PART I

PHYSICAL ENVIRONMENT AND HISTORY

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INTRODUCTION

During the summer of 1972-73, a severe wildfire consumed the vegetation of most of the eastern portion of Middle Island. A study of the effects of the fire, and of the regeneration of the vegetation, was initiated at the request of the Western Australian Wildlife Authority, the body in whom the Island reserve is vested.

A total of seven visits have been made to Middle Island in connection with this study. On four of these occasions the opportunity was taken to study other aspects of the island's biota. The results of all of these studies are detailed in the present publication.

PHYSICAL ENVIRONMENT

Middle Island (34°06'S, 123°11'E), with an area of approximately 11 km^2, is the largest island in the Archipelago of the Recherche (Willis 1953) and has a more varied geology, topography and coastline than any other island in the group. The island lies 9 km to the south-southeast of Cape Arid and is some 130 km by sea to the east of Esperance, the nearest town. The location, topography and names of prominent features of Middle Island are shown on Figure 1.

The island is composed primarily of a Precambrian migmatite which is continuous with the Western Shield rocks of the mainland. These granitic rocks are layered and folded as part of a series of parallel, northeast - southwest trending synclines and anticlines lying from Point Dempster west towards Esperance (Morgan et al. 1967; Lowry and Doepel 1974). This geological trend is reflected in the shape of Middle Island (Fairbridge and Serventy 1954).

At the western end of the island the migmatite forms an elongate hill with Flinders Peak (174 m) at its highest point. The migmatite slopes away towards South West Point and is exposed on all prominent points of the coastline except the central promontory opposite Goose Island, which is of schistose rocks. The migmatite also outcrops to the east of Lake Hillier and in the northwestern corner of Brown Bay (see Figure 1 in Part III of this publication).

In the central and southeastern portions of the Island, the migmatite is uncomformably overlain by Tertiary and Recent eolian deposits including travertine-capped coastal limestone (Fairbridge and Serventy 1954, Lowry and Doepel 1974). These formations form cliffs 60 m high around Limestone and Brown Bays. The underlying migmatite, which is exposed at sea level, tends to protect these cliffs from wave action.

Granular quartz rocks, which may be altered vein rocks, occur as a small outcrop on Andrews Point and as a larger outcrop on the western side of

Brown Bay. A late Precambrian intrusion of dolerite intersects the island centrally in a northwest - southeast direction (Morgan et al. 1967).

Middle Island was surveyed for phosphatic rock deposits in February 1943, but none was located (Dulfer 1943).

The varied geology, with the harder granitic rocks forming protective points, has allowed the formation of bays on both the northern and southern coastline. Those on the north coast, Goose Island Bay, have well-developed sandy beaches. The 1 km long Belinda Beach has calcareous beach rock deposits that form small reefs just offshore. These northern beaches provide protected landing sites. A small, shelly beach on the eastern side of the island is sheltered from normal wave action by boulders.

Middle Island is surrounded by water over 30 m in depth and has been calculated to have been isolated from the mainland by eustatic changes about 9 000-10 000 years ago (Burbidge et al. in press, Main 1961).

A shallow, pink salt lake about 0.6 km across and seasonal brackish swamps have developed in the low-lying area on the northeastern portion of the island. These are separated from Goose Island Bay by only a narrow, steep, 10 m high sand dune. That some shrubs of Melaleuca lanceolata in the central portion of this dune have been partially buried (see Part VI of this publication) indicates that some movement of the dune and accumulation of sand may have occurred. Chemical analyses of salt from the lake were reported by Simpson (1952) while results of tests on samples of the lake water have been given in Fairbridge and Serventy (1954). A calcareous crust has been deposited in the lake and has broken up to form pebbly beaches.

The soils of Middle Island are poorly developed and consist mainly of shallow, leached sands with uniformly coarse texture profiles and some organic staining (The Atlas of Australian Soils Unit Ca 26, Northcote et al. 1967). On the limestone slopes the soils are often very thin but are developed to a depth exceeding 1 m in the lowland areas. The coarse, gravelly soils associated with the quartzite rock outcrops adjacent to Brown Bay suggest in situ development of most of the soil profiles of the island. Soils derived from the migmatite on the island conform with the description of soils on Woody Island given in Goodsell et al. (1976). Exfoliation is a prominent feature of most of the areas of exposed migmatite. Some accumulation of humus has been noted in soils under unburnt woodland and forest associations, but none was observed in areas affected by recent fires.

CLIMATE

The climatic regime in the vicinity of Middle Island has been variously mapped as Mesomediterranean with an attenuated dry season (UNESCO-FAO 1963), Koeppen Csb., and BB's of Thornthwaite (Gentilli 1972). The nearest meteorological station is at Thomas River, some 37 km north-northwest of Middle Island on the mainland and in from the coast; details of 24 years of records (to 1971)

from that station have been published by the Bureau of Meteorology (1971), and unpublished records from 1899 to 1981 have been examined.

It seems reasonable to assume that the climate at Middle Island will be similar to that of Thomas River, although the island falls on the extrapolated 600 mm isohyet while Thomas river is closer to the 550 mm isohyet. Middle Island may experience a more maritime climate than areas of the adjacent mainland which would provide a moderating influence, particularly during the long, dry summer.

The climatic regime of Thomas River is presented in the ombrothermic diagram (Figure 2) prepared according to guidelines suggested by UNESCO-FAO (1963). The effective rainfall curve included is based on data derived from the Bureau of Meteorology (1971) which are calculated using Prescott's formula and include an adjustment for free water evaporation.

The prevailing summer winds are generally south-easterlies that tend to strengthen to 10 m/sec (20 knots) in the afternoon with the development of a sea breeze. Winter winds blow from the west with a more consistent speed of up to 10 m/sec throughout the day.

Rainfall records for the period covered by studies reported in this publication, together with accumulated averages for Thomas River, are presented in Table 1. Inspection of these data shows that although the rainfall over the period has been lower than average, the general patterns have conformed with that pictured in the ombrothermic diagram (Figure 2).

HISTORY

The earliest recorded sighting of Middle Island was by the French Admiral d'Entrecasteaux. This occurred some time after 17 December 1792, as he charted the group of islands he later named L'Archipel de la Recherche after one of his vessels (Bechervaise 1954). Middle Island being roughly in the middle of the archipelago, was then given the name Isle de Milieu, (Fairbridge and Serventy 1954). Parts of the archipelago had previously been charted by Nuyts in 1627, and by Vancouver in 1791, when he named Termination Island. D'Entrecasteaux's party, which included the collector La Billardiere, apparently did not land on Middle Island but sailed past it to the south (Willis 1953 Carr and Carr 1976).

In January 1802, Matthew Flinders anchored the 'Investigator' for two and a half days on the north side of the island, just below the peak which now bears his name. He reported "no trace of the island having been visited, either by Europeans or the natives of the mainland" (Flinders 1814). The island was explored, and botanical collections were made by Robert Brown (Bechervaise 1954 Willis 1953). Flinders revisited the island in May 1803 during his circumnavigation of Australia for the purposes of "cutting wood, boiling down seal oil and killing geese", and anchored just north-northeast of Sailors Rock (Flinders 1814). During this visit Flinders buried his boatswain, Charles Douglas (died 17 May), and seaman, William Hillier (died 20 May), and abandoned two anchors (1 Bower, 1 Stream),

which were not retrieved Janury 1973 (Cadby 1973).

Phillip King, accompanied by the botanist Allan Cunningham and surveyor J.S. Roe, visited Middle Island briefly in January 1818, when further plant collections were made (Bechervaise 1954).

The island was apparently not visited again until the 1820s, when sealers and whalers from overseas and from the eastern colonies began to send crews into the archipelago (Bechervaise 1954). It is possible, however, that American sealers had been operating all along the south coast of Western Australia since about 1800 (Wace and Lovett 1973). One of the first boats to sail from Sydney was the 'Belinda', a brig of 160 tons. In July 1824 it was wrecked on Middle Island, where the 26 surviving crew spent five months before being rescued (Bateson 1972). Two to three years later, several crews of sealers were noted by Lockyer (in Bechervaise 1954) to be operating in the archipelago, including one crew of eight who had been marooned on Middle Island by the captain of the sealing vessel 'Governor Brisbane'. Further accounts of the harsh existence and sometimes nefarious activities of the whalers and sealers, given by Bechervaise (1954) and Hicks (1966), suggest that during the 1830s and early 1840s Middle Island was a centre for the operations of the crews, including one ruled by Black Anderson, a black American of some notoriety. Some of the sealers and whalers built stone houses and gardens at the western end of Lake Hillier, and the island became known as "the Right Whale Station of the Bight" (Andrews 1959).

The use of Middle Island as a permanent base is thought to have ceased by the 1850s; the subsequent decay of the houses was apparently accelerated by the activity of sealers searching for the gold reputed to have been stored there by one of their fellows who died before he had a chance to spend his pay (Andrews 1959). However, the hunting of seals in the archipelago continued until the end of the century, when poor markets and the effects of excessive exploitation brought operations to an end (Andrews 1959, Parliamentary Select Committee 1912, Scott 1920-29). The depleted state of the seal populations was officially recognized in 1892, when the powers of the Game Act 1892 were invoked with the proclamation of a closed season for seals from November to March (Government Gazette 9 June 1892).

A five month closed season was again proclaimed in 1917 under the powers of the Game Act 1912-1913. However, in 1920 a Perth company promoter, Arthur Scott, took about 900 seals from the archipelago with the assistance of a loan from the Mitchell Government. In the following years Scott proposed the development of a much expanded industry based on Middle Island, but no further licences were issued (Scott 1920-29).

As early as 1827, Lockyer had proposed that the salt lakes of the Esperance region be exploited for salt (Hicks 1966). The Eastern Division was declared open for selection in 1862, and G.N. Larnach, a member of the Dempster Brothers party, which was first to seek exploitable land in the Division, leased Middle Island (Rintoul 1964,

Department of Lands and Surveys Lease Register). A year later, Larnach announced his intention to invest £14 000 in a salt mining plant on the island ('The Inquirer and Commercial News' 2.3.1864). However, he did not renew his lease and none of the money seems to have been spent (Andrews 1959, Department of Lands and Surveys Lease Register).

In 1890 an Albany building contractor, Edward Andrews, took out a lease on the lake and went to Middle island with his two sons to collect salt samples to test the market. They worked the lake for three months, and the two sons remained on the island for a further five months, but the venture was a failure (Andrews 1959, Department of Lands and Surveys Lease Register). Others who followed were more successful. From about 1899 to 1905 considerable quantities of salt were mined by employees of E.J. McCarthy, an Esperance storekeeper, and others. The lake was leased virtually continuously until 1924, but it would appear that there was little actual mining after 1905, perhaps a reflection of the seasonal and limited nature of the salt supply ('The West Australian' (newspaper) 12.9.1904, Department of Lands and Surveys Lease Register, Simpson 1952, Department of Mines 1920).

The land area of Middle Island was leased for pastoral or agricultural purposes from 1883 onwards by a series of relatively small-time local and Perth business people; these leases are detailed in Appendix 1 (Department of Lands and Surveys Lease Register, Battye Library Biogeographical Index). There is no evidence that grazing was ever carried out nor that a poultry farm proposed in 1901 was ever established (Andrews 1959, 'The West Australian' (newspaper) 12.9.1904). Around the turn of the century an Adelaide firm, A.W. Sanford & Co., did employ two youths to produce vegetables to be sold to the miners in the Eastern Goldfields. The venture was short-lived and probably foundered on a Government decision not to proceed with the construction of a Kalgoorlie-Esperance rail link (Andrews 1959, 'The West Australian' (newspaper) 12.9.1904). A proposal for a similar but larger scale agricultural operation on Middle Island by G.C. Monckton in 1904 appears not to have proceeded ('The West Australian' (newspaper) 12.9.1904).

The various events and proposals which comprised the European history of Middle Island were woven together by Arthur Scott as he attempted throughout the 1920s to persuade the Western Australian Government to finance him in a grand scheme combining salvaging the Fisheries research vessel 'Penguin', wrecked on Belinda Beach in 1920, (Chief Inspector of Fisheries 1921), fishing and sealing, salt mining, phosphate extraction, sheep grazing, Tammar skinning and irrigation farming on "2 500 acres of rich land" on Middle Island (Scott, 1920-29).

The island was to be the site of a series of factories, including an ice works, a fish processor and a fertilizer plant, and later, a tourist resort linked by aeroplane to the mainland (Scott 1920-29, Bechervaise 1954). However, the government and its advisers were not persuaded as to the viability of the proposals and no finance was provided.

Thereafter Middle Island was only subjected to a few more inactive grazing leases and to visits by tourist and fishing parties (Department of Lands and Surveys Lease Register).

Evidence of some of the activities on Middle Island is still visible. An "old camp with a hut in moderate condition at the western end of the salt lagoon", observed by members of the Australian Geographical Society Expedition in 1950 (Fairbridge and Serventy 1954) was probably constructed by men who went to salvage the 'Penguin' in 1921 (Andrews 1959, Basset Hull 1922). This hut no longer exists, probably as a result of the 1972 fire (Rothnie 1972), but the foundations of several stone huts, two lined wells with water that now appears useful only for an emergency, and the remains of railway tracks to the lake still survive from those early times.

In 1952, R. Fernie, a Kalgoorlie grocer, constructed a timber and iron hut on the granite a few hundred metres west of the first camp. It was used for holiday fishing (A. Chisholm pers. comm. 1974). Apart from the dwellings, wells, railway tracks and the wreck of the 'Penguin', the only other definite signs of human activity on the island are small dams on the granite near the hut, a cairn on the top of Flinders Peak, the remains of campfires and some general litter.

Extensive searches have recently been made for the copper plaque placed over Douglas' grave by Flinders, but apparently to no effect. The anchors abandoned by Flinders at the same time were recovered by a party from the Underwater Explorers Club of Adelaide under the leadership of G. Seton in January 1973 (Cadby 1973). Various items of historical interest have been recovered from the island, including an inscribed shell left in a cave on the south coast by Captain Douglas of the 'Grace Darling' on 5 January 1908 ('The Esperance Advertiser' (newspaper) 7.6.73).

Other recent visits to the island have involved numbers of holiday makers, crews of boats in transit along the south coast, local fishermen and amateur historians searching for the plaque on Douglas' grave. Some record of these visits has been kept in a visitors book left in the hut by the Geological Survey of W.A. team in April 1967. Whilst it can be expected that not all visitors will have made entires in this book, the data extracted from it and summarised in Table 2 provide some indication of recent visitor usage of the island.

Table 2. Visits to Middle Island 1967-1978. Data were extracted from visitors book left in the hut on Middle Island. Each person-entry was scored as 1 visitor day except where details of duration of stay were included with the entry.

Year	Total No. of Visitor Days
1967	19 (from April)
1968	0
1969	8
1970	61
1971	91
1972	113

1973	129
1974	146
1975	160
1976	294
1977	103
1978	62
1979	187
1980	57 to Oct.
Annual Average	100

Following his visit in 1950, Willis (1953) observed that, in spite of the level of human usage over the preceding 150 or so years, Middle Island was in remarkably good condition. The same would be true to-day but for the wildfires of the 1970s.

FIRES

There are no documented reports of fire on Middle Island prior to that of the summer of 1972/73, which prompted the studies reported in this volume. That fire, which burned for about two months, consumed the vegetation of most of the eastern portion of the island. A local press report of the fire suggested this to be the only known fire for Middle Island to that time ('The Esperance Advertiser' (newspaper) 8.12.72).

The fire was thought to have begun during a severe electrical storm two days prior to its being reported to the Esperance Police on 5 December 1972 (Rothnie 1972). It is reputed that the elctrical storm also caused some small fires to the east of Esperance. A local abalone fisherman noted severe electrical storms in the vicinity of Middle Island on 29 November and 7 December 1972 (G. Fry pers. comm. 1978). Weather records for Esperance for the period record lightning and thunder for 29 November and 4 December, both days being hot and windy (R. Baird pers. comm. 1977).

The fire was inspected by Fry on 7 and 8 December. He noted that it appeared to have started just southwest of the fishermen's hut. The approximate area burnt by 8 December is shown on Figure 3 (G. Fry pers. comm. 1978). By 9 December, the area burnt was estimated to be less than 40 hectares (Rothnie 1972). The area burnt by 8 January 1973 was mapped from aerial photographs (Figure 3); at the time of that inspection the fire was burning near the centre of the island and some 100 ha was estimated to have been burnt (Ellis 1973).

It is not known for how long the fire continued to burn. A note in the visitors book kept in the fishermen's hut suggested that the fire was smouldering on 27 January, but no comments were recorded by visitors on 17 February. Fry (pers. comm. 1978) noted the fire to have burnt out on the south-eastern portion of the island by 17 February, by which time Esperance had experienced showers and thunderstorms. An aerial inspection of the island was made on 8 April 1973, when no signs of fire activity were reported (Ostle 1973). The final extent of the fire, mapped after extensive ground traverses in November 1973, is shown on Figure 3.

Weather records for the period for which the fire is known to have burnt show the wind to have been blowing predominantly from the south at speeds averaging 5-8 m/sec (10-15 knots) with some days of easterlies and south westerlies.

Weston et al. (Part II of this publication) present arguments to support the contention that a fire burnt at least some portion of Middle Island two to four years prior to the visit by Flinders in 1802, though little evidence of fire was observed by the members of that party (see above quotation from Flinders 1814). Such a fire may have been started by American sealers who may have been operating along the south coast of Western Australia prior to Flinders' visit (Wace and Lovett 1973).

A small quantity of charcoal was found in the litter layer within the plot in the unburnt Melaleuca lanceolata stand (see Part VI of this publication).

The most recent fire on Middle Island was reported on 10 January 1977 (Noble 1977). Thunderstorms were reported by the Esperance Meteorological Office on the previous day, together with 8-10 m/sec south easterly winds (R. Baird pers. comm. 1977). The fire continued to burn until 7 February 1977, when Messrs R. Heckler and I. Hay were able to land on the island and isolate smouldering litter (Heckler 1977). During the period for which the fire is known to have burned, Esperance experienced periods of 8-12 m/sec westerly to south westerly winds alternating with periods of easterly winds (NE-SE) at 5-10 m/sec. Drizzle and light showers were recorded for six days, producing a total of 6 mm of rain.

The extent of the second fire, as mapped from aerial photography taken on 10 February 1977 and checked by ground survey in May 1977, is shown on Figure 3.

RESERVATION

All islands of the Archipelago of the Recherche, except Middle Island, were gazetted as reserve no. 22796 for the Conservation of Flora and Fauna on 21 May 1948. At that time Middle Island was under pastoral lease to Mr Alexander Chisholm of Kalgoorlie. Charlie, Gull and Woody Islands were the subject of a pastoral licence to the Bow Brothers until 30 June 1958 but were apparently not excluded from the reserve because of that.

The pastoral lease on Middle Island was cancelled on 22 August 1958, following a Pastoral Inspector's report to the effect that the island had not been grazed and was largely unsuited to that purpose (Johnson 1958a). Middle Island was included in the reserve on 21 November 1958. The whole reserve was classified A Class and vested in the Western Australian Wildlife Authority by proclamation in the Government Gazette on 20 September 1969. This followed recommendations by the Western Australian Sub-Committee of the Australian Academy of Science Committee on National Parks (Anon. 1962) that the reserve should be gazetted Class A and vested as a National Park for the principal purpose of conservation of the fauna and flora, but with public recreation on Charley, Gull,

Middle and Woody Islands.

In May 1971 the Western Australian Wildlife Authority considered an application for the release of Middle Island to permit the development of it as a tourist resort. The application was rejected in order to preserve the biological integrity of the island.

The Recherche Archipelago Nature Reserve was officially named on 22 December 1972. Coincidentally, Middle Island was then on fire; the recognition of a need to protect the regenerating vegetation led to Middle Island being declared a Prohibited Entry Area on 21 October 1974.

The Conservation Through Reserves Committee in its report to the Environmental Protection Authority in 1974 endorsed the status, purpose and vesting of the Recherche Archipelago Nature Reserve. This recommendation was accepted by the Environmental Protection Authority on 9 July 1976 and by State Cabinet on 20 October 1976, with the proviso that some concessions be made regarding public access to some islands (E.P.A. 1976).

Red Island was added to reserve A22796 on 1 December 1978 in accordance with a recommendation of the Conservation Through Reserves Committee (1974).

The matter of public access to Middle Island was again considered by the Western Australian Wildlife Authority in August 1979. It was resolved that the prohibited entry classification be cancelled and this was done by notice published in the Government Gazette on 18 April 1980.

BACKGROUND TO THE STUDIES

Following the severe wildfire on Middle Island over the summer of 1972-73, a general concern was expressed regarding the fate of the island's flora and fauna. A study of the effects of the fire and of the regeneration of the vegetation was initiated by one of us (A.S.W.) at the request of the Western Australian Wildlife Authority. Seven visits have been made to the island in connection with the regeneration study. On four of these occasions, studies of other aspects of the biota of the island also were undertaken. In this report, the results of all research undertaken during the seven visits to the island are presented.

