R = 0.9874) and highly significant $p<0.001$.

3.3.3 Species-Area Relationships in Tasmanian Dry Sclerophyll Habitat Islands

Over the 140-fold size range of dry sclerophyll habitat islands studied and for the five models tested, the best predictor of the number of bird species is the habitat island area.

Of the models considered the semi-log and the Schoener models using area alone as the independent variable are the most accurate in explaining the observed data. Only slightly less accurate are the log-log model, using area alone as the independent variable, and the simple linear model, using all three independent variables. Slightly less accurate again is the perimeter model. However it should be pointed out that statistically there is very little to choose between the five models.

A significant increase in the predictive value of the log-log model can be achieved if a minimum cut-off area is assumed. This may be because dry sclerophyll habitat islands of the order of 10 ha or less are comparable in size to only one territory for many dry sclerophyll species and, consequently, would only support a single pair. Since it is thus marginal whether species with minimum territory requirements can occur on these islands at all, the species number is lower than would be the case if the species-area relation were extrapolated to smaller areas.

Similarly, a significant increase in the predictive value of the perimeter model can be achieved if a maximum cut-off area is assumed. This is to be expected as the smaller the island is in size, the greater is the perimeter to area ratio and hence the greater would be the proportion of birds dependent on the edges.

In the past most studies of island biotas have been carried out using the MacArthur-Wilson (1963) equilibrium theory as a basis. There is evidence from the present study to demonstrate that equilibrium conditions exist for the dry sclerophyll habitat islands. For each of the islands, several species recorded in the first census study were not present in the second census study. However, reference to Appendix C shows that the number of species for each island remained remarkably constant over the five month period between the first and last census studies. This suggests that an equilibrium condition probably exists for the islands studied, whereby extinctions balance immigrations, even though most of these islands have only been isolated for about 50 years.

The slopes (Z) of the species-area relationships obtained from the log-log model are at the high end of the range (typically 0.20 to 0.35) calculated in studies of other insular biotas. The equilibrium theory developed by MacArthur and Wilson predicts that Z for an archipelago (or set of islands) should increase with increasing isolation.

However, their argument is based on scattered islands for which immigration is assumed to be inter-archipelago. The relevance of the slope Z has been discussed recently by Diamond (1976) and in more detail by Schoener (1976).

Schoener found that Z, estimated separately for the principal archipelagos of the south-west Pacific, shows a strikingly regular decrease with increasing distance from a source. He discussed this apparent contradiction mainly in the context of MacArthur-Wilson type models and pointed out that the relation of extinction to area underlines the species-area relation in this model. MacArthur and Wilson argued that larger islands have larger average population sizes for the same number of species and hence have lower extinction rates.

Schoener modelled this intervening variable, average population size, more explicitly and considered two cases. The first case assumes that species are independent of one another. By modelling, it was found that with increasing area (A), the equilibrium number of species (S) increases monotonically at a decreasing rate to the number of species in the source pool. It was also found that Z decreases with increasing per species immigration, density, area, or decreasing extinction, but was independent of the number of species in the source P. This is in contradiction to the bird data for individual archipelagos. The second case is more realistic and assumes species abundances are complementary. In this case individuals of the species divide amongst themselves some amount of resources which increase directly with area. By modelling, Schoener found again that S increases monotonically at a decreasing rate to P. However, in this case $Z = 1 - (\frac{1}{2 - S/P})$. There are two important consequences of this relation. The first is that Z depends only on S/P and not additionally on area, density, immigration, or extinction. This implies that Z varies continuously with S and therefore varies continuously with area (A). It is not constant as the power function implies. The second important consequence is that Z always decreases with increasing A, because S increases with this variable. This is as for the first case with the exception that Z always increases with increasing P, because S/P decreases with P. Hence islands supplied from a species rich source should have steeper species-area slopes than those supplied from a species poor source.

The relatively high slopes obtained from the present study may be explained by reference to the equation $Z = 1 - \frac{1}{(2 - S/P)}$, derived by Schoener. The dry sclerophyll habitat islands studied are not very isolated and each may be colonized from other near islands, or from near species rich pools. Thus for these islands it may be assumed that P = 42. For the smallest island (9 ha), the equilibrium number of species (S = 3) is a lot less than P(=42) and hence,

$$S \ll P, \qquad Z = 1 - \frac{1}{(2 - 0)} = 0.5$$

For the largest island, (1232 ha) S (=30) approaches P(=42) and hence,

$$Z = 1 - \frac{1}{2 - 30/42} = 0.23$$

For some larger island S must approach P and hence,

$$S = P, \qquad Z = 1 - \frac{1}{2 - 1} = 0$$

Thus at small areas Z is steep (approaching 0.5) but monotonically decreases with area A until at a certain size (transition size) Z = 0. This explains the results plotted in Figures 11 to 14, especially the dramatic decrease in species numbers at small areas.

As far as the present study is concerned, the important outcome of Schoener's work is that the log-log model may satisfactorily explain the species-area relation over a certain range of areas but Z cannot be assumed to be constant outside the studied range.

The species-area relationships obtained are similar to those obtained in other island studies even though the habitat islands are not very isolated relative to the mobility of Tasmanian dry sclerophyll bird species. However, Diamond (1971) and Willis (1974) have studied islands which are even less isolated than the dry sclerophyll habitat islands investigated in this study. Willis (1974) concluded that the extinction of some species on Barro Colorado Island was due to its insularization combined with low numbers of these species and their apparent inability to recolonize the island across a water barrier which, in some places, was less than 500 m. Diamond (1971) found some forest understorey species absent on a forested island only 55 m from mainland New Guinea.

Both Diamond and Willis explained the non-occurrence of some species on these islands by their inability to cross even a narrow water gap.

In the case of this study, the dry sclerophyll bird species are highly mobile and only two of the non-migratory and non-nocturnal dry sclerophyll species may be considered as being completely restricted to this habitat type. As the species-area relationships for the studied islands are similar to those obtained in other studies, it follows that for these species the effect of isolation is probably not important but the actual insularization and resulting island area is highly significant. Terborgh (1974) came to a similar conclusion when discussing the observations of Willis (1974) and Diamond (1971).

This view is further strengthened by a consideration of Maria Island, a largely dry sclerophyll island 7.5 km off the east coast of Tasmania. The area of dry sclerophyll forest on Maria Island is of the order of 6000 ha yet it only supports 34 (non-migratory, non-nocturnal) breeding dry sclerophyll species, 8 less than the full complement of 42 such species. All of the 8 "missing" species are perfectly capable of colonizing the island from the eastern mainland of Tasmania and, in fact, most have been recorded at some time on or over the island.

The important outcome of the study is that there is a relationship between the number of bird species inhabiting a dry sclerophyll habitat island and its area. Furthermore, the relationships obtained are similar to those obtained in other studies of oceanic and habitat islands. Thus there is very good justification for applying island biogeographical theories to dry sclerophyll habitat islands and for using the species-area relationships obtained to suggest the size of an effective dry sclerophyll reserve.

FIGURE 11

Relationship between the log of the total number of breeding species in dry sclerophyll islands and the log of the island area (in ha). +, dry sclerophyll islands. The straight line is the least mean squares fit to all points.

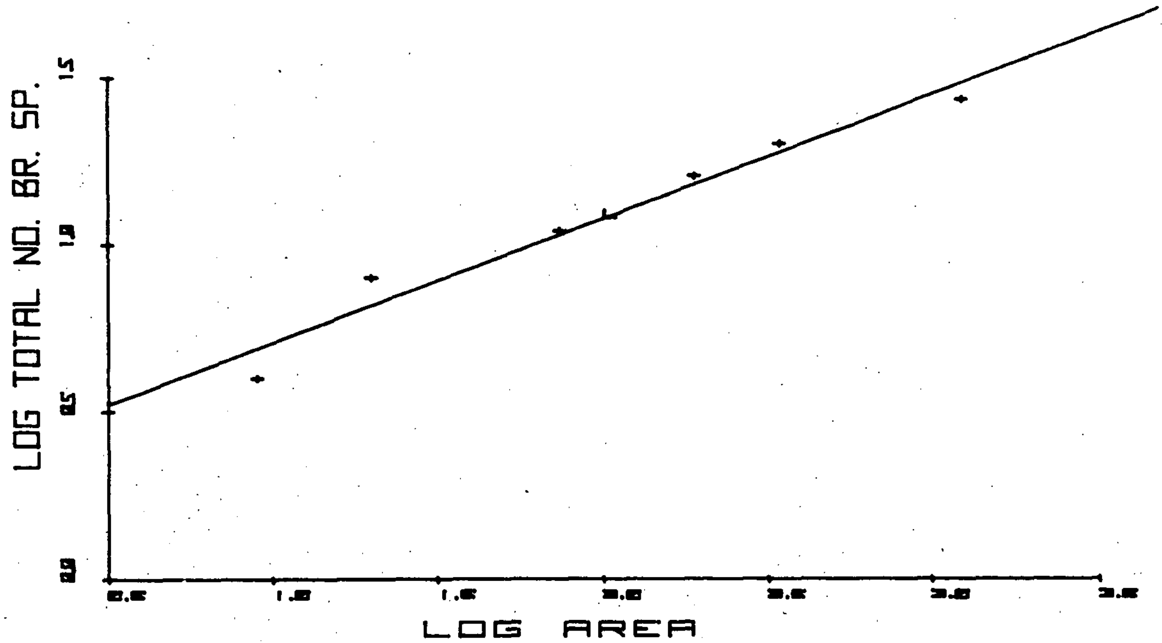


FIGURE 11a

Relationship between the log of the total number of breeding species in dry sclerophyll habitat islands and the log of island area (in ha), assuming a minimum cut-off area of 20 ha. +, dry sclerophyll habitat islands. The straight line is the least mean squares fit to all points.

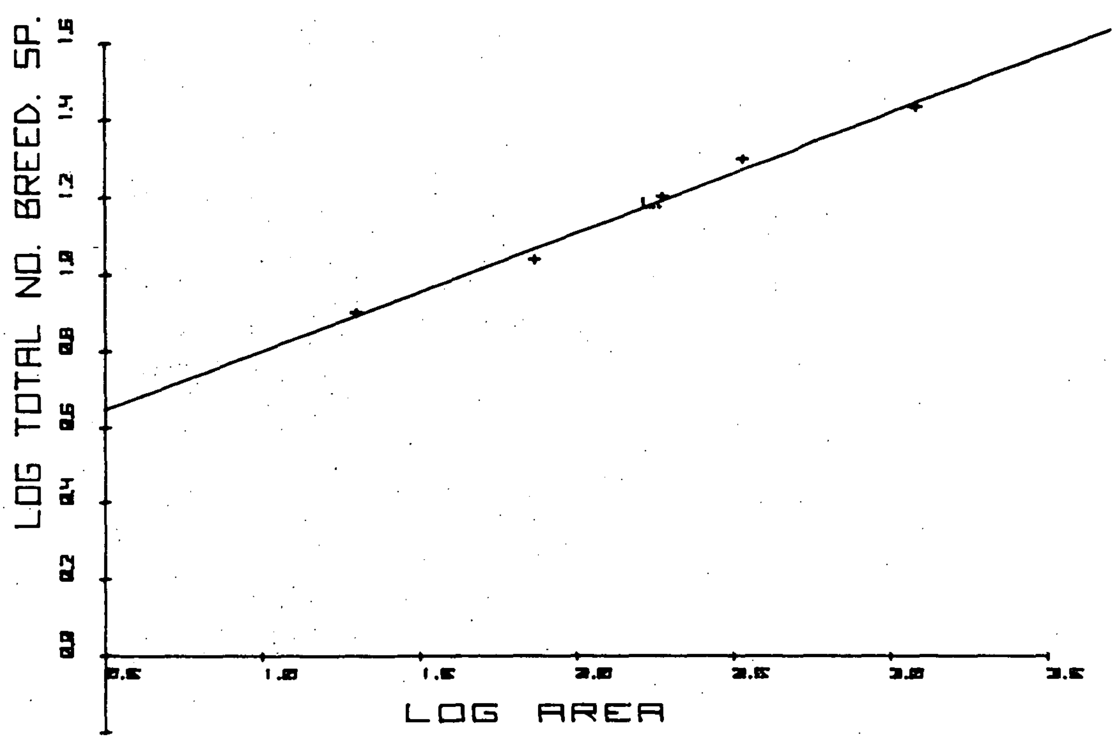


FIGURE 12

Relationship between the log of the number of breeding dry sclerophyll species in dry sclerophyll habitat islands and the log of island area (in ha). +, dry sclerophyll habitat islands. The straight line is the least mean squares fit to all points.

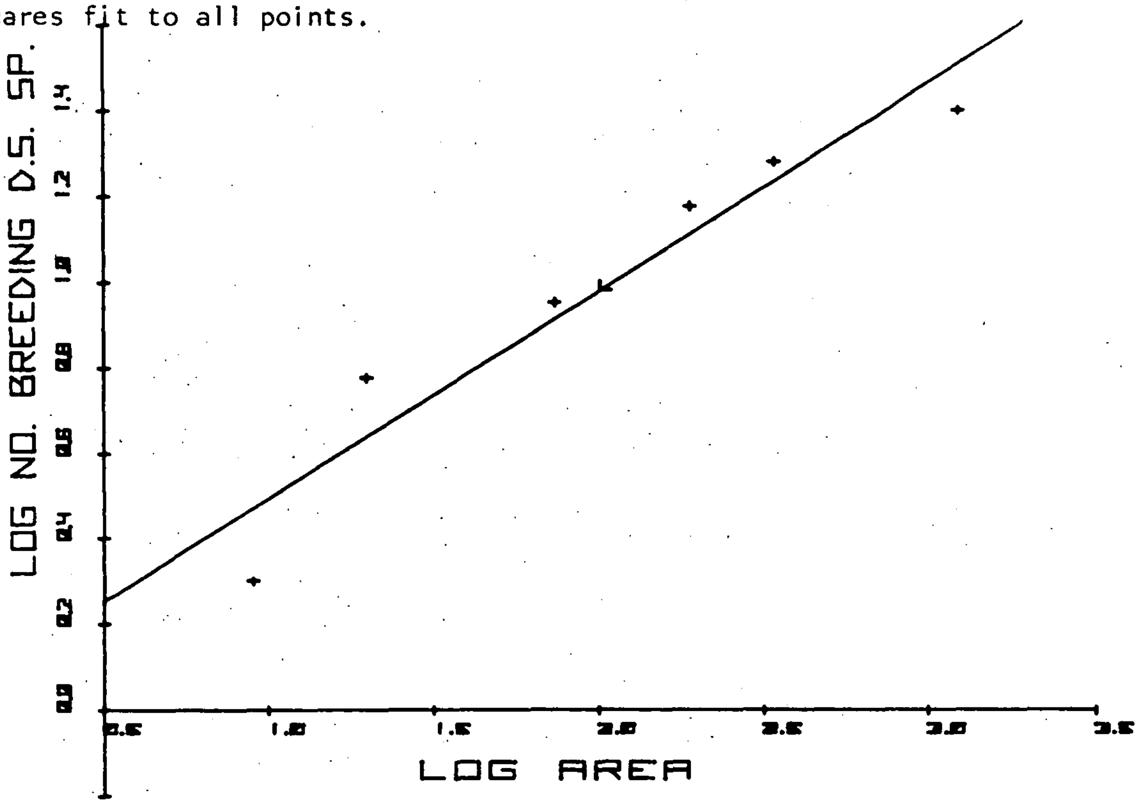


FIGURE 12a

Relationship between the log of the number of breeding dry sclerophyll species in dry sclerophyll habitat islands and the log of island area (in ha), assuming a minimum cut-off area of 20 ha. +, dry sclerophyll habitat islands. The straight line is the least mean squares fit to all points.

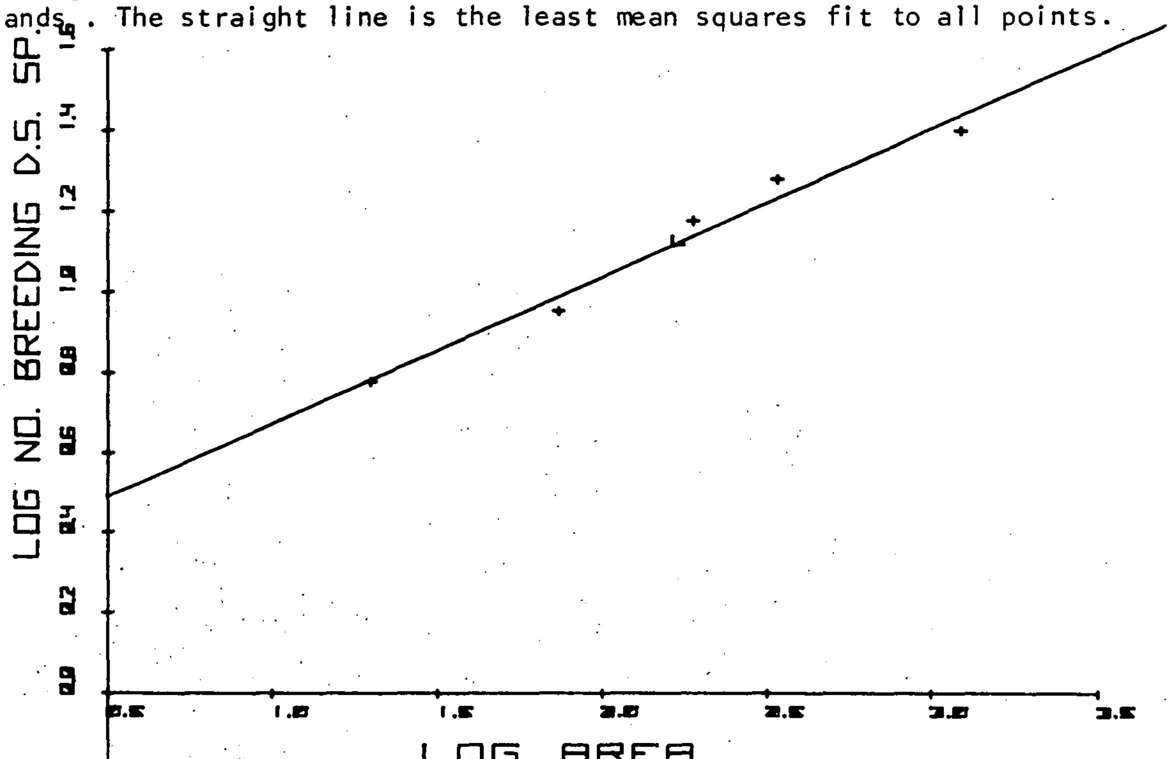


FIGURE 13

Relationship between the log of the total number of species recorded during winter in dry sclerophyll habitat islands and the log of island area (in ha). +, dry sclerophyll habitat habitat islands. The straight line is the least mean squares fit to all points.

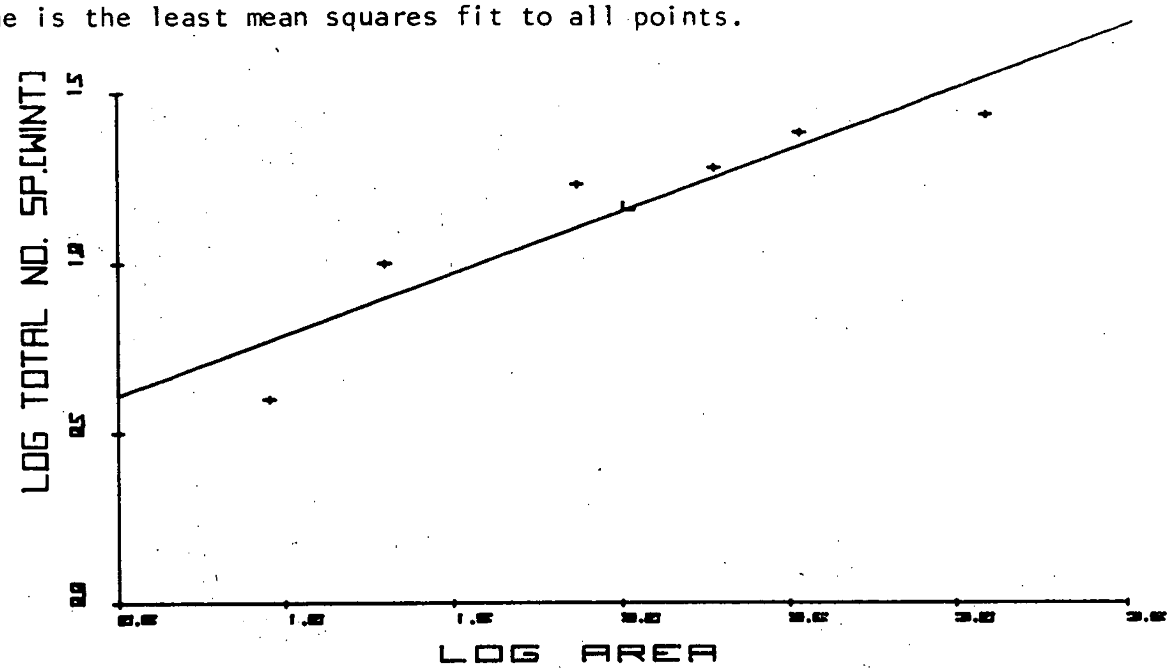


FIGURE 13a

Relationship between the log of the total number of species recorded during winter in dry sclerophyll habitat islands and the log of island area (in ha), assuming a minimum cut-off area of 20 ha. +, dry sclerophyll habitat islands. The straight line is the least mean squares fit to all points.

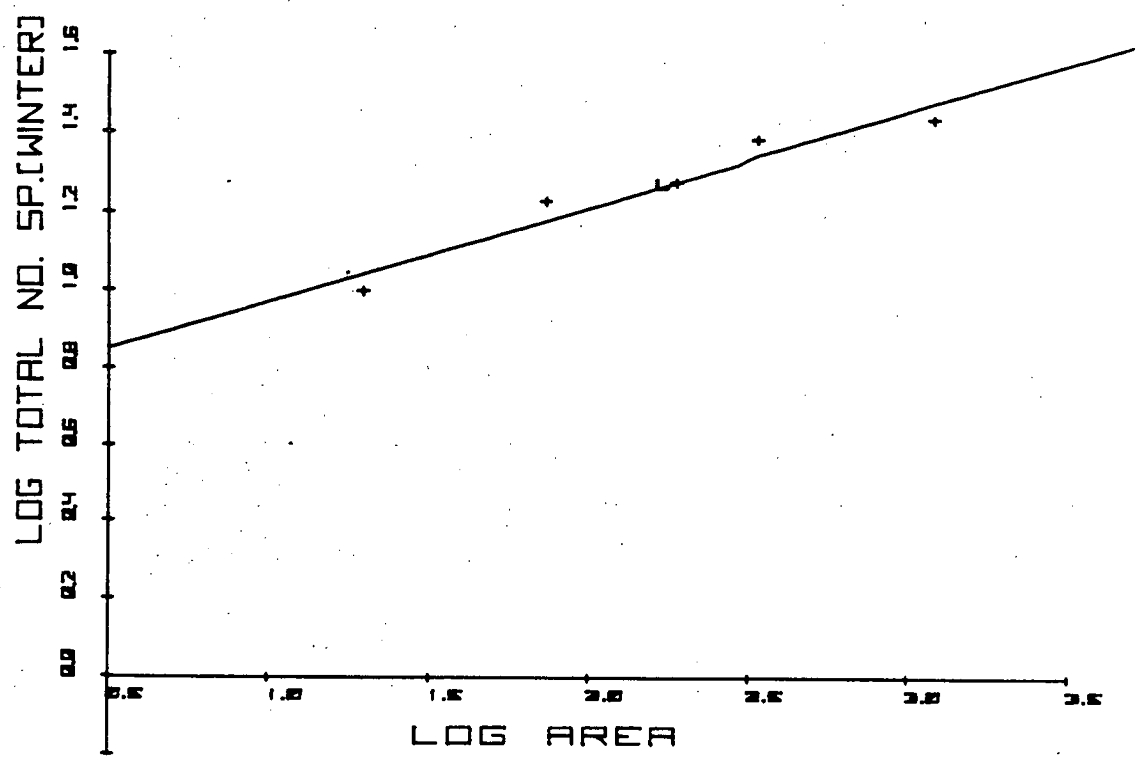


FIGURE 14

Relationship between the log of the number of dry sclerophyll species recorded during winter in dry sclerophyll habitat islands and the log of island area (in ha). +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

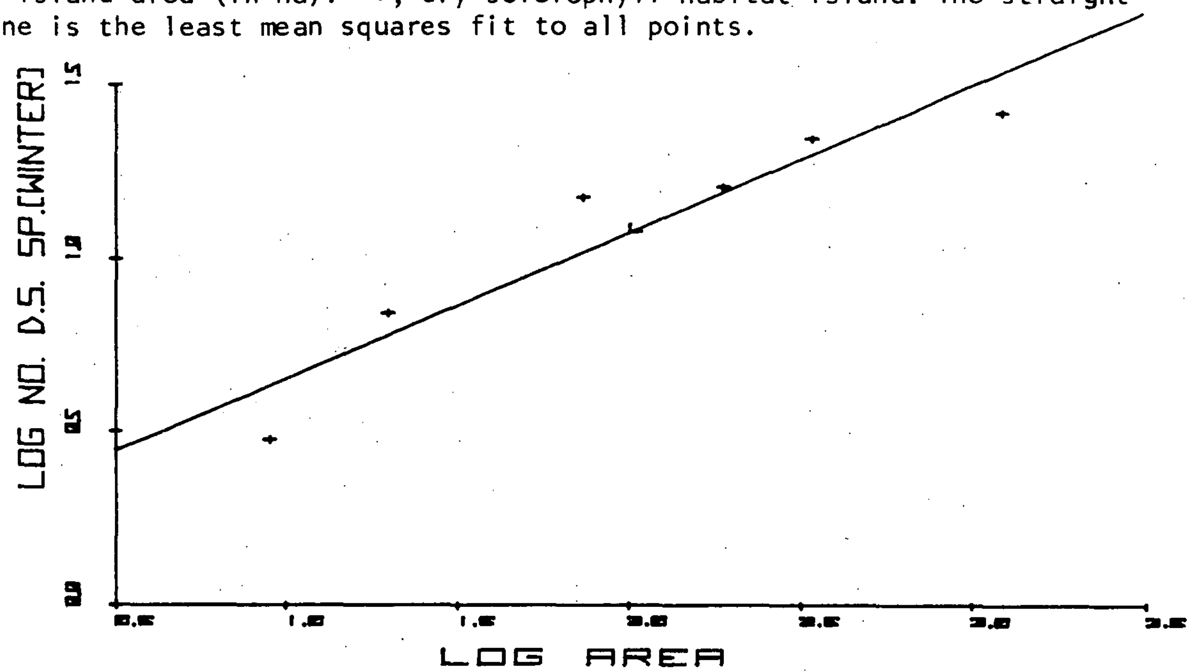


FIGURE 14a

Relationship between the log of the number of dry sclerophyll species recorded during winter in dry sclerophyll habitat islands and the log of island area (in ha), assuming a minimum area cut-off of 20 ha. +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

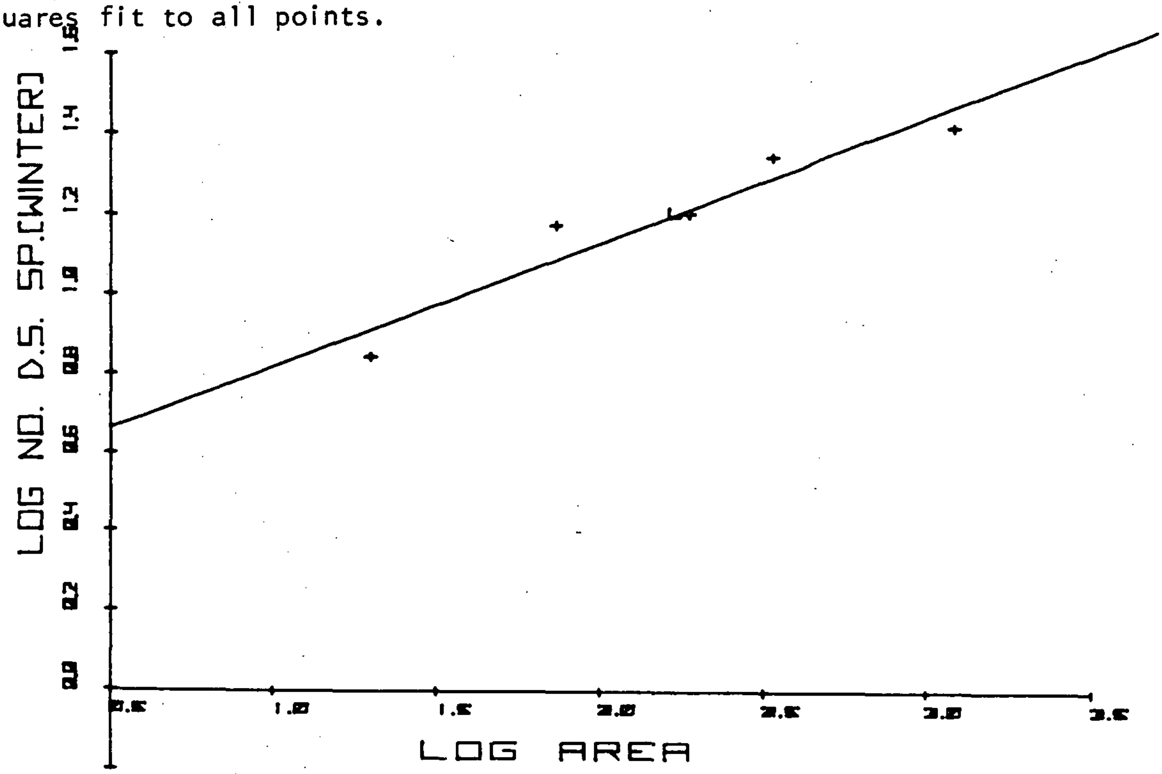


FIGURE 15

Relationship between the total number of breeding species in dry sclerophyll habitat islands and the log of island area (in ha). +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