Details of the visits are as follows:

13-25 November 1973	- M.E. Trudgen & A.S. Weston
6-15 November 1974	- H. Bakker, M.E. Trudgen & A.S. Weston
29 October to 3 November 1975	- A.J.M. Hopkins, M.E. Trudgen & M.E. Trudgen
5-16 November 1976	- A.J.M. Hopkins, M. Onus, A. Tingay, S.R. Tingay & M.E. Trudgen
9-12 May 1977	- M. Onus & A.S. Weston
5-11 November 1978	- A.J.M. Hopkins, C.J. Robinson & A.S. Weston
26 October to 7 November 1980	- J.M. Brown, A.J.M. Hopkins M.E. Trudgen & M.E. Trudgen

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REFERENCES

Andrews, T.C. (1959). Three letters between Athol Thomas (Weekend Mail) and Thomas C. Andrews 30.5.1959 - 25.6.1959. Unpublished. Battye Library : Perth.

Anonymous (1962). National Parks and Nature Reserves in Western Australia. (The Western Australian sub-committee of the Australian Academy of Sciences Committee on National Parks, Perth). (Cyclostyled).

Basset Hull, A.F. (1922). A visit to the Archipelago of the Recherche. S.W. Australia. Emu **21**, 277-289.

Bateson, C. (1972). "Australian Shipwrecks". (A.H. & A.W. Reed : Sydney).

Bechervaise, J.M. (1954). General History. In J.H. Willis (Ed.) The Archipelago of the Recherche. Aust. Geogr. Soc. Rept. No. 1. (Aust. Geogr. Soc. : Melbourne).

Bowler, S.W. (1958). A visit to the Archipelago of the Recherche. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

Burbidge, A.A., Fuller, P.J., Hopkins, A.J.M., Kinnear, J.E. and McKenzie, N.L. (in press). The wildlife of Salisbury Island, Archipelago of the Recherche, Western Australia. Dept. Fish. Wildl. West. Aust. Rept.

Bureau of Meteorology (1971). Climatic Survey. Region 5 - Esperance, Western Australia. Issued by the Director of Meteorology, Melbourne.

Cadby, A.L. (1973). The Search and Recovery of the Investigator Anchors. B.P. Accelarator **279**, 19-22.

Carr, S.G.M. and Carr, D.J. (1976). The French Contribution to the Discovery of Australia and its Flora. Endeavour **35**, 21-26.

Chief Inspector of Fisheries (1921). 'The Ann. Rept. for 1920'. (Dept. Abor. Fish. West. Aust. : Perth).

Conservation Through Reserves Committee (1974). Conservation reserves in Western Australia. Report to the Environmental Protection Authority. Dept. Cons. Env. West. Aust. :

Perth.

Dempster, W.E. (1950). Letter in 'The West Australian' (newspaper) 15 November 1950.

Department of Mines (1920). Ann. Rept. for 1919. (Dept. Mines West. Aust. : Perth).

Douglas, R.J.B. (1958). Report on Sheep and Goats on Islands of the Recherche Archipelago. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

Dulfer, J.C. (1943). A Visit to the Islands of the Recherche Archipelago, Western Australia. Unpublished Departmental Report. Geol. Survey. West. Aust. : Perth.

Ellis, M.C. (1973). The 1972-73 Summer Fire on Middle Island (Recherche Archipelago). Unpublished Report, Dept. Fish. Wildl. West. Aust. : Perth.

E.P.A. (1976). Conservation Reserves for Western Australia as Recommended by the Environmental Protection Authority. Systems 1,2,3,5. Dept. Cons. Env. West. Aust. : Perth.

Fairbridge, R.W., and Serventy, V.N. (1954). Physiography. In J.H. Willis (Ed.) The Archipelago of the Recherche. Aust. Geogr. Soc. Rept. No. 1. (Aust. Geogr. Soc. : Melbourne).

Flinders, M. (1814). "A Voyage to Terra Australis. Vols. I & II". (G.W. Nicol : London).

Fowler, S. (1945). The Fire on Mondrain Island. Emu 44, 334-345.

Gentilli, J. (1972). "Australian Climate Patterns" (Nelson : Melbourne).

Goodsell, J., Tingay, S.R. and Tingay, A. (1976). A Resource Survey of Woody Island, Archipelgago of the Recherche. Dept. Fish. Wildl. West. Aust. Rept. No. 21 (Dept. Fish. Wildl. : Perth).

Hanley, G. (1974a). Fire on Boxer Island. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

Hanley, G. (1974b). Control Burning, Woody Island. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

Heckler, R.G. (1977). Fire on Middle Island. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

Hicks, B. (1966). History of Americans in Albany. Unpublished Manuscript. Battye Library : Perth.

Johnson, R.F. (1958a). Pastoral Inspector's Report. Middle Island, Archipelago of the Recherche. Unpublished Departmental Report Dept. Lands Surv. West. Aust. : Perth.

Johnson, R.F. (1958b). Pastoral Inspector's Report. Woody Island - Recherche Archipelago. Unpublished Departmental Report. Dept. Lands Surv. West. Aust. : Perth.

Johnson, R.F. (1958c). Pastoral Inspector's Report. Gull Island, Archipelago of the Recherche. Unpublished Departmental Report. Dept. Lands Surv. West. Aust. : Perth.

Johnson, R.F. (1958d). Pastoral Inspector's Report. Charley Island, Recherche Archipelago. Unpublished Departmental Report. Dept. Lands Surv. West. Aust. : Perth.

Lowry, D.C. & Doepel, J.J.G. (1974). Malcolm - Cape Arid, Western Australia. 1:250 000 Geological Series - Explanatory Notes. Sheet S1/51-7,11. (Bur. Min. Res. Geol. Geophys. : Canberra).

Main, A.R. (1961). The occurrence of macropodidae on islands and its climatic and ecological implications. J. Roy. Soc. West. Aust. 41, 84-89.

Marshall, K.J. (1977). Fauna Observations - Recent Patrol, Gull Island, A22796 Archipelago of the Recherche. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

Morgan, K.H., Horwitz, R.C. & Sanders, C.C. (1967). Structural layering of the rocks of the Archipelago of the Recherche. Geol. Survey West. Aust. Ann. Rept. 1966-1967 pp. 44-45.

Noble, D. (1977). Fire on Middle Island. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

Northcote, K.H., Bettenay, E., Churchward, H.M. and McArthur W.M. (1967). Atlas of Australian Soils. Sheet 5. Perth-Albany-Esperance Area, with Explanatory Data. (CSIRO & Melbourne Uni. Press : Melbourne).

Ostle, C.W. (1973). Inspection of Fire Damage on Middle Island by Air. Unpublished Dept. Report. Dept. Fish. Wildl. West. Aust. : Perth.

Parliamentary Select Committee (1912). Report of Inquiry into the Game Bill. Parliamentary Paper No. A4 of 1911-12. Govt. Printer. West. Aust. : Perth.

Pearce, A.J. (1968). Goats on Islands of the Recherche Archipelago. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

Rothnie, J. (1972). Fire on Middle Island. Unpublished Report. Dept. Fish Wildl. West. Aust. : Perth.

Rintoul, J. (1964). "Esperance Yesterday and Today". (Service Printing Co. : Perth).

Scott, A. (1920-1929). Correspondence with Chief Inspector of Fisheries and Under Secretary for Lands. Unpublished Departmental Records. Dept. Fish. Wildl. West. Aust. : Perth.

Serventy, V.N. (1953). Mammals. In J.H. Willis (Ed.). The Archipelago of the Recherche. Aust. Geog. Soc. Rept. No. 1. Aust. Geogr. Soc. : Melbourne).

Simpson, E.S. (1952). "Minerals of Western Australia". (Govt. Printer West. Aust. : Perth).

Spence, T. (1970). A Visit to Islands in the Archipelago of the Recherche. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

UNESCO-FAO (1963). Ecological study of the mediterranean zone. Bioclimatic map of the mediterranean zone. Explanatory Notes. Arid Zone Res. 21, 2-58.

Wace, N. and Lovett, B. (1973). Yankee Maritime Activities and the Early History of Australia. Res. Sch. Pacific Stud. Aids to Research Series No. A/2 (Aust. Nat. Univ. : Canberra).

Whitney, G.P. (1944). Fire and Petrels : The Mystery of Mondrain Island. Emu 44, 6-7.

Williams, J. (1969). Inspection of Esperance Bay and some Islands of the Archipelago of the Recherche. Unpublished Departmental Report. Dept. Fish. Wildl. West. Aust. : Perth.

Willis, J.H. (1953). Land Flora. In J.H. Willis (Ed.) The Archipelago of the Recherche. Aust. Geog. Soc. Rept. No. 1. (Aust. Geogr. Soc. : Melbourne).

Wilson, H.H. (1955). Recherche Islands were once an Outlaw Stronghold. 'The West Australian' (newspaper) 20.8.1955.

PART II

THE VASCULAR FLORA

By A.S. Weston, M.E. Trudgen and A.J.M. Hopkins

INTRODUCTION

Middle Island, the largest and most diverse of the islands in the Recherche Archipelago, is also the most interesting from a botanical point of view. This interest derives from three factors which contribute to the unique botanical situation of the island: a history of extensive collecting over the last 175 years, a diversity of vegetation that reflects, in part, the environmental diversity of the island, and the development of this vegetation in the absence of major and repeated disturbance. The last factor has been radically altered by severe fires in 1973 and 1977, and the after-effects of the fires have led to the resolution of puzzling discrepancies in past collecting records.

Robert Brown, who visited Middle Island with Matthew Flinders in January 1802 and May 1803 (Willis 1959), was the second eminent botanist to collect in the archipelago and the first to collect on Middle Island. Earlier, in 1792, La Billardière had visited the archipelago with d'Entrecasteaux in and collected plant specimens on Observatory Island (Willis 1953; Goodsell et al. 1976; Carr and Carr 1976). Brown's collection of 47 species of vascular plants from Middle Island and Goose Island includes several type specimens and a few species which were not collected there again until 1973 and 1978.

In January 1818, Allan Cunningham collected at least 10 species of plants during a brief visit to the north coast (Lee 1925). George Maxwell collected on the island in 1863 and possibly again in 1875 (Willis 1953). Small collections were also made by F. Stoward and G. Simmonds before 1909, but apparently no further collecting was done until D.L. Serventy collected a few species during a visit to the island in the winter of 1948 (Willis 1953).

These early visits produced a species list for the island of about 65 species (Willis 1953, 1959). The Australian Geographical Society's expedition in November 1950 more than doubled that number (Willis 1953), and R.D. Royce's collections in February 1960 added a few more records.

At least one of the authors of this paper visited Middle Island between 1973 and 1978 for periods of three to twelve days during each of the seven research visits detailed in Part I of this publication. Collections made during the first visit increased the number of vascular plant species known for the island to 208, and each subsequent visit has added more records. However, the present list is considered virtually complete, and it seems likely that few additions, other than introduced aliens, will henceforth be made.

ENUMERATION OF SPECIES

A list of all species of vascular plants reported to occur on the islands of the Recherche Archipelago

is presented in Table 1. The species recorded from Middle Island and Goose Island are indicated in the first and second columns respectively, and those recorded from the remainder of the archipelago are indicated in the third column. All species recorded by the present authors, indicated by the letter A in the Table, are supported by voucher specimens lodged at the Western Australian Herbarium.

The species listed in Table 1 are grouped alphabetically within families, but the families are arranged in phylogenetic sequence following Green (1981).

Although the species names listed are generally those currently in use by the Western Australian Herbarium, in a few cases the listed names are not yet represented by any specimens in the herbarium's collection. Due to subsequent changes in taxonomic preferences for particular names, several of the names used by Willis and by Brown have been replaced by the names on the current list. In most such cases the names used by Willis are given in brackets. A number of cases of synonomy and variation in determination were encountered in the preparation of this list; these cases are indicated on the species list with a dagger (†) and are discussed further in the commentary section.

The Weston, Trudgen and Hopkins collections were determined by the collectors, with assistance from other members of the Western Australian Herbarium staff, by means of comparison with published descriptions and by comparison with what were regarded as accurately determined herbarium specimens. Positive determination of a few plants has proved uncertain or impossible, particularly where only vegetative material was collected, where closely related species are difficult to distinguish and where taxonomic status of the species is in need of further study. Some of these problem species are also discussed in the commentary section.

For all Middle Island species recorded (Column 1, Table 1), the collectors' dates of collections are indicated as: 'B' - Brown (1802, 1803), 'W' - Willis (1950), 'M' - Maxwell (1863), 'R' - Royce (1960), and 'A' - Weston, Trudgen and Hopkins (1973-1980). Collections by Cunningham are not indicated separately.

Species recorded for Goose Island are similarly annotated for collections (and dates) by Willis (1950), and Weston (May 1977) and Trudgen (November 1980).

Other records for the archipelago are indicated by annotation in the third column of Table 1. These records were drawn principally from Willis (1953), but include an additional 55 species reported by La Billardère (1804) - 'L', Brooker (1974) - 'H', Goodsell et al. (1976) - 'G' and Abbott and Black (1978) - 'I', and included in unpublished collections by Tingay and Tingay (Sandy Hook and Long Islands, 1977) - 'T' and by Weston (Observatory Island, 1974) and Hopkins (Mondrain, Wilson and Corbett Islands, 1977) - 'A'.

Alien species of plants are denoted by an asterisk

(*) preceding the name.

Some specimens of algae, fungi, mosses and a liverwort were also collected on Middle Island during the field work. The moss Funaria hygrometrica is common and dense after fires. The liverwort is Marchantia cephaloscypha, a new record for the archipelago. The basidiomycetes Trametes lilacino-gilva, Polyporus aff. tumulosus and an undetermined bolete are new for the island and probably for the archipelago. One or two as yet undetermined species of Chara or Nitella are also new records.

COMMENTARY

The following comments relating to species listed in Table 1 are presented in the same order as the species are listed. The comments are mainly concerned with reliability of identifications, synonymy and status of names.

Isoetes australis S. Williams

Willis' initial determination of his Middle Island specimens as I. drummondii R.Br. was later changed to I. humilior F. Muell. (Willis 1959), but both names are wrongly used for the Middle Island material. The use of the name I. humilior is now generally restricted to a species regarded as endemic to Tasmania.

Callitris preissii Miq. ssp. preissii

Since C. tuberculata R.Br. was described from Brown's Middle Island collection and is included in C. robusta F.M. Bailey, which is now regarded as synonymous with C. preissii, Willis' Middle Island material must belong to this subspecies.

Amphibolus antarctica (Labill.) Sond. & Asch. ex Asch. (=Cymodocea antarctica (Labill.) Endl.)

Triglochin minutissima F. Muell. and T. trichophora Nees

It is possible that the plants from Middle Island and Goose Island that Willis determined as T. trichophora are conspecific with the later collections determined as T. minutissima. This is assumed in the tallies.

Poa poiformis (Labill.) Druce and P. porphyroclados Nees

Willis (1953) recorded one species of Poa from the archipelago: P. caespitosa. This name, as applied to Australian material, was later reduced to synonymy with P. porphyroclados (Vickery 1970), and a Willis Long Island specimen was cited by Vickery as Poa poiformis, a synonym not for P. caespitosa but for P. australis R.Br. The authors' collections of Poa on Middle island have been determined both as P. poiformis and as P. porphyroclados. ASW 8767 is probably only a form common on limestone. Because of the uncertainty about determinations of archipelago material, the tallies take account of only one species of Poa.

Stipa flavescens Labill.

A specimen of Willis' from North Twin Peak Island lodged in the W.A. Herbarium was

originally determined as S. aff. elatior (Benth.) Hughes, but was redetermined by J. Vickery as S. flavescens Labill. Willis remarked on the label that this species was "abundant through the Recherche Archipelago". It is probably the same as the S. tenuiglumis Hughes on Willis' list for the archipelago and Middle Island (Willis 1953), and the authors' Middle Island material, originally determined as S. variabilis Hughes.

Isolepis cernua (Vahl) R. & S. (= Scirpus cernuus Vahl)

Isolepis ?cyperoides R.Br.
It is possible that the Middle Island collections regarded as this species belong to one of the previously collected, previously listed species.

Isolepis marginata (Thunb.) A. Dietr. (= Scirpus antarcticus as used in Australia)

Isolepis nodosus (Rottb.) R.Br. (= Scirpus nodosus Rottb.)

Lepidosperma angustatum R.Br.
The populations of Middle Island may comprise more than one species in the Lepidosperma angustatum complex.

Schoenoplectus supinus (L.) Palla (= Scirpus supinus L)

Schoenus submicrostachyus K. Kenth. (= S. drummondii of Willis)

Juncus bufonius L. (= J. plebeius R. Br.) Willis recorded J. bufonius on Goose Island and both J. bufonius and J. plebeius on the other islands in the archipelago.

Juncus kraussii Hochst. (= J. maritimus of Willis)

Wurmbea dioica (R.Br.) F. Muell. (= Anguillaria dioica R.Br.)

Thelymitra aristata Lindl. and T. nuda R.Br.
Willis lists T. aristata Lindl., which according to George (1971) does not occur in Western Australia. The name has often been misapplied to T. nuda, as must be the case with Willis' Middle Island collections.

Amyema melaleucae (Miq.) Tiegh. (= A. miraculosa (Miq.) Tiegh. var. melaleucae (Tate) Willis)

Atriplex cinerea Poir.
Willis includes A. isatidea Moq. in A. cinerea, a practice not followed by P.G. Wilson, who identified one ASW specimen from Goose Island as A. isatidea and another specimen as A. ?cinerea. Although both may occur there, only one species is listed and tallied.

Halosarcia halocnemoides (Nees) P.G. Wilson (= Arthrocnemum halocnemoides Nees)

Rhagodia baccata (Labill.) Moq. (= R. radiata Nees) and R. candolleana Moq.
Until recently, R. radiata has been the

favoured name for what is now recognised as R. baccata in Western Australia, while the name R. baccata has been used for the eastern species, R. candolleana (P.G. Wilson 1983 and pers. comm.). The ranges of the two species overlap on Middle Island and elsewhere in the Recherche Archipelago. Probably what Willis (1953) recorded as R. baccata is R. candolleana spp. candolleana and what he recorded as R. baccata var. linearis is R. baccata ssp. baccata.

Sarcocornia blackiana (Ulbr.) A.J. Scott (= Salicornia blackiana Ulbr.)
The name Salicornia australis ~~Banks & Sol.~~ as applied by Willis is a synonym for this.

Sueda Australis (R. Br.) Moq. (= S. maritima (L.) Dun.)
This is one of three species collected by Robert Brown on Middle Island and not subsequently collected anywhere in the archipelago.

Gyrostemon sheathii W.V. Fitz. (= G. crassifolium sens. R.Br.)

Carpobrotus aequilaterus (Haw.) N.E. Brown and C. virescens (Haw.) Schwantes
S.T. Blake (1969) does not include Western Australia in the range of C. aequilaterus, but ASW 9821 fits his description of this species. Willis' specimens determined as this species might be C. aequilaterus, C. virescens or both. One or both species are also present on Goose Island.

Disphyma crassifolium (L.) L. Bolus
The name Disphyma australe (Sol. & Forst.) J.M. Black is a synonym of D. clavellatum (Haw.) Chinnock. The authors' collections were previously determined as D. blackii Chinnock, also a synonym. Disphyma clavellatum (Haw.) Chinnock is now considered to be synonymous with D. crassifolium (L.) L. Bolus.

Calandrinia brevipedata F. Muell. (= C. cygnorum Diels)

Calandrinia granulifera Benth. (= C. pygmaea F. Muell. nom. illeg. and C. neesiana Hj. Eichler, at least in Western Australia)

Cassytha pomiformis Nees and C. racemosa Nees.
It is possible that only one species of Cassytha occurs on Middle Island, but two are tallied here.

Cakile maritima Scop. and Hymenolobus procumbens (L.) Nutt.
Common though they are on the mainland these two alien crucifers were found by Willis on a total of only three islands in the archipelago. The Cakile is a particularly conspicuous beach plant, not easily missed and now a common plant along the shores of both Goose Island and Middle Island. It is one of three alien species that have spread and become well established along the coast of Middle Island since Willis was there in 1950. H. procumbens, on the other hand, is a

small, short-lived annual that might be easily missed by a collector. Consequently, it cannot be so readily inferred that this species has increased in abundance and distribution.

Crassula colorata (Nees) Ostnf.

Crassula miriamae Ostnf., recorded by both Willis and Weston, is now regarded as a variety of C. colorata (Toelken 1981).

Crassula peduncularis (Smith) Meigen
According to Toelken (1981), C. purpurata (Hook. f.) Domin and C. bonariensis Cambess. are both synonymous with C. peduncularis.

Crassula sp. ASW 9865
Although this specimen has not been determined to species it is definitely distinct from the other species of Crassula and is considered as a new record for the archipelago.

Acacia ligulata Cunn. ex Benth., A. rostellifera Benth. and A. heteroclita Meisn.
If the two first species, often difficult to differentiate, are considered as one species, they are the only Acacia found by the authors on both Middle Island and Goose Island. It is possible that Willis misidentified his specimens of A. rostellifera/ligulata as A. heteroclita, as neither A. rostellifera, one of the commonest Acacias on Middle Island, nor A. ligulata, conspicuous on Goose Island, was listed by Willis for the archipelago.

Acacia nigricans (Labill.) R.Br. (=A. obscura DC.)

Albizia lophantha Benth.
The Middle island collection which Brown initially recorded as Mimosa amabilis was later described as Albizia lophantha.

Geranium solanderi Carolin (= G. pilosum Forst. ex Willd.)

Nitraria billardieri DC.
The species of Nitraria occurring in Australia has been regarded as a southern extension or early introduction of the otherwise northern hemisphere species Nitraria schoberi L., but it is now considered by some authors (Noble and Whalley 1978) to be distinct. The Nitraria is one of the species apparently collected by Robert Brown on Middle Island but not subsequently collected there by Willis or the authors. However, both Willis and the senior authors collected it on Goose Island. Robert Brown did land on Goose Island and Noble and Whalley (1978) state that in "the British Museum there is material of Nitraria collected by Robert Brown at Goose Bay Island.....on January 16, 1802.....". Noble and Whalley make no reference to any Nitraria specimen from Middle Island.

Zygophyllum cf. glaucum F. Muell.
It is assumed that what Willis calls Zygophyllum ?glaucescens F. Muell. is the same as what is here considered Z. cf. glaucum, which differs from typical Z.

glaucum in having winged filaments (ASW 8779). Both winged and wingless filament forms may be found on the island.

Rhadinothamnus euphemiae (F. Muell.) P.G. Wilson (= Phebalium euphemiae (F. Muell.) C.A. Gardn.)
Like Anthocercis genistoides Miers, this species was rare when Willis recorded it from Middle Island but locally abundant when the authors found it, one year after a major fire.

Euphorbia paralias L.
When Willis was on Middle Island this species was limited to the northeast corner of the island. By 1973 it had spread all around the island and is now one of the commonest species on the sand above high tide mark.

Phyllanthus calycinus Labill.
What Brown's manuscript refers to as P. inflexus is probably P. calycinus (Willis 1959).

Stackhousia huegelii Engl. monogyna Labill. (= S. huegelii Endl.)
A tendency to regard S. huegelii as a form of the more widely distributed S. monogyna Labill. is foreshadowed by Barker (1977).

Dodonaea oblongifolia Link. The Middle Island material of ths species is also regarded as D. ceratocarpa Endl. (cf. Willis 1959).

Trymalium floribundum Steud. (= T. spathulatum (Labill.) Ostnf.)
Alyogyne huegelii (Endl.) Fryx. (= Hibiscus huegellii Endl.)

Rulingia corylifolia Grah.
The fact that several R. grandiflora Endl. specimens in the W.A. Herbarium were first determined as R. corylifolia attests to the similarity of these two species and suggests the possibility that the authors' Middle Island R. corylifolia is conspecific with the Willis R. grandiflora collections from Mondrain Island and Woody Island.

Rulingia cygnorum (Steud.) C.A. Gardn.
On Middle Island this species was found in a recently burnt area and showed signs of heavy grazing, presumably by Tammar Wallabies (Macropus eugenii).

Hibbertia cuneiformis (Labill.) Smith
This is another species collected by both Robert Brown and W.A. Herbarium expeditions. It is a rare species, found in one unburnt area near Lake Hillier by the authors, and in an unburnt area by Royce in 1960. It was almost certainly present when Willis was on the island but was not recorded then.

Eucalyptus angulosa Schau. (= E. incrassata Labill. var. angulosa (Schau.) Benth.)

Eucalyptus conferruminata. Carr & Carr
Carr and Carr (1981) cite Brown, Weston and Willis specimens from Goose Island Bay, Middle Island and North Twin Peaks Island, respectively, as E. conferruminata and no Recherche Archipelago material as the closely related E. lehmanniii (Preiss. ex Schau.)

Benth.

Eucalyptus sp. ASW 8880.

This appeared to the collectors to be intermediate between E. cornuta Labill. and E. conferruminata. Some experts who later examined the specimens considered them to belong to an undescribed species often confused with E. cornuta. M.I.H. Brooker subsequently annotated a specimen of ASW 8880 as intermediate between E. conferruminata and E. lehmanniae, which suggests that E. lehmanniae, as well as the former species, may occur on Middle Island and in the archipelago. Unfortunately, the group of trees from which the specimens came were destroyed by the 1977 fire.

Eucalyptus sp. ASW 8895

The tree from which this specimen came was also destroyed by the 1977 fire. It superficially resembles a form of Eucalyptus platypus Hook. var. heterophylla Blakely but, unlike E. platypus, has no glands in the pith (Carr pers. comm. 1974). It too, is probably an undescribed species.

Kunzea baxteri (Klotzsch) Schau.

What Brown refers to in manuscript as Metrosideros quinquelocularis is probably K. baxteri (Willis 1959).

Melaleuca lanceolata Otto

This is the currently accepted name for the species previously called M. pubescens Schau. The form on Middle Island generally has a straight trunk and is never a paperbark.

Gonocarpus scordioides (Benth.) Orch. (= Haloragis scordioides Benth.)

Haloragodendron racemosum (Labill.) Orch. (= Haloragis racemosa Labill.)

Myriophyllum ? petraeum Orch.

Being the first Myriophyllum collected in the archipelago, this species is a new record regardless of the tentative determination to species.

Hydrocotyle trachycarpa F. Muell.

Although the specimens given this name are considered to be accurately determined, there is a possibility that they will be redetermined as the very similar species, H. hispidula Bunge, which would also be a new record for the archipelago.

Leucopogon revolutus R.Br. (= L. obovatus (Labill.) R.Br.)

Centaurium erythraea Rafn. (= Erythraea centaurium Pers. and C. minus Gars; see Melders 1972).

Royce's collection from Wilson Island determined as C. spicatum is probably conspecific with the Willis and Weston specimens listed here as C. erythraea and is tallied as such.

Anthocercis littorea Labill.

A. littorea is one of the three species

collected by Robert Brown that were not found subsequently anywhere in the archipelago. It could be expected to be abundant after a fire, as has been observed in King's Park by Baird (1978) and around Esperance by Weston (unpublished data).

Lycopersicon lycopersicum (L.) Karst.

As the several tomato plants found growing unassisted near the hut were probably the progeny of discarded tomatoes, and as the plants apparently did not reproduce, L. lycopersicum cannot yet be considered a naturalized alien. The species is not included in the tallies.

Limosella aquatica L. and L. australis R.Br.

Probably all collections of Limosella from Middle Island and Goose Island belong to only one or the other of these two species. They are tallied as one species.

Myoporum insulare R.Br. (= M. adscendens R.Br.)

Plantago drummondii Decne.

What Willis determined as P. varia R.Br. from other islands in the archipelago is probably the same as the species on Middle Island, tentatively determined as P. drummondii. P. varia is restricted to Eastern Australia (Briggs 1980). The "two" records are tallied as one species.

Galium migrans Ehrend. & McGilliv. (=G. australe auct. non DC.)

The Galium that Willis collected in other parts of the archipelago and determined as G. australe, he later redetermined as G. tenerum Schleich., partly because it has 5 leaves per whorl (Willis 1959). The Middle Island material, originally determined as G. australe, has (2-)4 leaves per whorl. G. migrans is the only species of Galium native to Western Australia (McGillivray 1983).

Galium tenerum Schleich.

This is generally considered to be a synonym or subspecies of G. aparine L. and consequently is not included in the tallies as a distinct species.

Lobelia alata Labill. var. alata

The Australian plants formerly called L. anceps Thunb. are now referred to L. alata (see Willis 1959). What Brown's manuscript refers to as L. pulchella is probably L. alata var. alata (Willis 1959).

Stylidium calcaratum R.Br. and S. perpusillum Hook. f.

Willis' material from Mondrain and North Twin Peaks Islands, initially determined as S. perpusillum, was later redetermined as S. calcaratum (Willis 1959). Pending examination of Maxwell's collection and re-examination of 1973 Middle Island material, S. perpusillum is considered to be on Middle Island only, unless it, too, is S. calcaratum.

Stylidium sp. ASW 8904

This specimen, of a species close to S. perpusillum, may represent a new record for

the archipelago.

ASTERACEAE (COMPOSITAE)

The majority of genus names that have been changed since Willis' 1959 paper are in the family Asteraceae. The changes are listed below.

Angianthus humifusus (Labill.) Benth.
Short (pers. comm.) regards this species as more appropriately left in Siloxerus: S. humifusus Labill.

Angianthus tenellus (F. Muell.) Benth. Specimens of this taxon from the archipelago have been redetermined as Chrysocoryne drummondii A. Gray.

Arctotheca calendula (L.) Levyns
The few plants of this species found near the fishermen's hut in 1974 were destroyed by the authors. Whether or not the attempt to remove this aggressive weed from the small group of established aliens on Middle Island was successful remains to be seen, but the outlook is good. None was observed in 1977 or 1978. The species is not included in the tallies.

Athrixia nivea (Steetz) Druce = Asteridea nivea (Steetz) Kroner.

Dittrichia graveolens (L.) W. Greuter
This is the correct name for the species erroneously listed by Abbot and Black (1978) as Vittadinia graveolens. It was initially described as Inula graveolens L.

Gnaphalium spp.
There is some doubt as to whether any of these is native.

Gnaphalium candidissimum Lam. = Vellereophyton dealbatum (Thunb.) Hill. & Burtt.

Graphalium lurteo-album L. = Pseudognaphalium luteo-album (L.) Hill & Burtt.

Gnaphalium sphaericum Willd.
The Recherche Archipelago material previously classified as G. involucratum Forst. is now placed in G. sphaericum.

Picris hieracioides L.
The Willis (1953) listing of this species for South Twin Peaks Island is the only published record of its occurrence in Western Australia. It is likely that the Willis collection is of another, possibly native, species (see Lack 1981).

Podotheca angustifolia (Labill.) Less. (= Podosperma angustifolium Labill.)

Sonchus megalocarpus (Hook.f.) Black = Actites megalocarpa (Hook.f.) N. Lander

Vittadinia australasica (Turcz.) N.T. Burb.
A specimen collected by Willis on Boxer Island in the archipelago is cited by Burbidge (1982) as V. australasica var. oricola. N.T.

Burb. Presumably this is the same specimen determined by Willis as V. triloba (Gaud.) DC., a synonym for V. dissecta (Benth.) N.T. Burb.

ASW 8911
This monocot found in the lower pool south of Flinders Peak summit has a lateral, suprabasal bulb and narrow leaves. It matches none of the known species from Middle Island and is considered to be a new record for the island, if not the archipelago.

RESULTS AND DISCUSSION

The total number of species and vascular plants recorded for the archipelago is 370. Middle Island has some 235 species. This tally for Middle Island is roughly equal to the number of native species recorded for the whole archipelago prior to the commencement of the studies reported in this publication.

Willis (1953) listed 132 species that he collected on Middle Island in 1950 and later listed 47 species previously collected there by Brown (Willis 1959). This second list included eleven species not included in Willis' own collections. Another eight species were included in unpublished collections by Maxwell and by Royce.

Three of the species collected by Brown and at least two of those collected by Willis were not found on Middle Island during the present study. Four other Willis species may be represented among the authors' collections by specimens which have been differently determined. One species, Spyridium spadiceum, has not been recorded since Maxwell's collection of it.

According to present records, 73 of the species of the archipelago are restricted to Middle Island. Three more occur only on Middle and Goose Islands, and one is restricted to Goose Island. Seven new records for Goose Island increase the flora for that island to 68 species. Of the 86 new records for Middle Island reported here, 45 are also new records for the archipelago.

Only 6% of the Middle Island flora is introduced. Thirteen alien plant species are established on the island; ten of these species are new records for the island. A further two species, Arctotheca calendula and Lycopersicon lycopersicum, were collected on Middle Island in 1975 but are apparently not established.

One objective of the 1950 Australian Geographical Society expedition was to ascertain whether any undescribed taxa of plants existed in the archipelago. Since then a Eucalyptus has been described from North Twin Peaks Island (Brooker 1974) and a Brachycome from Figure of Eight Island (Davis 1955). Both have also been discovered on the mainland. Two Eucalyptus specimens and a monocot collected on Middle Island in 1973, and a Eucalyptus specimen from Woody Island (Goodsell et al. 1976) may belong to undescribed species that are restricted to the archipelago.

Collecting Anomalies

Willis collected almost three times the number of species on Middle Island that Brown did, yet failed to locate eleven of Brown's species. Seven of these eleven species have been collected on Middle Island during the present study: Alyogyne hakeifolia, Alyogyne huegelii, Gyrostemon sheathii, Hibbertia cuneiformis, Scaevola aemula, Solanum simile and Villaris parnassifolia. The four species collected only by Brown are Anthocercis littorea, Myoporum parvifolium, Nitraria billardieri and Sueda australis.

Four reasons are suggested for these apparent anomalies, of which each may apply to one or more of the eleven Brown species not recollected by Willis:

1. The species is rare or has a very localised distribution.

2. The species was collected by Brown on Goose Island rather than on Middle Island.

3. The species was dormant or inactive at the time of Willis' visit.

4. The species had become extinct during the intervening period.

Each of these hypotheses is discussed with particular reference to the eleven species.

1. Rarity. The large number of species collected by Willis is indicative of his thorough collecting practices. However, because his visit to Middle Island was limited to portions of four days (Willis 1953) he was likely to miss some areas with localised or rare species. Hibbertia cuneiformis, found in 1974 only within a stand of Melaleuca lanceolata near Lake Hillier, is one such species.

2. Goose Island collections. While Flinders had the 'Investigator' anchored in Goose Island Bay, Brown not only visited Middle Island but also, according to the entry in his diary for 15 January 1802, "landed on the smaller island..." i.e. Goose Island. He made no reference in his diary to plants seen or collected on Goose Island, but material in the British Museum indicates that he made some of his collections there (Noble and Whalley 1978). Nitraria billardieri is the one species of all those collected by Brown which, subsequently, has been collected only from Goose Island (Willis 1953; Table 1 of this paper).

3. Dormancy and inactivity. Collections made from Middle Island at one time of the year are unlikely to include all species of flowering plants, because even at the most favourable time of the year for flowering (October-November) at least a few species will not be in flower. For example, of the twelve species noted as being in flower on Middle Island in May 1977, six were found by Willis (in November 1950) only in a vegetative condition. Nine of the twelve species were collected by Brown in January 1802 and May 1803. It seems reasonable to assume that Brown collected only specimens of species which were in flower at the time; thus it is likely that some of Brown's species were not in flower at the time of Willis' visit. Hibbertia cuneiformis may be one such

species. Furthermore, the poor flowering of many South-Western Province species in late summer-autumn (Specht et al. 1979) may explain in part why Brown's collection from Middle Island was not larger.

An extreme form of inactivity occurs when the entire above-ground portion of a plant is dead while the plant persists as a dormant seed or tuber. Six of Brown's collections represent this condition: Alyogyne hakeifolia, Alyogyne huegelii, Scaevola aemula, Solanum simile, Gyrostemon sheathii and Villarsia parnassifolia. All six were recorded in quantity on Middle Island soon after fire and during the period of the present studies, but they became rare or absent as flowering plants a few years later (see Figures 4 and 6, in Part V of this publication).

In 1974, twenty months after the first severe fire reported in Part I of this publication, five of the six species (G. sheathii excepted) were very abundant in the burnt area, though in more or less exclusive populations. Three formed dense carpets which were, in the case of the Alyogyne species, up to two metres tall. Because the flowers and inflorescences of all five species are amongst the largest and most conspicuous of any on the island, the species would be difficult to miss when present.

Most of these species again appeared in abundance following the 1977 fire (see Part I of this publication), and in addition, Gyrostemon sheathii was very common just below Flinders Peak and inland from Cormorant Cove. This species was first collected by the authors in 1978.

Willis, though he traversed the island and did a very creditable job of collecting during his brief visit there, found none of these six species. Since his visit coincided with their flowering period, it is unlikely that he would have missed them had they been present. The obvious conclusion which can be drawn is that the six species were not present as adult flowering plants but only as viable seed in the soil at the time of Willis' visit. Many weed and early succession plant species have attracted comment for the remarkable persistence of their seeds (Salisbury 1942; Thurston 1960; Thompson 1978).

This line of reasoning provides indirect but conclusive botanical evidence that Middle Island suffered a fire no more than a few years prior to the 1802 visit by Flinders and Brown, when Brown collected the six species of vigorous-growing, short-lived perennials mentioned above. Had there been no fire within the few years preceding 1802, it is unlikely that all six species would have attracted his attention.

Several other species were observed to be abundant after the 1972/73 fire but relatively uncommon or even absent in the then unburnt section of the island: Anthocercis genistoides, Kennedia nigricans, Muehlenbeckia adpressa, Rulingia corylifolia and Sida hookeriana. None of these species was collected by Brown. Willis did not collect the Rulingia or the Sida and found only one bush of the Anthocercis. These species are predominantly spring flowering (i.e. late winter to

early summer), a factor which may account for their not being included in Brown's collection of 47 species. Furthermore, Kennedia nigricans is probably the only one of these species which would be as likely to attract attention as such species as the two Alyogyne species.

Two additional species, Opercularia hispidula and Rhadinothamnus euphemiae, were abundant after the 1977 fire but restricted in distribution to Flinders Peak and the associated granitic ridge. Willis (1953) did not collect the Opercularia and reported finding only one plant of the Rhadinothamnus. Neither species was collected by Brown.

4. Immigration, Establishment and Extinction.

Despite thorough searching, four of Brown's species have not been recollected on Middle Island. Local extinction is a possible fate of these species, although a different explanation has already been provided for the Nitraria. Similarly, of the new records for the island some could be recent immigrants; other new records are certainly due to previous incomplete surveys of the island or to dormancy of the species at the time of previous surveys. A knowledge of habitat requirements of each possible immigrant, of phenology of its growth and flowering, and of the thoroughness and perceptiveness of previous surveyors permits the assessment of immigration potential. Consideration of these factors leads to the conclusions that Arctotheca calendula, A. populifolia and Cakile maritima are recent immigrants but that the species of Alyogyne, Gyrostemon, Rulingia, Solanum and Villarsia are not.

Probably the majority of new records that are non-aliens are long-term residents that were missed by other collectors. On the other hand, the majority of aliens are probably immigrants that have arrived or become established since 1950. Weedy aliens have a greater capacity for successful immigration and establishment, and greater potential for extinction in the absence of disturbance, than most of the native species.

Inferring extinction may be easier than determining that immigration has occurred but again is dependent upon a knowledge of the species' biology. If a previously recorded species can no longer be found, no matter how thorough the search, and if it can be ascertained that the species is not in a dormant state, then a reasonable conclusion is that it is extinct.

Three of the 47 species collected by Brown in 1802, Anthocercis littorea, Myoporum parvifolium and Sueda australis, have not been recollected, despite extensive searching. An additional two species collected by Willis in 1950, Clematis pubescens and Pomaderris oraria, were not seen by the present authors. These five species may now be extinct on Middle Island.

It is not possible to accurately estimate species turnover rates (cf. Diamond 1971) because of the incompleteness of the early collections. However, the data given above do indicate a low rate of extinction relative to values computed for much smaller insular floras near Perth by Abbott (1977). This is consistent with predictions from the model

of MacArthur and Wilson (1967), which postulates an extinction rate that is inversely related to island size and habitat diversity.

It is further suggested that the rate of natural immigration of plant species to Middle Island would be low because of the particular combination of distance and direction of Middle Island from the mainland and the direction of the prevailing winds. Some immigration from nearby Goose Island could be anticipated, yet only one of the five species of alien plants on Goose Island is also recorded for Middle Island. Of the other four species, one, Anagallis arvensis, is among the most broadly distributed weeds in the world.

Immigration has undoubtedly been enhanced by human activities, particularly in recent times (e.g., the presence of the Lycopersicon and Arctotheca calendula near the hut). However, it is probable that subsequent establishment of many immigrants has been restricted by the undisturbed nature of the natural vegetation on Middle Island. In contrast, the vegetation of Goose Island is highly disturbed, largely as a result of the activity of rabbits, which may have facilitated the establishment of alien species such as Anagalis arvensis there. To date, only fifteen alien immigrant plant species have been recorded for Middle Island, of which two are not established, whereas Woody Island (188 ha), which has suffered frequent fires and grazing, has thirty-five alien species in a flora of 170 species (Goodsell et al. 1976, Abbott and Black 1978). On Middle Island the alien plants are largely restricted to beaches and adjacent to granite outcrops.

SUMMARY AND CONCLUSIONS

The survey of the flora of Middle Island reported here is the most comprehensive one yet undertaken for any island of the Recherche Archipelago. Collections were made during seven visits to the island, which totalled sixty-three days over a seven-year period.

Vascular plants recorded for Middle Island number some 235 species, over half the known flora of the whole archipelago. The next largest floras are those of Woody Island (170 species) and Mondrain Island (156 species) (Abbott and Black 1978). The relative floristic richness of Middle Island is certainly a reflection of its size and environmental diversity as well as the thoroughness of the survey work.

A number of new records are reported, including some species that may be undescribed. However, evolutionary aspects of the island's flora (cf. Carlquist 1974) have not been examined. It is possible that future study will reveal taxonomic subtleties leading to an increase in the recorded flora.

Middle Island has a long history of botanical collecting, which begins with Robert Browns' visit in 1802. Information from early collectors, together with recent observations on the flora, permits a chronology of disturbance to be established. It is suggested that much of the island was burnt around 1800 AD, and that the fire in 1972/73 was the first of any major consequence

since that time.

Five species of plants appear to have become extinct on Middle Island since the time of the early collections, and at least fifteen species have immigrated to the island. Many of these immigrations have been assisted, either directly or indirectly, by humans. It is not possible to attribute a cause to the extinctions; rather, it is suggested that they are a part of the process of species turnover on an island having an equilibrium flora (cf. MacArthur and Wilson 1967).