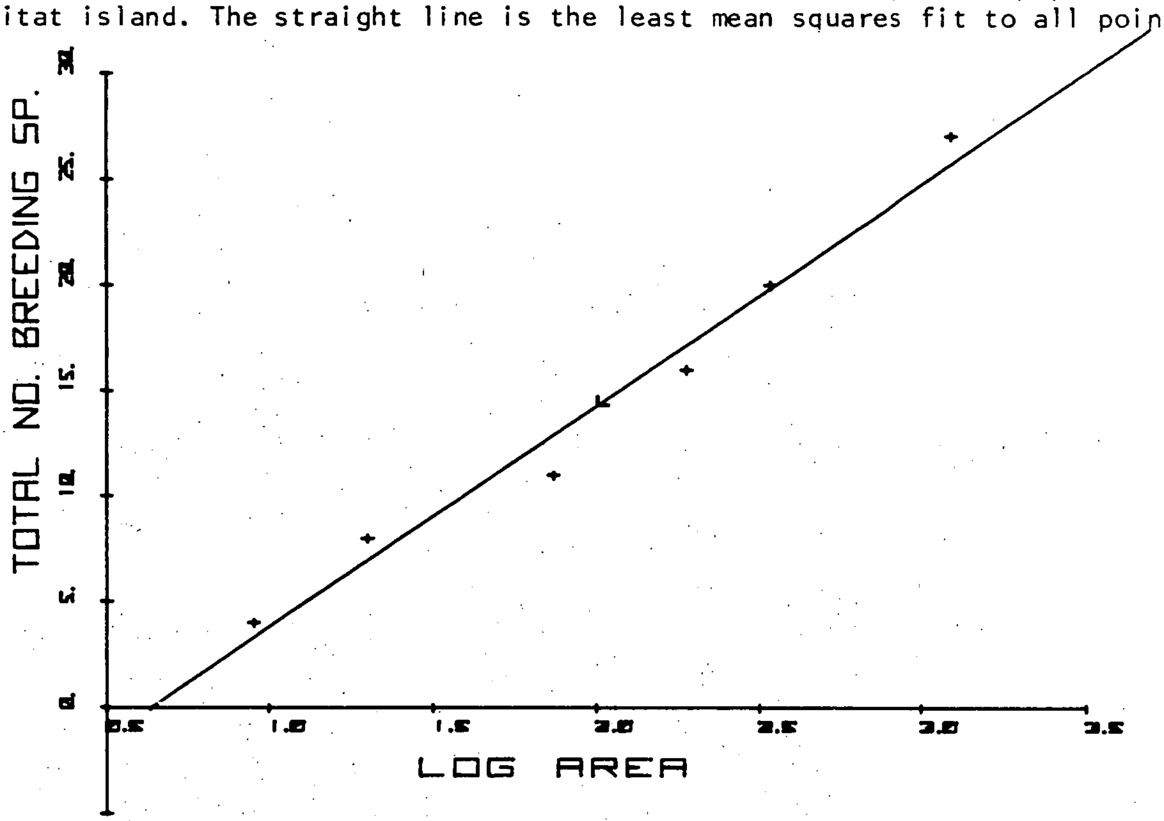


FIGURE 16

Relationship between the number of breeding dry sclerophyll species in dry sclerophyll habitat islands and the log of island area (in ha). +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

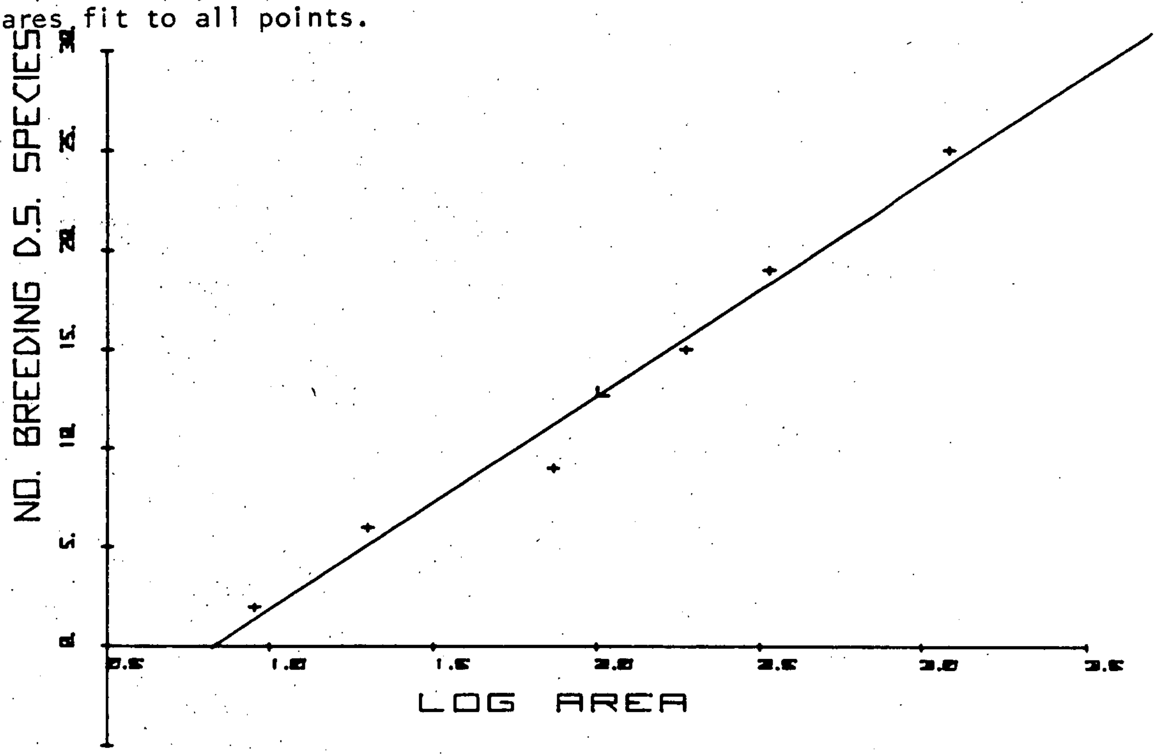


FIGURE 17

Relationship between the total number of species recorded during winter in dry sclerophyll habitat islands and the log of island area (in ha). +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

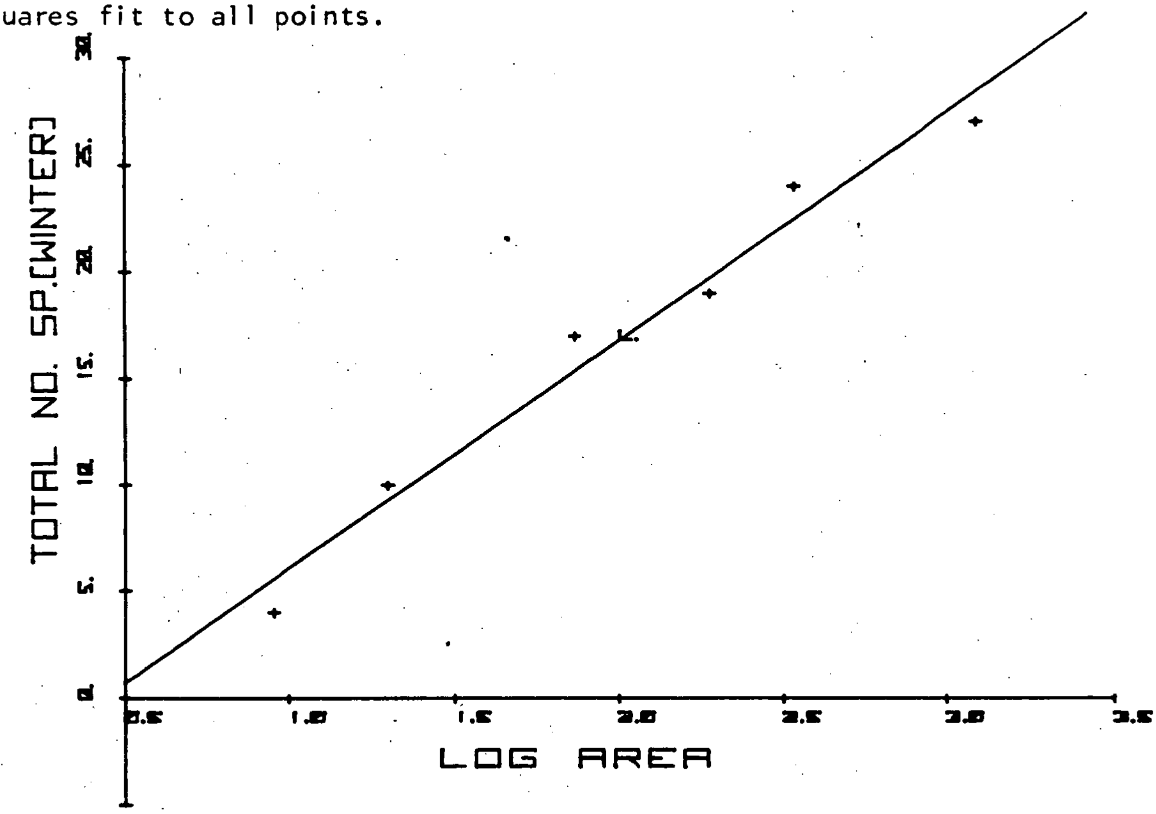


FIGURE 18

Relationship between the number of dry sclerophyll species recorded during winter in dry sclerophyll habitat islands and the log of island area (in ha). +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

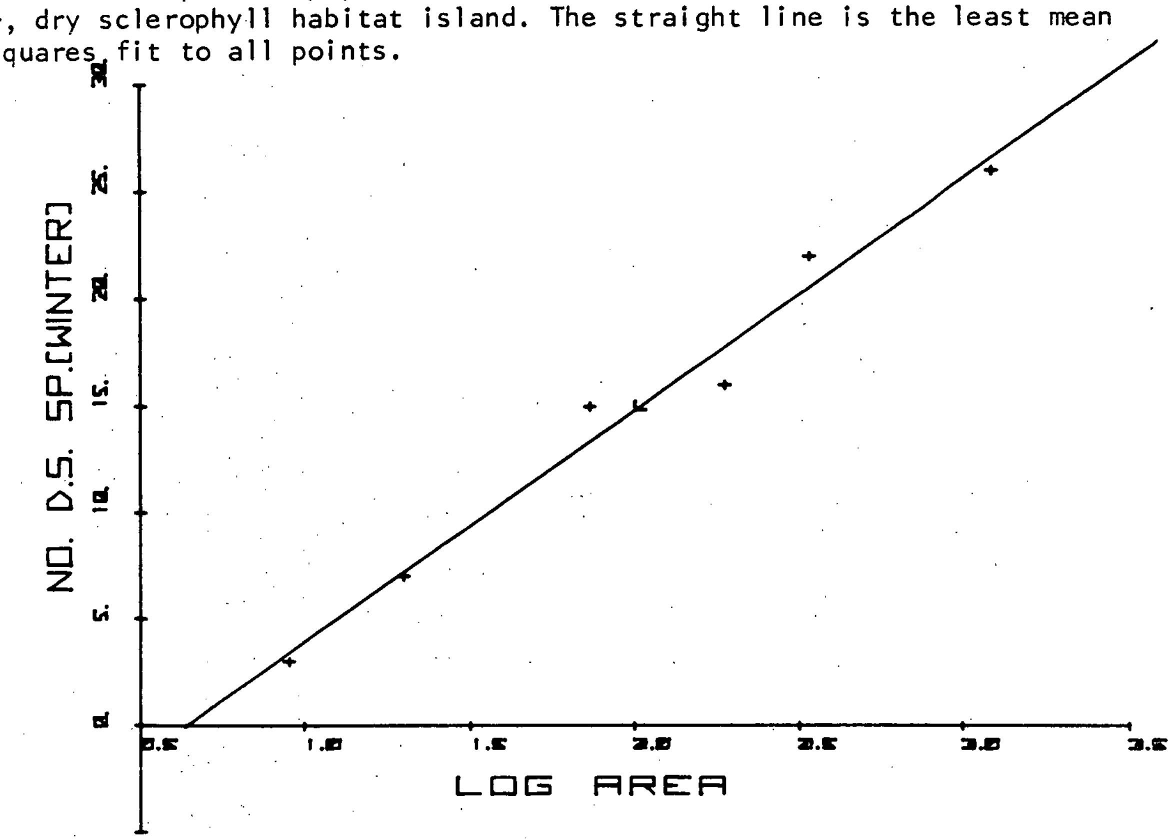


FIGURE 19

Relationship between the total number of breeding species in dry sclerophyll habitat islands and the square root of the island area (in ha). +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

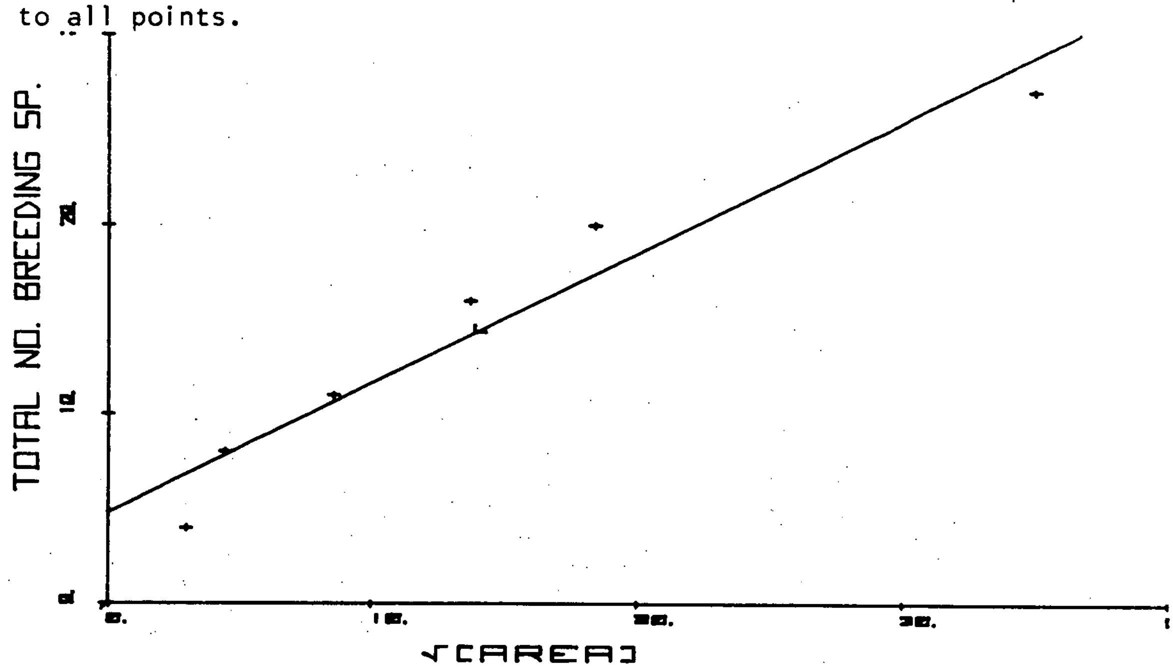


FIGURE 19a

Relationship between the total number of breeding species in dry sclerophyll habitat islands and the square root of island area (in ha), assuming a maximum cut-off area of 350 ha. +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

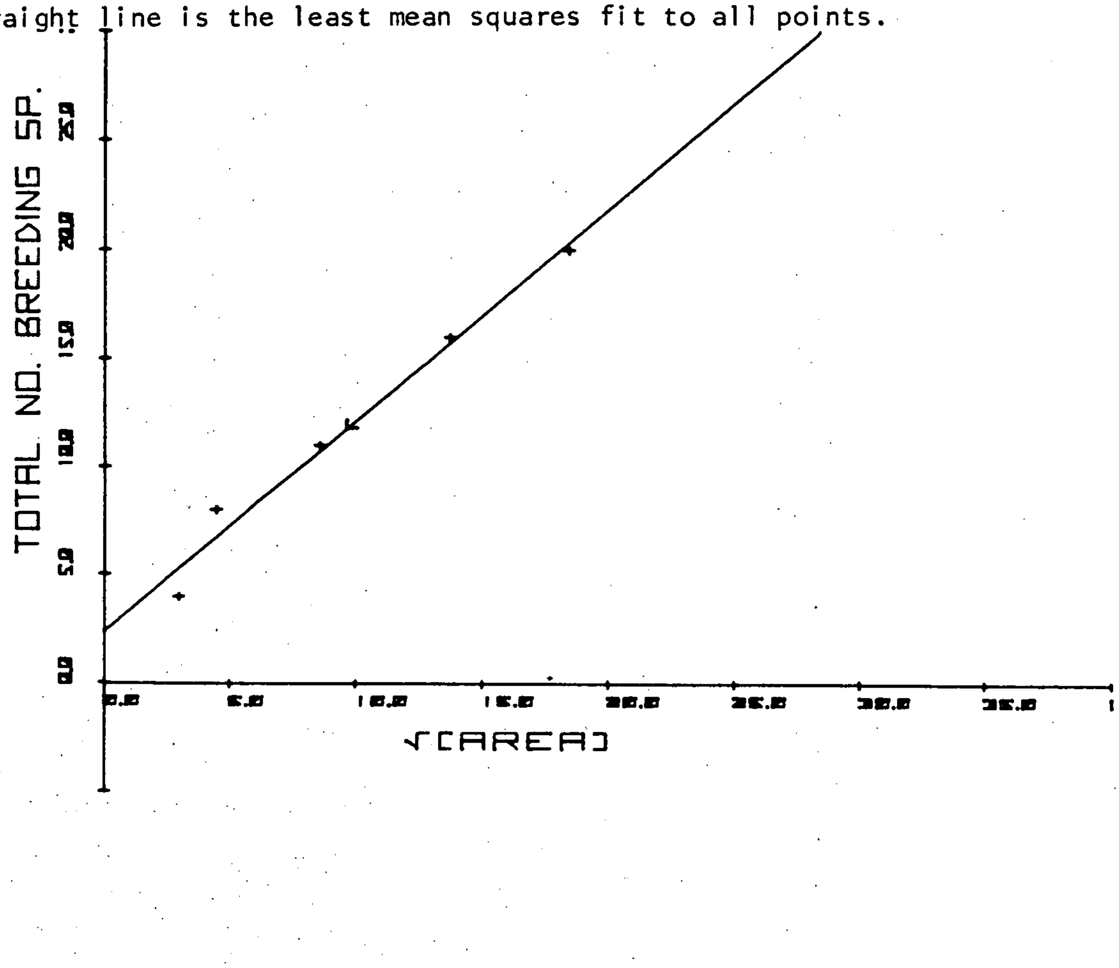


FIGURE 20

Relationship between the total number of species recorded in winter in dry sclerophyll habitat islands and the square root of island area (in ha). +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

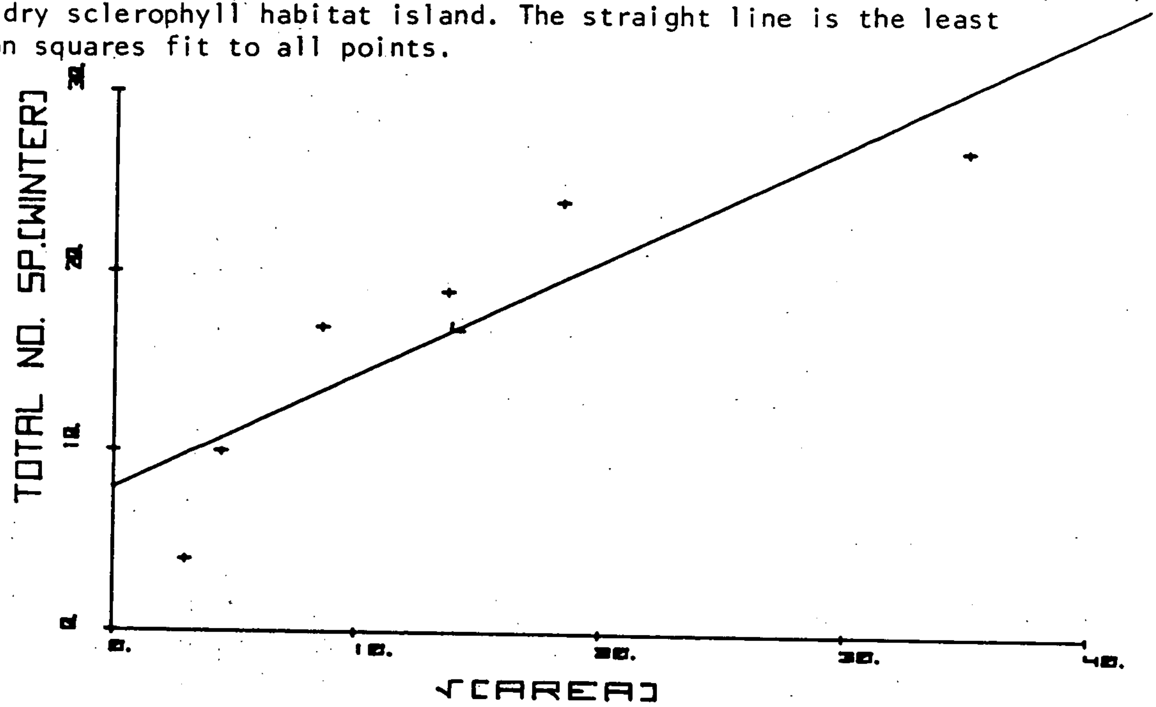


FIGURE 20a

Relationship between the total number of species recorded in winter in dry sclerophyll habitat islands and the square root of island area (in ha), assuming a maximum cut-off area of 350 ha. +, dry sclerophyll habitat island. The straight line is the least mean squares fit to all points.

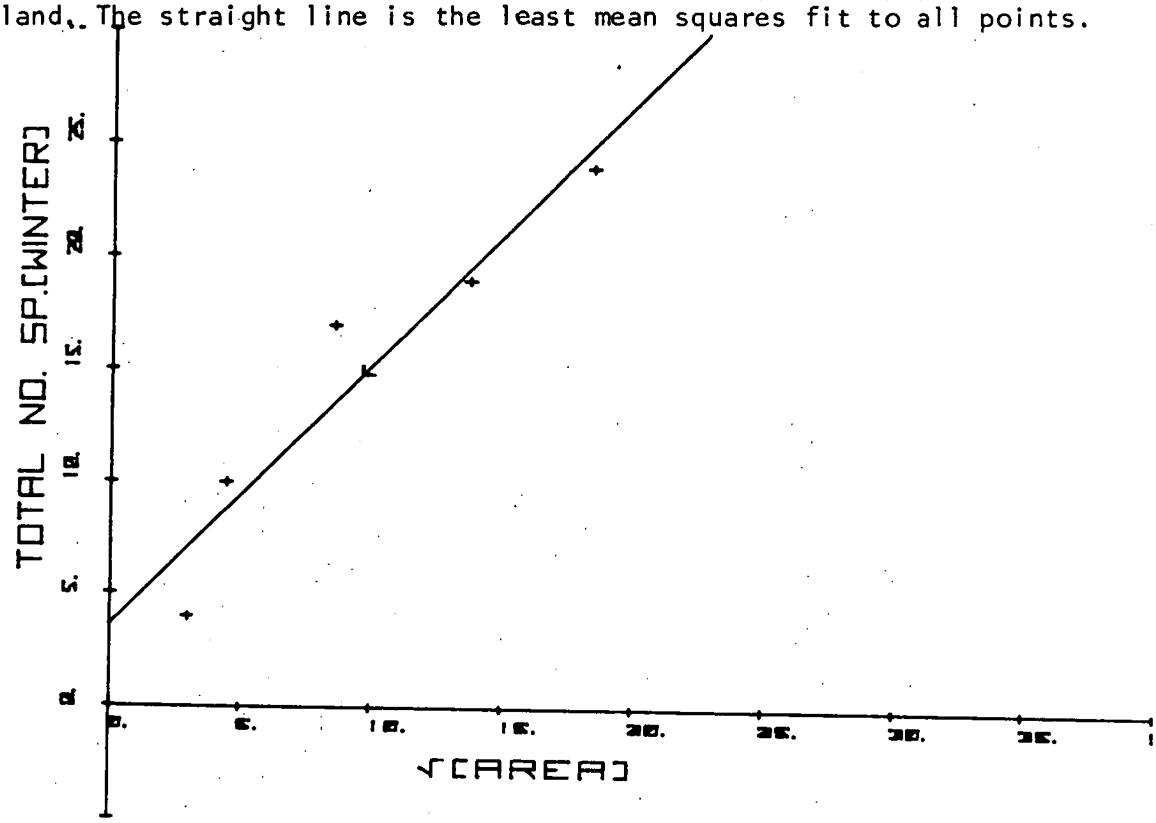
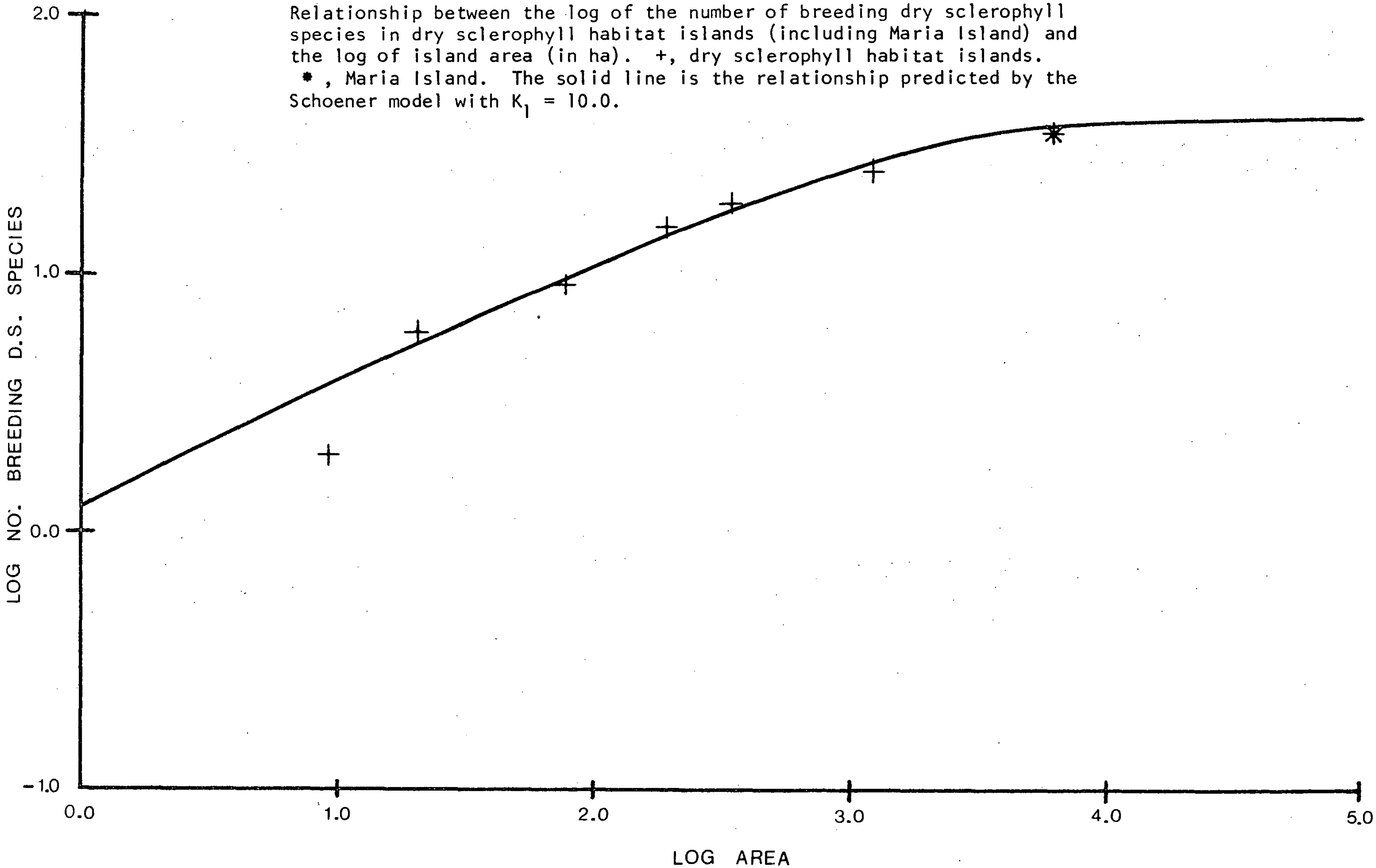


FIGURE 21

Relationship between the log of the number of breeding dry sclerophyll species in dry sclerophyll habitat islands (including Maria Island) and the log of island area (in ha). +, dry sclerophyll habitat islands. *, Maria Island. The solid line is the relationship predicted by the Schoener model with $K_1 = 10.0$.



4. ASSESSING THE EFFECTIVENESS OF TASMANIAN DRY SCLEROPHYLL RESERVES

4.1 The Need for an Effective Reserve System in Eastern Tasmania

4.1.1 Early Attitude Towards Conserving Dry Sclerophyll Forest

In the past, selection of reserve sites was a haphazard procedure; there has never been a well-defined purpose for reservation, and the reserves which have been proclaimed have not resulted from prior investigation to assess the suitability of sites (Mosley 1966a, 1966b, 1969). Reserves were usually proclaimed for their scenic, aesthetic and recreational qualities, often on areas of Crown land with little commercial value. Inevitably, this has resulted in the under-representation of certain ecosystems within the existing reserve system (Lake 1974).

The location of reserves within the State is indicated in Figure 22. The emphasis on land reservation for its scenic value has resulted in a concentration of reserves in the high rainfall, mountainous regions of Tasmania. In fact, seven National Parks comprising 92.5% of the total National Park area are located in predominantly mountainous areas, and of these 6 lie in regions of high rainfall (Tasmanian State Strategy Plan 1976). Consequently, the drier lowland ecosystems found in the eastern portion of Tasmania are less well-represented within the existing reserve system. The most extensive ecosystem of this part of the State, and that of most relevance to the outcome of the field study in this report, is the dry sclerophyll forest. The extent of this vegetation type is illustrated in Figure 23.

All reserves containing dry sclerophyll forest are listed in Table 4. Mt. William (9797 ha) and Freycinet (7541 ha) are the only lowland National Parks situated on the mainland of eastern Tasmania. Together they represent only 4.3% of the total area contained in National Parks (Tasmanian State Strategy Plan 1976).

A suspicion that the plant associations of the eastern half of the State were less well represented in reserves compared with those of the high rainfall areas has been entertained for more than a decade. This apparent anomaly, however, was not regarded as being particularly serious. In fact, it is possible to detect an attitude of complacency

FIGURE 22

The Use of Land for Conservation in Tasmania. Adapted from map in *Nature Conservation in Tasmania*, Working Paper No. 19, State Strategy Plan.