It has often been asserted that the flora of Western Australia is fire-dependent, and that plant species may become extinct in the absence of fire (e.g. Gardner 1957). The results of this study support a contrary view since the species of Middle Island appear to have persisted without fire for over 170 years. The current flora includes at least seven early succession species that appear to have remained as viable seeds in the soil for this period.

This study of the flora of Middle Island highlights the value of islands as biological laboratories. The substantial volume of data accumulated during the course of the study can provide a foundation for further work. Effects of the recent fires on the total flora deserve attention, as do more detailed biogeographical and evolutionary aspects of the flora. However, future human-induced disturbance, with the consequent establishment of other alien species and their contribution to future extinctions, could well preclude the possibility of continuing, long-term biological studies in one of Western Australia's most natural ecosystems. Management decisions should be made with the knowledge of the island's unique potential.

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REFERENCES

Abbott, I. (1977). 'Species Richness, Turnover and Equilibium in Insular Floras near Perth, Western Australia'. Aust. J. Bot. 25 : 193-208.

Abbott, I. and Black, R. (1978). 'An Ecological Reconnaissance of Four Islands in the Archipelago of the Recherche, Western Australia'. J. Roy. Soc. West. Aust. 60 : 11-128.

Baird, A.M. (1978). 'Regeneration after fire in King's Park, Perth, Western Australia'. J.

Roy. Soc. West. Aust. **60** : 1-22.

Barker, W.R. (1977). Taxonomic studies in Stackhousia (Stackhousiaceae) in South Australia. J. Adelaide Bot. Gard. **1** : 69-82.

Blake, S.T. (1969). 'A revision of Carpobrotus and Sarcozona in Australia, genera allied to Mesembryanthemum (Aizoaceae)'. Queensl. Herb. Contributions **7** : 1-65.

Briggs, B.G. (1980). Plantago multiscapa, a new species from eremaean Australia, and notes on Plantago in Western Australia. Telopea **2** : 77-81.

Brooker, M.I.H. (1974). 'Six New Species of Eucalytpus from Western Australia'. Nuytsia **1** : 297-314.

Brown, R. (1802). Diary. Unpublished. Microfilm. Dept. Agric. West. Aust. Perth.

Burbidge, N.T. 1982). A revision of Vittadinia A. Rich. (Compositae) together with reinstatement of Eurybiopsis DC. and description of a new genus, Camptacra. Brunonia **5** : 1-72.

Carlquist, S. (1974). Island Biology. (Columbia Univ. Press : New York).

Carr, S.J.M. and Carr D.J. (1976). 'The French Contribution to the Discovery of Australia and its Flora'. Endeavour **35** : 21-26.

Carr D.J. and Carr S.J.M. (1981). The Lehmannianae : a natural group of Western Australian eucalypts. Aust. J. of Bot. **28** : 523-550.

Davis, G.L. (1955). 'Supplementary Notes on the Genus Brachycome Cass'. Proc. Linn. Soc. N.S.W. **79** : 203-210.

Diamond, J.M. (1971). 'Comparison of Faunal Equilibrium Rates on a Tropical and a Temperate Island'. Proc. Nat. Acad. Sci. U.S.A. **68** : 2742-5.

Gardner, C.A. 1957). 'The Fire Factor in Relation to the Vegetation of Western Australia'. West. Aust. Nat. **5** : 166-173.

George, A.S. (1971). 'A check list of the Orchidaceae of Western Australia'. Nuytsia **1** 166-196.

Goodsell, J., Tingay, A. and Tingay, S.R. (1976). 'A Resource Survey of Woody Island, Archipelago of the Recherche'. Dept. Fish. Wildl. West. Aust. Rept. No. 21 (Dept. Fish. Wildl. : Perth).

Green, J. (1981). Census of the Vascular Plants of Western Australia. (Western Australian Herbarium : South Perth).

Grieve, B.J. and Blackall, W.E. (1975). How to Know Western Australian Wildflowers. Part IV. (Univ. of W.A. Press : Nedlands).

La Billardiere, J.J.H. (1804-06). Novae Hollandiae Plantarum specimen. (Huzard : Paris).

Lack, H.W. (1981). The Lactuceae (Asteraceae) in Australia and New Zealand in : Carr, D.J. ~~(ed).~~ (Ed.). XIII International Botanical Congress Abstracts Aust. Acad. Sci., p. 278.

Lee, I. (1925). Early Explorers in Australia. (Methuen : London).

MacArthur, R.H. and Wilson, E.O. (1967). The Theory of Island Biogeography. (Princetown Univ. Press : Princetown).

McGillivray, D.J. (1983). A revision of Galium (Rubiaceae) in Australia and New Zealand. Telopea 2(4) : 355-377.

Melders, A. (1972). 'Taxonomic studies on the European species of the genus Centaurium Hill'. Bot. J. Linn. Soc. 65 : 224-250.

Noble J.C. and Whalley, R.D.B. (1978). The Biology and Autecology of Nitraria L. in Australia. I. Distribution, Morphology and Potential Utilization. Aust. J. Ecol. 3 141-163.

Salisbury, E.J. (1942). The Reproductive Capacity of Plants. (G. Bell and Sons : London).

Specht, R.L., Rogers, R.W. and Hopkins, A.J.M. (1979). Seasonal Growth and Flowering Rhythms : Australian Heathlands. In : R.L. Specht (Ed.) 'Ecosystems of the World. Heathlands and Related Shrublands'. (Elsevier : Amsterdam) (in press).

Thompson, K. (1978). 'The Occurrence of Buried Viable Seeds In Relation to Environmental Gradients'. J. Biogeog. 5 : 425-430.

Thurston, J.M. (1960). Dormancy in Weed Seeds. In : J.L. Harper (Ed.) 'The Biology of Weeds'. (Blackwell : Oxford).

Toelken H.R. (1981). The species of Crassula L. in Australia. J. Adelaide Bot. Gard. 3 : 57-90.

Vickery, J.W. (1970). 'A Taxonomic Study of the Genus Poa L. in Australia'. Contr. N.S.W. Nat. Herb. 4 : 145-243.

Willis, J.H. (1953). Land Flora. In : J.H. Willis (Ed.). 'The Archipelago of the Recherche'. Aust. Geogr. Soc. Rept. No. 1. (Aust. Geogr. Soc. : Melbourne).

Willis, J.H. (1959). 'Plants of the Recherche Archipelago, W.A.'. Muelleria 1 : 97-101.

Wilson, P.G. (1983). A taxonomic revision of the tribe Chenopodieae (Chenopodiaceae) in Australia. Nuytsia 4(2) : 135-262.

PART III

THE PLANT ASSOCIATIONS OF MIDDLE ISLAND

by Arthur S. Weston and Malcolm E. Trudgen

INTRODUCTION

An essential prerequisite to the selection of permanent plots designed to monitor changes in vegetation over spans of several years or more is a basic knowledge of the structural, floristic and geographic parameters of the plant communities involved. This was especially important in the case of the Middle Island study because it was the intent of the study to observe the course and rate of fire succession in representative stands of the vegetation severely burnt in the 1972/73 fire. ~~Ergo~~, the communities had to be defined and their distributions mapped. Determination of the proportion of each association that escaped destruction by the fire necessitated mapping of the vegetation of the whole island.

The customary and most widely used approach to classifying and mapping the vegetation of Western Australia is to define formations on the basis of height, density and life form of the plants in the tallest stratum and to divide these formations into associations of species (see Smith 1973; Beard 1973; Beard and Webb 1974). In this approach the understorey is only occasionally mentioned and is not utilized in defining the formation or association unless the overstorey plants are so scattered as to be considered emergents. Yet the height, density and species composition of this understorey is important to the distribution and abundance of the fauna and may continue as an overstorey adjacent to the stand in which it is an understorey (e.g. Melaleuca lanceolata on Middle Island). Consequently, the classification of the vegetation on Middle Island, though based on the scheme proposed by Specht (1970, 1972) and used by Smith (1972, 1973, 1975)[1], considers the understorey and relies more on the dominant stratum (i.e. the one with the greatest biomass) than on the tallest, though the two usually coincide.[2]

This technique overcomes difficulties encountered in classifying communities with scattered emergents. Projective foliage cover, the percentage of substrate covered by a vertical projection of the foliage in the dominant stratum, is used to indicate density. It gives a more accurate indication of ~~biomass and~~ importance within the community than does crown cover although it is more difficult to estimate.

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[1] A summary of the scheme used by Smith is presented in Table 1.

[2] The vegetation classification scheme devised by Muir (1977) for desribing fauna habitats gives more weight to the understorey than Specht's, Smith's or Beard's schemes but was not developed by the time this Middle Island vegetation was done.

A second point of departure concerns the assignment of stands to structural categories. As a species association frequently has stands that vary in height and density and because other stands do not fall neatly within a particular structural formation, the classification and mapping (Figure 1) is of dominant species more than of structural forms.

The classification and description are based upon ground transects and many observations of mature, unburnt stands during five visits to the island. These led to successive refinements of the map and descriptions of associations prepared during and following the first visit, in 1973. For the eastern part of the island this map, plotted on 1971 aerial photographs, reconstructs the pre-1973 burn vegetation, and for the western section, the vegetation as it existed until the 1977 burn. However, because the aerial photographs, at 1:40 000, were far less than the optimum scale for a map prepared at 1:10 000 (see Kuchler 1967, p. 89) and due to difficulties inherent in identifying some postfire remnants of vegetation, small errors may exist on the map. With few if any exceptions the associations described and the communities mapped can be considered to be climaxes.

Although some very small communties and narrow bands of communities have been mapped it has not been possible to delimit smaller, narrower or less sharply defined communities on a map of this scale. The Eucalyptus Angulosa/Melaleuca globifera stand between the western quartzite heath and the south coast is an example of all three of these conditions.

The bracketed symbols on the map do not refer to the communities in which they are drawn but to neighboring, small communities indicated by a line drawn from the bracket.

PLANT ASSOCIATIONS

The following list of associations is arranged alphabetically relative to the two-digit abbreviations given in Table 2 and employed in Figure 1, the vegetation map of Middle Island.

Albizia lophantha Community

Consisting as they do of only one or two gnarled trees 2 m to 3 m tall, mature Albizia stands on the island are too small to assign to density classes and are in a height range that overlaps adjacent height classes. Albizia communities are rare and scattered and are limited to the lower slopes of granitic monadnocks and outcrops, particularly the north sides of Flinders Peak and the southwest central block, Willis Ridge. The only community mapped, at the base of the northeast central granitic outcrop, has one large mature tree, broadly spreading and partially killed by the 1972/73 fire. The understorey species, Pimelea argentea and Acacia spp., with young plants of both Albizia and Haloragodendron racemosum, have colonized the surrounding flat.

Acacia rostellifera Open scrub

The stands of A. rostellifera form one of the major associations on the island despite the fact

that few are shown on the map. Most of the stands are small patches in the Eucalyptus open forest, especially of E. angulosa, and in narrow belts along the dunes. Often A. rostellifera grades into mixed sand heath and elsewhere shares dominance with Pimelea clavata as open heath. The understorey of A. rostellifera open scrub is Poa porphyroclados, Carpobrotus virescens, Trachymene pilosa and Cheilanthes tenuifolia, in varying proportions. In many populations, particularly the largest one near the north coast, up to 50% of the Acacias were dead even before the 1977 fire reduced the communities to ash. There is no indication that the pre-1977 fire deaths were caused by burning. A large proportion of the Pimeleas in the north coast community was also dead, also from non-fire causes. Another community, on the west side of Willis Ridge and designated A?R, may be an open scrub of A. nitidula rather than of A. rostellifera. A positive determination is awaiting regeneration following the 1977 burn. Other species of Acacia are important components and even codominants of communities on Middle Island, but these communities are either too small or ill-defined to warrant description here.

austrotenuifolia

Calocephalus brownii Low shrubland

Bold

These communities are confined to coastal areas, where they are in some places a component of mixed sand heath. The largest populations are on the migmatite at the tips of the two limestone points, where the understorey is made up of low succulents, mostly chenopodiaceous and aizoaceous, and Frankenia tetrapetala.

Callitris preissii Low closed forest

Bold

C. preissii is common on Flinders Peak, but only at the south end of the Flinders Peak ridge is there a stand large and prominent enough to be mapped. The Callitris trees were over 6 m tall before the 1977 fire and very dense. Small trees or tall shrubs of Hakea suaveolens are common associates.

Eucalyptus angulosa Open forest/Low open forest/Open scrub

Bold

On the mainland E. angulosa is a mallee to 4.5 metres tall (Chippendale 1973; Blakely 1965). On Middle Island it occurs as a mallee as low as 4 m only on some sand dunes along the north coast and as small enclaves within or at the edge of other communities. Elsewhere it is a tree, sometimes mallee-like, usually 6-8 m high, but sometimes exceeding 15 m. The lowest branching begins as much as a metre or more above the base. In most stands E. angulosa is the sole dominant, but in some communities it shares dominance with Melaleuca globifera and occasionally overlaps slightly with E. platypus var. heterophylla. Melaleuca lanceolata 3 m to 4 m tall is a common understorey, and combinations of Poa tussocks, Trachmene pilosa, Carpobrotus virescens and Cheilanthes tenuifolia make up the herbaceous layer, though this layer is largely absent in the densest forests, where there are thick layers of litter. The E. angulosa forest was a major community on sand and near the migmatite before the hot 1972/73 and 1977 fires killed almost all of it.

austrotenuifolia

Eucalyptus cornuta Open forest/? Closed forest

The few small stands of E. cornuta were often mixed with E. conferruminata and trees that are intermediate between E. cornuta and E. conferruminata in fruit and inflorescence characters.

The populations ranged in height from 8 m to over 14 m and many of the trees were over 13 m high with unbranched boles more than 8 m high. The litter beneath the trees was often several decimetres deep. The understorey of Lepidosperma gladiatum, Bossiaea dentata, Leucopogon interruptus, Acacia myrtifolia, Agonis marginata and the only flowering Kennedia nigricans found on the island in 1973 was the most diverse forest understorey of any on the island. Until they were all destroyed by the 1977 fire, E. cornuta communities were restricted to soils at the bases of the south central migmatite, the western ridge and Flinders Peak.

Eucalyptus conferruminata Low open forest

Where in mixed stands with E. cornuta, E. conferruminata was often a tall, broadly branched tree, but in the extensive, monospecific stand, now totally burnt out by the 1977 fire, it formed a 4 m to 5 m tall, dense stand of poles a few centimetres in diameter, narrowly branching only near the top. Towards the centre of the community there was no understorey, only a deep litter of dead twigs and branches. Elsewhere the litter was mixed with an almost impenetrable mixed thicket of Leucopogon sp. and Acacia nigricans.

Eucalyptus platypus var. heterophylla Open forest/Low open forest/Open scrub

Because E. platypus communities have a similar appearance and composition to E. angulosa communities they can easily be confused with them, particularly on the 1:40 000 scale aerial photographs. However, E. platypus communities occur mainly on travertine or limestone, from which E. angulosa is absent except on sand at the edge of the E. platypus stands or as an occasional understorey plant within certain stands of E. platypus. The E. platypus forest is one of the major associations on the island, especially in the area of the 1972/73 burn. The stands are of trees commonly 6 m to 10 m high, with mallee-like branching sometimes to the base, but one stand at the edge of the 1972/73 burn is 15 m tall.

Granitic rock vegetation: bare or with lichens, low scattered shrubs, small shrub or herbaceous vegetation, seasonal pools or small shrub and heath communities, often dense but all too small to map individually

Most of the minute, ephemeral plants of the island are in the moss and mat swards and seasonal pools on the migmatite outcrops. Species of Centrolepis, Chara (or Nitella), Isolepis, Myriophyllum, Glossostigma, Triglochin and orchids not previously recorded from the archipelago were collected from these communities. The dominants of the moss and herbaceous plant communities are no more than a few centimetres tall and include a cushion form of

Juncus bufonius, Centrolepis spp., Isolepis spp. and Apium prostratum annuum.

Gastrolobium bilobum - Acacia spp. Open heath

A shrub community that is dominated by Gastrolobium bilobum and two species of Acacia, A. nitidula and A. cyclops, occupies rocky, possibly ironstone ground southwest of and below Flinders Peak.

Phebalium rude is common in the community, and Hakea suaveolens is present as a 4 m to 6 m tall emergent in the northern and eastern part of the community and gives way to Allocasuarina as an emergent in the south. Over 90% of this community was a casualty of the 1977 fire.

Mixed Granitic Rock Heath (Closed heath/Open heath/Low shrubland)

The commonest heath community on the granitic monadnocks is dominated by Astartea fascicularis that varies in height from 0.5 m to 3 m and frequently has a projective foliage cover of more than 70%. It frequently forms pure stands with no understorey, especially on Willis Ridge. On the northeast point it is largely replaced by severely wind-pruned, low, dense communities of Leucopogon revolutus, Eutaxia obovata, Dodonaea oblongifolia, Calytrix tetragona, Hakea clavata and other species. The heaths on Flinders Peak and on the western ridge are more heterogeneous, with communities of Astartea, a few of Leucopogon spp. mixed with Dillwynia pungens, impenetrable thickets of Hakea suaveolens, the common Kunzea baxteri, almost solitary individuals of Anthocercis viscosa and the abundant Melaleuca globifera and Agonis marginata. It is impossible to characterise a typical granitic heath; there is none. The above species and communities are variously intermingled and combined with each other and with numerous other shrubs such as Allocasuarina trichodon, Callitris preissii, Acacia myrtifolia and A. nitidula.

Mixed Limestone Heath (Closed heath/Open heath)

The Limestone heath covers much of the two limestone points and is more uniform and continuous than the granitic heath. It grades into the Melaleuca pentagona open scrub though is generally lower, between 0.5 m and 2 m high. The dominants are several; they vary in proportion and include Melaleuca pentagona, Melaleuca brevifolia, Melaleuca lanceolata, Acacia anceps var. angustifolia, and Spyridium spp. Phebalium rude is a common component of a lower stratum. Much of this climax association disappeared in the 1972/73 fire.

Quartzite Heath (Open heath)

The quartzite heath, where best developed, has an overstorey of shrubs between 1 m and 2 m tall, with dominance shared among Melaleuca globifera, Agonis marginata, Calothamnus quadrifidus and a shrubby form of Eucalyptus conferruminata. The proportions of these species, and of the locally common Allocasuarina ?trichodon, vary widely within the heath communities, but overall, M. globifera accounts for about 50% of the cover. C. quadrifidus is not only a codominant in the

overstorey but is also a common understorey component, a status shared with Phebalium rude, Dillwynia pungens and Hibbertia pungens. Except for scattered plants of Stylidium glandulosum and Waitzia citrina, there is no herbaceous layer and little litter. The substrate for quartzite heath is a soil-free layer of highly reflective, angular stones too large to be called gravel. The association is restricted to three or four pockets of such substrates near the south coast, south of Flinders Peak. Most stands of quartzite heath were consumed in the 1977 holocaust.

Sand-dune Heath (Open heath/Closed heath)

Sand-dune heath is usually limited to a narrow belt on the foredunes, mixed and variable in species composition, height and density but generally under 1 m high and with a projective foliage cover of 30% to 70%. The dominants include Acacia rostellifera, Scaevola crassifolia, Pimelea ferruginea, Westringia dampieri, Olearia axillaris and Spyridium globulosum, with Poa porphyroclados and Stipa flavescens commonly beneath. Where Melaleuca lanceolata stands, usually mixed and 2 m high, are growing on the seaward side of the foredunes they are designated sand-dune heath. There are a couple of stands of sand-dune heath too small to map associated with blow-outs near the south coast that are designated "S" on the map. Another type of sand-dune heath is represented by a community near the southern tip of the southeast point. It is under 1 m high and has a projective foliage cover of 70% to 90%. The dominant shrubs, Westringia dampieri, Pimelea ferruginea, Phebalium rude, Olearia axillaris and Myoporum insulare, are interspersed with Frankenia tetrapetala and Threlkeldia diffusa and other succulents, which contribute much of the high cover value to this community. Isolepis nodosa is common in the community and, with the low succulents, extends down into the Calocephalus brownii low shrubland.

Limestone cliff catena

The vegetation of the limestone cliffs, more than of most other sites, is a series of inter-related, over-lapping pieces of a mosaic. It is mostly open heath, low shrubland tussock grassland and Lepidosperma gladiatum. Limestone ledges, caves and seepages produce micro-associations that are rare or absent elsewhere on the island. It is interesting that the low species of the Pink Lake shore - Frankenia tetrapetala, Samolus repens and Isotoma scapigera - also occur here. Alyxia buxifolia, a white-flowered form of Lobelia alata var. alata and Pomaderris oraria were found only on these cliffs. It was within this community that Willis (1953) collected two indigenous Middle Island species that were then new records for Western Australia, Pomaderris oraria and Haloragis acutangula. A conspicuous and common shrub near the base of the cliffs is Atriplex cinerea.

Leucopogon revolutus Closed heath/Open heath

Leucopogon revolutus heath is commonly associated with the granitic monadnocks and outcrops, is on gravel adjoining them and is on sand overlaying the rock. The largest community of it, an almost monospecific stand, is at the southern edge of the

north-central granitic outcrop. The projective foliage cover of this dense stand was estimated to be close to 90%. The stand has no understorey.