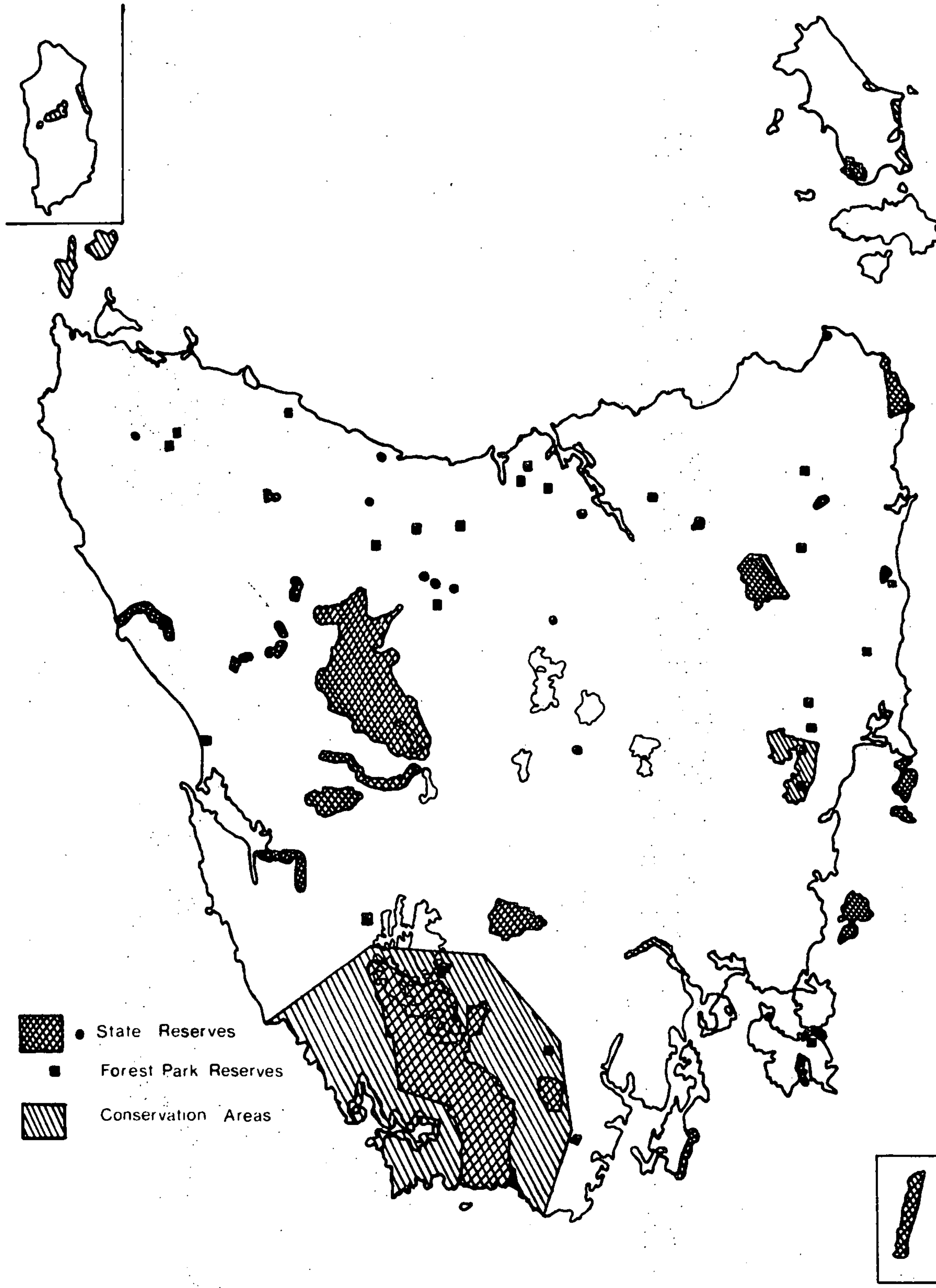


FIGURE 23

Distribution of Vegetation in Eastern Tasmania. Adapted from vegetation map of Tasmania, Forestry Commission, 1976.

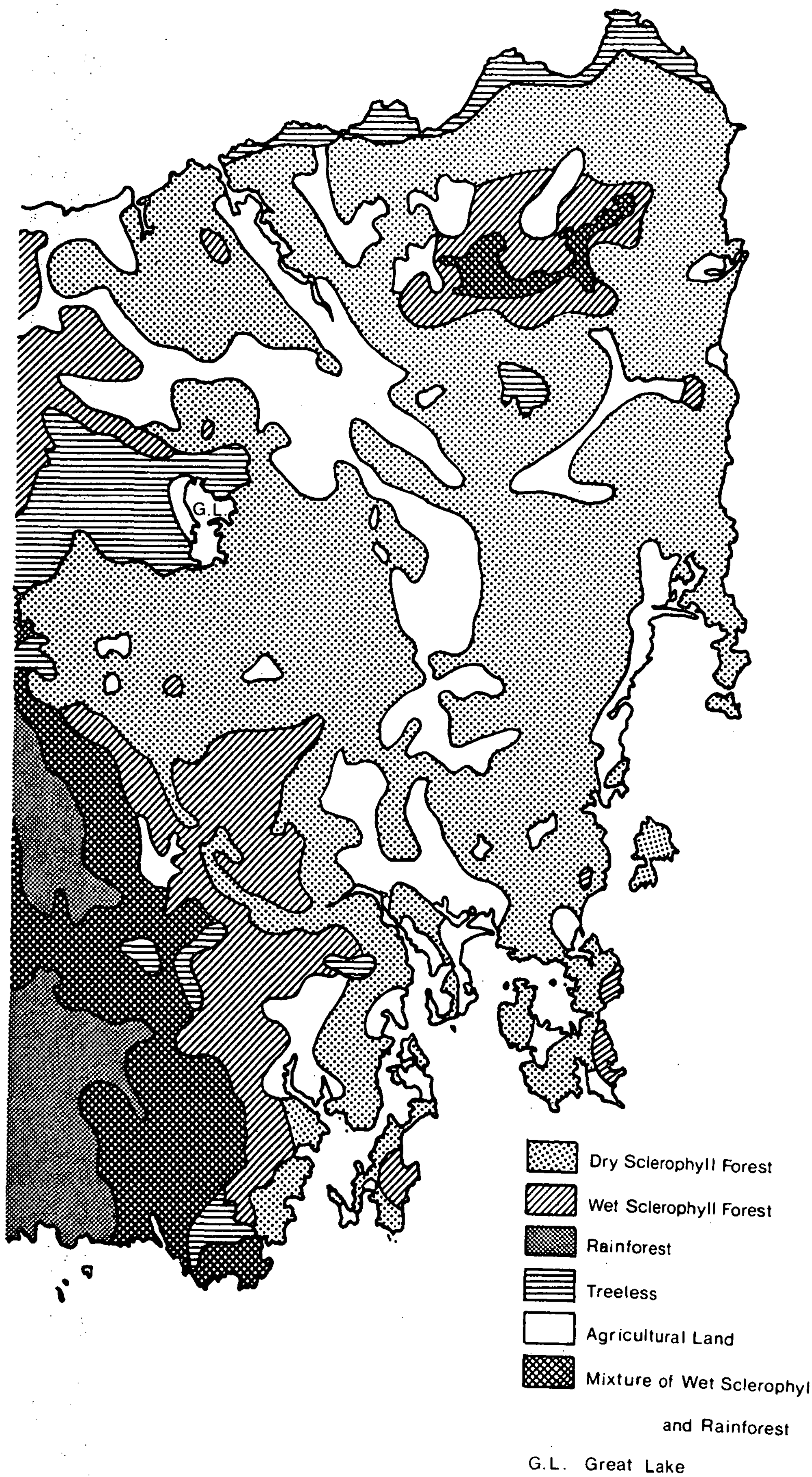


TABLE 4

Reserves in Eastern Tasmania Containing Dry Sclerophyll Forest Compiled from an inventory of Tasmanian State Reserves and conservation areas supplied by the National Parks and Wildlife Service

Reserve	Area (ha)	Classification
Tooms Lake	22,663	Conservation Area (Wildlife Sanctuary)
Mount William	9,797	State Reserve (National Park)
Maria Island	9.680	State Reserve (National Park)
Freycinet	7,451	State Reserve (National Park)
Strzelecki	3,946	State Reserve (National Park)
Southport Lagoon	3,600	Conservation Area (Wildlife Sanctuary)
Labillardiere	1,533	State Reserve
Lime Bay	1,310	State Reserve (Nature Reserve)
Glenorchy Water Reserve	712	Conservation Area (Wildlife Sanctuary)
Chauncy Vale	357	Conservation Area (Wildlife Sanctuary)
St. Marys Pass	273	State Reserve
Bruny Island - Fluted Cape - Cloudy Bay	243	State Reserve
Saltwater River	214	State Reserve
Mount Pleasant	172	Conservation Area (Wildlife Sanctuary)
St. Patricks Head	150	State Reserve
Kingston Golf Links	61	Conservation Area (Wildlife Sanctuary)
Launceston Golf Links	61	Conservation Area (Wildlife Sanctuary)
Tasman Arch & Blowhole	57	State Reserve
Steppes	50	State Reserve
Pt. Puer-Crescent Bay	37	State Reserve
Eaglehawk Neck Foreshore	36	State Reserve
Waterfall Bay	12	State Reserve
Stewarts Bay	4	State Reserve
Fossil Island	1	State Reserve

as regards the dry sclerophyll forest and its conservation during the 1960's. To illustrate this point, a leading conservationist of that time (Mosley 1966) advanced the following argument in justification of the lack of protection afforded to this vegetation type:

> *... the fact that the plant associations of eastern Tasmania are less well represented is less serious in that the typical dry sclerophyll forest is found in many of the mainland reserves.*

This seeming lack of interest, as far as creating additional reserves in eastern Tasmania is concerned, can probably be attributed to three factors.

Firstly, a continuation of the importance placed on setting aside scenic areas for man's enjoyment meant that reserves in the high rainfall, mountainous regions of Tasmania were valued more highly than those consisting of predominantly dry sclerophyll forest.

Secondly, many deficiencies in knowledge with respect to the distribution, structure and composition of Tasmanian plant communities were prevalent at this time. This situation was partly remedied by a recent publication (Specht, Roe and Boughton 1974) in which Professor Jackson gives an assessment of the conservation status of plant communities in Tasmania.

Thirdly, even though the dry sclerophyll forest community has been particularly susceptible to exploitative pressure in the past, there did not exist, at that time, an industry which visibly threatened the remaining natural areas of forest.

Modification of the dry sclerophyll forest by human agency commenced thousands of years before the advent of white man. The aborigines with their firestick almost certainly caused significant changes to the pattern of vegetation (Jackson 1965). Their burnings were probably one of the causes for the extension of the eucalypt forest into higher rainfall areas and for the creation of large tracts of open savannah-like country where previously forest had existed.

With white settlement these cleared areas were quickly taken over for pastoral use. Since that time, the forest has been steadily pushed back, by clearing and burning, to make way for urban and rural development. Where dry sclerophyll forest still exists it has often been considerably modified by frequent fires, grazing and selective logging.

Extraction of single or small groups of trees for the sawmilling industry in Tasmania has occurred for over 100 years with probably little adverse effect on wildlife and its habitat (Australian Conservation Foundation 1975). Recher, Thomas and Milledge (1971) and Thomas (1976)[1] have even suggested that the industry has improved habitat for wildlife by producing a more open, varied forest than otherwise might have resulted.

In any event, as long as sawmilling was the major forestry industry in Tasmania there did not appear to be any compelling reason to critically examine the adequacy of existing forest reserves.

4.1.2 Growing Concern for Conservation in Eastern Tasmania

4.1.2.1 Intensification of Forestry Activities

The recent intensification of forestry activities associated with the advent of an overseas market for woodchips was responsible for a concurrent increase in public concern as regards conserving the forest in eastern Tasmania. The commencement of woodchipping marked the beginning of a new era with respect to exploitation of the dry sclerophyll forest. In the space of four years (1969-1973), the major foresty industry in the State switched from sawmilling to pulpwood production with clearfelling and not selective logging as the predominant method of harvesting. It was the scale and intensity of the forestry operations,with its potentially hazardous environmental effects,which were the major causes for concern.

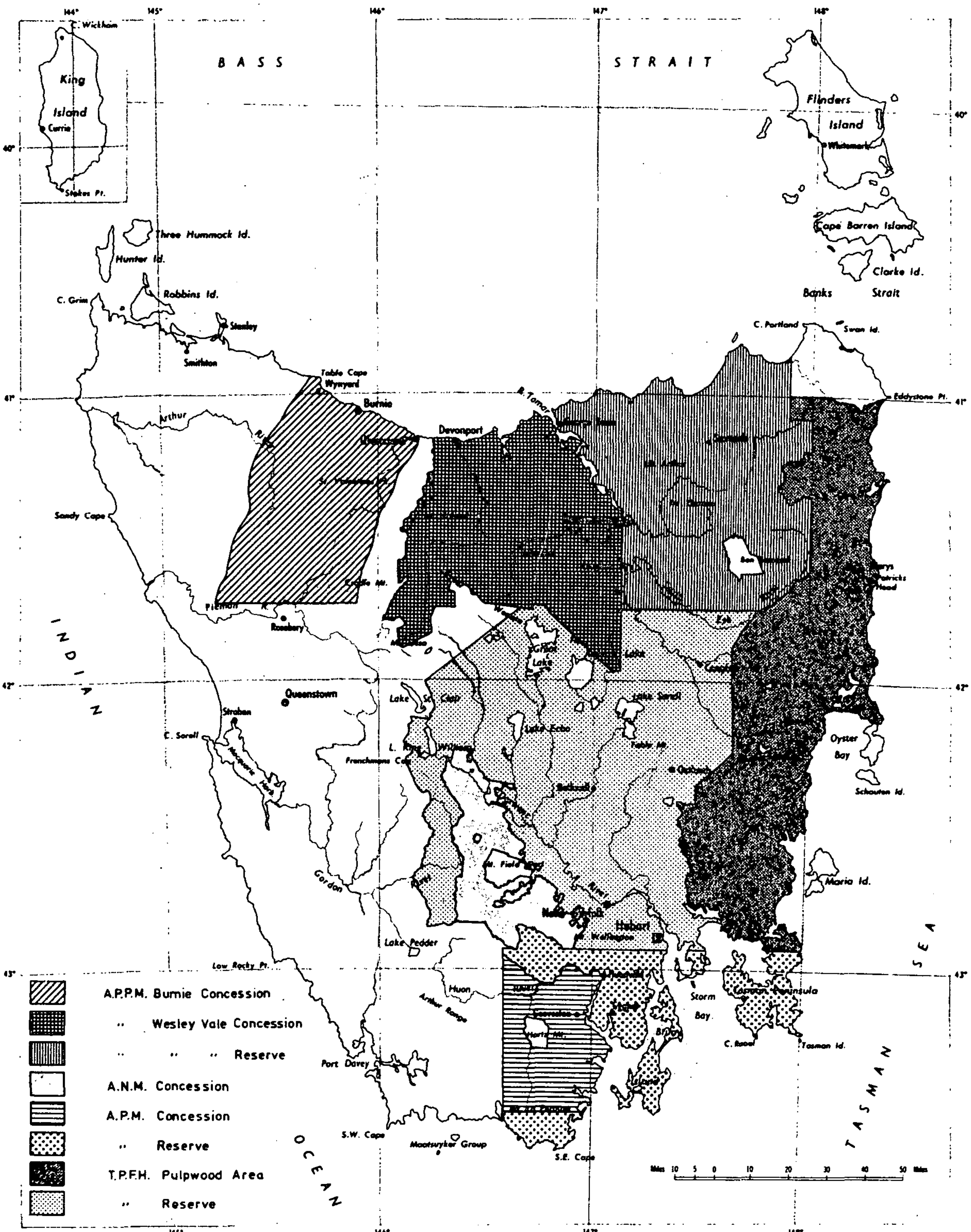
The extent of the woodchip concession boundaries is indicated in Figure 24. Comparison with Figure 23 demonstrates the importance of dry sclerophyll forest as a source of pulpwood. Very little of this habitat lies outside the concession areas.

---

1. This paper, on the effects of woodchipping on Tasmanian birds, was presented by D.G. Thomas at the ANZAAS Conference in Hobart 1976.

FIGURE 24

Timber Concession Areas in Tasmania.
Map supplied by the Forestry Commission, 1976.



Harvesting of pulpwood is not limited to Crown land. Private forests also represent a large exploitable resource to the woodchip companies.

One major company operating in eastern Tasmania is solely dependent on private forests for its pulpwood supply. The extent of woodchipping operations and the importance of the private forest asset is indicated in Table 5 below.

TABLE 5

Area of Potentially Productive Forest Within Woodchip Concessions.
(From Working Group set up by the Australian Ministers for the Environment and Conservation and Agriculture 1975).

State forest* (ha)	Vacant Crown Land** (ha)	Private land (ha)
372,000	304,000	803,000

*Also includes Timber Reserves and land acquired for Forestry purposes.

** Comprises all public land which has not been set aside in reserves or dedicated as State Forest.

For the duration of the overseas contracts to Japan, the three companies operating in eastern Tasmania have permission to export a total of approximately 33 million tonnes of woodchips, consequently exposing an area of 400,000 ha to clearfelling operations (Australian Conservation Foundation 1975; Bennison and Jones 1975). Assuming that woodchipping operations do not cease on the expiration of the export contracts, the area of forest cut over before pulpwood can once again be removed from regenerated coups is likely to embrace up to 80% of the total area of potentially available forest (Routley and Routley 1974).

4.1.2.2 Public Opposition Develops

Woodchipping in Tasmania has been controversial from the start. The earliest complaints by the public were the result of unsightly clearfelling and damaged roads caused by heavily-laden woodchip trucks (Australian Conservation Foundation 1975). Concern increased as the community became aware of the extent that their forests were being alienated for wood production.

The main area of conflict has arisen between the forestry interests on the one hand, whose main concern is maximizing productivity as economically as possible, and the growing conservation movement on the other, who see the forest as being important not only for wood production but also for conserving flora and fauna, for watershed protection, for recreation and for maintaining the character of the natural landscape.

This attitude of the Forestry Commission and private companies has been enforced by traditional legislation[2] which gave the "promoter" exclusive rights to exploit the forest resource (Environmental Law Reform Group 1975). Exploitation of resources can also be seen as part of an overall long-standing government plan to promote industrialization as an economic policy and to create employment opportunities (Davis 1975).

Concern for the environment in Tasmania, as a result of intensified forestry activities, was consistent with a similar trend appearing all over Australia. Several parliamentary enquiries have, subsequently, been set up to receive public submissions in relation to various aspects of forestry. The scale of the woodchip operations suddenly inflicted upon the native forests had highlighted the deficiencies in knowledge with respect to the existing biological resources of the concession areas. Accordingly, considerable criticism was levelled at the forestry services for the lack of research initiated to investigate the environmental consequences of the industry.

4.1.2.3 Acceptance of Environmental Principles

Official recognition of the need for further research into the environmental aspects of woodchipping was initially enshrined in the Report of the Operation of the Softwood Forestry Agreements Acts 1967 and 1972 (House of Representatives Standing Committee on Environment and Conservation 1975). There was thus verification at the parliamentary level that clearing of native forest

> *... is proceeding apace without adequate safeguards being taken and without proper research into the long-term effects of it ...*

---

2. The legislation referred to includes the Forestry Act 1920, Woodpulp and Paper Industry Encouragement Acts 1924 and 1926, a series of private Acts in the 1930's and the more recent pulpwood Acts 1961 and 1968.

The Standing Committee went on to recommend

> ... *that research be conducted into many areas of forestry, especially where native forest has been clearfelled. A great deal more needs to be known of wildlife populations, habitats and distributions. Work needs to be done surveying flora and identifying areas in need of protection. It is also paramount that environmental aspects of forestry management techniques be given far more attention.*

An interdepartmental working group from the Australian government departments of Agriculture and Environment and Conservation (1975) set up to report on the economic and environmental aspects of the woodchip industry also accepted the need for more information:

> *The existing data on biological and ecological features of any of the areas from which timber for the export woodchip industry is obtained, is fragmentary. Whereas production forestry aspects are relatively well known, there is less factual information concerning some of the long-term ecological consequences of intensive forest management. Consequently, a large degree of uncertainty surrounds the nature and significance of the environmental impacts associated with forestry operations for the export woodchip industry.*

Mounting evidence placed before various parliamentary enquiries[3] showed the enormous possibilities of large clear-cuts and current regeneration techniques for reducing the diversity of flora and fauna, for producing damaging effects on soils and watersheds, for decreasing recreational and amenity value of forests and for creating ecological instability.

Recognition at the parliamentary level of the potentially hazardous environmental consequences of woodchipping operations and the need for further research is, in many respects, an endorsement that:

(a) existing Forestry Acts are ineffectual for the overall control of an industry of such significance to the State both economically and environmentally, and

(b) scientifically-based criteria on which to plan an effective reserve system are needed for immediate application to Tasmania's eucalypt forests.

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3. These include the Select Committee of the Legislative Council enquiry into forest regeneration in Tasmania 1970-72, the Interdepartmental Committee enquiry into the economic and environmental aspects of the export hardwood woodchip industry 1975, and the Senate Standing Committee on Science and the Environment.

Although it is Forestry Commission policy "to systematically manage the Crown forest estate and its renewable resources in perpetuity" (State Strategy Plan 1976) the lack of legislative control over current forestry practices (Environmental Law Reform Group 1975) suggests there is little guarantee that this objective will be achieved, particularly with respect to ensuring that biological diversity at the species and community levels is not impaired.

The multiple-use concept of forest management, as outlined by the Australian Conservation Foundation (1974), is a useful guide for the re-orientation of legislation and decision-making at the political level. This approach ensures that all social, economic and environmental factors have been weighed and all prospective options evaluated. Ways in which the existing legislation might be amended so that the State's forest resources are not exploited at the expense of other less tangible values have been outlined by the Tasmanian Environmental Law Reform Group (1975).

Changes in legislation and a re-orientation of future long-term policy decisions towards environmental conservation as a concept, may take some time to take effect. In the meantime exploitation of forests in the east of the State is likely to continue at its present high rate. For this reason it is imperative that existing dry sclerophyll reserves are adequate to retain the non-wood forest values now recognized as being so important within the community. The object would be to set aside suitable protected "natural" areas of forest within the concession areas for the following purposes:

(a) to retain the diversity of plant and animal communities characteristic of eastern Tasmania;

(b) to act as a control to monitor the effects of woodchipping on the natural environment; and

(c) to provide the natural conditions for scientific research in such fields as soil ecology, hydrology, climatology, and plant and animal ecology.

4.1.3 <u>Attempts to Meet Environmental Objectives</u>

The acceptance of public attitudes towards conserving the dry sclerophyll forest in Tasmania has not yet been translated into government policies and legislation. There has been, however, some attempt by different government agencies to carry out conservation objectives.

The National Parks and Wildlife Service is the agency primarily responsible for the reservation of land for conservation purposes. One of the basic aims of the Service is to include representative samples of all vegetation types within State Reserves (Tasmanian State Strategy Plan 1976). The protection of vegetation within such areas is absolute insofar as alienation of any part of the reserve requires approval by both Houses of Parliament. However, there are no large State Reserves in the lowland, predominantly dry sclerophyll areas of the Tasmanian mainland and it is this region which is most likely to be affected by woodchipping operations.

Various conservation areas, originally set aside for the preservation of fauna, lie within the concession boundaries. These areas, however, do not possess the same degree of security afforded to State Reserves. Although some provisions are made for the conservation of fauna contained within the reserves, the habitat in which these animals occur is essentially unprotected. Consequently, woodchipping activities have been permitted on all but 3,700 ha of Tooms Lake Sanctuary.

The remaining conservation areas are very small in size, originally having been created with the preservation of one species in mind (Lake 1974). These areas are, therefore, virtually ineffective as conservation measures to maintain the biological diversity of the dry sclerophyll forest.

Within the woodchip concessions all reserved land under National Parks and Wildlife jurisdiction constitutes a very small percentage of the total forested area. The proportion of forested land reserved is indicated in Table 6.

That this proportion of land set aside as reserves is inadequate to include representative samples of all vegetation types found in eastern Tasmania, has been demonstrated by Jackson in his assessment of the conservation status of plant communities within the State (Specht, Roe and Boughton 1974). This survey shows that many alliances are poorly represented in existing reserves. Table 7 indicates the extent of conservation by floristic zone, of the 305 alliances recorded in the State.

TABLE 6

Disposition of Forested Land Within Concession Areas.
Compiled from information given by the Working Group set up by the Australian Ministers for the Environment and Conservation and Agriculture, 1975.

Woodchip Concession	State Forest*	Vacant Crown Land	Reserved Land	Private land
TPFH	14%	23%	4%	59%
Wesley Vale	42%	14%	2%	42%
% of total Concession Area	24%	20%	3%	53%

*Also includes Timber Reserves and land acquired for forestry purposes.

TABLE 7

Conservation Status of Tasmania's Plant Alliances.
From Specht, Roe and Boughton, 1974 .

Floristic Zone	Total No. of Alliances Recorded	No. of Alliances not Conserved	No. not conserved as % of total
King Island	51	51	100
Flinders Island	61	61	100
Macquarie Island	16	0	0
Central Plateau	173	82	47
National Park	-	-	-
North West	96	77	80
North	86	74	86
North East	162	104	64
East	127	65	51
South East	213	57	27
South West	140	0	0
West	157	30	19

A high proportion of the alliances not conserved in the east and north-east of the State are characteristic of the dry sclerophyll forest. The gravity of this situation is further illuminated by a table compiled by

Specht (in the same survey) on the conservation of rare and endangered species. Recorded in this table are several poorly conserved dry sclerophyll eucalypt species occurring in eastern and north-eastern Tasmania which are endemic to this State. Failure to provide adequate reserves to protect these species and the relatively rich endemic fauna dependent on the dry sclerophyll forest could seriously deplete Tasmania's biological resources.

Jackson's assessment of the conservation status of plant communities (Specht, Roe and Boughton 1974) can also be used to determine the area of dry sclerophyll habitat contained in reserves in eastern Tasmania.[4]

Data relevant to this computation is contained in Table 8.

TABLE 8

Area of Dry Sclerophyll Forest Contained in Effective* Reserves

Reserve	Total Area (ha)	Area of Dry Sclerophyll (ha)
Mt. William National Park	9,797	6,466
Ben Lomond National Park and Conservation Area	18,774	0
Freycinet National Park	7,546	4,528
Schouten Island Scenic Reserve	3,443	1,550
Maria Island National Park	9,680	5,130
Tooms Lake Sanctuary*	3,700	3,700
		21,374 TOTAL

*Tooms Lake Sanctuary is 22,680 ha in area but in effect only 3,700 ha of this is excluded from woodchipping operations.

Accounting for reserves smaller than those listed in the table above did not significantly alter the resultant area of dry sclerophyll forest. Consequently, the value of approximately 21,500 ha obtained by this method can be taken as a good indication of the total area of this habitat conserved. An assessment of data from various sources[5]

4. Advice in the interpretation of relevant tables within Jackson's survey was sought from the author himself.
5. Information pertinent to the determination of this figure was obtained from Professor Jackson and with reference to vegetation maps available from the Forestry Commission.

has suggested that the total area of dry sclerophyll forest in Tasmania is in the vicinity of 1.2 million ha. On this basis, the amount of dry sclerophyll forest contained in effective reserves represents only about 1.9% of the total area of this habitat.

Various other forested areas have been temporarily excluded from woodchipping operations by the Forestry Commission. Long, narrow strips of forest are sometimes left along major streams and roads for such reasons as watershed protection, aesthetic value and public amenity. Other areas have been reserved from cutting for recreational purposes, for the conservation of certain plant populations or for reasons of inaccessibility and economy. Of the 42 existing Forest Park Reserves and Recreational Areas within Tasmania, only 19 have been set aside in the east of the State. The size of these reserves is given in Table 9.

TABLE 9

Forest Parks and Recreation Areas in Eastern Tasmania. Adapted from Bennison and Jones, 1975.

P denotes picnic areas too small to warrant size specifications

Name and Location	Area (ha)
Triabunna District	
White Gum Reserve	12
Meetus Falls Reserve	40
Lost Falls Reserve	20
Myrtle Reserve	16
Taranna Camp Reserve	16
Fortescue Bay	4
Long Marsh Water Reserve	1620
Fingal District	
Tower Hill Forest Park	P
Saddleback Forest Park	8
Musselrow River	P
Scottsdale District	
Mt. Paris Dam	10
Jackey's	P
Fiona's	P
Myrtle Grove	P
Amalia's	P
Mt. Horror	P
J.M. Firth Grove	P
Sidling	P
St. Patrick's River	P

The majority of these reserves are less than 40 ha in size and, as such, are too small to function as viable units. To add further to their ineffectiveness in helping to retain the diversity of the dry sclerophyll forest, virtually all these reserves have been set aside in areas characterized by the wetter vegetation types.

The temporary setting aside of forest reserves by the Forestry Commission has been the result of an increase in public demand for recreation areas. An awareness within the community of the importance of native forest for preserving biological diversity and other non-wood values serves to emphasize the limitations in function at present exhibited by these reserves. Making minor concessions to non-wood values by setting aside areas largely for recreational purposes is quite inconsistent with the concept of multiple-use originally outlined in the U.S. Multiple-Use Sustained Yield Act of 1960 and which, subsequently, formed the basis of a model developed in this country by the Australian Conservation Foundation (1974).

Provisions, however, do exist under current legislation for the Forestry Commission to assume a much greater role in conservation. Under the Forestry Act 1975 the Commission has the right to set aside land:

> *(a) for use by members of the public for recreational purposes,*
>
> *(b) for the preservation or protection of any features of the land of aesthetic, scientific or other value or interest that the Commission is of the opinion should be preserved or protected; or*
>
> *(c) for the preservation or protection of the fauna or flora contained in that land or of any such fauna or flora.*

Until now this section of the legislation has largely been utilized with respect to part (a). The leeway does exist, therefore, to accommodate a broadening in outlook towards conservation of the dry sclerophyll forest communities.

4.2 Developing Management Principles for Reserves in Eastern Tasmania

The preceding section gives an account of the development of public concern towards conserving the ecosystems of eastern Tasmania which has paralleled the intensification of forestry activities in this part of the State. It is apparent that this change in community thinking is not consistent with attitudes at the government level or with existing legislation controlling the use of forest resources.

Given this situation, there is a need for the development of a scientific method which can be used to demonstrate more objectively what the needs are with regard to providing adequate reserves of dry sclerophyll forest communities. Jackson's assessment of the conservation status of plant communities in Tasmania (Specht, Roe and Boughton 1974) is valuable in pointing to deficiencies in the reserve system. Now, however, island biogeographic theory has proved to be extremely useful in suggesting suitable size, shape and location criteria upon which planning and subsequent management of an effective reserve system can be based.

The ways in which island biogeography can be adapted to serve these purposes has been demonstrated by Diamond (1975) in the development of a series of reserve design principles. These principles were briefly considered in Chapter 2, pages 15 to 17, and illustrated diagrammatically in Figure 1.

This section outlines the manner in which the species-area relationship derived from the field study on birds can be used to suggest the size of an effective dry sclerophyll reserve in Tasmania. The adequacy of existing reserves in the east of the State is then assessed using this size criterion in conjunction with the other design principles developed by Diamond. The section concludes with some suggestions, based on these principles, for the management of dry sclerophyll reserves in Tasmania.

4.2.1 Selecting a Suitable Reserve Size

An effective reserve size for dry sclerophyll bird species would be one which could support the full complement of 42 species (not including nocturnals or migrants). Sullivan and Shaffer (1975) have described this as the transition size, below which an area acts as an island and above which it acts as a "continent."

Due to the pioneering nature of the field study little was known of the likely species numbers in the habitat islands, and in particular the larger islands. Most species-area relationships obtained in previous studies indicate that a ten-fold increase in island area means a two-fold increase in island species numbers. For this reason the largest range of available dry sclerophyll habitat island areas was chosen for investigation. Of necessity, this range was limited by the lack of suitable large habitat islands. The census study data shows that the largest island investigated (1232 ha) does not support anywhere near the full complement of dry sclerophyll species. As a consequence, any prediction of transition size involves extrapolation of the species-area relationships obtained under different models.

Of the four models considered to explain the species-area relationships for the studied dry sclerophyll habitat islands, three were linear relationships. From the work of Schoener (1976), discussed earlier, the slope (Z) of the species-area relationship decreases monotonically with area until the transition size is reached, whereupon $Z = 0$. Thus, although the linear species-area relationships obtained are accurate over the studied area range, it would be inaccurate to extrapolate them to larger areas. However, the species-area relationship obtained from the fourth model, derived by Schoener (1976), may be extrapolated to larger areas as the non-constancy of the slope (Z) is implicit in the model. Further accuracy may be obtained if a larger dry sclerophyll island was included in the species-area relationship. The most logical choice for inclusion is Maria Island, off the east coast of Tasmania. Being surrounded by sea and not cleared land it is obviously a different sort of island to those studied. Nevertheless, there are several reasons that merit its inclusion. Firstly,it is largely (approximately 60%) dry sclerophyll and secondly, the width of sea barrier to the mainland of eastern Tasmania is only seven km.

The dry sclerophyll forest of Maria Island is approximately 6,000 ha in extent and supports 34 breeding dry sclerophyll bird species. For the dry sclerophyll habitat islands studied previously, the Schoener model predicts a species-area relationship of the form:

$$S = \frac{K_1 A}{2}\left[-1 + \sqrt{1 + \frac{168}{K_1 A}}\right]$$

with $K_1 = 10.0$.

The above equation predicts that there would be 36.3 species of dry sclerophyll birds breeding on Maria Island. The number of breeding dry sclerophyll species observed for the six studied islands plus Maria Island are shown in Figure 21 along with the curve obtained from the above equation.

The correlation between the data obtained from the Schoener model and the observed data is very good ($R = 0.9912$) and is highly significant ($p < 0.001$).

From Figure 21 it can be seen that the species-area curve is very flat for areas greater than 10,000 ha. That is, for areas above this in size a very large increase in area produces a negligible increase in the number of species. Furthermore, the above equation predicts that a dry sclerophyll habitat island of 10,000 ha would support 39 breeding species of dry sclerophyll birds. Thus the results of this study demonstrate that a habitat island area of at least 10,000 ha is required to support the full complement (42 species) of dry sclerophyll birds.

Bird species have been used as an indicator in this study to determine the species-area relationship for dry sclerophyll habitat islands. As only two of the 42 dry sclerophyll species are restricted to this habitat type, the question of whether a dry sclerophyll habitat island of 10,000 ha would be effective in supporting all the remaining dry sclerophyll fauna must now be considered. Sullivan and Shaffer (1976) have pointed out that, for any habitat type, there are certain range sensitive species and have suggested that if these were properly provided for then there would be sufficient room for organisms that demanded less space. Therefore, one may look at the space requirements of rare (not necessarily endangered) species such as large-bodied carnivores. Being of large size and high on the trophic structure, these species have fairly large range requirements and are often quite susceptible to human developments. Of the Tasmanian dry sclerophyll forest fauna such a species would be the wedge-tailed eagle or the forester kangaroo. Thus if a dry sclerophyll reserve of at least 10,000 ha supports all 42 dry sclerophyll bird species, including the wedge-tailed eagle, then it should support all the other dry sclerophyll fauna.

It is pertinent to consider the area of dry sclerophyll reserve suggested by island biogeographic study with that suggested by the criteria of effective population number as discussed in Chapter 2. Effective population number is the population size that will retain the original genetic diversity of the species, or a large fraction of it, in perpetuity and provide the genetic means for continued evolution (Tyndale-Biscoe and Calaby 1975). It must take account of natural fluctuations and be large enough to withstand the vissicitudes of fire, disease, and drought; it is the lowest number that the population can fall to under these circumstances. Crow and Kimura (1970) examined the concept theoretically from the standpoint of population genetics and showed that for an outbreeding population with random mating, a minimum effective population of 1000 individuals will retain 99% of the genetic variability after 20 generations, a population of 100 will retain 90%, and 10 will retain only 37%.

From this it would appear that an effective population of 1,000 individuals is near to the minimum to ensure the continuance of genetic variability. This has been supported by analysis of actual Australian situations (Main and Yadav 1971; Tyndale-Biscoe and Calaby 1975). Tyndale-Biscoe and Calaby used this method to determine that a reserve area of no less that 6,000 ha would be required for the greater glider, a dependent resident species of Tall Open Forest.

The effective population criteria may be applied to the largest bodied Tasmanian animal, the forester kangaroo. Habitat favoured by the forester kangaroo is dry sclerophyll forest and light scrub land with natural clearings or open grassland (Green 1973). The former range of this species was probably consistent with that of dry sclerophyll habitat but it now occupies only a small fraction of the range it occupied 150 years ago. The present range is fragmented into three major areas, one in the north-east of the State, and two in the Midlands. Wapstra (1976) investigated the status and management of this species and without any real justification, recommended an effective reserve size of 10,000 ha. However, Wapstra (1976) made use of survey data to estimate the density of forester kangaroos in different localities. The criteria of effective population number may be applied to the estimated densities to obtain an area of dry sclerophyll forest capable of supporting 1000 individuals. Wapstra's estimates for the Ross area ranged from 15.0/100 ha in a high density division to 3.8/100 ha in a low density division.

An effective population of 1000 forester kangaroos would be maintained in a high density reserve of 6,667 ha or alternatively, in a low density reserve of 26,300 ha. Assuming an average density of 9.4/100 ha then the effective reserve size would be 10,638 ha.

It is significant that the size of an effective dry sclerophyll reserve suggested from effective population criteria is in close agreement with that suggested from island biogeographic considerations.

4.2.2 Applying Biogeographic Criteria to Reserve Design

The study of dry sclerophyll habitat islands has demonstrated that an effective dry sclerophyll reserve should be at least 10,000 ha in area. It is now pertinent to consider Diamond's first principle in the light of this information. Reference to Table 4 shows that only one reserve on the eastern mainland of Tasmania (Mt. William National Park) approaches this size requirement. All other dry sclerophyll reserves are much less than 10,000 ha. For this reason they would, if insularized by land clearance in the future, lose species by extinction.

Mention must also be made here of Maria Island National Park. Although the total area of this reserve approximates 10,000 ha, only about 60% of this area is dry sclerophyll forest. The fact that it is an oceanic island further detracts from its value as an ecologically viable dry sclerophyll reserve owing to the effect that an aquatic barrier has on the number of dry sclerophyll species held at equilibrium. In fact, there are only 34 breeding species of dry sclerophyll birds on Maria Island, eight short of the full complement of 42 species. Thus despite its importance as a fauna reserve and as a wholly protected east coast island, Maria Island cannot be classified as an effective reserve which is representative of the dry sclerophyll habitat of the eastern mainland of Tasmania.

Diamond's second design principle is that one large reserve is better than several disjunctive reserves. In the past, reserves were often created for historic and scenic reasons or for the protection of one species only. As can be seen from Figure 22, this has resulted in the establishment of many small and scattered reserves at a time when it would have been possible to set aside fewer reserves of greater magnitude.

The third design principle is that if the available reserve area must be broken up into several disjunctive reserves, then they should be as close together as possible. Reference to Figure 22 shows that there has been no deliberate attempt to create reserves in close proximity to each other. Distances between the larger dry sclerophyll reserves are, in most cases, considerable as illustrated in the following table.

TABLE 10

Distance (in km) between large dry sclerophyll reserves

Large Dry Sclerophyll Reserves	Distance (in km) to nearest large reserve
Mt. William National Park	160
Freycinet National Park	1
Schouten Island Scenic Reserve	1
Maria Island National Park	32
Toom's Lake Sanctuary	35

Diamond's fourth principle is that if there are several disjunctive reserves, then they should be grouped equidistant from each other, rather than grouped linearly. The fifth principle states that if there are several disjunctive reserves, then these should be connected by strips of the protected habitat. The failure of the existing Tasmanian dry sclerophyll reserve system to satisfy the third principle has automatically precluded compliance with either the fourth or fifth principle . In the only case where there are two close reserves (Freycinet National Park and Schouten Island Scenic Reserve) the intervening habitat is water.

Diamond's sixth principle is that any reserve should be as near circular in shape as possible in order to reduce boundary effects. Many of the existing dry sclerophyll reserves have elongated shapes which tend to follow topographic features. Of the larger dry sclerophyll reserves, both Freycinet National Park and Tooms Lake Sanctuary fit into this category. Freycinet National Park is on a peninsula and has a long narrow shape. Tooms Lake Sanctuary has a complicated shape, assuming a dumb-bell configuration with dead-end peninsulas. Consequently, these reserves do not satisfy the sixth principle. The handicap of a large perimeter to area ratio means that such reserves will maintain fewer species at equilibrium than could be inferred from a consideration of their actual area alone.

Apart from reserves under the jurisdiction of the National Parks and Wildlife Service there are many Forest Parks, stream and road-side reserves that are considerably elongated in shape. This undesirable configuration, combined with the small size of these areas, makes their value as viable reserves rather doubtful.

From the above discussion, it is clear that the present reserve system in Tasmania does not comply with the principles developed by Diamond to conserve the maximum number of species and to minimize extinction rates.

At present, it may seem that Diamond's design principles are highly idealized and not very relevant. However, it should be borne in mind that in the future all our reserves may in fact be islands. These principles are designed to ensure the preservation of the diversity of natural species in the long term, rather than just a human lifetime. In the future it is hoped that a serious attempt will be made to apply these principles to the planning of a system of reserves which will be viable in the long term instead of an unplanned piecemeal approach which is only viable in the short term.

4.2.3 Additional Considerations in Reserve Management

Although the value of creating reserves that are sufficiently large to be naturally viable cannot be too greatly emphasized, smaller reserves are often extremely important for the conservation of particular plant or animal species which have restricted distribution. Such areas may also be useful in acting as stepping-stones to larger reserves. This would help to maintain a high degree of biotic exchange between reserves which could, subsequently, assist in the alleviation of local extinctions. It should be noted, however, that reserves of this type usually require intensive management to avoid decimation by fire, disease, pest attack or drought. The susceptibility of small reserves to disasters was demonstrated by the wildfire which completely razed the Nadgee Nature Reserve in 1972. A fire occurring in this reserve again in the near future could eliminate entirely many plant and animal species (Recher, Lunney and Posamentier 1975).

The minimum critical size of a reserve is dependent to some extent on its susceptibility to man-made disturbances. A reserve which is completely surrounded by modified habitat may be particularly vulnerable to ecological pressure from adjacent land in the form of introduced plants and animals, diseases, pests and pesticides. Once again bush fires tend to be singularly devastating, unless the reserve is extremely large, because opportunities for recolonization are significantly reduced.

Impact on the reserve from activities on adjacent land can be minimized if the shape of the reserve is characterized by a low periphery:area ratio. To satisfy this requirement, the reserve should be as near circular as possible.

Where reserves are surrounded by relatively unmodified habitat, adverse effects from external disturbances can be reduced if activities in adjacent areas are restricted. The encircling vegetation thus acts as a buffer zone which serves to augment the effective size of the reserve.

Roads, tracks and fire-trails, which are common in many reserves, may provide a further avenue for deterioration of the natural environment. Such developments may increase the accessibility of the reserve to exotic species and disease organisms. The opportunities for dispersal by certain native species within the reserve may also be substantially increased. On the other hand, roads may act as barriers to the movement of small animals (Oxley *et al*. 1974). For these species, the effective size of the reserve is considerably reduced. Thus, to help maintain the natural functioning of the reserve, it is desirable that road constructions are kept to a minimum. Wherever access routes or fire-trails are unavoidable, the size of the reserve should be sufficiently large to resist any deleterious effects on the natural environment.

Consequently, the size of a reserve may often need to be considerably greater than any estimated "transition value" depending on its vulnerability to external interference. For the purpose of maintaining its natural diversity, the most desirable location for a reserve would be in a largely inaccessible region where the surrounding vegetation is similar to that contained within the reserve.

4.3 Towards an Effective Reserve System

In view of the inadequacy of the existing reserve system in the dry sclerophyll regions of Tasmania and the susceptibility of this habitat type to exploitation, the only way to ensure preservation of natural diversity in the long-term is to create additional reserves. At the present time, the only State Reserve containing dry sclerophyll forest on the Tasmanian mainland which approaches the minimum size requirement for an effective reserve is Mt. William National Park in the far north-east. There is a need for a large, lowland dry sclerophyll reserve to be set aside in the east in order that the forest types characteristic of this part of the State are adequately conserved and multiple-use objectives are achieved.

In accordance with the requirements established elsewhere in this report, some possible sites can now be suggested for the location of an additional viable reserve in eastern Tasmania.

4.3.1 Some Suggestions for the Location of Additional Reserves

The location of an area suitable for reservation is particularly difficult because of the commitment of most of the dry sclerophyll regions of eastern Tasmania to forestry activities. With the exception of a few small areas, practically all the lowland dry sclerophyll forest within the State lies within the woodchip concession boundaries. Within the concession areas much of the Crown land is State Forest, under the management of the Forestry Commission. Reservation of such lands by the National Parks and Wildlife Service is difficult to obtain, requiring the agreement of the Forestry Commission to revocation of the land and for this to be presented before Parliament. In the case of vacant Crown land, the Forestry Commission has the power to revoke an area from a woodchip licence for a public purpose, provided the company concerned is in agreement.

In view of these restraints, and the added difficulty of finding sufficiently large areas which had not been affected by logging, attempts to locate areas of forest suitable for reservation were generally unsuccessful. However, from our investigations four sites could be suggested but none of these proposals is, for different reasons, considered completely satisfactory.

It should be pointed out that when assessing the suitability of each proposal, emphasis was placed on biological aspects whilst other considerations such as the administrative, political and legal problems associated with reserving an area, were considered of secondary importance. It will be necessary, however, for such factors to be given due consideration before making final recommendations. Attempting to deal with such problems is beyond the scope of the study but it is important to acknowledge their existence and to emphasize the weight given to such factors in the planning process.

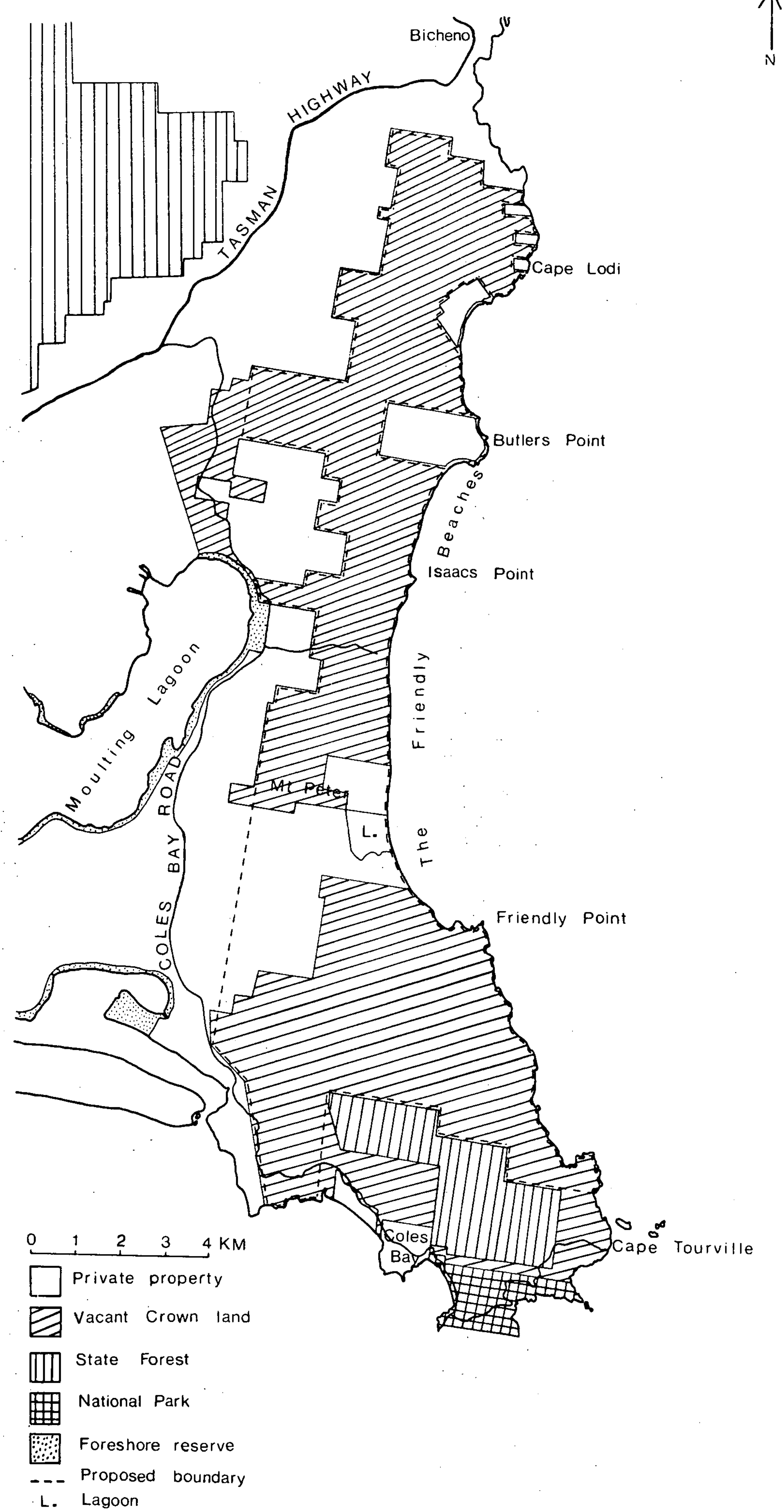
Thus the proposals discussed below are, at this stage, preliminary suggestions. In certain instances, for example, the possibility of acquiring private property, to increase the biological effectiveness of the reserve, is discussed. Such a statement is by no means a prescription of what should be done but serves to point out one of the difficulties associated with this proposal and one which needs further investigation by the relevant agencies involved in the planning of reserves.

First Proposal : Freycinet Site

In certain instances, land lying within a concession area is unsuitable for logging for reasons of inaccessibility or poor timber quality. Maps are available (courtesy of the Forestry Commission, Triabunna) which indicate some areas on the east coast where it is expected that logging will not occur. In general, most of these are small and it is difficult to find a continuous large area.

However, one area of a reasonable size was located on Freycinet peninsula. A set of proposed boundaries for a reserve, enclosing an area of about 7,000 ha, are shown in Figure 25. This proposed reserve consists of two narrow strips of vacant Crown land lying within the T.P.F.H. concession boundary separated by an area of private land.

Reservation of the total area, indicated by the boundaries in Figure 25, would depend on the purchase of the private land lying between the two areas of vacant Crown land. The acquisition of additional areas of private land (not included in the proposal) at Butlers Point and opposite Isaacs Point, would increase the value of this reserve by extending the width of this narrow strip. Acquisition of other private land lower down the peninsula, adjacent to Coles Bay Road and the proposed boundary, would also enhance the effectiveness of the reserve. Unfortunately, little is known concerning the extent of the development of these private lands. Obviously therefore, before contemplating inclusion of any such areas investigations to determine the quality of the vegetation must be undertaken. Of prime importance is the area


N
Bicheno
TASMAN HIGHWAY
Cape Lodi
Butlers Point
Beaches
Isaacs Point
The Friendly
Moulting Lagoon
COLES BAY ROAD
Mt Peter
L.
Friendly Point
Coles Bay
Cape Tourville
0 1 2 3 4 KM
Private property
Vacant Crown land
State Forest
National Park
Foreshore reserve
Proposed boundary
L. Lagoon

separating the two blocks of vacant Crown land as extensive clearing of this land may seriously affect the functioning of the reserved area as a whole.

It should be pointed out, however, that not all the vegetation of this region is dry sclerophyll forest as areas of heath and scrubland are present in coastal districts; therefore the actual area of dry sclerophyll forest contained within the proposed boundaries would be less than the area of the reserve.

In terms of island biogeographical principles, the area proposed is far from satisfactory. It is long and narrow with a large perimeter: area ratio, as opposed to the "ideal" circular shape of reserves. It is possible that the area could be reserved by the National Parks and Wildlife Service. Accordingly, the land must be revoked by the Forestry Commission from the woodchip company's licence. It is quite probable that there would be little interest in the area in view of the amount of timber which could be taken from the forest, therefore, it appears likely that permission would be granted for revocation.

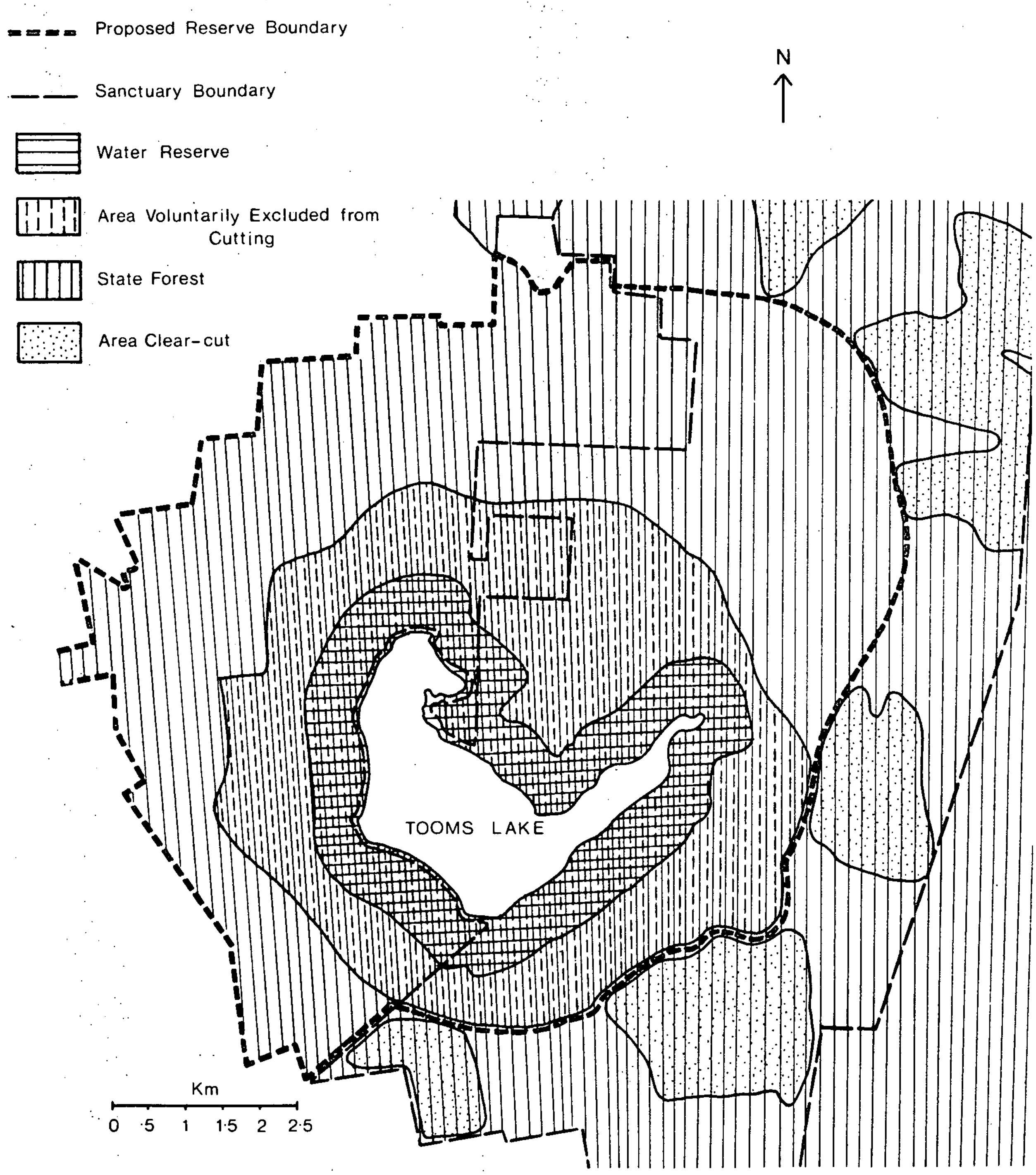
Second Proposal : Tooms Lake Site

The second site for a possible reserve includes that area of dry sclerophyll forest which encircles Tooms Lake. The area concerned forms part of the Tooms Lake Sanctuary. The forest surrounding the lake has essentially been unaffected by logging in contrast to the rest of the Sanctuary. At present, land within forty chains of the lake is under the control of the local council which is responsible for managing the area to protect the water quality of the lake (Figure 26).

In 1972, the Forestry Commission voluntarily decided to exclude from logging an area of about twice the width of the present water reserve. This represents approximately 3,800 ha of intact dry sclerophyll forest, as indicated in Figure 26. Reservation of this area would be desirable in view of the many purposes it would serve, namely, protection of the lake from soil run-off, as a refuge for aquatic bird species, as well as conservation of a relatively large area of dry sclerophyll forest.

FIGURE 26

Location of a Possible Reserve Site at Tooms Lake. Map constructed from information supplied by the Forestry Commission and the Lands Department, 1976.



This area would not, however, be large enough to function as an effective reserve for dry sclerophyll species. If the surrounding State Forest (as indicated in Figure 26) was included, the area reserved would approximate 8,000 ha. With the exception of the water reserve, all the land under discussion is classified as State Forest and could be set aside under the jurisdiction of the Forestry Commission in accordance with Section 12 of the Forestry Act 1975.

Certain disadvantages of this proposal, in terms of its value as a reserve for dry sclerophyll species, may relate to the central position of a large body of water in the reserve. In the first instance, the effect that aquatic birds may have on the dry sclerophyll species is essentially unknown. Consideration must be given as well to possible barrier effects due to this lake and the extra perimeter length arising from both the internal and external boundaries. Obviously the effects of both these factors decreases with increasing reserve size and, in view of the suitability of this area for reservation as compared with the other proposals, such shortcomings may be relatively unimportant.

Third Proposal : Buckland Site

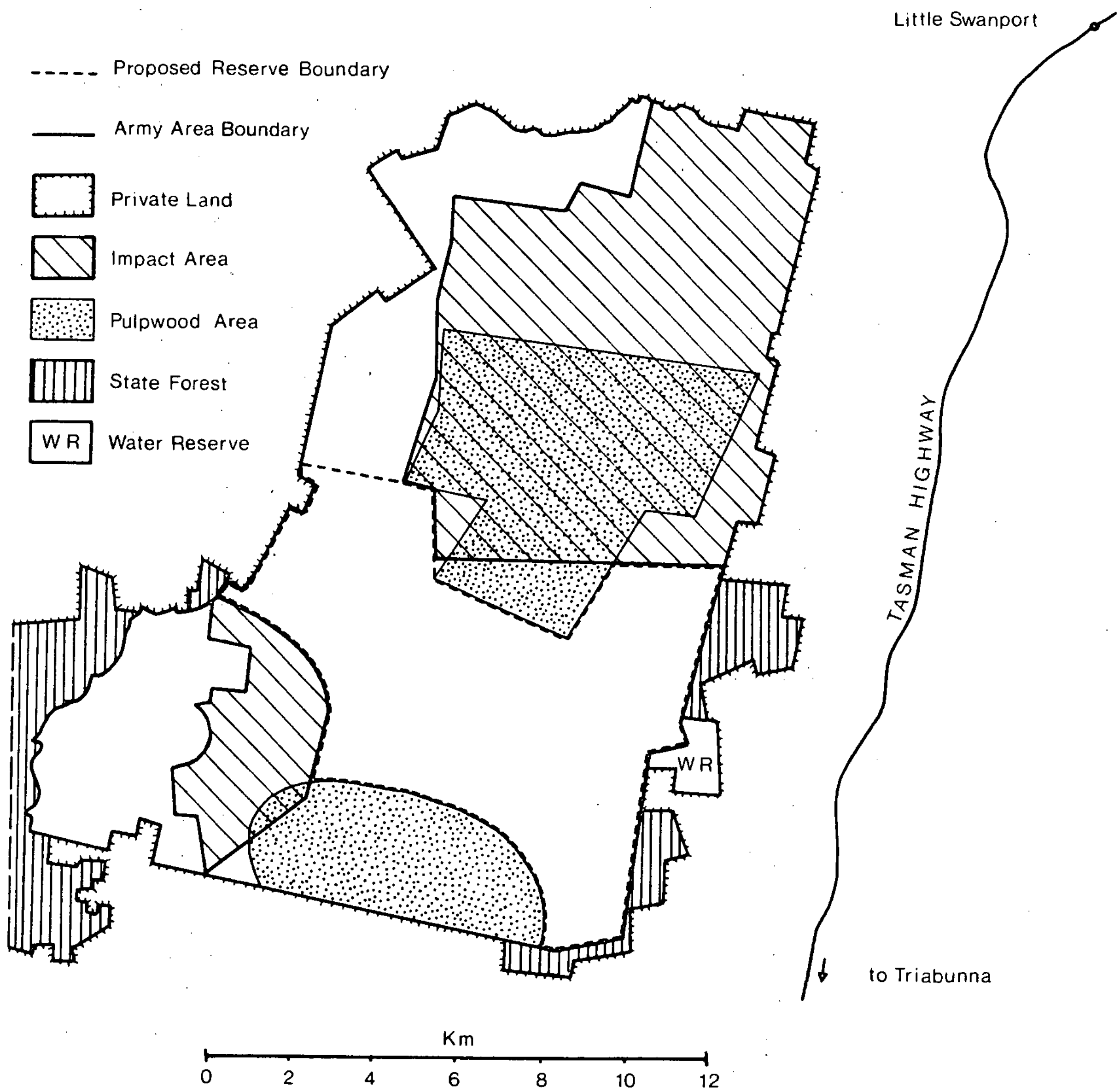
Another possible area of dry sclerophyll forest which may be suitable for reservation includes land vested in the Department of Defence as a military training area at Buckland (Figure 27). At present, most of the land is under a lease which expires in 2016 A.D.