Pink-Lake-Strand Vegetation

This narrow belt is only marginally mappable and is itself made up of narrower, concentric though interrupted belts. An idealised transect running inland from the lake's edge would pass through stands of Samolus repens and Salicornia australis, Isotoma scapigera, Frankenia tetrapetala, Juncus kraussii, Gahnia trifida and Pultenaea obcordata. The idealised transect would be a composite of transects run perpendicularly from various points around the lake's margin.

Melaleuca globifera Low open forest

Most of the Melaleuca globifera low open forest is in the northeast quadrant of the island, where it attains heights of more than 10 m. More commonly it is between 4 m and 6 m tall and is usually found in the neighbourhood of migmatite and on inner dunes. Where it comes close to the sea further west along the north coast it is a windswept, low closed forest or closed scrub only 2 m tall. On Willis Ridge it is associated with Eucalyptus angulosa in a forest that has practically no understorey, and on Flinders Peak M. globifera communities range from under 1 m to over 4 m in height with 50% - 90% projective foliage cover. The densest communities are monospecific, with thick litter layers and no understorey, but even the more open stands, with shared dominance, have little low undergrowth.

Melaleuca lanceolata Low open forest

Melaleuca lanceolata is the most widespread tree or large shrub on the island. Not only is it the dominant in extensive stands, it is also a common tall understorey in the Eucalyptus angulosa and E. platypus communities and a major component of some of the limestone heath and the sand dune heath. The stands of M. lanceolata low open forest are similar to the contiguous populations of M. lanceolata understorey in the Eucalyptus forests except that the Eucalyptus overstorey is absent. The understorey is usually almost absent, and the majority of M. lanceolata forest was missed by both the 1972/73 and 1977 fires.

Melaleuca pentagona Scrub

Previously a major community on the eastern half of the island, the Melaleuca pentagona community was destroyed by the 1972/73 fire. It was probably closed scrub to open scrub with a common height of about 2 m and the dominant vegetation on sand over limestone on the high plateau bordering the cliffs on the south coast. Scrubs of Eucalyptus angulosa were scattered within the community. In November 1973 most of the ground within the community was still bare or with only small seedlings and some regeneration from rootstocks or stem bases. M. pentagona continues south down the southeast point at a height of 0.5 m to 1.5 m but is here considered to be a member of mixed limestone low shrubland.

Pimelea clavata Open heath

Where Pimelea clavata is not an understorey of Acacia rostellifera and Melaleuca globifera it forms pure stands at the edges of these communities and bordering Leucopogon revolutus. Like the Acacia rostellifera, much of it is dead for an unexplained reason, and other populations of it were burnt in the 1972/73 and 1977 fires.

Sand vegetation Bold

Most of the sand communities shown on the vegetation map are sparsely vegetated or barren beaches plus their bordering dunes where these are too narrow to be shown seperately. The dunes are dotted with sand-dune heath, the beaches with Euphorbia paralias, Cakile maritima, Spinifex hirsutus, Sporobolus virginicus, Arctotheca populifolia and Senecio lautus. The category also includes two sets of inland dunes, blow-outs, that bear dune heath on their margins.

Seasonal swamps Bold

The seasonal swamps are ~~one of~~ among the few mature associations eliminated from the island by the 1972/73 fire. The communities embraced by the swamps before that fire are unknown, and certainly some of the species that are most abundant in the swamps now were not evident before the fire. These latter include Rulingia cygnorum, Dichondra repens and Sida hookerana. Villarsia parnassifolia, now common, was not found by Willis (1953). More characteristic swamp species present are Baumea juncea, Isolepis nodosa and Isolepis marginata.

DISTRIBUTION

Eucalyptus and Melaleuca forests characterize the central lowlands and the broad, shallow north-south oriented trough of the island, the northern slope of the limestone and the skirts of the granitic monadnocks, and the otherwise unbroken spread of the forests in the central lowlands is interrupted only by several discrete, mostly small, stands of Acacia rostellifera, by small migmatite outcrops in the proximity of the pink lake and by the pink lake itself. Four species of Eucalyptus — E. angulosa, E. platypus var. heterophylla, E. conferruminata and E. cornuta — and two of Melaleuca — M. lanceolata and M. globifera — in some instances and combinations share dominance but more commonly are single dominants of mutually exclusive, clearly delineated stands.

The distribution of forest associations on Middle Island appears to be closely correlated with soil patterns and the underlying parent material, an appearance that is supported by field observations and published information on the rock/soil types associated with some species (Chippendale 1973). Although investigations sufficiently detailed to determine the nature and degree of correlation are lacking, some generalizations can be made. In particular, E. platypus stands are mainly limited to the lower, soil-covered limestone slopes and E. angulosa stands to lower-lying sandy soil north of the limestone and between the main granitic ridges, distributions that reflect the edaphic preferences of the two dominants on the mainland (Chippendale ibid.). E. platypus and E. angulosa,

single dominants in most of their stands, occur together only in narrow ecotones, primarily where the lowland sand overlaps the lower margin of the limestone.

The Eucalyptus conferruminata forest was of two distinct types, the more common one being a dense stand of relatively short, straight, narrow-stemmed trees with a moderately dense Acacia understorey on what appears to be a sandy-loam soil over-lying quartzitic/granitic rock in a broad, shallow depression between two granitic ridges. E. cornuta shared dominance in the less common but more impressive E. conferruminata/E. cornuta forest on the damp loamy soils and deep humus at the base of the granitic ridges and near the old wells. The differences between the E. conferruminata associations and the other Eucalyptus communities are not solely edaphic; the shrub layer under the former is well-developed, often dense, the latter usually have only low herb layers mainly. Their recent histories are also different; the stands of both E. conferruminata associations were almost totally consumed by the 1977 fire, which little-affected the several E. angulosa and E. platypus communities that survived the 1972/73 fire.

Melaleuca lanceolata, occurring as it does as a forest dominant, as a tall understorey of E. platypus forest and as a dominant or co-dominant in dense scrub communities on the south coast limestone, has a more widespread and complex distribution than have any of the eucalypts. There is no apparent correlation between the distribution of this species and of the soil and parent material on which it is found. M. globifera forests and shrublands seem to be fairly closely restricted to soil-filled channels and pockets on the migmatite and shallow, rocky, sometimes sandy soil near the base of migmatite outcrops and on quartzitic and other metamorphic parent material. Not so complex and diverse as the communities of which M. lanceolata is a member, the M. globifera communities do, however, vary more and cover a wider range of soils than any of the Eucalyptus associations.

More complex floristically, more variable and more difficult to define are the heath and shrub communities. These communities can, however, be grouped into six or more sets on the basis of their species compositions and edaphic/parent material substrates. These are the granite associations, the quartzite heaths and shrublands, the limestone heath and cliff catena, the Gastrolobium/Acacia open heath on red-brown, lateritic, possibly quartzitic gravel, the heath on the stabilized dunes and the taller shrub communities near the pink lake, though these last may be only a seral stage. There is also an association of low, succulent, chenopodiaceous plants on and just below granite surfaces above the ocean splash level, which might be considered heath or scrub and might be considered as separate from the granite group. Some of the chenopods are more appropriately considered herbaceous where they occur, with Samolus repens, as a mat adjacent to the pink lake. Three types of sedge heath or herbland are represented by stands near the pink lake and in a seasonal swamp in the northeastern corner of the island.

DISCUSSION

Until the fires of recent years, the islands off the southwest coast presented an excellent, but underexploited, opportunity to study vegetational characteristics of forests similar to what may have existed on the mainland prior to colonization by Europeans. There was no better island in the Recherche Archipelago for such an endeavour than Middle Island, the largest in the group and one of the few with no introduced animals and few alien plants. The absence of any remains of post-fire species (e.g. Alyogyne hakeifolia) prior to the 1972/73 burn, the paucity or absence of charred wood except near the summit of Flinders Peak, near old campsites and, rarely, below the deep accumulation of litter in Melaleuca lanceolata forest, all lend support to the hypothesis that the island had not had a major fire since before Robert Brown collected there almost two centuries ago and that the still unburnt vegetation was in a climax state. This is further indicated by the demographic studies of Melaleuca lanceolata forest by Hopkins and Trudgen reported upon elsewhere in this volume.

Thus far the synecological investigations of Middle Island communities have concentrated upon the forests, the associations most readily defined. Several conclusions about the indigenous forests that can be drawn from the Hopkins and Trudgen demographic studies (op cit.) and from observations of community composition and structure, conflict with observations and conclusions about comparable mainland communities. The following three conclusions relate to the M. lanceolata associations and the Eucalyptus forests with sparse understoreys. Firstly, the Hopkins and Trudgen studies indicate that the low open forests of M. lanceolata are stands of climax vegetation and not a seral stage in the successional development of eucalypt forest, as postulated by Beard (1973) for mainland situations. Secondly, climax forests of E. platypus and E. angulosa on the island typically have an herbaceous, not a shrubby, understorey, often composed mainly of Poa porphyroclados. No comparable community has been found on the mainland by either of the authors, and it is suggested that grazing by livestock and rabbits plus frequent fires with subsequent invasion by alien grasses and other weeds have prevented the persistence and regeneration of Poa tussock grasslands under eucalypt forest in the southwest[3].

It is obvious on Middle Island that fire, far from being important in the maintenance of an open understorey, has quite the opposite effect. Early, as yet tentative, conclusions are that many years, probably decades, without another fire will be

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[3] The Middle Island tussock grass understorey communities, possibly totally destroyed by the 1977 fire, plus a few similar, smaller communities on some other islands of the Recherche, are probably the last remaining Eucalyptus grassy open forests (see "grassy woodland", Specht, 1970, pp 55, 56) in southwestern Australia. The claim made before the Middle Island fires that a stand of tuart forest near Busselton was "the only savanna forest in the state" (Gardner 1973, p 91) was inaccurate or misleading on two counts even if revised to include

only the southwest. First, natural grassy forests did exist on Middle Island at that time, and, second, the grasses of the tuart forest are aliens. Should the tuart forest be accepted as a "savanna" so too must be Kings Park and other Metropolitan woodlands with predominantly veldt grass understories.

x This is part of Footnotes and should go with it on the previous page. ?? check

necessary for the reestablishment of Eucalyptus forest with Poa porphyroclados understorey. Where the Eucalyptus/Poa communities regenerate is a function of where the communities existed prior to the fires, of the availability of propagules and of various edaphic factors, soil moisture, texture, depth and slope and the nature of the parent material.

REFERENCES

Beard, J.S. (1973). Vegetation Survey of Western Australia 1:250 000 Series : The Vegetation of the Esperance and Malcolm Areas, memoirs p. 37 (Vegmap Publications : Perth).

Beard, J.S. and Webb, M. (1974). The Vegetation Survey of Western Australia, its aims, objects and methods. Part I of Great Sandy Deserts, Explanatory Notes to Sheet 2, Veg. Survey W.A. 1:1 000 000 Series. (Univ. of West. Aust. Press : Nedlands).

Chippendale, G.M. (1973). Eucalypts of the Western Australian Goldfields (and the adjacent wheatbelt) pp. 57, 58, 172, 173 (Australian Government Publishing Service : Canberra).

Gardner, C.A. (1973). Wildflowers of Western Australia 11th Edition. (West Australian Newspapers Ltd. : Perth).

Kuchler, A.W. (1967). Vegetation Mapping p. 89 (Ronald Press : New York).

Muir, B.G. (1977). Vegetation and habitat of Bendering Reserve. Part 2 of Biol. Survey of West. Aust. Wheatbelt. Rec. West. Aust. Mus., Suppl. No. 3.

Smith, F.G. (1972). Vegetation Survey Western Australia, Vegetation Map of Pemberton and Irwin Inlet (Western Aust. Dept. Agric. : Perth).

Smith, F.G. (1973). Vegetation Survey of Western Australia, Vegetation Map of Busselton and Augusta. (Western Aust. Dept. Agric. : Perth).

Specht, R.L. (1970). In G.W. Leeper (Ed.) "The Australian Environment" pp. 46, 55, 56 (C.S.I.R.O. in assoc. with Melb. Univ. Press : Melbourne).

Specht, R.L. (1972). The Vegetation of South Australia 2nd Edition. (Govt. Printer : Adelaide).

Willis, J.H. (1953). 'Archipelago of the Recherche, pt 3a - Land Flora.' Repts. Aust. Geog. Soc. (Melbourne) No. 1.

TABLE 1.

STRUCTURAL PLANT FORMATIONS

Life-form and height of tallest stratum	Projective foliage cover of tallest stratum, as %	Description
Trees over 30 m	70–100	High closed forest
	30–70	High open forest
	10–30	High woodland
	under 10	High open woodland
Trees 10–30 m	70–100	Closed forest
	30–70	Open forest
	10–30	Woodland
	under 10	Open woodland
Trees under 10 m	70–100	Low closed forest
	30–70	Low open forest
	10–30	Low woodland
	under 10	Low open woodland
Shrubs over 2 m	70–100	Closed scrub
	30–70	Open scrub
	10–30	High shrubland
	under 10	High open shrubland
Shrubs up to 2 m	70–100	Closed heath
	30–70	Open heath
	10–30	Low shrubland
	under 10	Low open shrubland
Herbs	70–100	Closed herbland, Closed grassland, Closed sedgeland,
	30–70	Herbland, Grassland, Sedgeland,
	10–30	Open herbland, Open grassland, Open sedgeland,

Not cleared (95W)

Table 1. Structural Plant Formations

Life-form and height of tallest stratum	Projective foliage cover of tallest stratum, as %	Description
Trees over 30 m	70-100	High
	30-70	High open forest
	10-30	High woodland
	under 10	High open woodland
Trees 10-30 m	70-100	Closed forest
	30-70	Open forest
	10-30	Woodland
	under 10	Open woodland
Trees under 10 m	70-100	Low closed forest
	30-70	Low open forest
	10-30	Low woodland
	under 10	Low open woodland
Shrubs over to 2 m	70-100	Closed scrub
	30-70	Open scrub
	10-30	High shrubland
	under 10	High open shrubland
Shrubs up to 2 m	70-100	Closed heath
	30-70	Open heath
	10-30	Low shrubland
	under 10	Low open shrubland
Herbs	70-100	Closed herbland
		Closed grassland
		Closed sedgeland
	30-70	Herbland
		Grassland
		Sedgeland
	10-30	Open herbland
		Open grassland
		Open sedgeland

Table 2. Index to Plant Associations

AL	Albizia lophantha community
AR	Acacia rostellifera open scrub
CB	Calocephalus brownii low shrubland
CP	Callitris preissii low closed forest
EA	Eucalyptus angulosa open forest/low open forest/open scrub
EC	Eucalyptus cornuta open forest/?closed forest
EL	Eucalyptus ~~lehmannii~~ low open forest
EP	Eucalyptus platypus var. heterophylla open forest/low open forest/open scrub
G	Granitic ~~associations:~~ bare or with lichens, low scattered shrubs, herbaceous vegetation, seasonal pools or small shrub or heath communities, often dense but all too small to map individually
GA	Gastrolobium bilobum-Acacia spp. open heath
HG	Mixed ~~granite~~ heath (closed heath/open heath/low shrubland)
HL	Mixed limestone heath (closed heath/open heath)
HQ	Quartzite heath (open heath)
HS	Sand-dune heath (Open heath/closed heath)
LC	Limestone-cliff catena
LR	Leucopogon revolutus closed heath/open heath
LS	Pink-lake-strand vegetation
MG	Melaleuca globifera low open forest
ML	Melaleuca lanceolata low open forest
MP	Melaleuca pentagona scrub
PC	Pimelea clavata open heath
S	Sand
SS	Seasonal swamps

PART IV THE VERTEBRATE FAUNA

BY A. TINGAY AND S.R. TINGAY

INTRODUCTION

Although the long and colourful history of Middle Island has included a number of visits by early explorers and botanical collectors, as well as sealers, survivors of shipwrecks and salt miners (see Part I of this publication) early records of the fauna are few. Flinders (1814, p 88) recounted "...A small species of kangaroo seemed to be numerous on Middle Island, in parts thickly covered with brush wood and small trees, though none were caught.", and noted the presence of Little Penguins *(Eudyptula minor)* and Cape Barren Geese *(Cereopsis novaehollandiae)* on nearby Goose Island.

The recollections of T.C. Andrews, resident on the island in 1890 (in Andrews 1959), are the next account, but it was not until 1904 that the first systematic observations were made by J.T. Tunney, who was collecting for the Western Australian Museum (see Whittell 1938). The island was subsequently visited by D.L. Serventy in June 1948 and the Australian Geographical Society expedition in November 1950 (Serventy 1952, 1953, Glauert 1954). Although the visit of the A.G.S. lasted only two days, it added considerably to knowledge of the flora and fauna, both

The present survey occurred during an eleven day visit from 5 to 16 November 1976 made in conjunction with officers of the Western Australian Department of Fisheries and Wildlife. A preliminary evaluation of the effect of the 1972/73 fire on the population of the Tammar Wallaby *(Macropus eugenii)* was also undertaken; the results of that study are reported in Part VII of this publication. During the survey, one amphibian, eleven reptile, thirty-one bird and two mammal species were located. An annotated list of all vertebrate species recorded from Middle Island is given below.

AMPHIBIA AND REPTILES

The only herpetelogical record from Middle Island prior to the visit of the Australian Geographical Society (A.G.S.) in 1950 was of the skink, *Ctenotus labillardieri*. That expedition failed to locate this species again but added one amphibian and six other reptiles to the list (Glauert 1954). Incidental collecting has occurred since then and various specimens are lodged in the Western Australian Museum as a result.

LIST OF SPECIES

AMPHIBIA

HYLIDAE

Litoria cyclorhynchus (Boulenger) Spotted-Thighed Frog.

This large frog has a distribution along the south coast of W.A. including Mondrain Island within the

Archipelago of the Recherche. The A.G.S. expedition in 1950 collected it from Middle Island and the present authors found it in shallow pools in depressions on exposed granite.

REPTILIA

GEKKONIDAE

Phyllodactylus marmoratus (Fitzinger) Marbled Gecko

First noted by H. Bakker in 1974 (WAM 47659), this species was common under exfoliating granite during the present survey.

Phylurus millii (Bory) Thick-Tailed Gecko

This species was not located by the A.G.S. expedition but was subsequently collected by A. Weston when the plant ecology studies were initiated in 1973 (WAM 45597). During the present survey it was common under exfoliating granite particularly on Flinders Peak.

AGAMIDAE

Ctenophorus ornatus (Gray) Ornate Dragon

Certainly the most conspicuous reptile on Middle Island, the Ornate Dragon was very common on granite outcrops where it sheltered under exfoliating rocks.
A Brown Goshawk, *Accipiter fasciatus*, was observed predating Ornate Dragons on Flinders Peak.

There is a description of the insular form in Glauert (1954) from specimens collected on Mondrain Island and

this corresponds with individuals on Middle Island. It was originally located by the A.G.S. expedition (WAM 1963/65).

VARANIDAE

Varanus rosenbergi (Mertens)

The presence of a large goanna on Middle Island was first noted in 1890 by T.C. Andrews (in Andrews 1959). It was again sighted by Willis during the A.G.S. expedition but was not caught and its identity remained unknown.

The present authors caught and examined two individuals, one in mixed limestone heath and one in *Melaleuca globifera* scrub, and others were sighted elsewhere. It appeared to be common throughout the island.

SCINCIDAE

Cryptoblepharus virgatus (Garman)

A specimen of this small skink was collected on Middle Island by H. Bakker in November 1974 (WAM 47626). It was not located during the present survey.

Ctenotus labillardieri (Duméril and Bibron)

This species was first collected on Middle Island by J.P. Whitley in 1944 (WAM R8684). It was not recorded during the A.G.S. expedition or by subsequent visitors. Two individuals were located during the present survey,

one on Flinders Peak and another on North East Point, both on exposed granite. The species does not appear to be common.

Egernia kingii (Gray) **King's Skink**

This large skink was common in the eucalypt and melaleuca forests at the base and on the slopes of Flinders Peak, where it sheltered under large granite boulders. A number of dead individuals were located at the base of Flinders Peak following the fire of 1977 (Hopkins pers. comm. 1979). It was first collected on Middle Island by M.C. Ellis in 1973 (WAM 41[illegible]).

Egernia napoleonis (Gray)

E. napoleonis was collected by H. Bakker on Middle Island in 1974 (WAM 47657). During the present survey it was common only under exfoliating granite on the slopes of Flinders Peak and among rounded boulders on the beach of Goose Island Bay.

Hemiergis peronii (Fitzinger)

Although this species was noted during the short visit of the Australian Geographical Society, only one individual was located during the present survey. This specimen was found under exfoliating granite in the central granite outcrop of the island.

Leiolopisma trilineatum (Gray)

This species was collected by M. Ellis in 1973 (WAM 41916). It is the only record from Middle Island.

Morethia obscura (Storr)

The A.G.S. expedition obtained two individuals of this species (as *Ablepharus lineo-ocellatus*) from Esperance but none was observed on any of the islands. In the present survey, two *Morethia obscura* were caught under driftwood on the northern beaches of the island.

Tiligua rugosa (Gray) **Bobtail**

Two individuals of this species were found in regenerating *Melaleuca globifera - Eucalyptus angulosa* ~~formation~~ vegetation to the west of Lake Hillier.

It was recorded by the A.G.S. expedition on Middle, Mondrain, North Twin Peaks and Salisbury Islands.

ELAPIDAE

Notecty's coronatus (Schlegel) **Crowned Snake**

Recorded by the A.G.S. expedition from Mondrain, Round and Christmas Islands, the Crowned Snake is also common on Middle Island. The species was originally collected there by M.C. Ellis in 1973 (WAM 41915) and subsequently by Bakker (WAM 47725). During the present survey, individuals were usually found under exfoliating granite particularly on Flinders Peak and one was sighted in a *Eucalyptus angulosa* ~~formation~~ vegetation.

DISCUSSION

The herpetofauna of Middle Island now stands at fourteen species including one frog, twelve lizards and one snake. The present expedition located one species previously unrecorded for the island and also confirmed the identity of the varanid lizard known to occur there. The total is only exceeded by Mondrain Island in the Archipelago of the Recherche with species.

PART IVA

BIRDS

Middle Island has been visited at least three times in the last century by bird observers and collectors; Tunney in 1904 (see Whittell 1938), D.L. Serventy in June of 1948 (see Serventy 1952) and the Australian Geographical Society (A.G.S.) expedition on 22 November 1950 (Serventy 1952). The results of the surveys were summarised in Serventy's paper. Earlier records are provided by the accounts of Flinders (1814) and Andrews (1959).

The present survey was the longest so far and thirty-one species of birds were recorded. This included fourteen new records for Middle Island and two new records for the Archipelago of the Recherche. Five species listed by Serventy (1952) were not recorded. The present overall total of birds recorded on the island is 37 compared with

a total of 64 for the Archipelago of the Recherche. This is the highest total yet recorded for any of the islands. These totals may be compared with the more than 100 species recorded for the adjacent mainland by Sedgwick and Sedgwick (1950) and Dell (1975).

The nomenclature in the species list follows

LIST OF SPECIES

PROCELLARIIDAE

Pterodroma macroptera (Smith) **Great-winged Petrel**

The first record of this species nesting in the Archipelago of the Recherche was made on Goose Island just north of Middle Island by Thomson and Shipway (1948). The A.G.S. expedition recorded it as nesting on a further five islands: Boxer, Figure of Eight, Douglas, Termination and Christmas.

On Middle Island, burrows of this species (confirmed by the location of 4 dead specimens adjacent to burrows) were found in shallow sandy soils above the high limestone cliffs of the southern coast. A straight line transect of approximately 150 m intercepted 52 burrows. As very little of the south coast was surveyed, this indicates that the nesting population on the island during winter may be quite large.

PODICIPEDIDAE

Poliocephalus poliocephalus (Jardine & Selby) **Hoary-headed Grebe**

Serventy (1952) notes a sighting by a member of the A.G.S. expedition of this species on Lake Hillier. It was also mentioned in the notes of Andrews from 1890. Hoary-headed Grebes are nomadic and these sightings would be of occasional visitors. They were not present during the present survey.

PHALACROCORACIDAE

Phalacrocorax carbo (Linnaeus) **Black Cormorant**

A single Black Cormorant was observed standing on a granite promontory into the sea on the north side of the island.

Phalacrocorax fuscescens (Vieillot) **Black-faced Cormorant**

A breeding colony of this species located at the foot of Flinders Peak on the north shore was described and photographed by Serventy (1952). The colony was also known to T.C. Andrews in 1890 and was present and active during the present survey 86 years later. Cormorant Cove was named because of the presence of this colony.

ARDEIDAE

Egretta sacra (Gmelin) **Reef Heron**

A single Reef Heron was resident in the small rocky bays of the northwest coast throughout the survey period.

ANATIDAE

Tadorna tadornoides (Jardine and Selby) **Mountain Duck**

A pair of Mountain Ducks was sighted on the northern beach of the island. This is the first record of the species for the Archipelago of the Recherche but it regularly visits and nests on other islands off the coast of Western Australia.

ACCIPITRIDAE

Accipiter fasciatus (Vigors and Horsfield) **Brown Goshawk**

An active nest of this species was discovered in a tall tree of *Eucalyptus platypus* and individual birds were seen over the regenerating vegetation on the eastern part of the island, roosting in small trees overlooking the southern limestone cliffs, and on the summit of Flinders Peak. It is likely, therefore, that one or two pairs were resident on the island. One was seen with an adult Ornate Dragon *(Ctenophorus ornatus)* in its talons.

Haliaetus leucogaster (Gmelin) **White-breasted Sea-eagle**

At least one pair of Sea-eagles were based on Middle Island during the present survey although they were observed ranging beyond Goose and Miles Islands to the north. Two inactive nests were located, both in the Tate forest *(Eucalyptus cornuta)* on the slopes of Flinders Peak, but only one had any appearance of recent use.

Aquila audax (Latham) **Wedge-tailed Eagle**

Andrews (1959) mentions this species as nesting on Middle Island in 1890 and Serventy (1952) sighted an individual in 1950. None were seen during the present survey and it is probably an occasional visitor from the mainland.

Circus aeruginosus (Linniaus) **Swamp Harrier**

A single Swamp Harrier was sighted flying along the northern coast of the island. In Tasmania this species is known to be capable of moving long distances and of crossing the ocean to the mainland (Templeman 1974). The individual sighted may have been such a nomad or a visitor from the mainland (9 km to the north). An individual has also been sighted over Woody Island, which is approximately 5 km from the mainland (Goodsell, *et al.* (1976)).

FALCONIDAE

Falco cenchroides (Vigors and Horsfield) **Nankeen Kestrel**

A Nankeen Kestrel was observed hovering over the mixed limestone heath formation in the south-east of the island.

PHASIANIDAE

Coturnix australis (Latham) **Brown Quail**

The Brown Quail has been positively or tentatively recorded on a number of islands of the Archipelago of the Recherche and its presence on Middle Island was suspected from the accounts of Andrews from 1890. The present authors had a good sighting of an individual in mixed granitic heath on Miles Island Point but the species did not appear to be common

HAEMATOPODIDAE

Haemantopus fuliginosus (Gould) Sooty Oystercatcher

This species is common throughout the Archipelago of the Recherche. Small groups were always present on the sandy beaches and rocks of the northern coast of Middle Island.

CHARADRIIDAE

Vanellus tricolor (Vieillot) Banded Plover

D.L. Serventy recorded two birds on Lake Hillier in July 1947 (Serventy 1952). It has not been recorded by any subsequent expedition including the present survey and undoubtedly is an occasional visitor.

Charadrius ruficapillus (Temminck) Red-capped Plover

Previously recorded from the shores of Lake Hillier by Serventy (1952), flocks of up to 30 birds were observed during the present survey in the same location. Smaller groups were seen feeding in front of the tide on the sandy beaches.

ARENARIIDAE

Arenaria interpres (Linnaeus) Turnstone

This and the following three wader species arrived on the northern sandy beaches following three days of rough weather accompanied by strong westerly winds. Only three individuals were sighted. Serventy (1952) recorded 30-40 on Termination and six on Westall (Combe) Island.

SCOLOPACIDAE

Tringa hypoleucos (Linnaeus) Common Sandpiper

A single Common Sandpiper was sighted on a low granite promontory on the north coast. It has previously been recorded from Woody Island (Goddsell *et al.* 1976) and Mondrain Island (Abbott and Black 1978).

Tringa brevipes (Vieillot) Grey-tailed Tattler

A new record for the Archipelago of the Recherche, a single Grey-tailed Tattler was observed feeding on the sandy shore in the company of Red-capped Plovers, Red-necked Stints and Turnstones.

Calidris ruficollis (Pallas) Red-necked Stint

Serventy (1952) recorded groups of up to 30 birds of this species on four islands of the Archipelago of the Recherche and groups of 200-300 at Israelite Bay on the mainland. The maximum number we recorded on Middle Island, where it had not been previously sighted, was seventeen. Like the other waders, these were feeding on the sandy beaches of the north coast.

LARIDAE

Larus novaehollandiae (Stephens) Silver Gull

An uncommon species on the islands of the Archipelago of the Recherche, the Silver Gull was recorded by Serventy (1952) as possibly nesting on Middle Island. A small flock with a maximum of 28 birds was recorded during the present survey. Two birds were seen feeding on drowned termites on the edge of Lake Hillier.

Larus pacificus (Latham) **Pacific Gull**

This species was always present on the sandy beaches and granite headlands and a nest with two eggs was located. Serventy (1952) also found a nest with two young.

Hydroprogne caspia (Pallas) **Caspian Tern**

Caspian Terns were often observed flying alone or in pairs over the beaches or just out to sea. Serventy (1952) recorded ~~it~~ the species from Middle Island and located a nest on nearby Goose Island.

Sterna nereis (Gould) **Fairy Tern**

A single bird and later a pair were observed fishing a few metres out from the northern beaches after three days of rough weather.

COLUMBIDAE

Phaps elegans (Temminck) **Brush Bronzewing**

A common species in all plant associations of the island, Brush Bronzewings were often observed drinking from the small freshwater pools that form in depressions on the granite outcrops. It was described by Serventy (1952) as not abundant so its numbers may have increased since his visit.

PSITTACIDAE

Glossopsitta porphyrocephala (Dietrichsen) **Purple-crowned Lorikeet**

A small flock of this species was recorded feeding on the flowers of *Eucalyptus cornuta* and *E. Lehmanii* on the lower slopes of Flinders Peak.

Neophema petrophila (Gould) **Rock Parrot**

An apparently uncommon species, it was observed in small flocks flying low over vegetation close to the beaches and at pools on the granite outcrops.

CUCULIDAE

Cacomantis pyrrhophanus (Vieillot) **Fan-tailed Cuckoo**

This cuckoo was common in the thick, regenerating *Melaleuca globifera* forests and was also recorded in the tall Yate *(Eucalyptus cornuta)* forest at the base of Flinders Peak. It has previously been recorded from Mondrain Island during April (Abbott and Black 1978).

ALCEDINIDAE

Halcyon sancta (Vigors and Horsfield) **Sacred Kingfisher**

D.L. Serventy recorded a single Sacred Kingfisher in the eucalypt forests of Middle Island in June 1948 (Serventy 1952). It has not been noted since and is no doubt a very occasional visitor.

HIRUNDINIDAE

Hirundo neoxena (Gould) **Welcome Swallow**

The Welcome Swallow occurs on most islands in the Archipelago of the Recherche. It is common on Middle Island, particularly over the mixed limestone heath, mixed granitic heath, and other associations regenerating after the 1972-73 fire.

ACANTHIZIDAE

Sericornis frontalis (Vigors and Horsfield) **White-browed Scrub-wren**

This species was plentiful at the time of the A.G.S. expedition in 1950. It was still abundant during the present survey, particularly where there was low and dense vegetation as in most of the regenerating areas, the heath communities, *Melaleuca globifera* low open forest and the *Eucalyptus cornuta* - *E. lehmanii* forest on the slopes of Flinders Peak.

MUSCICAPIDAE

Pachycephala pectoralis (Latham) **Golden Whistler**

Golden Whistlers appeared to be largely confined to tall plant communities such as the various unburnt eucalypt stands. A juvenile bird was sighted suggesting that this is probably a resident nesting species. Serventy (1952) suggested that Golden Whistlers may be confined to the larger islands of the Archipelago of the Recherche.

ZOSTEROPIDAE

Zosterops lateralis (Latham) Silvereye

Silvereyes were common throughout all plant associations. They were also recorded by Serventy (1952).

MELIPHAGIDAE

Meliphaga virescens (Vieillot) Singing Honeyeater.

Serventy (1952) recorded this species on Middle Island but provides no details. It was not present during the present survey.

Phylidonyris novaehollandiae (Latham) New Holland Honeyeater

Another very common species, individuals were observed in all plant associations. Serventy (1952) recorded family parties with fledged young.

Anthochaera carunculata (Shaw) Red Wattlebird

D.L. Serventy heard one individual of this species calling in eucalypt forest in June 1948. It has not been recorded by subsequent surveys.

ESTRILDIDAE

Emblema oculata (Quoy and Gaimard) Red-eared Firetail

Serventy (1952) noted that the records of Andrews from 1890 indicated that a species of finch was fairly common on Middle Island at that time. He suggested that this was most likely to be the Red-eared Firetail but was unable to confirm this hypothesis with a sighting.

A single Red-eared Firetail was first noted by the present authors at a small shallow pool on the granite outcrop surrounded by regenerating vegetation and just behind the base camp. Further individuals were sighted in the same situation on subsequent days but not in other associations. The species did not appear to be common.

CORVIDAE

Corvus coronoides (Vigors and Horsfield) Australian Raven

Pairs and small groups of up to four Ravens, including one recently fledged juvenile, were noted during the present survey in both the burnt and unburnt plant communities. Serventy (1952) recorded two birds but noted that Andrews referred to "black clouds" of this species in 1890. However, Dell (1975) commented that these may have been Little Crows *(Corvus bennetti)*, which are common on the adjacent mainland and more often congregate in large flocks than does the Australian Raven.

DISCUSSION

The total list of bird species recorded for Middle Island by all surveys and observations is shown on Table 1. Thus far, 37 species have been recorded, 20 of which are principally land-birds while the remainder prefer littoral or pelagic habitats.

Weston and Onus sighted a pair of White Owls in a cave on Flinders Peak in 1977. The species may have been the Barn Owl *(Tyto alba)* which has been recorded on Woody Island by Goodsell, *et al*. 1976. These, together with increasing records of visiting waders, indicate that the list of bird species for the island could increase with subsequent surveys. However, no new resident species is likely to be located and the number of these is, therefore, probably about 16 species, of which 11 are land birds. These details of status are shown on Table 1.

Of the 23 species previously recorded for the island, five were not seen during the present survey. However, fourteen previously unrecorded species were seen. These differences in species recorded during the present survey and previous ones may be largely attributed to the presence of nomadic and migratory species. Middle Island is only 9 km from the mainland at Cape Arid and it is possible that previously recorded species such as the Singing Honeyeater *(Meliphaga virescens)* and the Red Wattle-bird *(Anthochaera carunculata)* could cross a sea barrier of this distance and remain for short periods. The Hoary-headed Grebe *(Poliocephalus poliocephalus)*, Banded Plover *(Vanellus tricolor)*, Wedge-tailed Eagle *(Aquila audax)*, Sacred Kingfisher *(Halcyon sancta)*, Purple-crowned Lorikeet *(Glossopsitta porphyriocephala)* and Fan-tailed Cuckoo *(Cacomantis pyrrhophanus)* are almost certainly episodic visitors from the mainland.

The 11 land birds were nearly all recorded by Serventy in 1950 and a few were known to be present in 1890 from the records of Andrews. It would appear that no new species have colonized the island in the past 26 years except perhaps the Brown Goshawk *(Accipiter fasciatus)* and Nankeen Kestrel *(Falco cenchroides)*, but these may have been overlooked by Serventy who only remained on Middle Island for one day. No species except perhaps the Red-wattle Bird and Singing Honeyeater have become extinct on the island. The Red-eared Firetail appears to have persisted for 86 years.

MAMMALS

Middle Island has long been known to support a population of Tammar Wallaby *(Macropus eugenii)*. Matthew Flinders (1814, p.88) noted the presence of an apparently large population of a "small species of kangaroo" but the species was not identified until Tunney surveyed the island in 1904 (Whittell 1938). Serventy (1953) noted that the Andrews Brothers, who lived on Middle Island for about 9 months in 1890, claimed to have snared over 800 wallabies (see also Andrews 1959).

This did not seem to affect the population in the long-term as they still appeared to be numerous some 60 years later, at the time of the Australian Geographical Society expedition (Serventy 1953). The Tammar is now considered rare on the

Australian mainland but has been recorded on six offshore islands ~~(see Part ... of this publication)~~.

Apart from a reported sighting of a single ship rat *(Rattus norvegicus)* by Bowler (1958), no other mammals have been recorded for Middle Island. During the present survey, medium Elliott traps (32 cm x 10 cm x 8 cm) were set in the sand-dune heath, the *Melaleuca globifera* and *M. lanceolata* Low Open Forests and the *Eucalyptus* ~~cornuta~~ Open Forest units mapped by Weston and Trudgen (Part II of this publication). Cage traps (20 x 20 x 50 cm) and small Elliott traps (23 x 8 x 7 cm) were set in regenerating *E. angulosa* Open Forest with *Kennedia nigricans*, *M. globifera* Low Open Forest, regenerating *E. platypus* Forest with *M. lanceolata* and *Acacia rostellifera* and *A. rostellifera* Open Scrub with *Poa* understorey. A universal bait based on peanut paste was used.

LIST OF SPECIES

MARSUPIALIA

MACROPODIDAE

Macropus eugenii (Demarest) **Tammar Wallaby**

No individuals of this species were trapped but many were observed during the present survey, and a number of skulls were collected. The species appeared to be

common in all vegetation types. The results of a preliminary investigation of the abundance of Tammar Wallabies in the burnt and unburnt vegetation formations is reported separately in this publication.

RODENTIA

MURIDAE

Rattus fuscipes (Waterhouse) Southern Bush Rat

A skull of this species was found in a small rock hole at the base of Flinders Peak. The specimen is lodged at the W.A. Museum. No other evidence of the presence of this species was noted. It is possible that the rat seen by Bowler (1958) was actually this species.

CETACEA

DELPHINIDAE

Delphinus delphis (Linnaeus) Common Dolphin

A dead specimen was found stranded on the east coast of Middle Island.

CARNIVORA

OLARIIDAE

Neophoca cinerea (Peron and Lesueur) Australian Sea-lion

A single individual was observed swimming close to the shore on three occasions. No seals were observed on Middle Island but small numbers have been reported on Goose Island.

DISCUSSION

This survey has confirmed the presence of a few mammal species on and in the vicinity of Middle Island. The status of *Rattus fuscipes* on the island has not been determined. This species has been recorded for Mondrain, Hood and Woody Islands in the Archipelago of the Recherche, as well as for the adjacent mainland at Cape Le Grand (see Table 4).

Populations of *Rattus fuscipes* have been shown to recover after a fuel reduction burn within about 36 months in the Karri forest (*Eucalyptus diversicolor*, 1350 mm rainfall p.a.) (Christensen and Kimber 1975). The present survey was carried out some 46 months after the first severe wildfire on Middle Island (600 mm p.a.). If the island supported a viable population of *Rattus*, that fire, which burned only

half of the island, should not have caused extinction. Furthermore, sufficient time should have elapsed for recolonization of burnt areas. No animals were trapped in either burnt or unburnt formations; this suggests the species is not extant on Middle Island. It is possible that the specimen recovered was that of a chance immigrant perhaps brought by a nesting raptore.

CONCLUSIONS

The present survey has confirmed that Middle Island is probably the most faunistically diverse of all the islands in the Archipelago of the Recherche. Nevertheless, many vertebrate species recorded on other islands appear to be absent from Middle Island. This is probably due to differences in island size, topography, vegetation, time since isolation from the mainland, distance from mainland and distance from other islands and interaction effects of these variables.

With the paucity of information from the Archipelago, conclusions on the biogeography of its fauna are not warranted but there are two indications: (1) that the vertebrate fauna of the islands consists of far fewer species than that of the adjacent mainland; and (2) that the number of species and island size are positively correlated. These are typical findings for islands and both are probably simply related to variety of habitats.

Answers to the more interesting questions of distribution of fauna among islands, particularly the less mobile mammal and herpetofauna, and the survival and extinction of species in limited ecosystems (which all Nature Reserves and National Parks are becoming) remain to be answered. Obtaining these answers will be more difficult if the islands are exploited for tourism and recreation in the future. Development would increase the possibility of species extinction due to uncontrolled human-induced factors such as increased incidence of fire, damage to and reduction of particular habitats, and even species introduction. Extinctions have already occurred on islands off the west coast of Australia and pressures for the use of other islands, including those of this archipelago, are increasing. The islands should be surveyed thoroughly and then managed wisely for the conservation of their unique biotas.

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REFERENCES

Part V

REGENERATION OF THE VEGETATION AFTER FIRE

By A.J.M. Hopkins, A.S. Weston and M.E. Trudgen

INTRODUCTION

The response of the indigenous biota to fire is a topic of increasing interest amongst Australian ecologists and land managers. This interest is evidenced by the extensive literature, which is reviewed in Gill et al. (1981). Fires have long been recognised as being part of the Australian environment, but the question of the relative importance of this factor in the evolution of the biota has not been resolved unequivocally. Many plant (and animal) species show "adaptive traits" (Gill 1981) that enable them to survive or avoid the effects of a single fire and to recover afterwards.

An understanding of the effects of fire on the biota is particularly critical for the south-western portion of Australia, much of which experiences a Mediterranean fire bioclimate (sensu Naveh 1974). The long, hot, dry summers together with the dense, highly flammable vegetation produce a potential for regular and intense conflagrations. However the critical need for this understanding is not reflected in the quantity of published studies relating to south-western Australia. The few studies on the response of plant communities to fire which have been reported have mainly involved contemporaneous observations of several sites that have similar vegetation but differ in their fire histories (Bell and Koch 1979; Brown and Hopkins 1983; Christensen and Kimber 1975; Hopkins and Robinson 1981). However, floristic differences from one site to another generally obscure any successional trends (Bell and Koch 1979); thus long-term studies at fixed sites are of central importance in developing an understanding of regeneration processes. Here we report quantitive observations of regeneration after fire of major plant communities on Middle Island over a period of eight years. Permanent quadrats were established for this purpose in the area burnt in the 1972/73 fire. This regeneration study provided the impetus for all the work undertaken on Middle Island in recent years. The other studies reported in this publication were carried out to provide supporting documentation for this study or to take advantage of existing logistic arrangements.