Woodchipping has occurred in two separate regions within the training area (the parts affected are shown very approximately in Figure 27), whilst most of the forest throughout has been selectively logged. The boundaries of the impact areas (associated with the firing of shells) are also indicated in Figure 27.

An area of approximately 6,500 ha, delineated by the boundaries of the impact areas and woodchipping operations, represents a suitable size for reservation. Whilst it is not used specifically for the firing of weapons, some training of army personnel does occur here.

FIGURE 27

Location of a Possible Reserve Site Within the Army Training Area at Buckland. Map constructed from information supplied by the Forestry Commission and the Lands Department, 1976.



The Buckland site is highly valued by the Department of Defence as a training area. It is unlikely, therefore, that control of the land would be transferred to the National Parks and Wildlife Service for reservation. However, the Department of Defence appears to be aware of some of the problems associated with conservation and are interested in developing a management plan for the area. The C.S.I.R.O. have been working in the Buckland area studying the effects of woodchipping operations on the vegetation and wildlife. Reseeding programmes of some of the clearfelled areas have also been instigated by the C.S.I.R.O. and the Forestry Commission.

The setting aside of this area as a reserve to be managed by the Department of Defence with the assistance of relevant agencies (such as the C.S.I.R.O.) may be the most suitable approach in this case. Thus the Department of Defence would retain control of the land whilst, at the same time, creating a reasonable reserve of dry sclerophyll forest.

Fourth Proposal : Scamander Site

Although a practice of coup dispersal has been adopted by T.P.F.H., the distribution of areas to be logged is also dictated by economic considerations. This has resulted in a "concentration" of dispersed aggregates around the chip-plant at Triabunna. Therefore, to find a large area of forest unaffected at the present time by woodchipping operations, it is necessary to consider the most northern regions of the T.P.F.H. concession.

One potential reserve site in this locality is an area of largely vacant Crown land, bounded in the west by Upper Scamander and Cornwall, and in the east by Scamander and Falmouth. To constitute the desired 10,000 ha it would be necessary to include in this proposal some State Forest adjoining the vacant Crown land at its western limits.

Although this northern section of the T.P.F.H. concession has not been woodchipped at present, there are plans to commence cutting in the next 5 years.

One further disadvantage with this site is its relative proximity to Mt. William National Park. Locating a reserve in this part of the

State would not alleviate the need to conserve forest types representative of the more southern regions of the concession.

The potential for creating additional reserves in eastern Tasmania has been seriously threatened by land-use conflicts, exacerbated by the extent of Forestry Commission control over forest assets in this part of the State. Unless there is a re-orientation of government policy towards minimizing environmental damage as a consequence of resource use, it is inevitable that several dry sclerophyll species will become extinct in the future.

Unfortunately, by the time changes in policy and legislation occur there is likely to be very little "natural" dry sclerophyll forest remaining in eastern Tasmania. In order, therefore, that the pace of species extinction is retarded, it is imperative that the National Parks and Wildlife Service and other government agencies at least accept the principles developed in this report and promote them with a view to creating an additional reserve in the region of Tasmania's central east coast. With these principles accepted, reservation of either or both of the two most suitable sites discussed above, namely the Tooms Lake site and the Buckland site, should be a relatively straightforward process.

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APPENDICES

APPENDIX A

AERIAL PHOTOGRAPHS AND DESCRIPTION OF THE ISLAND SITES

FIGURE 1

Site 1

FIGURE 2

Site 2 and Site 4

FIGURE 3

Site 2a

FIGURE 4

Site 3

N

FIGURE 5

Site 5

FIGURE 6 Site 6

FIGURE 7

Site 7 (city site)

(continued)

TABLE 1

Description of the Island Sites

SITE	AREA (ha)	DOMINANT PLANT SPECIES[1]	COMMENTS[2]
5	341	*Eucalyptus viminalis* *Eucalyptus pulchella* *Eucalyptus globulus* *Eucalyptus rubida* *Acacia dealbata* *Bursaria spinosa*	Island is well isolated except for the northern edge where the forest thins rather than a distinct boundary being apparent. It is situated mainly on one face of a steep hill. A substantial amount of logging and burning has occurred in the southern half of the island and the ground layer here is quite sparse. A few gullies are present but these are fairly shallow.
6	1232	*Eucalyptus viminalis* *Eucalyptus rubida* *Acacia melanoxylon* *Acacia dealbata* *Coprosma quadrifida*	Island is well isolated, located on the top of a large hill. This island contains the greatest variation in vegetation structure and type. Towards the north-western edge is one particularly deep gully, which supports a variety of ferns and thick undergrowth. Logging and burning has occurred in different parts of the island.
7 (city site)	46	*Eucalyptus viminalis* *Eucalyptus pulchella* *Acacia dealbata* *Epacris impressa* *Exocarpus cupressiformis* *Casuarina littoralis*	Located on the side and top of a hill, surrounded by a zone of houses. The vegetation consists mainly of scattered eucalypts with a dense shrub layer. A number of roads lead to the eastern side of the island where a water reservoir is located.

1. The investigation of the vegetation present in each of the sites was fairly superficial. Samples of the dominant eucalypt species and shrub species were collected and certain structural features (for example, the amount of undergrowth present) were also noted. On the basis of these investigations it was felt that the sites were sufficiently similar and that to conduct more detailed studies, in particular to complete full lists of the plant species present, would very probably be unnecessary and involve a great deal of time.

2. Whenever possible, information was sought from the landowner concerning the age of the island. It is believed that each of the rural sites has been isolated for at least twenty years or more.

TABLE 1

Description of the Island Sites

SITE	AREA (ha)	DOMINANT PLANT SPECIES[1]	COMMENTS[2]
1	9	*Eucalyptus viminalis* *Eucalyptus pulchella* *Eucalyptus rubida* *Acacia dealbata*	Island is well isolated, located on flat land. Some logging and burning has occurred in the area. The ground layer is composed mainly of ferns.
2	20	*Eucalyptus viminalis* *Eucalyptus pulchella* *Acacia dealbata*	Island is well isolated, located on the top and side of a low hill. Some logging has occurred in the area. The vegetation is sparse on the top of the hill due to the presence of rocky outcrops. Lower down the face of the hill the undergrowth becomes quite dense but the taller trees and canopy layer is missing here.
2a	28	*Eucalyptus viminalis* *Eucalyptus pulchella* *Acacia dealbata* *Leucopogon fricoides* *Exocarpus cupressiformis*	Island is well isolated, located on top of a low hill. Some parts have been logged. Island is separated from a public road by a strip of land (approximately two hundred metres in width) which had been cleared and is now covered by a regrowth of *Acacia* species, small shrubs and grasses. This island differed from the others in containing a large amount of plant material which was in flower at the time of each census study.
3	74	*Eucalyptus viminalis* *Eucalyptus pulchella* *Eucalyptus rubida* *Acacia dealbata*	Island is situated on the top and sides of a low hill. It is well isolated, with the exception of the northern boundary where only a thin strip of cleared land (approximately fifty metres wide) separates the island from other forested areas. Logging has occurred in some parts. The ground layer is sparse on the top of the hill but becomes quite dense on the hill slopes.
4	189	*Eucalyptus viminalis* *Eucalyptus pulchella* *Acacia dealbata*	Island is quite well isolated, located on one side and top of a hill. Some of the flatter land has been cleared and the presence of rocky outcrops on the steep southern face adds to the sparseness of the vegetation. Fairly extensive burning and logging has occurred in the western half of the island and the ground layer is almost absent here. Several gullies occur throughout the area. Scattered trees at the opposite ends of the island may provide a link with other forested areas.

(continued over)

APPENDIX B

CENSUS STUDY INFORMATION (METHODOLOGY)

FIGURE 8

An example of the recording sheet used in the census studies. Details of methods used to record the physical data are presented overleaf.

CENSUS STUDY	AREA	
	DATE	
	OBSERVER	
	FOLIAGE INDEX	
	TEMPERATURE	
	WEATHER	
	SUN	
	WIND	
	OTHER NOISE	
	TIME PERIOD	

SPECIES	SEEN	HEARD	FORAGING HEIGHT		
			1	2	3
YELLOW-THROATED HONEYEATER	X	X	I	III	IIII
BLACK-HEADED HONEYEATER	X	X		II	IIIIII
STRONG-BILLED HONEYEATER	X	X		IIII	II
GOLDEN WHISTLER		X			
.....					

Notes on the methods used to record the physical data

Temperature was recorded in descriptive terms (for example, cool, cold) rather than in degrees Centigrade.

A note was made of recent past showers or showers which occurred during the census period.

Wind and sun measurements were based on those used by Dawson and Bull (1975), and are described below.

The amount of time the sun shone during the recording period was noted and this was expressed as a ratio (0 - 8/8). Wind was recorded according to a scale (0 - 3).

0 - leaves still or move without noise

1 - leaves rustle

2 - leaves and branchlets in constant motion

3 - branches and trees sway

A Foliage Index was recorded for each of the sites when conducting the first census study. This was recorded as the percentage contribution of each foliage zone (as described on page 30 of the text) to the total foliage present and was an attempt to describe the difference in vegetation structure between the sites. In practice, a fair amount of variation occurred in many of the sites and the use of a single value may be misleading. Nevertheless the index is useful in certain cases as, for example, it emphasizes the difference between Site 2a (which contained a large amount of flowering plant material) and the rest of the sites.

TABLE 2

Recording Times for the Island Sites

SITE	1	2	2a	3	4	5	6	7
Island area (ha)	9	20	28	74	189	341	1232	46
Estimated recording time (hr/min)	/24	/48	1/12	3/15	8/10	14/45	54/	2/
Actual recording time Census study 1	/30	1/	1/30	3/	8/	15/	45/	3/
Census study 2	/30	1/	1/30	3/	8/	15/	43/30	3/
Census study 3	/30	1/	1/30	3/	7/30	15/	45/30	3/

As discussed in the text, the total recording time spent in each site (with the exception of site 1 and site 2) was shared equally among the three observers. For the two smallest sites each observer undertook a half-hour census. One set of observations were then selected at random for site 1 records; two sets of observations for site 2 records.

TABLES 3 TO 5

Information concerning the dates and times of the recording periods and physical conditions encountered for each of the three census studies conducted.

TABLE 3

Census study 1 (17/5/76 to 2/6/76).

SITE	1	2	2a	3	4	5	6	7
DATE AND TIME OF RECORDING PERIODS	17/5/76 1030/1100	2/6/76 1115/1145	17/5/76 1510/1540	17/5/76 1230/1330	18/5/76 1320/1440 19/5/76 1100/1220	19/5/76 1500/1600 20/5/76 1120/1300 1450/1710	21/5/76 1230/1430 25/5/76 1015/1215 1300/1500 26/5/76 1020/1220 1310/1510 27/5/76 1030/1230 28/5/76 1015/1315	2/6/76 1450/1550
TEMPERATURE	COOL	COLD	COOL	COOL	COLD	COOL	COOL	COOL
WEATHER	FINE	FINE	FINE	FINE	PAST SHOWERS	FINE	SLIGHT SHOWERS	FINE
SUN	0/8	5/8	5/8	4/8	5/8	0-2/8	MOSTLY OVERCAST	5/8
WIND	2	1	0-2	0-3	0-3	0-1	0-3	1
NOISE	JETS, DOGS TRAFFIC	DOGS	-	JETS TRACTOR	SHEEP DOGS	JETS, SHEEP CATTLE	JETS	CITY NOISE
FOLIAGE INDEX	5:25:70	10:25:65	40:10:50	30:20:50	10:15:75	10:20:70	10:15:75	35:35:30
FLOWERING PLANTS	NIL	NIL	MOST OF GROUND LAYER IN FLOWER	NIL	NIL	NIL	NIL	NIL

TABLE 4

Census study 2 (26/7/76 to 12/8/76)

SITE	1	2	2a	3	4	5	6	7
DATE AND TIME OF RECORDING PERIODS[3]	27/7/76 1255/1355	27/7/76 0925/0955	27/7/76 1100/1145	28/7/76 0945/1115	2/8/76 1100/1300 1415/1615	26/7/76 1030/1210 1240/1420 1450/1630	30/7/76 1015/1245 1300/1500 9/8/76 1045/1245 1315/1515 11/8/76 1115/1315 1400/1600 12/8/76 1015/1245	28/7/76 1215/1345
TEMPERATURES	COOL	COLD	COOL	COLD	COLD	COLD	COOL	COOL
WEATHER	SHOWERS	FINE	FINE	FINE	FINE	SOME SHOWERS	MOSTLY FINE	FINE
SUN	4/8	8/8	8/8	8/8	1/8	2/8-5/8	0-8/8	8/8
WIND	0-2	0	0-1	0-1	0-2	0-2	0-2	0
NOISE	TRAFFIC DOGS FARM ANIMALS	TRACTOR	CARS CATTLE	TRACTOR JETS SMALL PLANES	PLANE	JETS, CAR DOGS, SHEEP	JETS	CITY NOISE
FLOWERING PLANTS	NIL	NIL	MOST OF GROUND LAYER IN FLOWER	NIL	NIL	NIL	NIL	NIL

3. Most of the field work for census study 2 was undertaken by only two observers. For this reason the recording periods listed for sites 2a,3,4 and 5 appear longer than for census studies 1 and 3.

TABLE 5

Census study 3 (20/9/76 to 4/10/76)

SITE	1	2	2a	3	4	5	6	7
DATE AND TIME OF RECORDING PERIODS	20/9/76 1020/1050	27/9/76 1620/1650	20/9/76 1430/1500	20/9/76 1145/1245	27/9/76 1330/1600	21/9/76 1025/1205 1300/1440 27/9/76 1010/1150	24/9/76 1015/1215 1320/1520 30/9/76 1030/1230 1320/1520 1/10/76 1015/1415 4/10/76 1130/1400	22/9/76 0910/1010
TEMPERATURE	MILD	MILD	COOL	MILD	MILD	COOL	COLD	COOL
WEATHER	FINE	FINE	FINE	FINE	FINE	SLIGHT SHOWERS	MOSTLY FINE	FINE
SUN	4/8	8/8	3/8	5/8	8/8	0/8	0-8/8	0/8
WIND	0	0-1	0-2	0-1	0-1	0-2	0-3	0-1
NOISE	TRUCKS, JET	TRUCKS, DOGS	CATTLE	JETS	CARS	JETS, SHEEP TRACTORS	CATTLE, JETS	CITY NOISE
FLOWERING PLANTS	A FEW PLANTS IN FLOWER	NIL	MOST OF GROUND LAYER IN FLOWER	A FEW PLANTS IN FLOWER	A FEW PLANTS IN FLOWER	A FEW PLANTS IN FLOWER	A FEW PLANTS IN FLOWER	A FEW PLANTS IN FLOWER

APPENDIX C

CENSUS STUDY DATA

TABLE 6

Census Study I (17/5/76 to 2/6/76)

BIRD SPECIES	SITE 1				SITE 2				SITE 2a				SITE 3				SITE 4				SITE 5				SITE 6				SITE 7			
	SEEN OR HEARD	FORAGING HEIGHT 1	2	3	SEEN OR HEARD	FORAGING HEIGHT 1	2	3	SEEN OR HEARD	FORAGING HEIGHT 1	2	3	SEEN OR HEARD	FORAGING HEIGHT 1	2	3	SEEN OR HEARD	FORAGING HEIGHT 1	2	3	SEEN OR HEARD	FORAGING HEIGHT 1	2	3	SEEN OR HEARD	FORAGING HEIGHT 1	2	3	SEEN OR HEARD	FORAGING HEIGHT 1	2	3
BROWN GOSHAWK																									*				*			
COLLARED SPARROWHAWK																																
WEDGE-TAILED EAGLE																									*							
SWAMP HARRIER																																
BROWN FALCON																																
BROWN QUAIL													*				*															
SPUR-WINGED PLOVER					*								*																			
COMMON BRONZEWING																																
YELLOW-TAILED BLACK COCKATOO																									*							
GREEN ROSELLA	*			2(100)	*				*				*				*			6(100)	*	1(7)		13(93)	*	9(12)	4(5)	61(83)				
EASTERN ROSELLA	*				*												*				*											
BLUE-WINGED PARROT																																
FAN-TAILED CUCKOO																																
HORSEFIELD BRONZE CUCKOO																																
WELCOME SWALLOW																																
TREE MARTIN																																
BLACK-FACED CUCKOO-SHRIKE																									*							
SUPERB BLUE WREN					*				*	2(100)			*	8(100)			*	13(87)	2(13)		*	19(100)			*	54(100)						
BROWN THORNBILL					*		10(100)		*	4(31)	9(69)		*	5(20)	20(80)		*	15(42)	18(50)	3(8)	*	30(34)	32(36)	27(30)	*	77(34)	100(44)	49(22)	*			
YELLOW-RUMPED THORNBILL									*	12(100)											*	4(100)			*	10(91)	1(9)					
BROWN SCRUB-WREN																	*								*							
SCARLET ROBIN									*				*				*	7(100)			*	2(67)	1(33)		*	20(100)			*			
FLAME ROBIN																									*							
DUSKY ROBIN									*				*	3(60)	2(40)		*			1(100)	*	1(50)		1(50)	*	19(48)	20(50)	1(2)	*			
GREY FANTAIL					*		2(100)		*		7(64)	4(36)	*		2(100)		*		1(100)		*	1(17)	5(83)		*	1(3)	27(82)	5(15)	*			
GOLDEN WHISTLER																	*			1(100)	*			3(100)	*		3(50)	3(50)				
GREY SHRIKE-THRUSH									*				*		1(100)		*				*				*		18(90)	2(10)	*		1(100)	
SPOTTED PARDALOTE					*				*				*			3(100)	*			5(100)	*	2(7)	2(7)	23(86)	*		2(40)	3(60)	*	3(11)	5(18)	20(71)
YELLOW-TIPPED PARDALOTE																									*							
GREY-BREASTED SILVEREYE																	*	2(100)							*		10(100)					
YELLOW-THROATED HONEYEATER									*			1(100)	*		1(33)	2(67)	*		5(33)	10(67)	*		10(27)	27(73)	*		19(49)	20(51)	*		2(33)	4(67)
BLACK-HEADED HONEYEATER																	*		10(30)	23(70)	*		10(14)	60(86)	*		19(22)	56(78)	*		2(10)	18(90)
STRONG-BILLED HONEYEATER																					*		8(15)	47(85)	*		13(31)	29(69)				
CRESCENT HONEYEATER									*	6(100)			*								*			1(100)	*			1(100)				
NEW HOLLAND HONEYEATER																					*											
EASTERN SPINEBILL									*	4(100)			*		2(100)																	
NOISY MINER	*		2(67)	1(33)	*			1(100)					*			2(100)	*	1(17)	3(50)	2(33)	*											
YELLOW WATTLEBIRD																					*			2(100)	*			1(100)				
BEAUTIFUL FIRETAIL																									*							
DUSKY WOOD-SWALLOW																																
CLINKING CURRAWONG																	*				*				*							
GREY BUTCHERBIRD																									*		1(100)					
WHITE-BACKED MAGPIE	*		1(100)		*																											
FOREST RAVEN	*				*				*				*				*				*				*				*			
LAUGHING KOOKABURRA					*				*								*				*				*							
STARLING																													*			
BLACKBIRD																													*			
GOLDFINCH																					*				*			10(100)				
HERON									*								*								*							
HOUSE SPARROW																																
TOTAL NUMBER OF SPECIES (EXCLUDING MIGRANTS)	5				11				15				15				20				22				30				12			
NUMBER OF DRY SCLEROPHYLL SPECIES(EXCLUDING MIGRANTS)	3				8				14				13				18				21				28				10			

NOTE:

1. * DENOTES SEEN OR HEARD
2. (B) DENOTES BREEDING
3. FORAGING HEIGHT: FOR EACH SPECIES THE NUMBER OF BIRDS RECORDED FORAGING IN EACH FORAGING LAYER IS TABULATED. THE FIGURES IN BRACKETS ARE THE PERCENTAGE OF THAT SPECIES IN EACH FORAGING LAYER.

TABLE 7

Census Study 2 (26/7/76 to 12/8/76)

BIRD SPECIES	SITE 1				SITE 2				SITE 2a				SITE 3			
	SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT		
		1	2	3		1	2	3		1	2	3		1	2	3
BROWN GOSHAWK																
COLLARED SPARROWHAWK																
WEDGE-TAILED EAGLE																
SWAMP HARRIER																
BROWN FALCON																
BROWN QUAIL																
SPUR-WINGED PLOVER																
COMMON BRONZEWING																
YELLOW-TAILED BLACK COCKATOO																
GREEN ROSELLA					*				*				*	1(100)		
EASTERN ROSELLA	*				*											
BLUE-WINGED PARROT																
FAN-TAILED CUCKOO																
HORSEFIELD BRONZE CUCKOO																
WELCOME SWALLOW																
TREE MARTIN																
BLACK-FACED CUCKOO-SHRIKE																
SUPERB BLUE WREN									*				*	4(100)		
BROWN THORNBILL					*		8(73)	3(27)	*	3(12)	22(85)	1(3)	*	16(25)	24(38)	23(37)
YELLOW-RUMPED THORNBILL									*	3(100)						
BROWN SCRUB-WREN																
SCARLET ROBIN									*				*	2(100)		
FLAME ROBIN																
DUSKY ROBIN									*		2(100)		*	2(67)	1(33)	
GREY FANTAIL									*				*	2(33)	4(67)	
GOLDEN WHISTLER													*			
GREY SHRIKE-THRUSH									*			1(100)	*			1(100)
SPOTTED PARDALOTE					*				*			2(100)	*			5(100)
YELLOW-TIPPED PARDALOTE																
GREY-BREASTED SILVEREYE																
YELLOW-THROATED HONEYEATER											1(50)	1(50)	*		10(67)	5(33)
BLACK-HEADED HONEYEATER									*		3(19)	13(81)	*			2(100)
STRONG-BILLED HONEYEATER																
CRESCENT HONEYEATER									*				*	2(100)		
NEW HOLLAND HONEYEATER																
EASTERN SPINEBILL									*				*	15(83)	3(17)	
NOISY MINER	*	1(25)		3(75)	*								*			
YELLOW WATTLEBIRD																
BEAUTIFUL FIRETAIL																
DUSKY WOOD-SWALLOW																
CLINKING CURRAWONG																
GREY BUTCHERBIRD																
WHITE-BACKED MAGPIE					*				*				*			
FOREST RAVEN	*				*				*				*	10(100)		
LAUGHING KOOKABURRA	*				*				*				*			
STARLING					*				*	20(100)						
BLACKBIRD																
GOLDFINCH					*											
HERON																
HOUSE SPARROW																
TOTAL NUMBER OF SPECIES (EXCLUDING MIGRANTS)	4				10				17				17			
NUMBER OF DRY SCLEROPHYLL SPECIES(EXCLUDING MIGRANTS)	3				7				15				15			

BIRD SPECIES	SITE 4				SITE 5				SITE 6				SITE 7			
	SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT		
		1	2	3		1	2	3		1	2	3		1	2	3
BROWN GOSHAWK	*				*				*				*			
COLLARED SPARROWHAWK																
WEDGE-TAILED EAGLE									*							
SWAMP HARRIER																
BROWN FALCON																
BROWN QUAIL																
SPUR-WINGED PLOVER																
COMMON BRONZEWING																
YELLOW-TAILED BLACK COCKATOO																
GREEN ROSELLA	*			4(100)	*			4(100)	*	2(9)	1(4)	20(87)				
EASTERN ROSELLA					*			1(100)								
BLUE-WINGED PARROT									*							
FAN-TAILED CUCKOO																
HORSEFIELD BRONZE CUCKOO																
WELCOME SWALLOW																
TREE MARTIN																
BLACK-FACED CUCKOO-SHRIKE																
SUPERB BLUE WREN	*	13(100)			*	7(100)			*	64(100)						
BROWN THORNBILL	*	4(13)	23(77)	3(10)	*	48(30)	63(39)	49(31)	*	154(38)	169(42)	84(20)				
YELLOW-RUMPED THORNBILL					*	30(100)			*	1(100)						
BROWN SCRUB-WREN									*	2(100)						
SCARLET ROBIN	*	1(100)			*	9(100)			*	28(100)			*			
FLAME ROBIN	*								*	11(92)	1(8)					
DUSKY ROBIN	*				*	5(71)		2(29)	*	9(41)	8(36)	5(23)				
GREY FANTAIL					*		4(40)	6(60)	*	2(6)	27(75)	7(19)				
GOLDEN WHISTLER					*			1(100)	*			6(100)				
GREY SHRIKE-THRUSH	*		2(100)		*		3(100)		*	2(13)	10(67)	3(20)	*		1(100)	
SPOTTED PARDALOTE	*			7(100)	*			12(100)	*		2(33)	4(67)	*		1(50)	1(50)
YELLOW-TIPPED PARDALOTE	*		2(50)	2(50)					*		1(100)					
GREY-BREASTED SILVEREYE	*		2(100)						*		1(100)		*			
YELLOW-THROATED HONEYEATER	*		11(79)	2(21)	*		20(43)	27(57)	*	1(1)	37(55)	29(44)	*		3(75)	1(25)
BLACK-HEADED HONEYEATER	*		16(30)	37(70)	*		7(11)	57(89)	*		21(18)	93(82)				
STRONG-BILLED HONEYEATER					*		14(30)	32(70)	*		17(29)	41(71)				
CRESCENT HONEYEATER					*		3(43)	4(57)	*			1(100)	*			
NEW HOLLAND HONEYEATER					*											
EASTERN SPINEBILL																
NOISY MINER	*				*			1(100)								
YELLOW WATTLEBIRD					*			1(100)	*							
BEAUTIFUL FIRETAIL									*	1(100)						
DUSKY WOOD-SWALLOW																
CLINKING CURRAWONG					*				*							
GREY BUTCHERBIRD																
WHITE-BACKED MAGPIE	*				*											
FOREST RAVEN	*	1(100)			*				*				*			
LAUGHING KOOKABURRA	*				*				*							
STARLING	*								*				*			
BLACKBIRD													*			
GOLDFINCH	*			10(100)	*				*				*			
HERON																
HOUSE SPARROW																
TOTAL NUMBER OF SPECIES (EXCLUDING MIGRANTS)	19				24				27				11			
NUMBER OF DRY SCLEROPHYLL SPECIES(EXCLUDING MIGRANTS)	16				22				26				9			

NOTE:

1. * DENOTES SEEN OR HEARD
2. (B) DENOTES BREEDING
3. FORAGING HEIGHT: FOR EACH SPECIES THE NUMBER OF BIRDS RECORDED FORAGING IN EACH FORAGING LAYER IS TABULATED. THE FIGURES IN BRACKETS ARE THE PERCENTAGE OF THAT SPECIES IN EACH FORAGING LAYER.

TABLE 8

Census Study 3 (20/9/76 to 4/10/76)

BIRD SPECIES	SITE 1				SITE 2				SITE 2a				SITE 3				SITE 4				SITE 5				SITE 6				SITE 7			
	SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT			SEEN OR HEARD	FORAGING HEIGHT		
		1	2	3		1	2	3		1	2	3		1	2	3		1	2	3		1	2	3		1	2	3		1	2	3
BROWN GOSHAWK																									*(B)							
COLLARED SPARROWHAWK																																
WEDGE-TAILED EAGLE																									*(B)							
SWAMP HARRIER																																
BROWN FALCON																	*								*(B)							
BROWN QUAIL																	*								*(B)							
SPUR-WINGED PLOVER																																
COMMON BRONZEWING					*												*(B)															
YELLOW-TAILED BLACK COCKATOO																																
GREEN ROSELLA					*(B)				*(B)			1(100)	*				*(B)	1(33)		2(67)	*(B)	6(26)	4(17)	13(57)	*(B)			4(100)				
EASTERN ROSELLA	*(B)			3(100)	*(B)				*(B)				*(B)				*				*			5(100)								
BLUE-WINGED PARROT																									*							
FAN-TAILED CUCKOO													*				*				*				*(B)							
HORSEFIELD BRONZE CUCKOO																					*(B)											
WELCOME SWALLOW					*								*				*								*							
TREE MARTIN					*												*				*											
BLACK-FACED CUCKOO-SHRIKE					*				*(B)				*(B)				*(B)								*(B)							
SUPERB BLUE WREN					*(B)	2(100)			*(B)	4(100)			*				*(B)				*(B)	10(100)			*(B)	46(100)						
BROWN THORNBILL					*(B)		5(100)		*(B)	5(50)	3(30)	2(20)	*(B)	12(38)	12(38)	8(24)	*(B)	1(7)	8(56)	5(37)	*(B)	10(16)	27(42)	27(42)	*(B)	20(13)	109(70)	27(17)				
YELLOW-RUMPED THORNBILL																					*	1(100)			*	2(100)						
BROWN SCRUB-WREN																									*(B)	8(80)	2(20)					
SCARLET ROBIN													*	1(100)			*(B)	7(88)	1(12)		*(B)	10(91)	1(9)		*(B)	15(100)			*			
FLAME ROBIN																	*(B)	1(100)			*(B)				*(B)	18(95)	1(5)					
DUSKY ROBIN									*	1(100)			*(B)				*(B)				*(B)	2(100)			*(B)	8(50)	3(19)	5(31)	*			
GREY FANTAIL									*		5(63)	3(37)	*(B)			3(100)	*(B)		1(100)		*(B)		8(73)	3(27)	*(B)	20(17)	68(58)	30(25)				
GOLDEN WHISTLER													*				*(B)				*(B)			1(100)	*(B)		1(50)	1(50)				
GREY SHRIKE-THRUSH									*(B)				*(B)				*(B)		2(100)		*(B)	1(100)			*(B)	2(9)	17(77)	3(14)				
SPOTTED PARDALOTE									*				*		3(100)		*		1(100)		*			7(100)	*			1(100)				
YELLOW-TIPPED PARDALOTE					*(B)			2(100)	*(B)			1(100)	*(B)		1(25)	3(75)	*(B)	2(5)	1(28)	26(67)	*(B)		19(33)	39(67)	*(B)	3(3)	40(34)	74(63)				
GREY-BREASTED SILVEREYE																									*(B)			4(100)	*(B)		7(100)	
YELLOW-THROATED HONEYEATER									*(B)		1(100)						*(B)		4(44)	5(56)	*(B)		17(50)	17(50)	*(B)		7(54)	6(46)	*(B)		1(100)	
BLACK-HEADED HONEYEATER									*(B)				*(B)			6(100)	*(B)		6(33)	12(67)	*(B)		3(10)	27(90)	*(B)		22(37)	33(63)	*(B)			
STRONG-BILLED HONEYEATER																					*(B)		7(16)	37(84)	*(B)	4(6)	26(41)	34(53)				
CRESCENT HONEYATER																					*(B)			23(100)	*(B)		8(38)	13(62)				
NEW HOLLAND HONEYEATER																					*(B)			4(100)	*(B)			4(100)				
EASTERN SPINEBILL													*(B)												*	2(100)						
NOISY MINER	*(B)			2(100)	*(B)				*(B)				*(B)				*(B)				*(B)											
YELLOW WATTLEBIRD																	*				*(B)			1(100)	*							
BEAUTIFUL FIRETAIL																									*							
DUSKY WOOD-SWALLOW					*				*				*(B)				*								*							
CLINKING CURRAWONG																					*(B)				*(B)							
GREY BUTCHERBIRD	*				*																*				*							
WHITE-BACKED MAGPIE	*(B)				*								*(B)				*				*											
FOREST RAVEN	*(B)								*(B)				*(B)				*(B)				*(B)	1(100)			*(B)				*(B)			
LAUGHING KOOKABURRA					*(B)				*(B)								*(B)				*(B)				*(B)							
STARLING					*(B)																				*(B)				*			
BLACKBIRD					*				*(B)								*								*(B)	6(100)			*(B)	2(100)		
GOLDFINCH																					*	4(100)			*(B)				*			
HERON																																
HOUSE SPARROW																					*											
TOTAL NUMBER OF SPECIES	5				16				17				20				28				31				38				9			
NUMBER OF DRY SCLEROPHYLL SPECIES(EXCLUDING MIGRANTS)	2				8				13				14				20				25				31				7			
TOTAL NUMBER OF BREEDING SPECIES(EXCLUDING MIGRANTS)	4				8				12				11				16				20				27				5			
NUMBER OF BREEDING DRY SCLEROPHYLL SPECIES (EXCLUDING MIGRANTS)	2				6				10				9				15				19				25				4			

NOTE:

1. * DENOTES SEEN OR HEARD
2. (B) DENOTES BREEDING
3. FORAGING HEIGHT: FOR EACH SPECIES THE NUMBER OF BIRDS RECORDED FORAGING IN EACH FORAGING LAYER IS TABULATED. THE FIGURES IN BRACKETS ARE YHE PERCENTAGE OF THAT SPECIES IN EACH FORAGING LAYER.