Sites and Methods

The general physical and biological environment of Middle Island is adequately described in Parts I and III of this publication. Some discussion of the 1972/73 fire, supported by a fire history map, is included. An important feature of the fire history relevant to the present study is the long-unburnt nature of the vegetation prior to 1972 (ca. 170 years old, see Weston et al., Part II of this publication), and the probable, consequent, intense nature of the fire.

Eight sets of permanent quadrats were established in the unburnt section of the island in November 1973, at the same time as the vegetation map was

being prepared. Sites were selected by examination of pre-fire aerial photographs (February 1971) supported by ground inspection of post-fire remnants of the vegetation. Sites were selected to encompass a range of vegetation units and the variation within each unit.

Each set of quadrats consisted of from one to ten quadrats, generally laid out along transects through the study sites. A total of thirty-six quadrats was established. The locations of the study sites are shown on Figure 1.

A 4.63m^2 trapezoid quadrat (base 3) was utilised and permanently marked with steel pins. This unusual shape was selected to permit photographic recording of regeneration from two fixed photo-points at each quadrats (cf. Noble 1977).

On each sampling occasion, data recorded for each quadrat included presence of species rooted within the quadrat, density of each species (number of individuals or obviously separate clumps), percent foliage cover of each species including species rooted outside but overhanging the quadrat and dimensions of the largest individual of each species. All quadrats except one were sampled five times during the period 1973-80. Details of the visits are given in Part I of this publication. The single F plot was not found in 1975 and 1976.

A description of each of the study sites at the time of the initial sampling in 1973, together with the layout of the quadrats, is given below.

A Plots *Leucopogon revolutus* Heath

Five quadrats were placed semi-randomly in a heavily burnt section of the largest *Leucopogon revolutus* community shown on the vegetation map (Figure 1, Part III of this publication). Bare ground comprised 80-98% of the area of the plots in 1973. Much of the remainder of the cover was contributed by *Muehlenbeckia adpressa*, *Anthocercis genistoides* and, to a lesser extent, *Trachymene pilosa*. Seedlings of *Leucopogon revolutus* and *Hibbertia racemosa* were abundant, as were mature individuals of *Isolepis marginata*. *Anthocercis genistoides* and *Pelargonium littorale* appeared to be heavily grazed, and Tammar tracks were abundant in the area.

B Plots ? *Melaleuca lanceolata* Low Open Woodland.

A line of five quadrats was run eastwards from the eastern end of Lake Hillier. The quadrats were about thirty metres apart in an area that was probably dominated by *Melaleuca lanceolata* before the fire. The stand was burnt to the ground and only partial stumps of either *Acacia* sp. or *M. lanceolata* remained in 1973. Air-photo interpretation suggested that the latter species had been dominant. However, it did not regenerate strongly after the fire.

In 1973, the principal species, *Muehlenbeckia adpressa*, *Acacia rostellifera*, *Solanum simile* and *Anthocercis genistoides*, contributed less than 50% cover in any one quadrat, with bare ground contributing up to 95% cover per quadrat.

C Plots Eucalyptus platypus - E. angulosa Forest.

Ten quadrats were laid out along a northeast-southwest 105m transect. At the eastern end, the quadrats were sited in what had been a 15m tall, well developed stand of E. platypus var. heterophylla with ocasional Melaleuca lanceolata to 5m (quadrats 1 and 2). The western quadrats (quadrats 9 and 10) were located in a 10m tall, intensely burnt stand of E. angulosa. This E. angulosa stand included occasional E. platypus and had an understorey which included Melaleuca lanceolata and Acacia sp. Between the two stands was an area of mixed eucalypt forest which probably supported a population of Acacia rostellifera in the understorey, an understorey totally destroyed by the fire (quadrats 5, 6 and 7).

Seedlings of both species of Eucalyptus were present in the quadrats and, in addition, individuals of E. angulosa with all above-ground parts killed were sprouting from the base. Other prominent species were Trachymene pilosa, Muehlenbeckia adpressa, Acacia sp. (resprouting and seedlings) and Phyllanthus calycinus. In 1973, over 80% of the cover of each plot was bare ground.

D Plots Melaleuca pentagona Open Scrub

Five quadrats were located at regular intervals along a 100m transect running approximately parallel to, and some 250m in from, the cliffs of Limestone Bay. Only dead stems remained after the apparently intense fire. Eucalyptus angulosa and Leucopogon revolutus were sprouting from the base, but neither species occurred in the quadrats. The small amount of plant cover was mainly contributed by Scaevola aemula, with abundant seedlings of Pultenaea obcordata and occasional seedlings of Melaleuca pentagona, Alyogyne hakeifolia and Anthocercus genistoides present in the quadrats in 1973.

E Plots Sand Dune Heath

A line of four quadrats was run over the crest of the dune which separates Lake Hillier from the sea. The first quadrat was located about two-thirds of the way up the dune from Belinda Beach, the second was on the level crest of the dune, the third was about halfway down the lee slope, and the fourth quadrat was at the base of the dune on the lake side.

The quadrats showed minimal regeneration in 1973 (bare ground 95-99% cover) with a few shoots of Acacia rostellifera and Muehlenbeckia adpressa present.

F Plot Acacia rostellifera Scrub

A single quadrat was located in a stand of A. rostellifera with occasional, tall Melaleuca globifera trees present as an overstorey. Ninety-five percent of the quadrat was covered by a carpet of the moss Funaria hygrometrica, which was sporulating in 1973. Seedlings of Melaleuca globifera and Trachymene pilosa were present, together with some individuals of Stylidium adnatum.

G Plots *Melaleuca globifera* Low Open Forest

A transect of three quadrats was laid out in the *M. globifera* stand just west of the fisherman's hut. Bare ground comprised only 70-80% of each quadrat's area. The remaining cover was provided chiefly by *M. globifera* (seedlings and coppice), *Muehlenbeckia adpresa* and *Kennedia nigricans*. Seedling regeneration was prolific in all quadrats.

H Plots *Eucalyptus angulosa* Low Open Forest

A transect of three quadrats was run through the *E. angulosa* was coppicing freely as well as regenerating from seedlings. Other important species regenerating from seedlings were *Melaleuca globifera*, *Kennedia nigricans* and *Alyogyne hakeifolia*. However, bare ground in each quadrat exceeded 90% cover in 1973.

Results

All of the quadrats were laid out in areas that were completely burnt in the fire of summer 1972/73. Basically, the ground was bared to mineral earth with only dead plant remains standing. When the plots were established less than 12 months after the fire, some regeneration was evident but the quadrats were still essentially bare.

Quantative observations on the regeneration study plots from the time they were established in November 1973 (=Year 1) until 1980 (Year 8) are summarised in Tables 1-8. Data have been pooled for each set of quadrats. Species have been grouped using Raunkiaer's life form classes (in Kershaw 1973). Cover data are also presented graphically in Figures 2-5 to better illustrate changes that have occurred during the observation period.

Results show the rapid regeneration of the vegetation within the first two years after the fire, after which time the special floristic characteristics of each group of quadrats become of overriding importance to regeneration patterns. Data from years 2-6 illustrate the complex, dynamic interactions between individuals and species. Of particular note is the rapid growth, then senescence, of fire ephemeral species (see later definition) in some plots. By the eighth year, the amount of bare ground was still declining as the woody perennial species (phanerophytes) increased in size and overall dominance.

The use of Raunkaer's life-form classes provides a convenient method of summarising regeneration patterns; species in each of the classes typically respond in similar ways. Phanerophytes, for example, regenerate from seed or by resprouting from below-ground parts or both. Phanerophytes are mainly long-lived, relatively slow-growing species that are important in mature (climax) vegetation.

The two major species of lianas, *Kennedia nigricans* and *Muehlenbeckia adpresa*, both regenerated rapidly and profusely from soil-stored seed and were very important contributors to vegetative cover for the first two years after fire; thereafter they decline in importance. Geophytes

have below ground parts (bulbs, tubers, rhizomes) that were little-affected by the fire. New shoots were developed from these vegetative organs the following winter and spring. However, the two geophytic orchid species seemed to appear later in the pyrosere. Therophytes generally have abundant, wind-dispersed seed and rapidly colonize bare or disturbed areas. They were abundant in some quadrats for the first one to two years after the fire, but since the individual plants are small, they generally contributed little cover. Therophytes diminished in abundance as the perennial species became established and began to dominate.

Additional insight into regeneration patterns is facilitated by the use of classifications specifically developed for studies of fire effects. There has been a proliferation of such classifications since the pioneering work of Kujala (1926a, b, cited in Ahlgren and Ahlgren 1960) and Jarrett and Petrie 1929), particularly in recent years (eg. Gill 1980, Naveh 1975, Purdie 1979a, b, Purdie and Slatyer 1976) Three sub-classes of phanerophytes useful in this study are:

a) fire ephemerals - species of phanerophytes that appear in abundance after fire through germination of soil-stored seed, grow rapidly for 2-3 years and then decline, often disappearing altogether from quadrats within 6 years. Species of this type that appeared in quadrats are Alyogyne hakeifolia (D, H plots), and Scaevola aemula (D plots). Other species of Middle Island that display similar characteristics include Solamim simile, Myoporum adscendens and Gyrostemon sheathii. The importance of the fire ephemeral species in developing a chronology of fire on Middle Island is discussed in Part 2 of this publication.

b) Resprouting phanerophytes - woody species that regenerate from a store of buds either below-ground (in lignotubers of some Eucalyptus species or rootstocks of other woody species) or in stem tissue (epicormic buds). Resprouting enables a plant to recover relatively quickly after fire since the existing, well-developed root system is maintained. This root system may be a store of carbohydrates and nutrients as well as provides ready access to soil moisture supplies. On Middle Island the fire was so intense that all above ground parts were killed and resprouting was observed only from below-ground parts. Major resprouting species in quadrats were Eucalyptus angulosa (C, H plots), Leucopogon revolutus (A, D, E, G, H Plots) and Melaleuca globifera (A, B, F, G, H, plots). In some plots Acacia rostellifera resprouted from roots at a distance of up to several metres from the original stem. Seedlings of resprouting species also made important contributors to regeneration. For example, in the A plots (Table 1), there was a decline in the contribution of Leucopogon revolutues in 1978 because seedlings were not as abundant in quadrats in that year as in previous years. Subsequently, in 1980, a further crop of seedlings became established. In the F plots, Melaleuca globifera was establishing from seedlings in the first year after the fire. These seedlings all died within two years: perhaps they were in some way adversely affected by dense moss cover that was developed

in that time.

c) Obligate-seeder regenerating, long-lived phanerophytes - woody species that regenerate only from seed ~~which may be~~ stored either in the soil (Acacia acuminata, Anthocercis genistoides, Lasiopetalum discolor, Pimelea spp., Pultenaea obcordata and Spyridium globulosum) or in fruits amongst the foliage (Eucalyptus platypus, Melaleuca lanceolata, M. pentagona). There was a profusion of seedlings of these species after the fire. Generally each stand gradually thinned out as individual plants increased in size. The thinning process is exemplified by Eucalyptus platypus in the C plots: numbers declined from 455 in Year 1 to between 250-300 in Years 2, 3, 4 to 120 in Year 8. At that stage the individual saplings were up to 3.8 m tall and some had produced flowers and fruit.

DISCUSSION

The results reported here, with observations spanning an eight year period, can be regarded as indicative of the patterns of regeneration of Middle Island vegetation after fire. Further observations will be necessary to substantiate the indicated patterns. In general, though, the rate of change (e.g. in cover and abundance) has stabilized in the last few years and regeneration in most plots is quite well-advanced and continuing. Yet no vegetation type has recovered its former structure. The eucalypt formations, for example, are less than 50% of the height of pre-fire stands. It seems likely that the slow growth of the dominant woody species will continue for many years ~~yet~~.

Precise estimation of regeneration time would be premature. The data suggest that it may take between 25 and 40 years for the pre-fire structure to redevelop, but changes in species densities could continue to occur for much longer. Some aspects of the pre-fire character of the vegetation (e.g. tree size and spacing and understorey composition; see Part ~~VI~~ VII of this publication) may well not develop for 100 years. This is not an unreasonable estimate since it has been estimated that 170 years had elapsed between the previous fire and the one of 1972/73. These estimates compare favourably with ones from a study of post-fire regeneration of woodland at 90 Mile Tanks, north west of Esperance (Hopkins and Robinson 1981). For that site, which received only about half the average annual rainfall of Middle Island, a regeneration time of around 100 years was given.

A range of regeneration and life-history strategies has been exhibited by species in the study plots. The rapid regeneration, then death, of fire-ephemerals was spectacular. The lianas also showed major changes in cover and abundance throughout the observation period. Seedlings of long-lived phanerophyte species mainly appeared in Year 1 and grew slowly, with many species showing density-dependent thinning. Some phanerophytes also resprouted from below-ground parts, but these species were in the minority. The small contribution of resprouts to overall regeneration patterns on Middle Island is in marked contrast with observations on sclerophyllous shrublands and woodlands elsewhere in southern Australia, where resprouting species have comprised around 70% of the total species present (Bell and Koch 1980,

Russell and Parsons 1978, Specht et al. 1958, van der Moezel 1981). These other communities were considered quite stable in response to fire mainly because of the predominance of resprouting species present in them.

Some floristic drift seems to have occurred in specific areas of Middle Island as a result of the fire: the regenerating vegetation differs from that existing in those areas prior to the fire. The B plots were located in an area mapped as Melaleuca lanceolata Low Open Woodland. Unfortunately precise pre-fire data are not available. However, the regenerating vegetation is best described as Acacia scrub/heath. Only a few Melaleuca lanceolata seedlings established after the fire and most of these died as regeneration progressed; only one of the B quadrats had a Melaleuca plant nearby by the ~~8th~~ year. It is possible that the fire was so intense that it destroyed much of the Melaleuca seed store.

~~A further~~ probable case of floristic drift occurred in the area of the single F quadrat. That area was formerly Acacia rostellifera scrub with occasional emergents of Melaleuca globifera. By the third year after the fire neither of the dominant species was present in or around the quadrat; subsequently it was colonized by Acacia cyclops and Pimelea spp.

The weather pattern during the observation period has not been uniform. For example, the annual rainfall recorded at Thomas River for the years 1977 and 1980 was only 70% of the mean value. The fluctuations in rainfall may have been responsible for some variations in species populations but it has not been possible to establish any correlation.

The generally observed pattern of regeneration ~~at~~ on Middle Island involved early establishment after the fire followed by thinning, senescence and death. This general pattern has been described as the Initial Floristic Composition Model (Purdie and Slatyer 1976) and ~~it~~ is now considered to be characteristic of Australian sclerophylous vegetation types. However, some species on Middle Island demonstrated the ability to establish long after fire, e.g. Carpoprotus virescens, Hibbertia racemosa, Leucopogon revolutus, Phyllanthus calycinus, Pimelea argentea, Pimelea clavata and Poa porphyroclados. The possibility of some long-term floristic change of a type more in accordance with the Relay Floristic Model (see Noble and Slatyer 1981, Purdie and Slatyer 1976) can therefore not be ruled out.

A corollary to the Initial Floristic Composition Model of Succession is that there may be a decline in species richness with the passage of time. Individuals senesce and die and little recruitment is likely. Furthermore, no new species colonize. The behaviour of the fire-ephemeral species characterise this particular syndrome; all of these species disappeared entirely within 6 years. However, they probably persist as long-lived seeds in the soil. At Middle Island, trends in richness were partly obscured by the behaviour of the therophytes that were subject to year-to-year fluctuations in abundance. The G and C plots showed a marked decline in richness after the second and third years respectively, whereas values in the other

plots were still high at the ends of the observation periods.

So far this regeneration study has provided valuable insight into the processes involved in regeneration of a few insular vegetation types. The observations made on the life histories of the fire ephemeral species in the course of this study have facilitated development of the fire chronology outlined in Part 1 of this publication. The study has scope to provide further background data that would be useful in natural area management throughout southern Australia and for this reason will be continued as far as practicable.

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References

Ahlgren, I.F., and Ahlgren, C.E. (1960). Ecological effects of forest fires. Bot. Rev. 26, 483-533.

Bell, D.T. and Koch, J.M. (1980). Post-fire succession in the northern jarrah forest of Western Australia. Aust. J. Ecol. 5, 9-14.

Brown, J.M. and Hopkins, A.J.M. (1983). The kwongan (sclerophyllous schrublands) of Tutanning Nature Reserve, Western Australia. Aust. J. Ecol. 8, 63-73.

Christensen, P.E. and Kimber P.C. (1975). Effects of prescribed burning on the flora and fauna of south-west Australian forests. Proc. Ecol. Soc. Aust. 9, 85-106.

Gill, A.M. (1981) Adaptive responses of Australian vascular plant species to fires. In A.M. Gill, R.H. Groves and I.R. Noble (eds) "Fire and the Australian Biota". (Aust. Acad. Sci: Canberra).

Gill, A.M., Groves, R.H. and Noble, I.R. (eds) (1981). "Fire and the Australian Biota". (Aust. Acad. Sci: Canberra).

Hopkins, A.J.M. and Robinson, C.J. (1981). Fire induced structural change in a Western Australian woodland. Aust. J. Ecol. 6, 177-188.

Jarrett, P.H. and Petrie A.H.K. (1929). The vegetation of the Blacks, Spur Region. A study in the ecology of some Australian mountain Eucalyptus forests. II. Pyric succession J. Ecol. 17, 249-281.

Kershaws, K.A. (1973). "Quantative and Dynamic Plant Ecology. 2nd Editon" (Edward Arnold: London).

Kujala, V. (1926a). Einfluss von Waldbranden auf die Waldvegetation in Nordfinnland. Metsatieteellisne Koelaitoksen Julkaisuja 10, 1-36.

Kujala, V. (1926b). Untersuchungen uber den eirfluss von Waldbranden auf die Waldvegetation In Nordfinnland. Inst. Quadest. Forest. Fenn. Commun 10, 1-41.

Naveh, Z. (1974). Effects of Fire on the Mediterranean region. In T.T. Kozlowski and C.E. Ahlgren (eds) "Fire and Ecosystems". (Academic Press: New York).

Noble, I.R. (1977). Long-term dynamics in an arid chenopod shrub community at Koonamore, South Australia. Aust. J. Bot. 25, 639-53.

Noble, I.R. and Slatyer R.O. (1981). Concepts

and Models of succession in vascular plant communities subject to recurrent fire. In A.M. Gill, R.H. Groves, and I.R. Noble (eds) (Aust. Acad Sci: Caberra), "Fire and the Australian Biota".

Purdie, R.W. (1977a). Early stages of regeneration after burning in dry sclerophyll vegetation. I. Regeneration of the understorey by vegetative means. Aust. J. Bot. 25, 21-34.

Purdie, R.W. (1977b). Early stages of regeneration after burning in dry sclerophyll vegetation. II. Regeneration by seed germination. Aust. J. Bot. 25 35-46.

Purdie, R.W. and Slatyer, R.O. (1976). Vegetation succession after fire in sclerophyll woodland communities in south-eastern Australia. Aust. J. Ecol. 1, 223-36.

Russell, R.P. and Parsons R.F. (1978). Effects of time since fire on heath floristics at Wilson's Promontory, southern Australia. Aust. J. Bot. 26, 53-61.

Specht, R.L., Rayson, P., and Jackman, M.E. (1958). Dark Island Heath (Ninety-mile Plain, South Australia). VI. Pyric succession: changes in composition, coverage, dry weight and mineral nutrient status. Aust. J. Bot. 6, 59-88.

van der Moezel, P.G. (1981). "Management of natural vegetation in the Badgingarra area for multiple land uses". Honours Thesis, Univ. of Western Australia.