APPENDIX D

SPECIES-HABITAT LIST

	COASTAL HEATH	SAVANNAH WOODLAND	DRY SCLEROPHYLL	WET SCLEROPHYLL	MIXED FOREST	RAIN FOREST	SUB-ALPINE FOREST	CONIFEROUS FOREST	WET MALLEE	SEDGELAND	MOORLAND
GREY GOSHAWK				X	X						
AUSTRALIAN GOSHAWK			XX		X		X	X			
COLLARED SPARROWHAWK			XX								
WEDGE-TAILED EAGLE	X	X	X			X	X	X		X	XX
SWAMP HARRIER [m]	XX	XX	X							X	X
PEREGRINE FALCON											X
NANKEEN KESTREL	X	X									
BROWN FALCON	XX	XX	XX				X			XX	X
BROWN QUAIL	XX	X	X							X	
SPUR-WINGED PLOVER	XX	XX									X
BANDED PLOVER	X	X									
COMMON BRONZEWING	X	X	XX								X
BRUSH BRONZEWING				XX	XX	X				X	
MUSK LORIKEET			X								
SWIFT PARROT	X	X	XX	X							
YELLOW-TAILED BLACK COCKATOO	XX	X	X	XX	XX	XX	XX	X		X	
SULPHUR-CRESTED COCKATOO										X	
GREEN ROSELLA	XX	XX	XX	XX	XX	XX	X	X	XX	XX	X
EASTERN ROSELLA		XX	X								
BLUE-WINGED PARROT [m]	X	X	X							XX	XX
GROUND PARROT	X									XX	
PALLID CUCKOO [m]	XX	X	XX							X	
FAN-TAILED CUCKOO [m]	XX	X	XX	XX	XX		XX		XX	X	X
HORSEFIELD BRONZE CUCKOO [m]	X		XX								
GOLDEN BRONZE CUCKOO [m]	X	X	XX	XX	XX	X	X		X	X	
BOOBOOK OWL			X			X	X			X	
MASKED OWL			X								
TAWNY FROGMOUTH			X						X		
OWLET NIGHTJAR			X								

NOTE: m, MIGRATORY SPECIES

X, RARE SPECIES IN THIS HABITAT

XX, COMMON SPECIES IN THIS HABITAT

	COASTAL HEATH	SAVANNAH WOODLAND	DRY SCLEROPHYLL	WET SCLEROPHYLL	MIXED FOREST	RAIN FOREST	SUB-ALPINE FOREST	CONIFEROUS FOREST	WET MALLEE	SEDGELAND	MOORLAND
WELCOME SWALLOW m	XX	XX			X				XX	X	X
TREE MARTIN m	X		XX	X	X					X	XX
PIPIT	XX	X	X					X		X	XX
BLACK-FACED CUCKOO-SHRIKE m	X	XX	XX	X	X		X		X	X	X
GROUND THRUSH				XX	XX	XX				X	
SPOTTED QUAIL THRUSH			XX								
SUPERB BLUE WREN	XX	XX	XX	XX	XX		X		XX	XX	XX
EMU-WREN	X								XX	XX	
TASMANIAN THORNBILL	XX			XX	XX	XX	XX	XX	XX	XX	XX
BROWN THORNBILL	XX	XX	XX								
YELLOW-RUMPED THORNBILL	X	XX	X								
SCRUB-TIT				XX	XX	XX	XX	X			
BROWN SCRUB-WREN	XX		XX	XX	XX	XX	XX	X	XX	X	X
FIELD WREN	XX						X	XX	XX	XX	X
WHITE-FRONTED CHAT	XX	X									
SCARLET ROBIN	X	XX	XX							X	
FLAME ROBIN	XX	XX	XX	XX	X	X	XX	X	X	XX	XX
PINK ROBIN				XX	XX	XX	X				
DUSKY ROBIN	XX		XX	XX			XX			XX	
GREY FANTAIL	XX	X	XX	XX	XX	XX			X	X	
SATIN FLYCATCHER m	X	X	XX	X	XX						
GOLDEN WHISTLER	X		XX	XX	XX	X	X		X	X	
OLIVE WHISTLER	X			XX	XX	XX	XX	X	XX	XX	
GREY SHRIKE-THRUSH	XX	XX	XX	XX	XX	XX	XX		XX	XX	XX
SPOTTED PARDALOTE	XX	X	XX	XX	XX		XX		XX		X
YELLOW-TIPPED PARDALOTE	XX	XX	XX	XX	XX	X	XX				X
GREY-BREASTED SILVEREYE	XX	X	XX	XX	XX	XX	XX		XX	XX	X
YELLOW-THROATED HONEYEATER	XX	XX	XX	XX	XX	X	XX		XX	XX	X

NOTE: m, MIGRATORY SPECIES

X, RARE SPECIES IN THIS HABITAT

XX, COMMON SPECIES IN THIS HABITAT

	COASTAL HEATH	SAVANNAH WOODLAND	DRY SCLEROPHYLL	WET SCLEROPHYLL	MIXED FOREST	RAIN FOREST	SUB-ALPINE FOREST	CONIFEROUS FOREST	WET MALLEE	SEDGELAND	MOORLAND
BLACK-HEADED HONEYEATER	X	X	XX	X	X		X		X		X
STRONG-BILLED HONEYEATER	X		XX	XX	XX	X	X		XX	X	X
CRESCENT HONEYEATER	XX		XX	XX	XX	XX	XX	XX	XX	XX	XX
NEW HOLLAND HONEYEATER	XX	X	X	X					XX	X	
TAWNY-CROWNED HONEYEATER	XX										
EASTERN SPINEBILL	X		XX	XX	XX	X	X		XX	X	
NOISY MINER			XX								
LITTLE WATTLEBIRD	XX	X	X								
YELLOW WATTLEBIRD		X	XX	X	X	X	XX			X	X
BEAUTIFUL FIRETAIL	X		X	XX	X		XX		XX	XX	
DUSKY WOOD-SWALLOW m	XX	XX	XX							X	
BLACK CURRAWONG	X		X	XX	XX	XX	XX	XX	XX	XX	XX
CLINKING CURRAWONG	X		XX								
GREY BUTCHERBIRD	X	XX	XX								
WHITE-BACKED MAGPIE		XX									
FOREST RAVEN	XX	XX	XX	XX	XX	XX	XX	X	XX	XX	XX

<u>NOTE</u>: m, MIGRATORY SPECIES
X, RARE SPECIES IN THIS HABITAT
XX, COMMON SPECIES IN THIS HABITAT

APPENDIX E

Characteristics of Island Species

1. Literature Review
2. Foraging Behaviour in Tasmanian Dry Sclerophyll Habitat Islands
3. Foraging Height Diagrams

1. Literature Review

Apart from the studies conducted on quantitative aspects of island biogeography (as discussed in Chapter 2), there is also a vast amount of literature related to the characteristics of island species. The smaller number of species on islands as compared with equivalent mainland areas has led to the belief that competition between species is less severe or less frequent in the island situation (MacArthur *et al*. 1972).

To date, much of the evidence for reduced competition has come from comparative ecological studies of bird species present on oceanic islands and adjacent mainland areas (for example, Crowell 1962; Grant 1965; Diamond 1970a, 1970b; MacArthur *et al*. 1972). MacArthur and Wilson (1967) have discussed the theoretical implications of this reduced competition and maintain that habitat expansion, rather than a change in range of diet items, is the most likely short-term response of a species when colonizing an island freed from its mainland competitors.

The literature contains many examples of habitat expansion by island bird species (for example, Lack and Southern 1949; Boatman 1951; Bourne 1955; Rand and Rabour 1960; MacArthur *et al*. 1972) as well as for other animal taxa (documented by MacArthur and Wilson 1967). To illustrate habitat expansion with an example, both Diamond (1970) and MacArthur *et al*. (1972) working in their respective study areas (New Guinea and its satellite islands; Puercos Island and the Panama mainland) found that bird species most commonly expanded into moist-forest areas on the island. On the mainland they were restricted to areas of secondary growth as a result of competition from congeners. The latter species however, are "bad" colonizers and therefore are not present on the islands, thus allowing the use of both habitat types by the island species.

Apart from horizontal habitat expansions, changes in vertical feeding heights of insular bird species are also frequently recorded. Diamond (1970a) and MacArthur *et al*. (1972) found that the mainland fauna as a whole utilises a narrower range of vertical foraging strata than does an island fauna.

Diamond (1970a) also discussed expansion of altitudinal ranges of species on the New Guinea islands. In both relative and absolute terms New Guinea has far more area at high elevations and many more montane species than its satellite islands. Thus on the smaller islands some lowland birds have expanded their altitudinal ranges upwards. Similarly, Terborgh and Weske (1975) who studied a non-oceanic island/mainland situation (an isolated massif separated from the main body of the Peruvian Andes), showed an upward altitudinal expansion of bird species on the "island" in response to a deficiency in competition from high altitude species.

Changes in diet and morphology may also be associated with island species. These differ from the other types of shifts (as discussed previously) in that they probably require changes at the genetic level and therefore are not immediately obvious and are less frequently recorded in the literature (Yeaton 1974). Grant (1968, 1972) however, has described examples of character release that have occurred on islands. He interpreted the longer bills of island species (which were proportionally greater than changes in overall body size), previously documented by himself and by several others, as examples of character release in the absence of competition (either from a homogeneric or heterogeneric source) which enables a species to exploit a larger size and wider range of food items.

Keast (1971) compared niche utilization and the morphological attributes of Tasmanian bird species with their mainland counterparts and found evidence which supported the above statement. However, he also documented three separate cases where an island species had a shorter bill than the corresponding mainland species. In one instance, where the species was the only representative of that genus in Tasmania whilst on the mainland three related species were present, the bill of the Tasmanian species was intermediate in length between the bills of the three mainland species. Keast interpreted this as an adaptation by the island species for occupying the roles of the two absent species. In each of the other documented cases another species, related to that species which exhibited bill reduction, was found to be present in Tasmania. Keast explained this reduction in bill length by one member of each congeneric pair as an example of character divergence which supported the thesis of Schoener (1965), that closely related species pairs on islands minimize interspecific competition by exaggerating morphological differences.

The belief that species generally experience reduced competition on islands has led to the postulation of increased abundance of island populations as compared with equivalent mainland populations. Regarding the total densities of all species combined, several workers have examined whether niche expansions and the resulting higher abundance of some island species can fully compensate for the absence of mainland species. The results of the studies are varied; total densities of all species on islands may be higher (Crowell 1962; Grant 1966; MacArthur *et al.* 1972), comparable to (Yeaton 1974), or less than (Diamond 1970b) densities in similar mainland areas. These results apparently depend on colonization by species "appropriate" to the island habitat (MacArthur *et al.* 1972). The appropriateness of coloniser is related to the proximity and abundance of the island habitat on the mainland, and to history. Thus, for example, land bridge islands presumably had a better chance than other types of islands to try mainland species for suitability.

Still others have considered the question of whether or not islands contain "vacant" niches. Working on bird species communities off the Californian coast, Yeaton (1974) maintained that the reduced diversity was compensated by a greater niche overlap of those species present and that the island community was in equilibrium, approaching a state of saturation equivalent to that of the mainland. Similarly, but using different methods and reasoning, both Keast (1971) and Thomas (1974) concluded that the impoverished Tasmanian dry sclerophyll habitats (as compared with similar habitats on the Australian mainland) were saturated and that the addition of bird species could only be achieved at the expense of those present.

These claims appear to refute the belief expressed earlier that as a consequence of the reduction in the total number of species present, island species are likely to experience less competition as compared with mainland species. Thus if all niches are "filled" and the available habitat is saturated it is logical that competition would be equally severe for an island species as for a mainland species.

Another frequently discussed feature of island populations relates to the existence of homogeneric species on islands. Grant (1969a) has claimed that in view of the fact that it is not possible to forecast the number of congeners which should occur on an island, the question of whether an island contains proportionally fewer congeners (in addition to its total species deficit) than an equivalent mainland area is essentially unknown. However, he maintains that this does not deny the possibility that coexistence for congeners is more difficult in the island situation. Grant quotes the large difference in bill length between pairs of congeners (not necessarily the same species) recorded on certain islands and their adjacent mainland areas by Schoener (1965) and himself, as evidence of this. As a result of later work (1969b) he was able to show that this difference was primarily due to colonization of the islands by a higher proportion of dissimilar mainland pairs rather than post-colonization adaptive (divergent) changes as discussed earlier. In the case of species pairs that were too similar extinction of either one or other individuals (or perhaps both) has probably occurred.

Grant's initial assumption (that competition on islands is likely to be most severe between congeneric species) has, however, been seriously questioned by several workers (Greenwood 1968; Thomas 1974). Thomas quotes Lack's (1969) postulate that, because of ecological limitations island birds have special adaptations which enable fewer species with broader niches to exclude a greater number of species, as a basis for his argument. If one accepts this statement and assumes saturation of island communities it follows that competitive exclusion would most likely occur between those species which are not necessarily related but which seek to exploit the same resources.

The question of whether island populations are more or less variable than their mainland counterparts has been frequently discussed in the literature. The character most often studied in bird populations is the bill, in particular the length of the bill. In some cases the bill of an island species may be more variable in its dimensions (Lack 1947; Amadon 1950; Crowell 1962; Van Valen 1965; Grant 1967) or less variable (Crowell 1962; Grant 1967) than its mainland relative. Grant (1967) has discussed the problem at length. Explanations of the variability of this character centre on two assumptions; that bill length differences reflect differences in the type of food exploited (Soulé and Stewart (1970) have seriously questioned this), and that a variety of bill length reflects a greater variety of food types used. Grant maintains that since we cannot generalise about the variety of food types available or exploited by island and mainland species there can be no *a priori* decisions as to the variability in bill length of island populations and mainland populations. Explanations for each situation need to be sought individually.

2. Foraging Behaviour in Tasmanian Dry Sclerophyll Habitat Islands

The main purpose of recording bird species foraging behaviour was to determine whether habitat island area had a significant effect of species foraging behaviour. A further purpose was to determine whether significant differences in species foraging behaviour could be discerned between seasons.

Analysis of Foraging Data

The foraging data for all three census studies is tabulated in Appendix C. For each island, the percentage of each species foraging in each of the three height layers was calculated and the information plotted on a phase diagram. The diagrams for all eight islands are shown overleaf.

Effect of Habitat Island Area on Foraging Behaviour

A consideration of the data for some of the more common dry sclerophyll species (yellow-throated honeyeater, black-headed honeyeater, strong-billed honeyeater, and brown thornbill) in the two larger islands (5 and 6) does indicate the existence of some differences between species feeding behaviour in habitat islands and in mainland areas (see Table 9). These differences suggest that the habitat island species may be more versatile in their foraging behaviour than those of "mainland" areas of dry sclerophyll habitat. However, as the data for each species is based on a relatively small sample taken over relatively short periods, these results are not statistically significant.

TABLE 9

Seasonal Changes in Vegetation Zone Usage. (Thomas, unpublished data).

SPECIES	SEASON	VEGETATION ZONE 1	2	3
Yellow-throated honeyeater	Summer	4	16	80
	Winter	1	25	74
Black-headed honeyeater	Summer	1	15	84
	Winter	2	15	83
Strong-billed honeyeater	Summer	4	18	78
	Winter	1	16	83
Brown Thornbill	Summer	16	37	47
	Winter	37	44	19

Nevertheless, the foraging diagrams for all census studies indicate that small islands have no small ground or shrub foragers until an area greater than 20 ha is reached. The diagrams for the city island (island 7) also show that no bird species were recorded foraging in the ground and shrub layers of this island in any census study. As mentioned previously, this island is on the hill between Lindisfarne and Geilston Bay and is bounded on four sides by suburbia. Hence the influence of humans and domestic animals, especially cats, would explain the lack of small ground and shrub foraging bird species.

Effect of Season on Species Foraging Behaviour

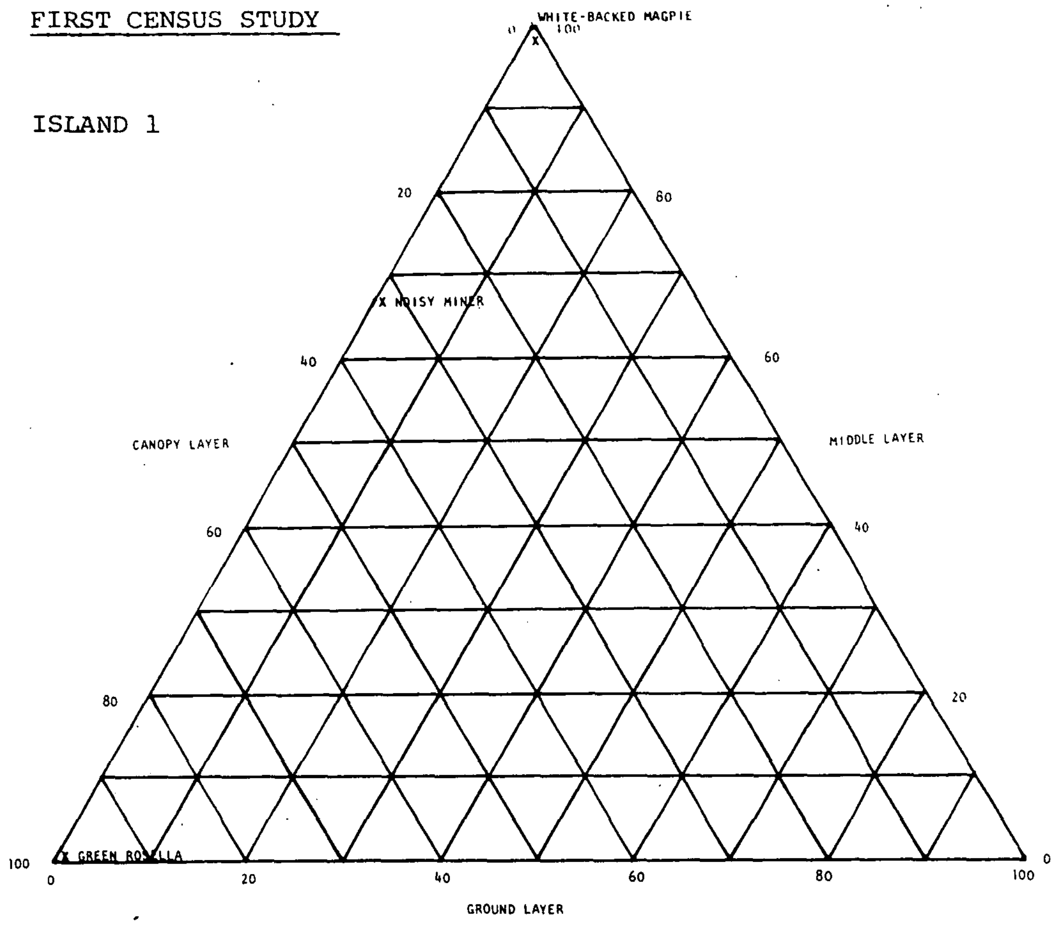
The only species for which sufficient data was collected to show a seasonal effect was the brown thornbill. Reference to the foraging diagrams for the largest island (6) show that in winter (census studies 1 and 2) 34% forage in the ground layer, 44% in the middle layer, and 22% in the canopy layer; in spring (census study 3) 13% forage in the ground layer, 70% in the middle layer, and 17% in the canopy layer. Thus for some reason or reasons, brown thornbills are more versatile in their foraging behaviour during the winter months.

For all other species the foraging data is based on such a small sample that significant differences could not be discerned.

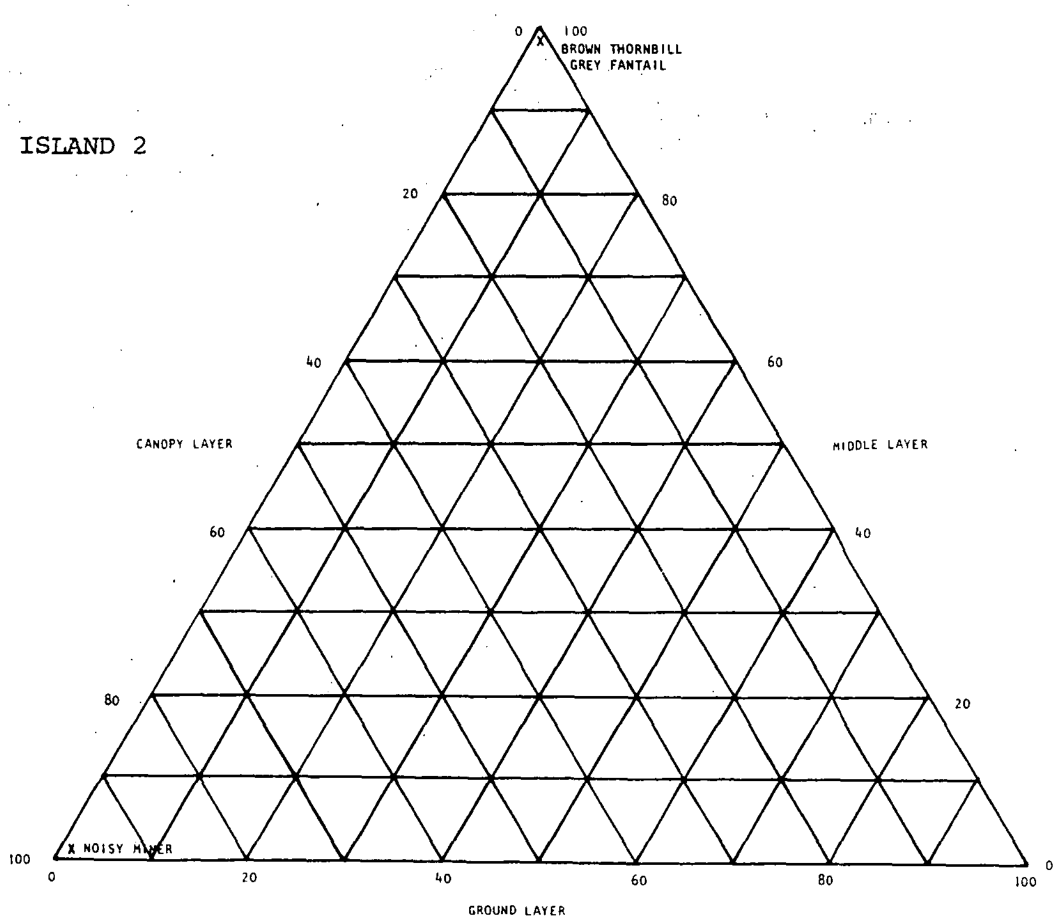
3. Foraging Height Diagrams

FIRST CENSUS STUDY

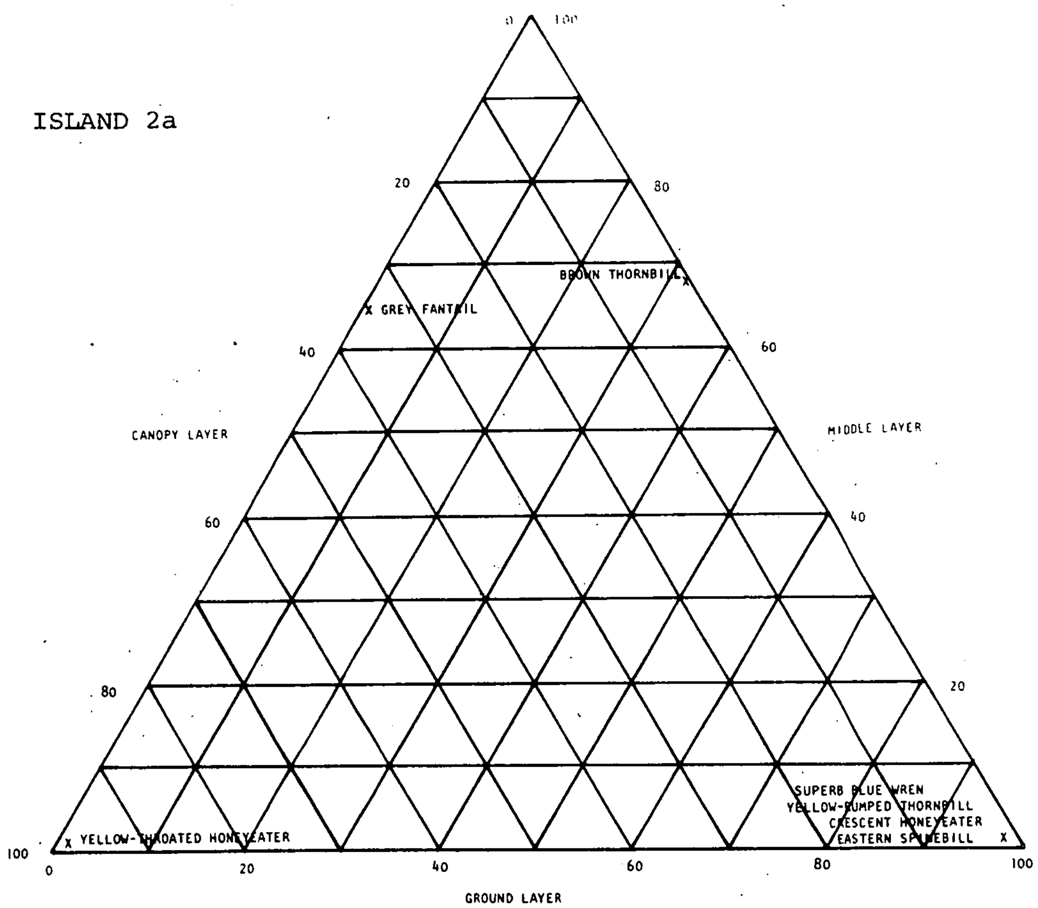
ISLAND 1



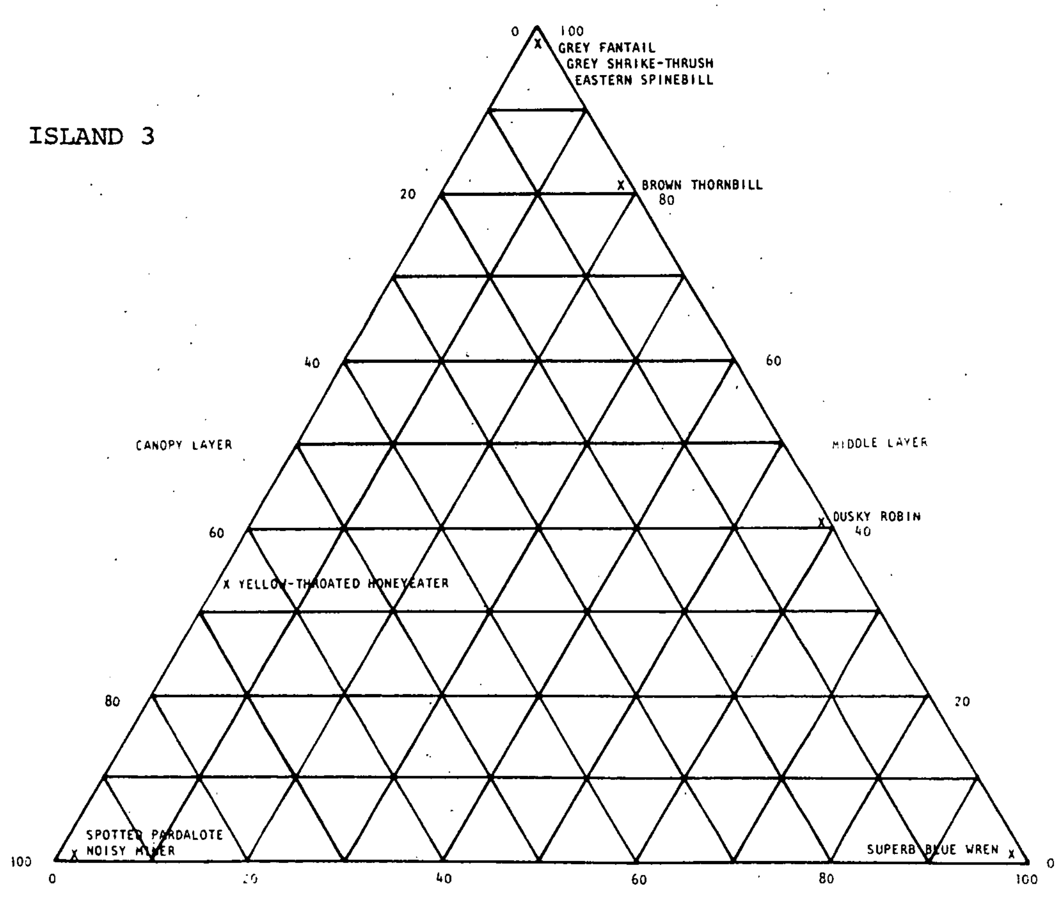
ISLAND 2



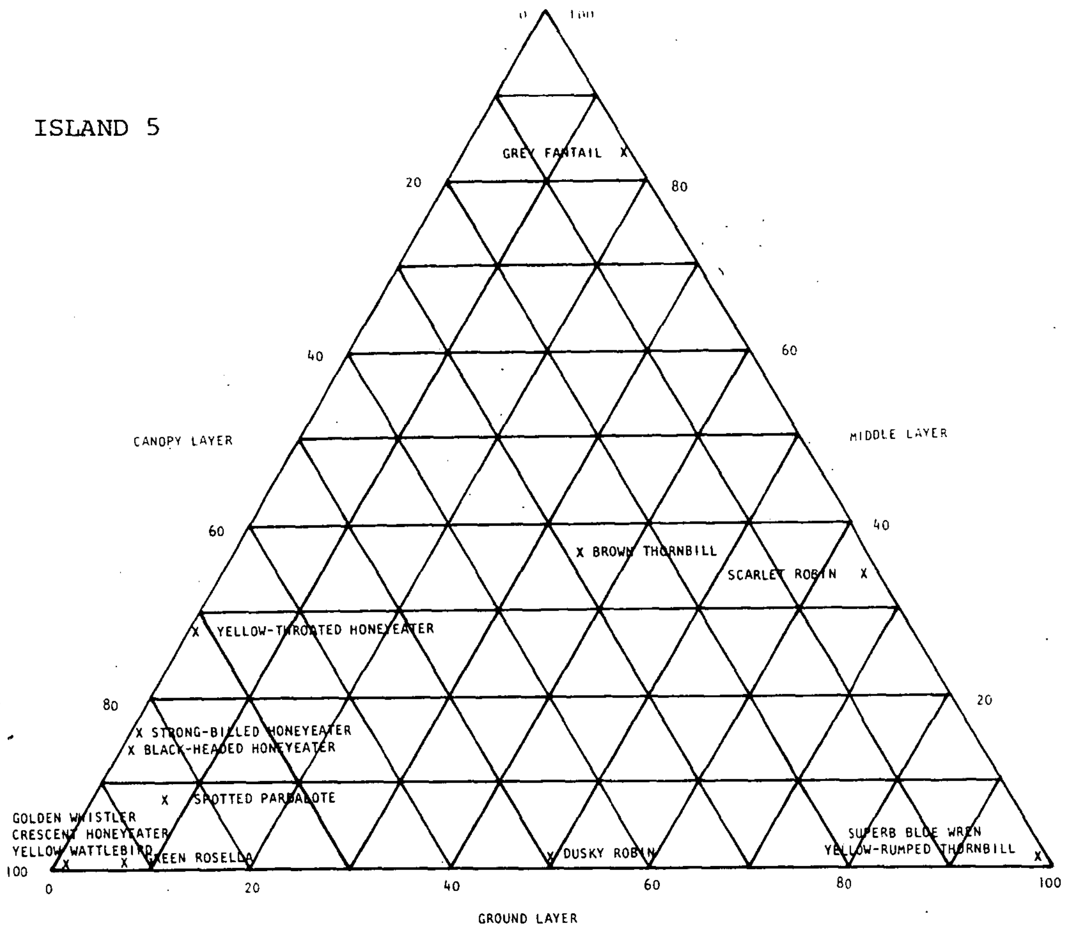
ISLAND 2a



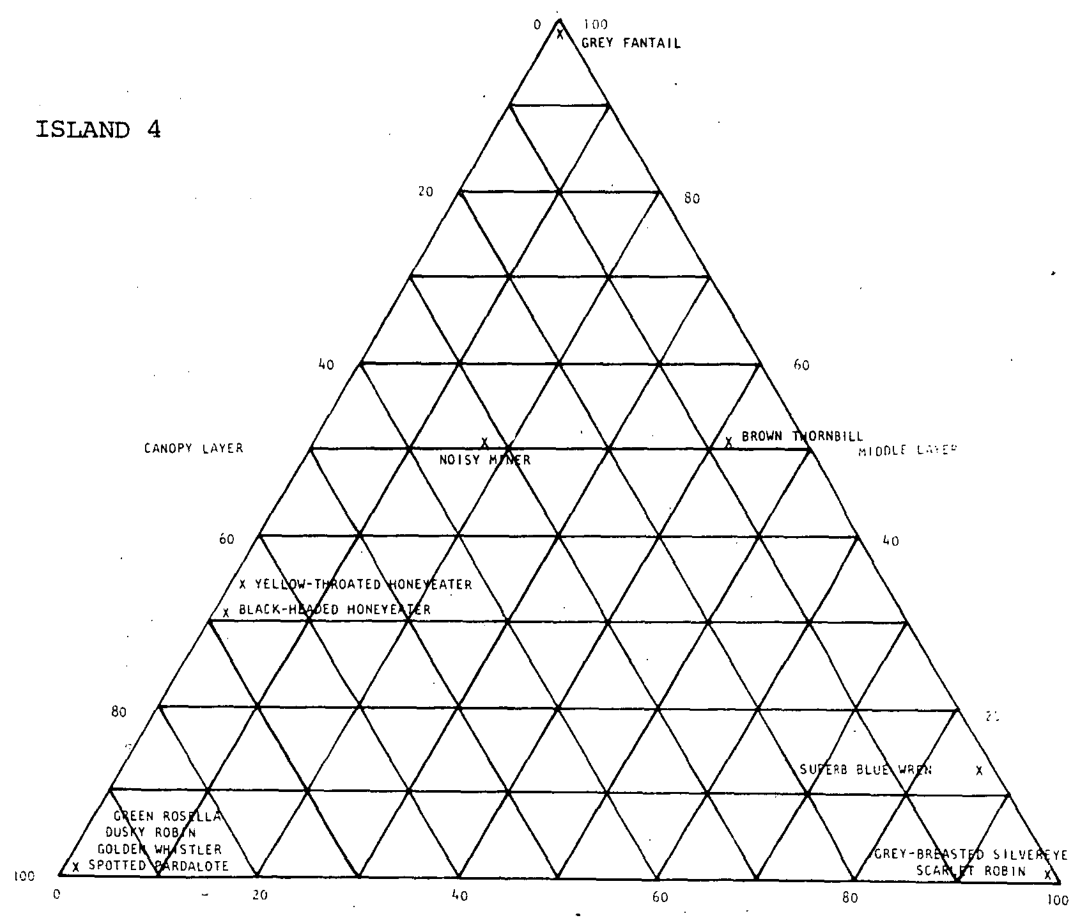
ISLAND 3



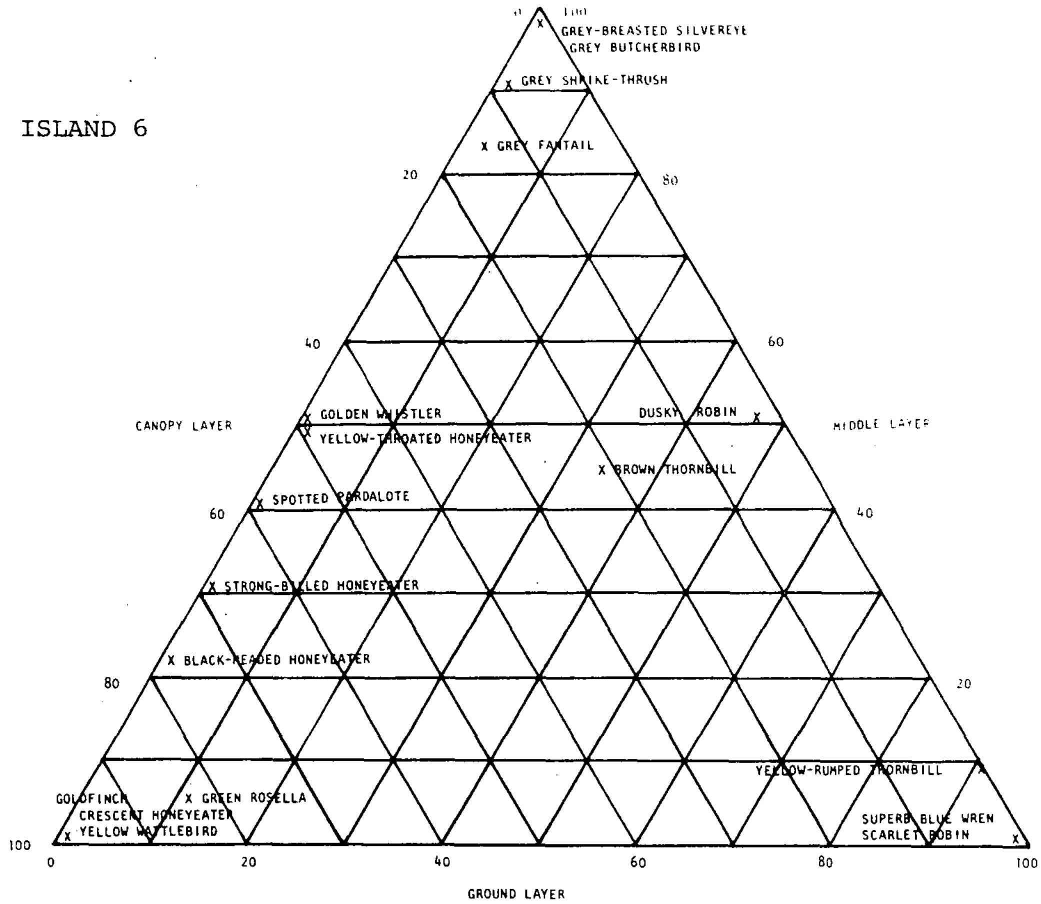
ISLAND 5



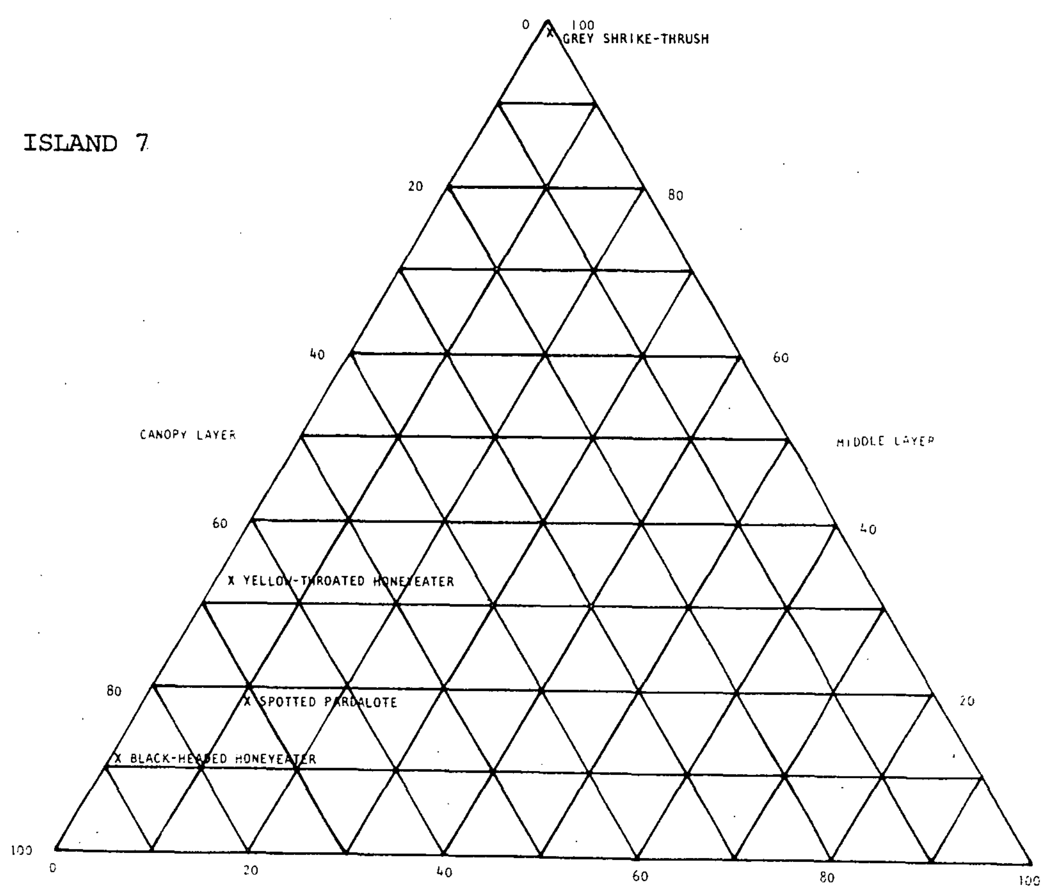
ISLAND 4



ISLAND 6

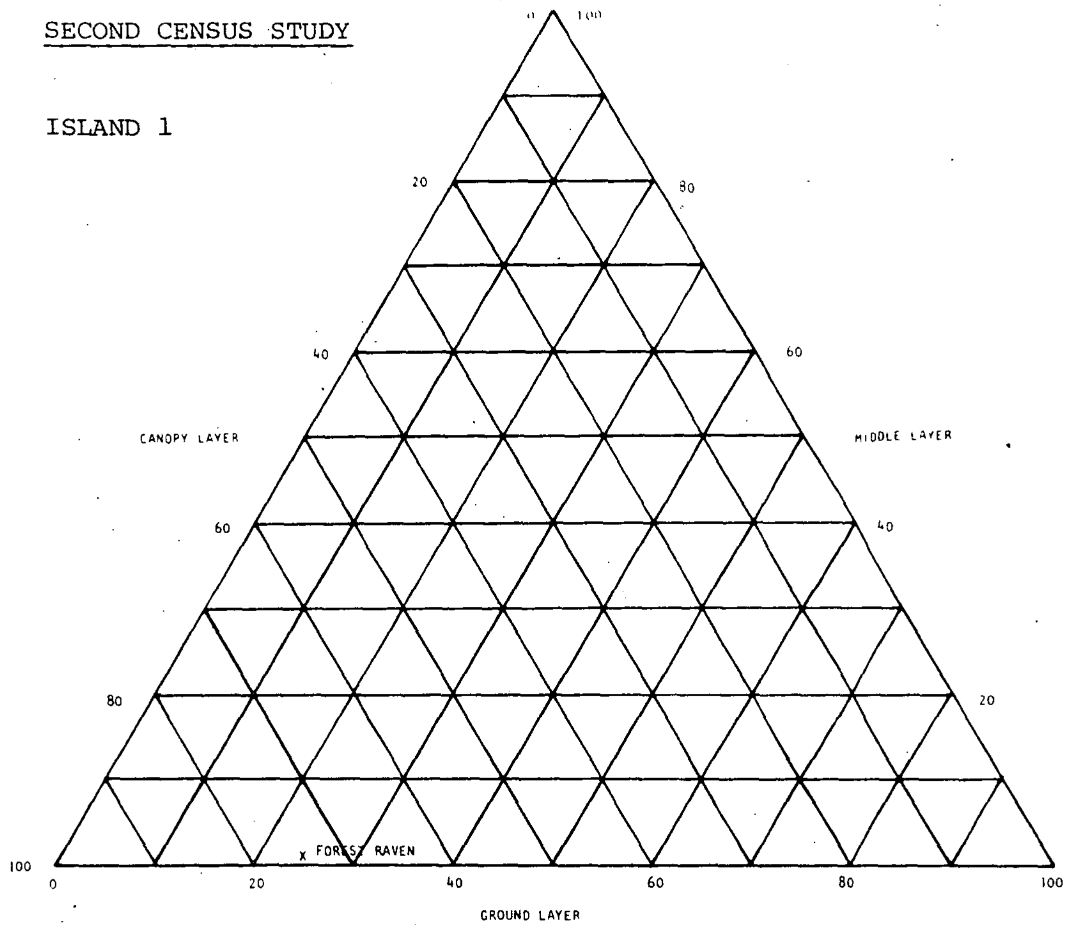


ISLAND 7

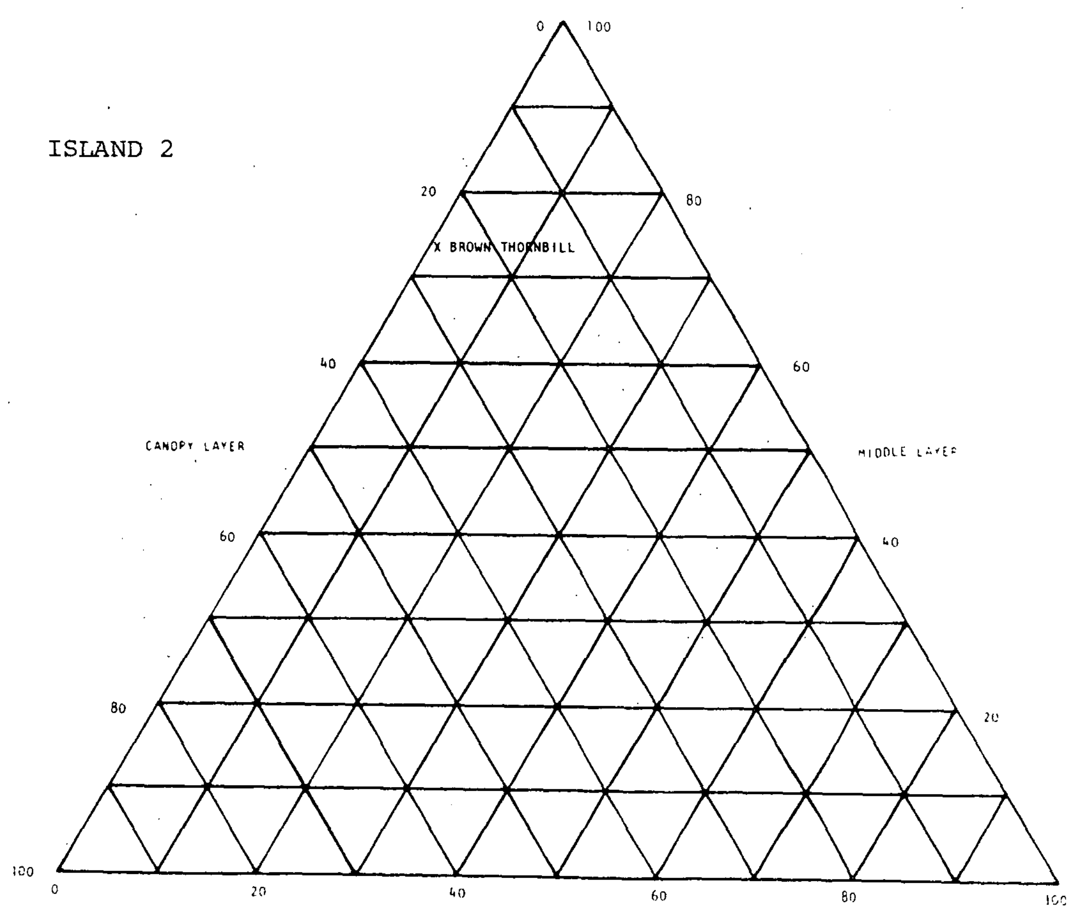


SECOND CENSUS STUDY

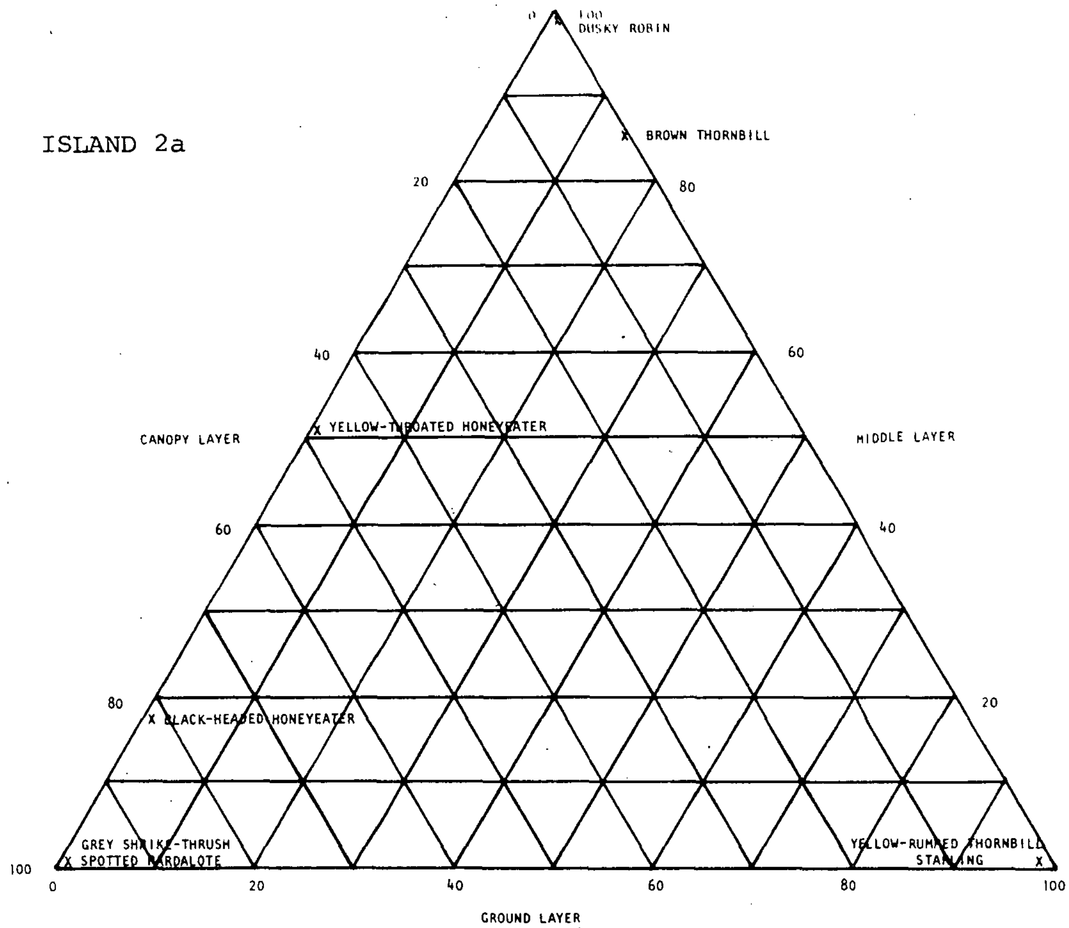
ISLAND 1



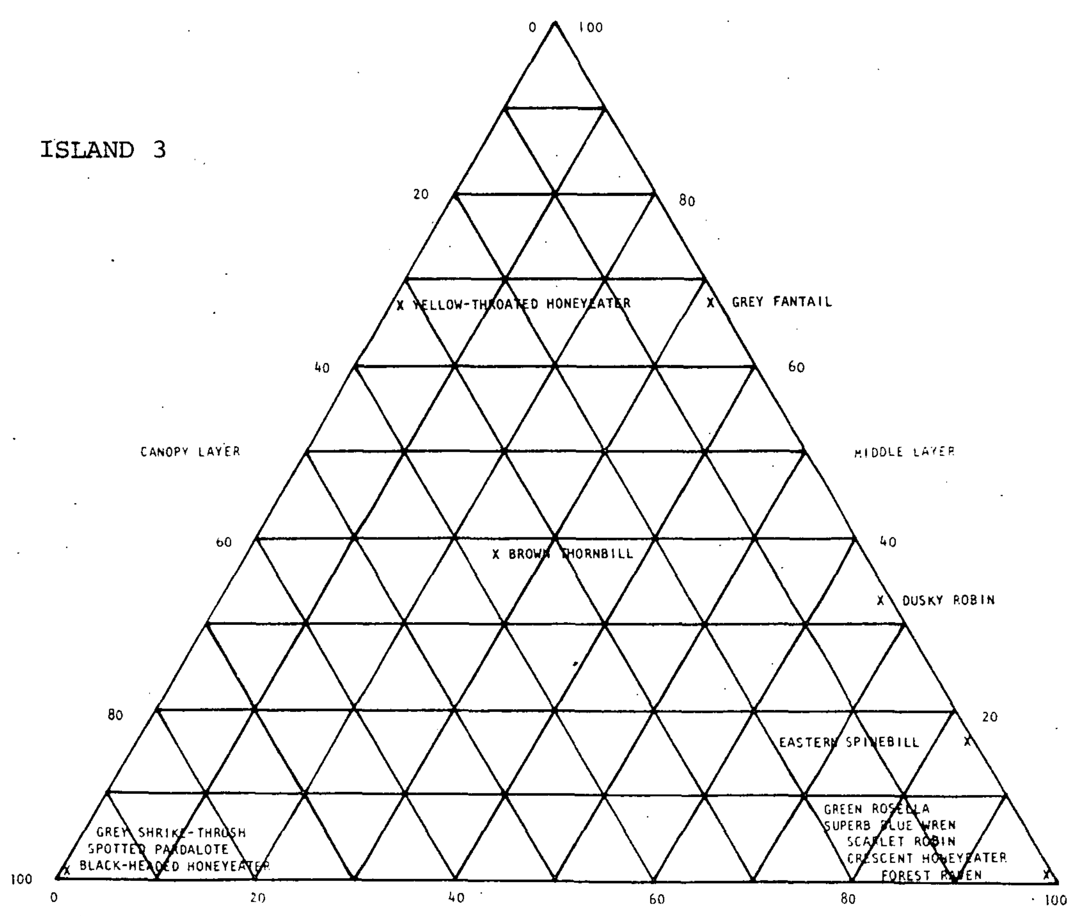
ISLAND 2



ISLAND 2a



ISLAND 3



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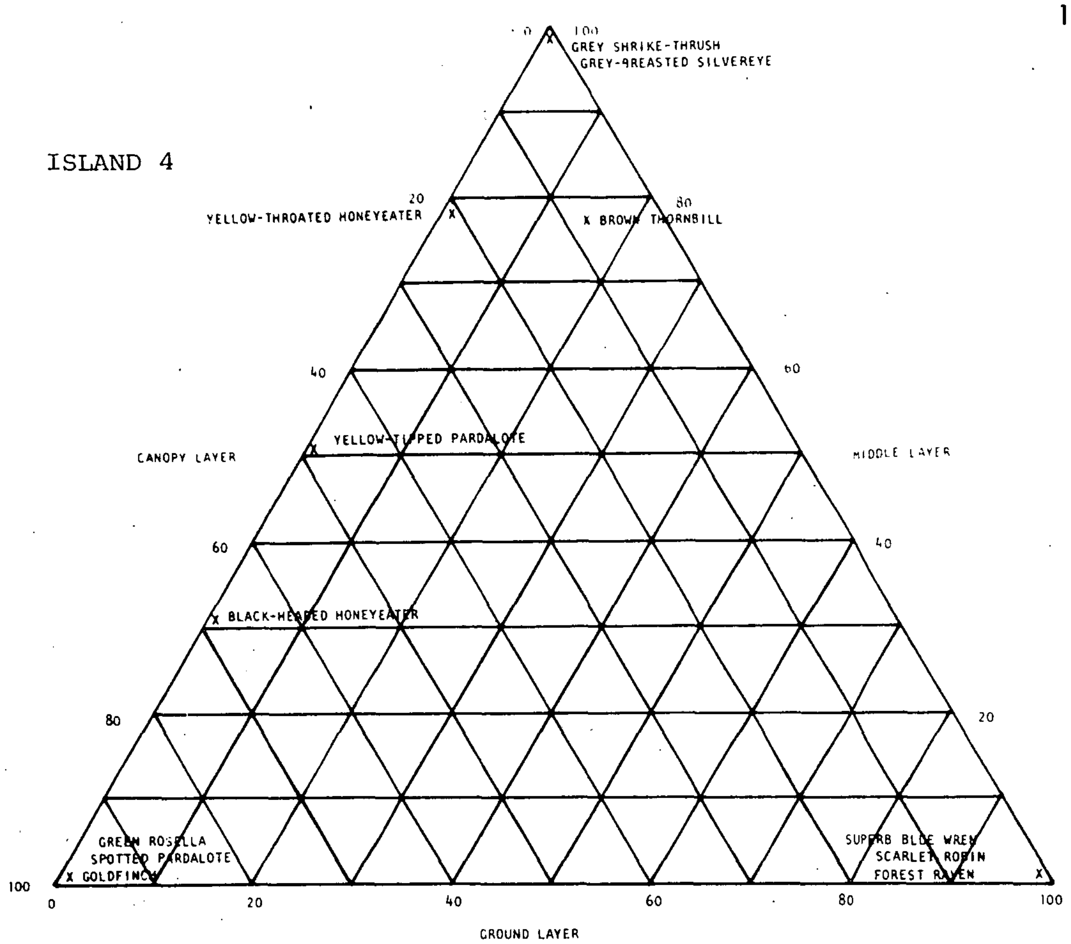
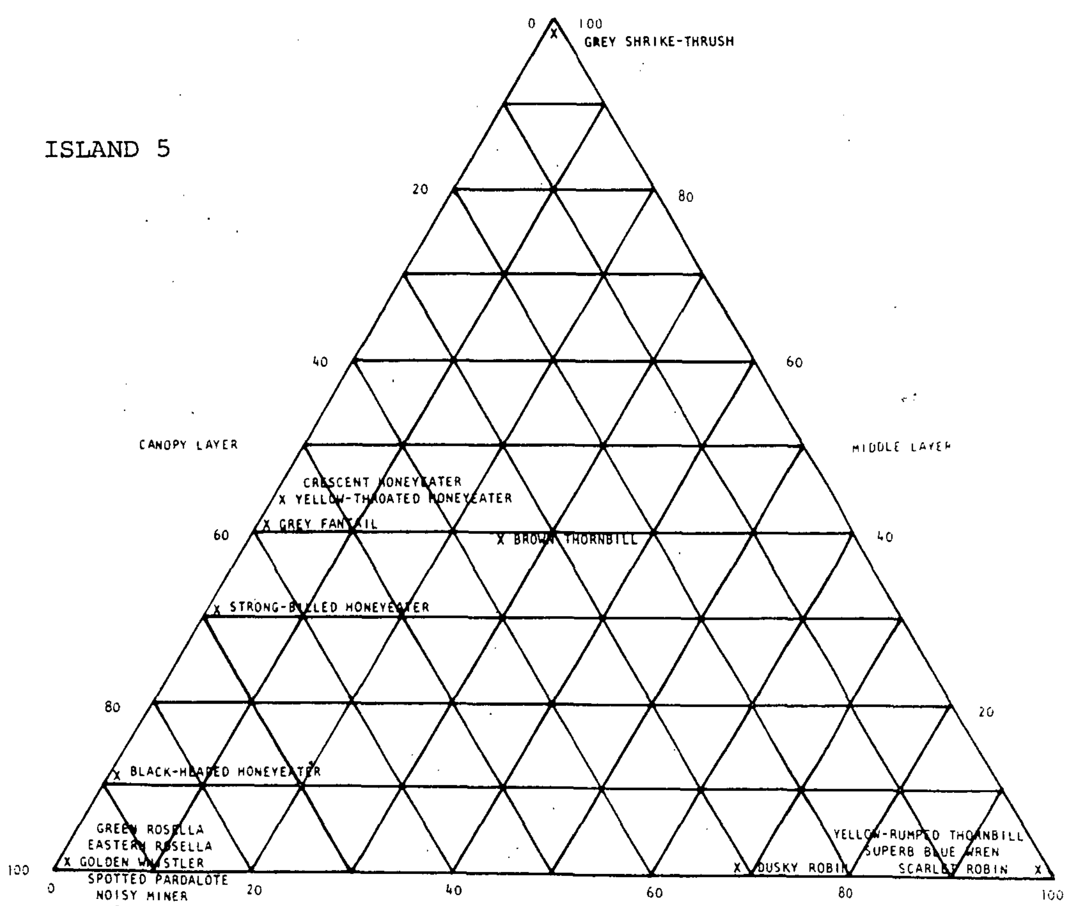
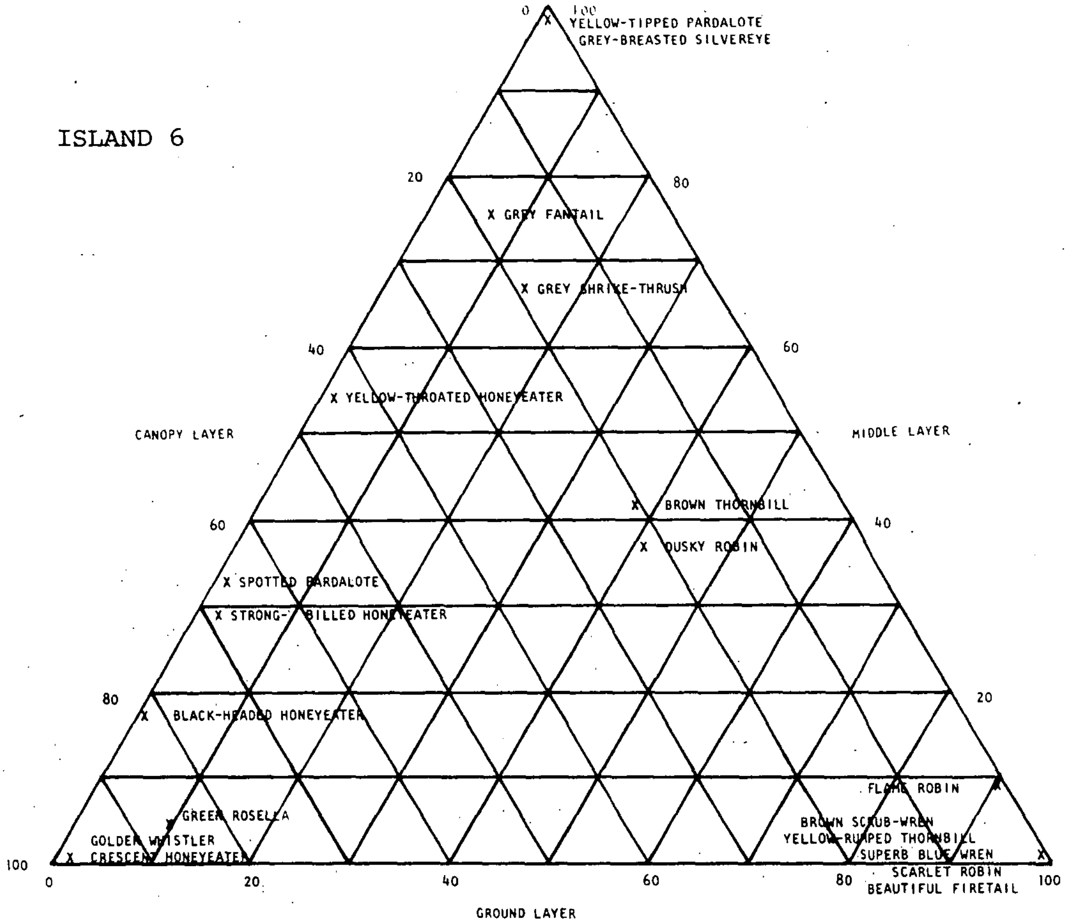


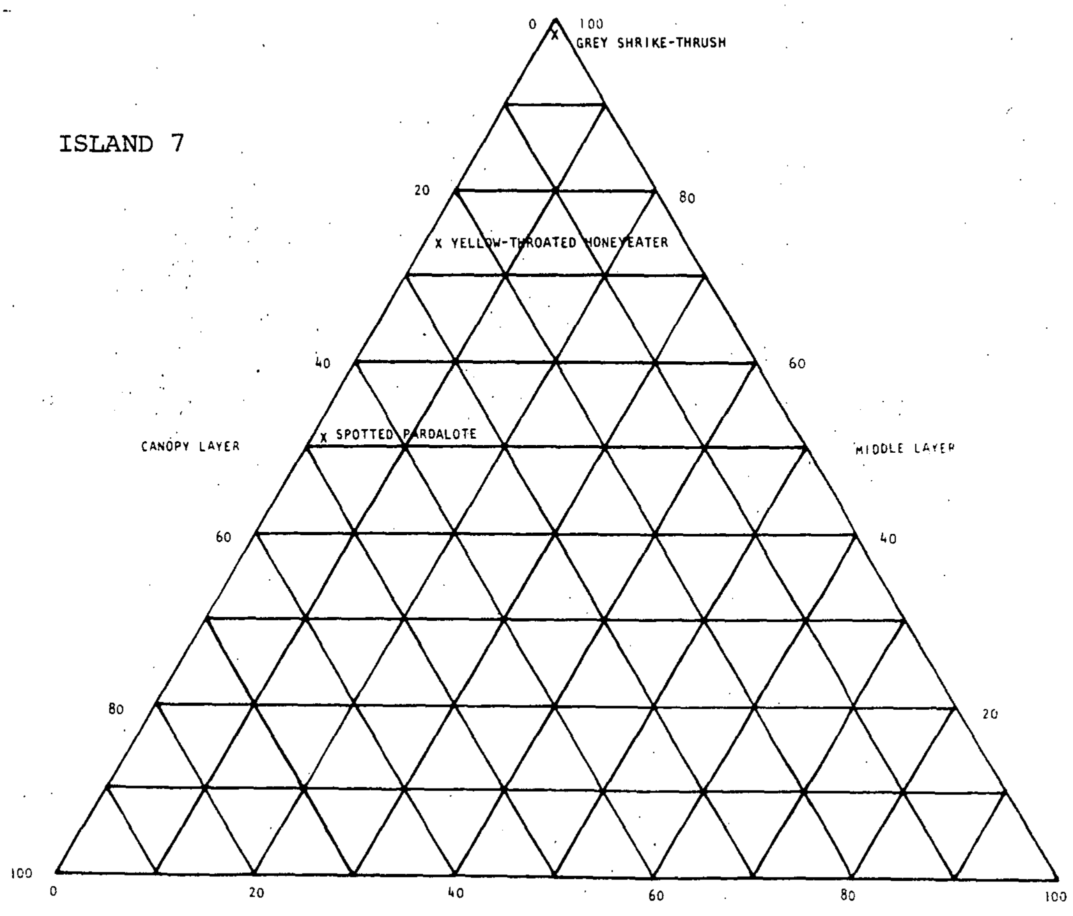
ISLAND 5



ISLAND 6

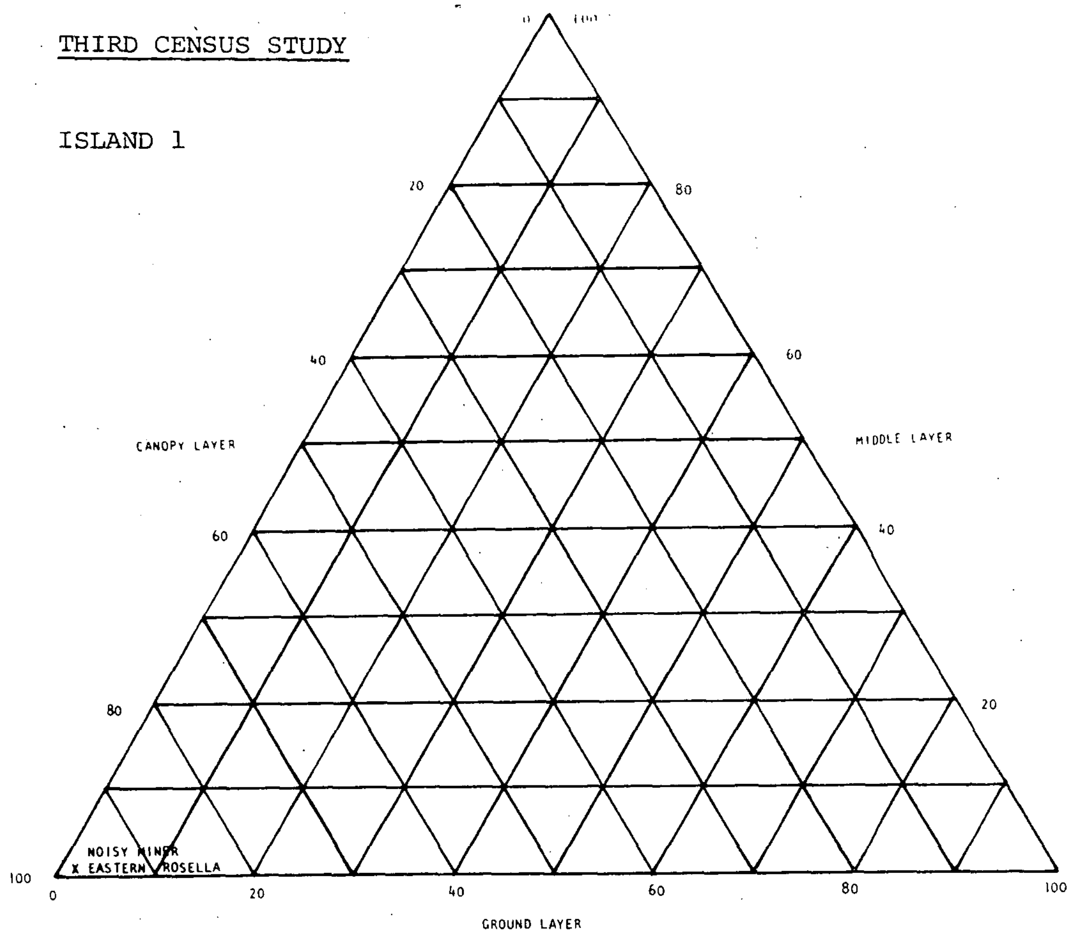


ISLAND 7

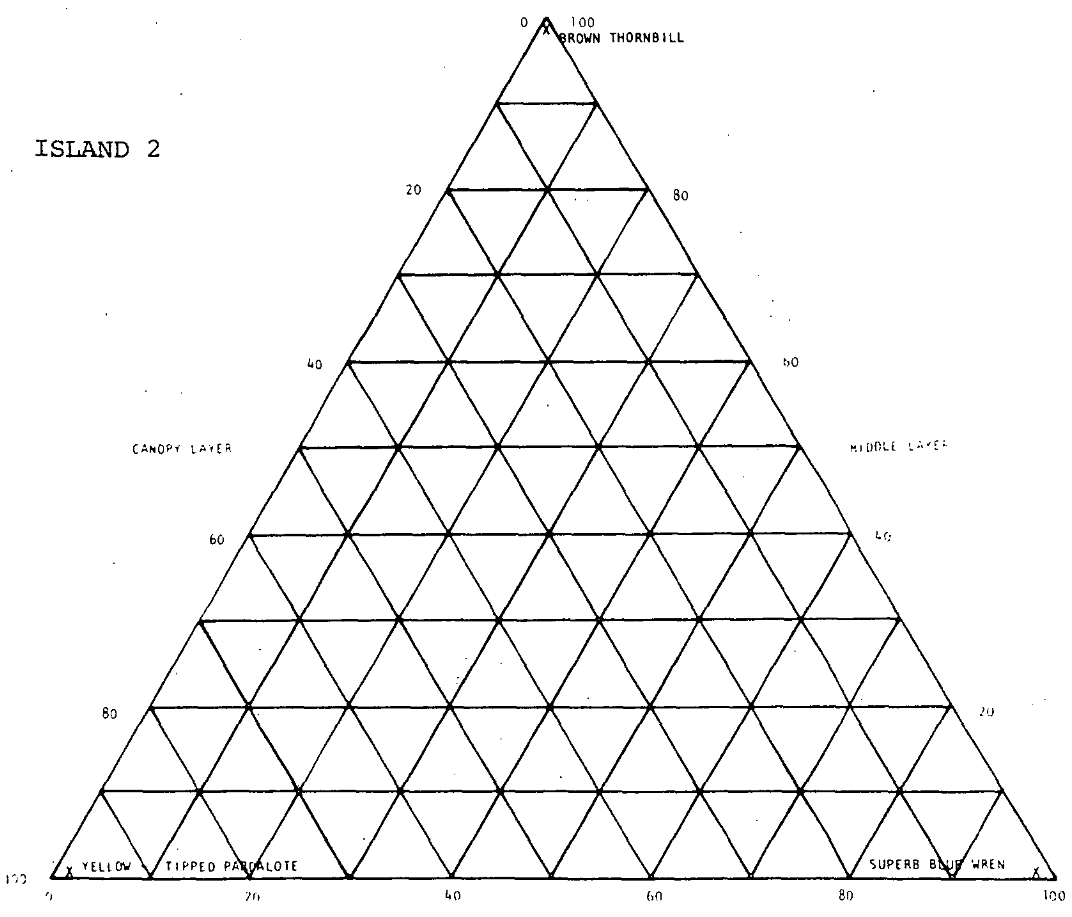


THIRD CENSUS STUDY

ISLAND 1



ISLAND 2



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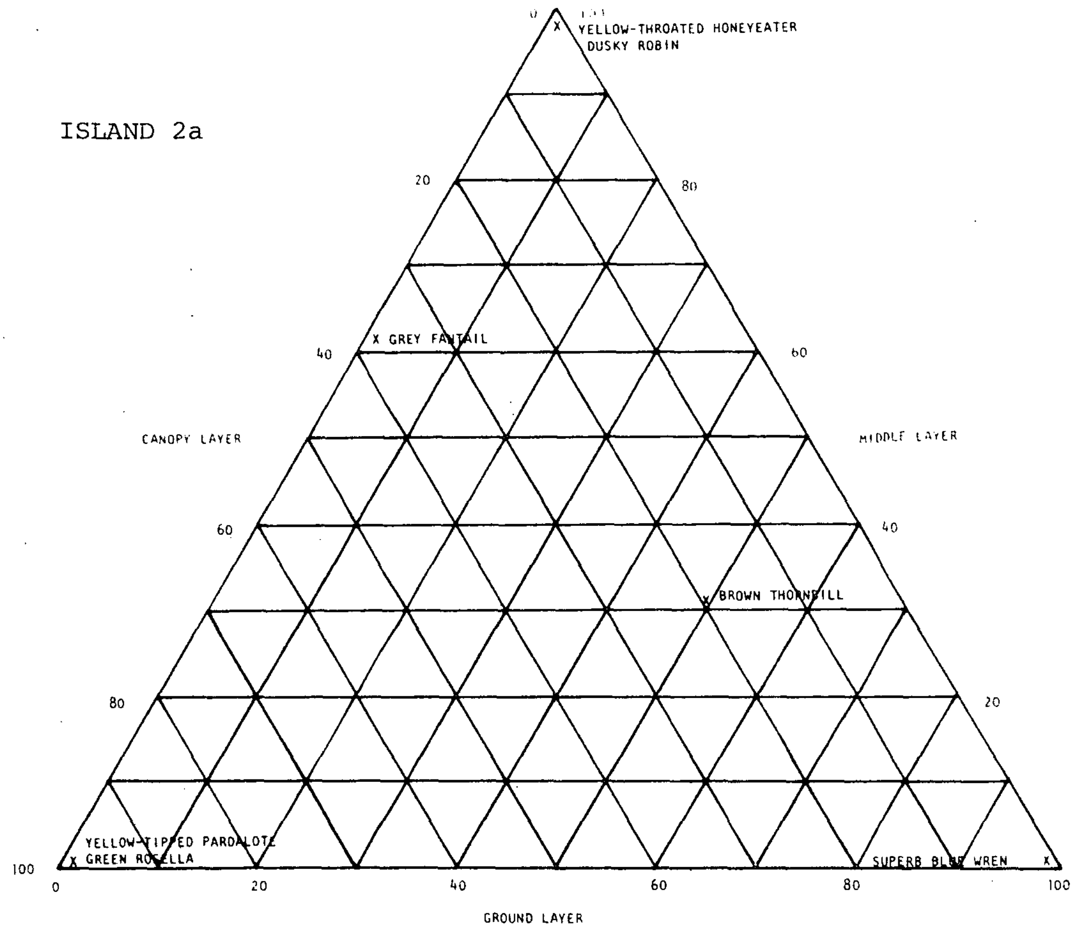

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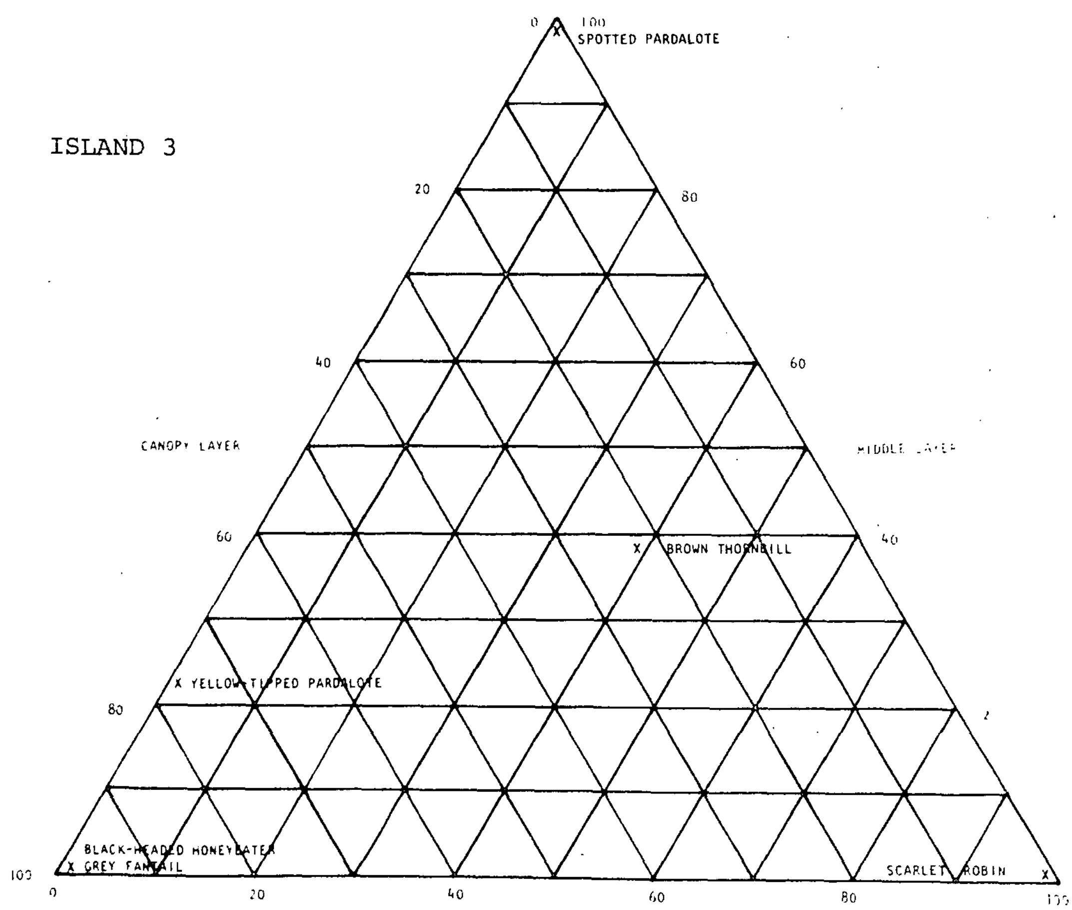

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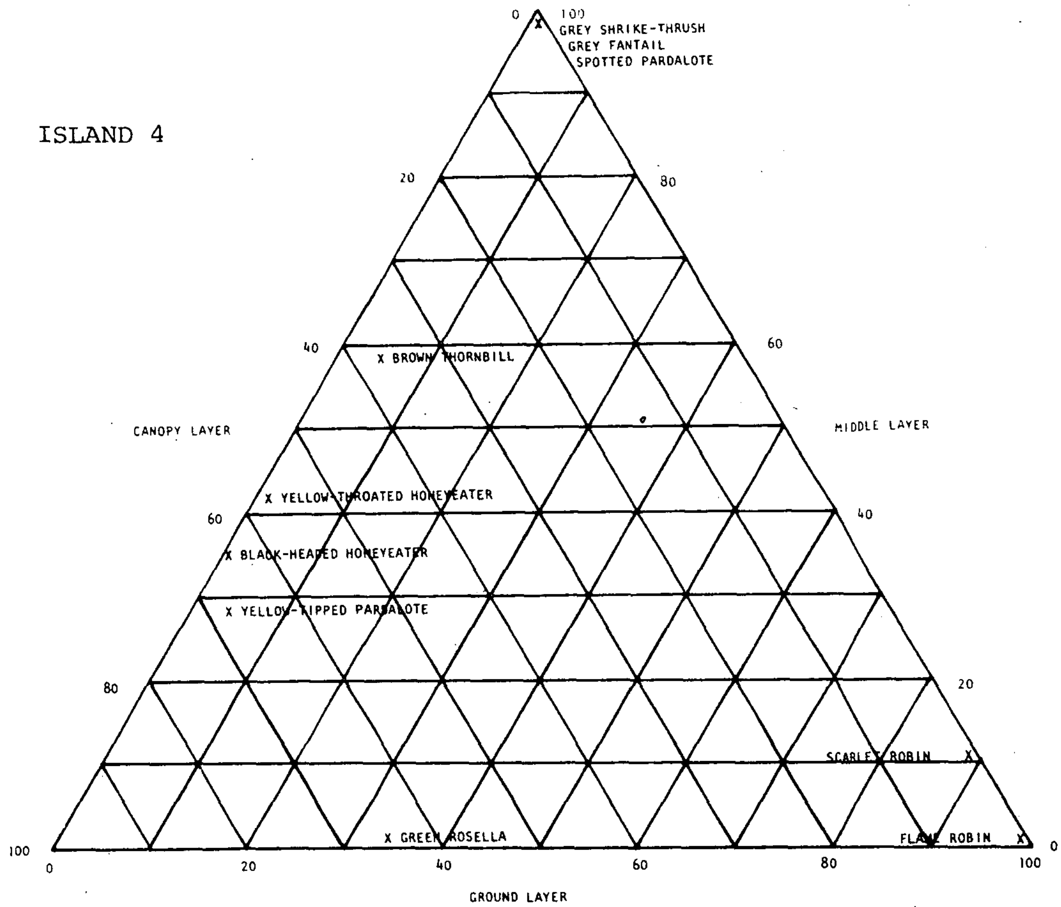

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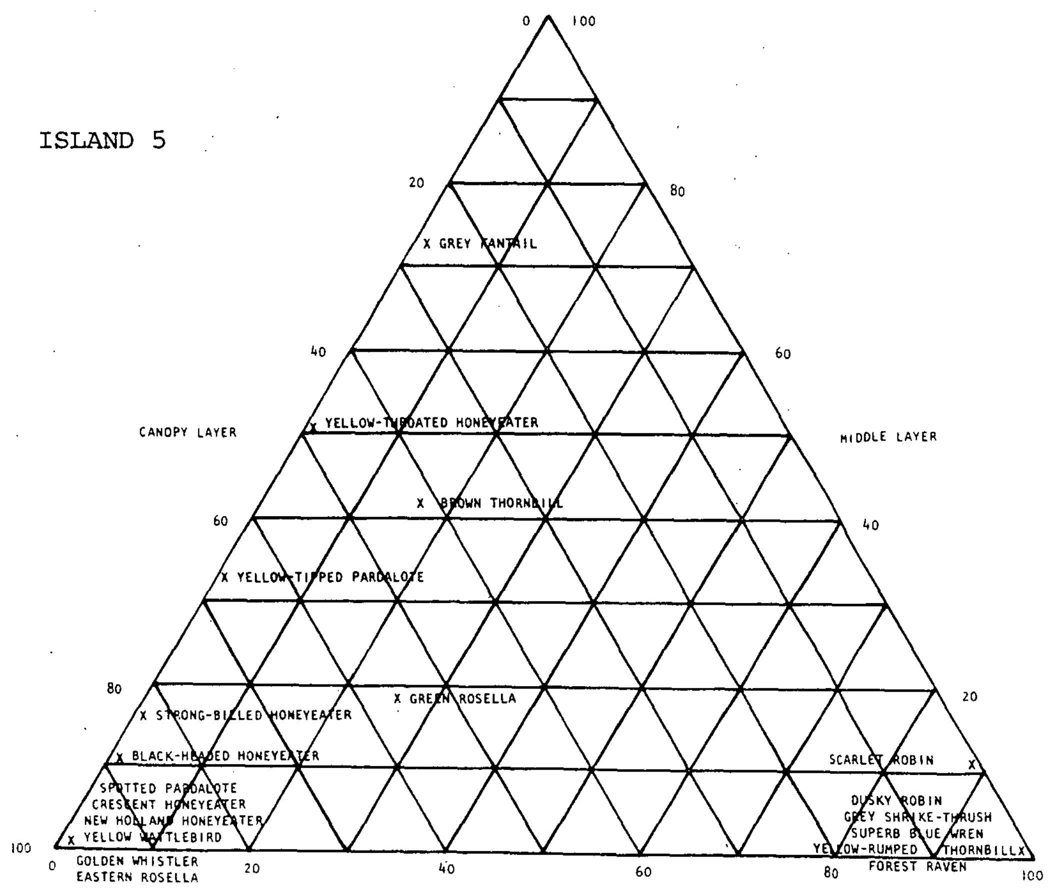
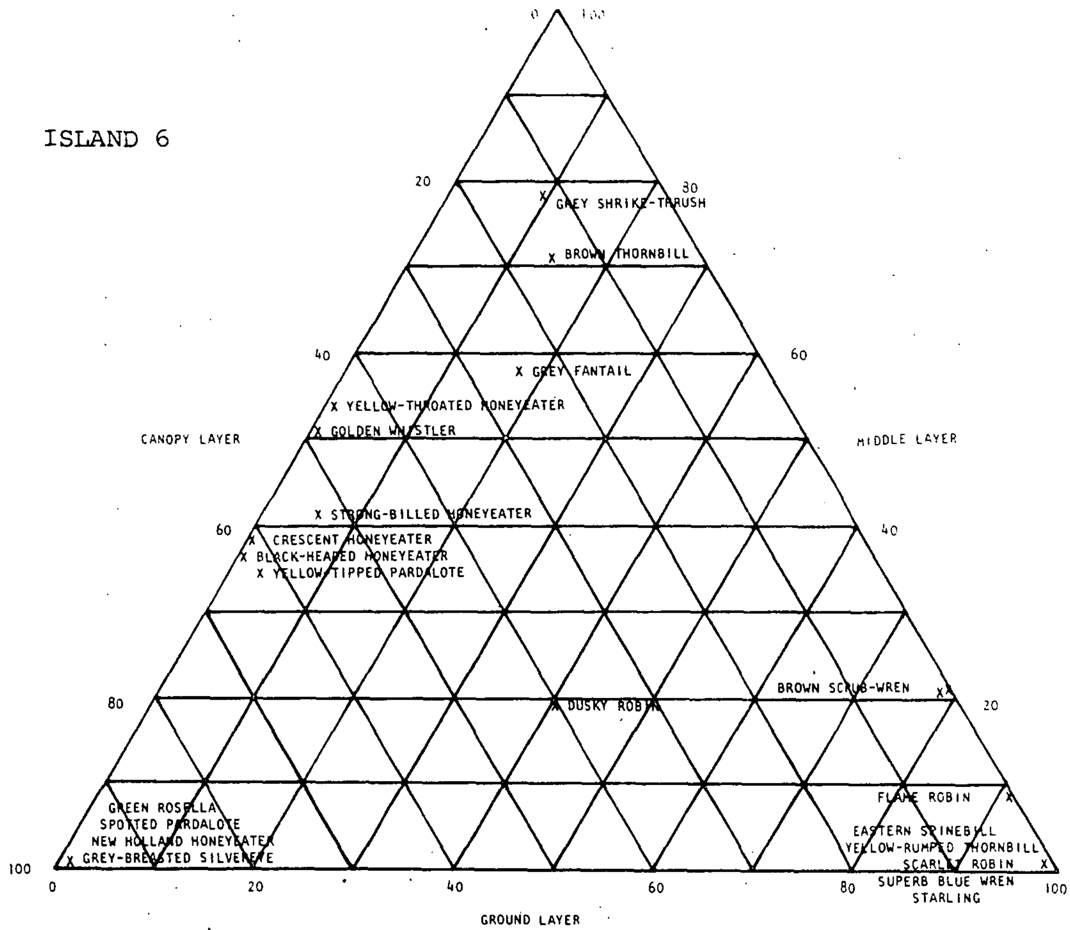


ISLAND 6



ISLAND 7