A PLOTS

SPECIES	TOTAL DENSITY (FREQUENCY)						MEAN COVER %					
	1973	1974	1975	1976	1978	1980	1973	1974	1975	1976	1978	1980
Bare Ground							86	50	37	22	37	21
Total Cover							15	55	68	100	85	95
PHANEROPHYTES												
Acacia cyclops		1(1)	1(1)	-	1(1)	0(2)	-	+	+	+	2	5
Acacia myrtifolia	17(2)	23(3)	18(4)	23(4)	10(2)	8(4)	<1	9	14	21	9	10
Anthocercis genistoides	85(4)	61(4)	60(4)	56(4)	30(4)	43(4)	2	5	5	12	19	24
Astartea fascicularis	44(1)	33(1)	21(3)	21(1)	pres(2)	2(2)	<1	2	2	4	9	8
Hibbertia racemosa	>330(4)	>310(4)	>300(5)	>340(5)	194(5)	36(4)	2	21	23	25	9	2
Leucopogon revolutus	341(5)	>326(4)	>350(5)	>376(4)	96(5)	219(5)	<1	2	10	21	11	25
Melaleuca globifera	4(3)	5(4)	4(3)	8(5)	3(2)	3(2)	<1	1	1	1	3	4
Pimelea argentea	-	1(1)	1(1)	1(1)	-	-	-	+	+	+	-	-
Pimelea ferruginea	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	+	+	+	+	2	2
Solanum simile (Sterculiaceae)	2(1) -	- -	- 1(1)	- -	- -	- -	+ -	- -	- +	- -	- -	- -
Syridium	1(1)	2(1)	1(1)	-	-	-	+	+	1	-	-	-
CHAMAEPHYTES												
Agrostis avenacea	-	-	-	-	1(1)	-	-	-	-	-	+	-
Carpobtorus virescens	32(4)	26(4)	>14(3)	27(4)	16(5)	11(4)	2	2	2	3	8	4

Poa porphyroclados	2(1)	3(1)	3(2)	3(1)	2(2)	2(2)	+	+	+	+	1	1
Stackhousia heugelii	48(3)	34(3)	57(4)	34(3)	101(3)	17(2)	+	2	4	3	3	1
LIANAS												
Kennedya nigricans	-	pres(1)	pres(1)	7(1)	1(1)	0(2)	-	<1	1	4	<1	2
Muehlenbeckia adpressa	120(4)	49+(5)	15+(4)	16+(4)	pres(4)	13(4)	5	6	3	3	3	3
GEOPHYTES												
Caladenia menziesii	-	-	5(1)	-	8(1)	-	-	-	+	-	+	-
Pterostylis nana	-	-	-	-	3(1)	5(1)	-	-	-	-	+	+
Stylidium adnatum	144(4)	68(4)	91(4)	110(3)	380(5)	188(3)	1	4	2	3	2	1
THEROPHYTES												
Centrolepis drummondii	pres(2)	>50(3)	pres(2)	pres(1)	116(1)	-	+	+	+	+	1	+
Centrolepis strigosa	pres(2)	>50(3)	20(2)	pres(1)	9(1)	24(2)	+	+	+	+	+	+
Crassula	pres(1)	pres(2)	-	-	>2(2)	21(1)	+	+	-	-	1	
? Fumaria ? Nasella Funaria hydrogrametrica	-	-	-	-	pres(1)	-	-	-	-	-	+	-
Gnaphalium indutum	-	-	-	pres(1)	38(1)	-	-	-	-	+	<1	-
Gnaphalium sphaericum	pres(2)	3(1)	pres(2)	pres(1)	48(2)	44(1)	+	+	+	+	<1	+
Sagina apetala	pres(1)	>20(1)	-	-	-	-	+	+	-	-	-	-
Scirpus antarcticus	>200(4)	6+(5)	23+(3)	pres(1)	52(4)	2(1)	<1	+	+	+	1	+
Trachymene pilosa	14(2)	5(1)	4(2)	1(1)	133+(5)	80(3)	1	+	+	+	1	1

Wahlenbergia gracilenta	-	-	-	-	pres(1)	-	-	-	-	-	<1	-
UNKNOWN Indet. Seedling					1(1)	-						-
~~Grass~~ Seedling Vulpia?						3(2)						+
Galium murale						16(1)						+

B PLOTS

SPECIES	TOTAL DENSITY (FREQUENCY)						MEAN COVER %					
	1973	1974	1975	1976	1978	1980	1973	1974	1975	1976	1978	1980
Bare Ground							75	40	37	51	35	19
Total Cover							28	75	64	50	67	91
PHANEROPHYTES												
Acacia cyclops	4(3)	3(3)	3(3)	5(4)	5(3)	4(4)	<1	11	2	5	11	17
Acacia rostellifera	58(4)	43(4)	54(5)	68(5)	60(5)	33(5)	4	13	20	25	28	35
Anthocercis genistoides	15(2)	14(2)	11(2)	11(3)	8(2)	8(2)	1	3	3	4	7	8
Eucalyptus angulosa	-	-	-	-	-	-	-	+	+	+	3	1
Hibbertia racemosa	-	1(1)	4(2)	4(3)	8(3)	-	-	+	+	+	1	1
? Leucopogon sdlg. (B4)			1									
Melaleuca globifera	-	1(1)	1(1)	1(1)	-		-	+	+	+	-	+
Melaleuca lanceolata	3(2)	2(1)	2(1)	2(1)	-		+	+	<1	+	1	+
Myoporum ~~adscedens~~ insulare	1(1)	1(1)	2(2)	2(2)	-	1(2)	<1	2	4	2	-	9
Myoporum ? parvifolium	-	-	-	-	-	-	-	-	-	-	<1	-
Pimelea argentea	-	1(1)	1(1)	1(1)	-	1(1)	-	+	+	+	-	+
Pimelea clavata	-	-	-	-	16(1)	17(1)	-	-	-	-	<1	3
Pimelea ferruginea	3(2)	3(1)	3(1)	4(1)	3(1)	6(1)	+	<1	<1	1	2	3
Phyllanthus calycinus	3(2)	-	-	1(1)	3(1)	1(1)	+	-	-	+	+	+

Pultanaea obcordata	14(2)	15(1)	18(1)	12(1)	12(1)	11(1)	+	1	2	2	5	6
Solanum simile	9(3)	2(2)	-	-	-	-	1	2	-	-	-	-
Spyridium globulosum	5(2)	4(2)	4(2)	3(3)	4(3)	-	<1	<1	<1	<1	1	-
Westringia dampieri	-	2(1)	2(1)	2(1)	2(1)	3(2)	-	+	+	+	1	2
CHAMAEPHYTES												
Carpobrotus virescens	-	-	-	-	1(1)	1(1)	-	-	-	-	+	1
LIANAS												
Muehlenbeckia adpressa	43(5)	33(5)	27(5)	11(5)	5+(4)	5(3)	20	50	30	8	5	3
GEOPHYTES												
Stylidium	2(2)	7(5)	6(4)	10(4)	88(3)	92(3)	+	+	<1	1	1	1
THEROPHYTES												
Crassula	1(1)	-	-	-	-	-	+	-	-	-	-	-
Gnaphalium indutum	pres(1)	1(1)	8(2)	-	-	-	+	+	-	-	-	-
Gnaphalium sphaericum	pres(1)	7	3	-	2(1)	-	+	<1	-	-	<1	-
~~Scirpus~~ Isolepis marginata antarcticus	pres(1)	pres(1)	-	-	1(1)	-	+	+	-	-	<1	-
~~Scirpus~~ Isolepis nodosus	-	pres(1)	-	-	-	-	-	+	-	-	<1	-
Senecio lautus	-	-	-	-	1(1)	-	-	-	-	-	+	-

Trachymene pilosa	-	3	-	-	-	-	-	+	-	-	-	-
Indet Seedlings	9(3)	-	3(1)	-	7(1)	-	+	-	+	-	+	-
Leaf ? orchid	-	-	1(1)	-	-	-	-	-	+	-	-	-

C PLOTS

SPECIES	TOTAL DENSITY (FREQUENCY						MEAN COVER %					
	1973	1974	1975	1976	1978	1980	1973	1974	1975	1976	1978	1980
Bare Ground							80	40	33	43	38	31
Total Cover							21	72	70	59	76	77
PHANEROPHYTES												
Eucalyptus platypus	455(8)	297(8)	268(8)	249(8)	157(8)	120(8)	9	28	29	30	34	37
Eucalyptus angulosa	71(6)	67(6)	64(6)	61(6)	52(6)	46(5)	2	8	7	9	15	16
Acacia acuminata var. latifolia	31(6)	45(7)	40(7)	48(7)	31(6)	31(6)	<1	3	6	4	7	4
Acacia rostellifera	46(9)	47(9)	37(9)	31(9)	27(8)	15(6)	2	17	17	12	14	12
Melaleuca lanceolata	79(9)	61(9)	57(9)	57(9)	53(9)	48(9)	<1	2	3	2	6	6
Myoporum ~~adscendens~~ insulare	1(1)	2+(3)	3(3)	-	-	-	+	1	<1	+	-	-
Phyllanthus calycinus	14(1)	16(1)	-	-	-	-	<1	1	-	+	<1	-
Pimelea clavata	1(1)	4(1)	3(1)	3(1)	-	1(1)	+	1	<1	<1	-	+
? Rhagodia	-	-	5(4)	1(1)	-	-	-	-	+	+	-	-
Solanum simile	-	pres(1)	-	-	-	-	-	+	-	-	-	-
Spyridium globulosum	1(1)	1(1)	1(1)	1(1)	pres(1)	-	+	+	+	+	<1	-
CHAMAEPHYTES												
Carpobrotus virescens	6(3)	7(4)	14(5)	9(4)	2(1)	1(1)	1	3	2	1	<1	+

LIANAS												
Muehlenbeckia adpressa	2(2)	pres(4)	pres(5)	pres(1)	-	-	1	6	4	+	-	-
THEROPHYTES												
Crassula	pres(3)	pres(4)	-	-	-	-	+	+	-	-	-	-
Gnaphalium	-	1(1)	-	-	-	-	-	+	-	-	-	-
Scirpus antarcticus	pres(3)	pres(2)	1(1)	-	-	-	+	+	+	-	-	-
Trachymene pilosa	123(4)	75(7)	39(2)	-	-	-	5	2	<1	-	-	-
Funaria hydrogrametrica	-	-	pres(2)	pres(5)	-	-	-	-	1	<1	-	-
Olearia	-	1(1)	1(1)	-	-	-	-	+	+	-	-	-
Indet. seedlings				2(1)								

D PLOTS

SPECIES	TOTAL DENSITY (FREQUENCY)						MEAN COVER %					
	1973	1974	1975	1976	1978	1980	1973	1974	1975	1976	1978	1980
Bare Ground							95	34	60	48	34	18
Total Cover							6	90	43	56	92	107
PHANEROPHYTES												
Acacia cyclops	-	6(2)	18(4)	16(5)	11(4)	9(3)	-	+	1	1	2	2
Acacia myrtifolia	14(3)	4+(3)	12(4)	15(3)	11(3)	16(4)	+	1	2	3	7	5
Alyogyne hakeifolia	20(3	21(4)	14(4)	15(3)	-	-	<1	8	5	6	-	-
Anthocercis genistoides	4(1)	4(1)	5(1)	3(1)	4(1)	5(1)	+	1	1	1	3	3
? Atriplex	-	-	-	3(1)	-	-	-	-	-	+	-	-
Lasiopetalum discolour	37(5)	42(5)	35(5)	41(5)	45(5)	38(5)	<1	10	12	19	23	28
Leucopogon revolutus	-	-	-	1(1)	1(1)	1(1)	-	-	-	<1	1	+
Melaleuca pentagona	14(3)	2(1)	3(2)	4(2)	4(3)	5(4)	+	+	<1	1	5	5
Phebalium rude	10(3)	6(2)	16(4)	14(4)	11(4)	4(2)	+	+	<1	<1	2	1
Pimelea ferruginea	1(1)	-	-	1(1)	1(1)	-	+	-	-	+	+	-
Pomaderis myrtilloides	48(3)	10(3)	34(4)	43(4)	30(4)	24(4)	<1	<1	1	2	6	7
Pultenaea obcordata	>400(5)	>340(5)	>355(5)	>410(5)	138(5)	153(5)	<1	11	18	22	41	60
Rhagodia radiata	-	-	-	-	1(1)	-	-	-	-	-	1	-
Scaevola aemula	97(5)	pres(5)	14(4)	-	-		4	58	1	-	-	-
Spyridium globulosum	-	-	1(1)	1(1)	1(1)	1(1)	-	-	+	+	<1	+
Westringia dampieri	1(1)	-	1(1)	-	pres(1)	1(1)	+	-	+	-	+	+

CHAMAEPHYTES												
Lepidosperma	1(1)	-	-	-	-		+	-	-	-	-	
LIANAS												
Muelenbeckia adpressa	-	-	pres.	1(1)	-		-	-	<1	+	+	-
GEOPHYTES												
Thysanotus patersonii	-	-	-	1(1)	-	-	-	-	-	+	-	-
THEROPHYTES												
Poranthera microphylla	-	-	6(2)	pres(1)	23(2)	-	-	-	+	+	<1	-
Senecio lautus	-	-	8(3)	2(1)	-	-	-	-	<1	+	-	-
Indet. seedling	1(1)	-	-	1(1)	2(1)	-	+	-	-	+	+	-

E PLOTS

SPECIES	TOTAL DENSITY (FREQUENCY)						MEAN COVER %					
	1973	1974	1975	1976	1978	1980	1973	1974	1975	1976	1978	1980
Bare Ground							98	44	57	48	40	22
Total Cover							3	61	49	62	76	77
PHANEROPHYTES												
Acacia cyclops	-	2(2)	-	-	-	-	-	+	-	-	-	-
Acacia rostellifera	46(4)	29(4)	30(4)	30(4)	28(4)	20(4)	1	5	5	7	15	11
Leucopogon revolutus	-	1(1)	2(1)	3(1)	7(1)	7(1)	-	+	+	1	2	2
Phyllanthus calycinus	-	-	-	-	2(1)	-	-	-	-	-	<1	-
Pimelea ferruginea	32(1)	13(1)	16(1)	15(1)	13(1)	13(1)	+	1	3	4	6	8
Scaevola crassifolia	108(3)	80(3)	80(3)	81(3)	82(3)	53(3)	<1	14	21	35	33	35
Solanum simile	1(1)	-	-	-	-		+	-	-	-	-	-
Spyridium globulosum	41(3)	6(2)	11(3)	6(2)	8(2)	6(2)	+	+	<1	<1	1	4
Westringia dampieri	-	-	-	1(1)	1(1)	1(1)	-	-	-	+	<1	<1
CHAMAEPHYTES												
Carpobrotus virescens	1(1)	1(1)	1(1)	pres(1)	pres(1)	6(2)	+	1	5	5	2	1
Lepidosperma gladiatum	1(1)	1(1)	1(1)	1(1)	4(1)	5(1)	+	+	<1	1	4	<1
Poa porphyrocladós	1(1)	-	1(1)	1(1)	3(2)	5(2)	+	+	+	+	1	1

Sporobolus virginicus	11(1)	pres(1)	pres(1)	pres(1)	pres(1)	35(1)	+	1	1	1	1	1
Zygophyllum billardieri	1(1)	-	-	-	-		+	-	-	-	-	-
LIANAS												
Clematis microphylla	7(1)	-	1(1)	-	-		+	-	+	-	-	-
Muehlenbeckia adpressa	22(3)	pres(3)	pres(3)	5(3)	pres(2)	pres(1)	1	38	11	6	5	2
GEOPHYTES												
Stylidium adnatum	-	-	-	1(1)	13(1)	4(1)	_	_	_	+	<1	+
THEROPHYTES												
Senecio lautus	3(2)	5(3)	12(2)	8(3)	14(2)	9(3)	+	1	1	<1	1	1
Isolepis marginata ~~Scirpus antareticus~~	-	-	-	8(1)	6(1)	-	-	-	-	+	<1	-
Trachymene pilosa	-	1(1)	-	-	1(1)	1(1)	-	+	-	-	<1	+
Indet. seedling (E1).			1									

F PLOTS

SPECIES	TOTAL DENSITY (FREQUENCY)						MEAN COVER %					
	1973	1974	1975	1976	1978	1980	1973	1974	1975	1976	1978	1980
Bare Ground							5	4			45	30
Total Cover							99	151			66	79
PHANEROPHYTES												
Acacia cyclops					7	16					5	5
Hibbertia racemosa					1	2					1	1
Melaleuca globifera	84	1					1	1				
Pimelea argentea					222	138	-	-			25	35
Pimelea clavata					2	8					3	1
Rhagodia					1						<1	-
GEOPHYTES												
Stylidium adnatum	12	5			75	173	1	30			5	10
THEROPHYTES												
Funaria hydrogrametrica	pres.	pres.			pres.	pres.	95	90			20	-
Gnaphalium luteo-album					4						1	+

Gnaphalium sphaericum			110	1			1	+
? Marchantia	1	-			1	-		
Scirpus antarcticus			60	16			<1	1
Trachymene pilosa	1	40	74	22	1	30	5	1

G PLOTS

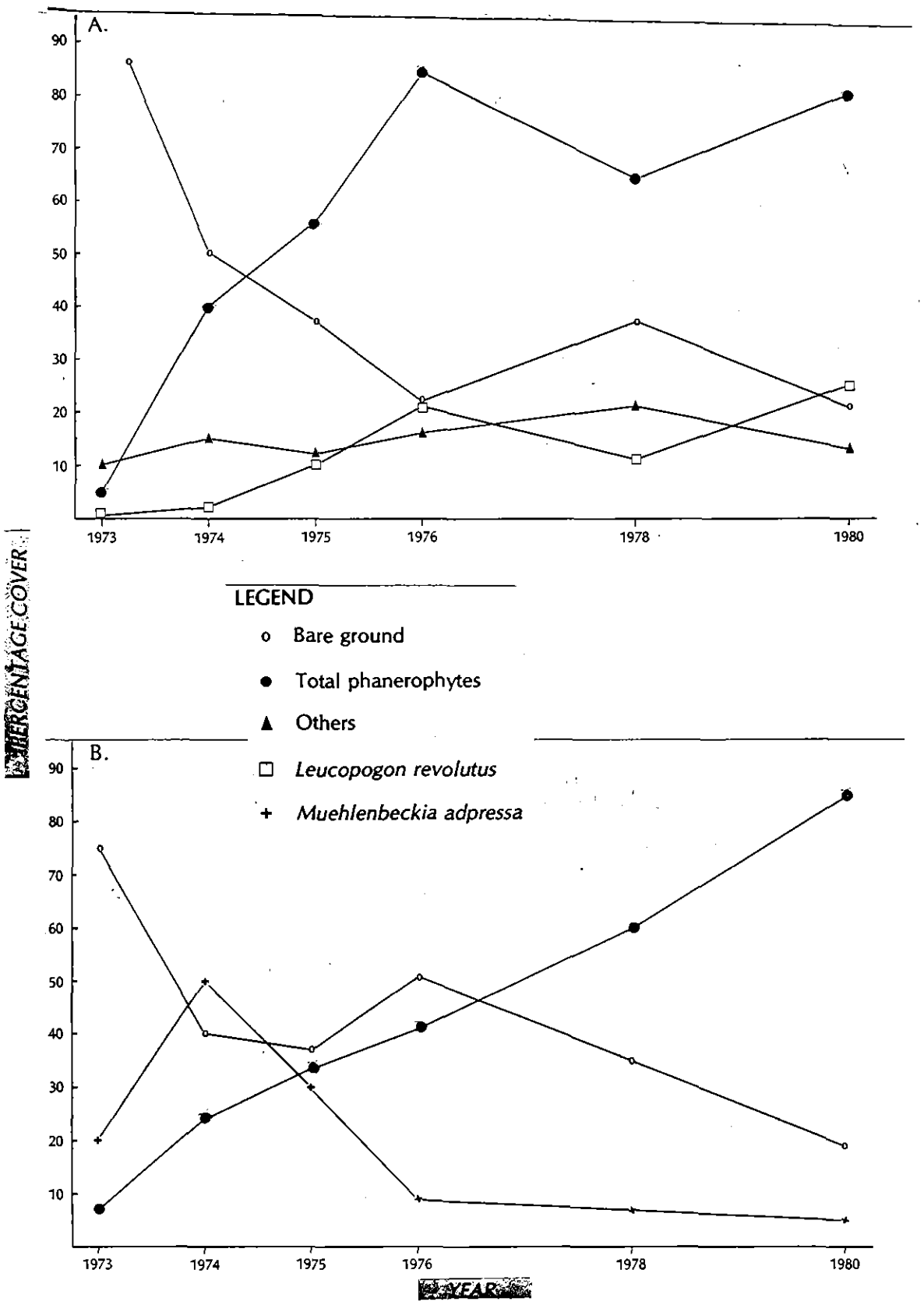
SPECIES	TOTAL DENSITY (FREQUENCY)						MEAN COVER %					
	1973	1974	1975	1976	1978	1980	1973	1974	1975	1976	1978	1980
Bare ground							73	25	20	27	31	20
Total Cover							32	99	87	74	73	88
PHANEROPHYTES												
Acacia acuminata var. latifolia	16(3)	14(3)	9(2)	12(2)	8(2)	7(2)	+	1	1	4	15	23
Acacia	6(2)	2(1)	1(1)	1(1)	1(1)	-	+	+	+	+	+	-
Alygoyne hakeifolia	-	-	-	-	-	-	-	+	+	-	-	-
Anthocercis genistoides	23(3)	17(2)	10(2)	9(2)	6(2)	2(2)	1	2	2	2	4	2
Eucalyptus	3(1)	3(1)	-	-	-		+	+	-	-	-	-
Hibbertia racemosa	55(3)	92(3)	46(3)	52(3)	103(3)	22(3)	1	11	10	6	3	1
Leucopogon	42(2)	5(2)	-	-	-		+	<1	-	-	-	-
Melaleuca globifera	>350(3)	>350(3)	365(3)	365(3)	188(3)	163(3)	11	40	57	51	39	47
Pelargonium	3(1)	1(1)	-	-	-	-	+	+	-	-	-	-
Phebalium rude	-	-	-	2(1)	5(1)	4(1)	-	-	-	+	1	2
Pimelea argentea	1(1)	1(1)	1(1)	1(1)	-	-	+	1	1	1	-	-
Pimelea clavata	2(1)	2(1)	-	-	-	1(1)	+	1	-	-	-	+
Spyridium	1(1)	-	-	1(1)	1(1)	1(1)	+	-	-	+	1	1

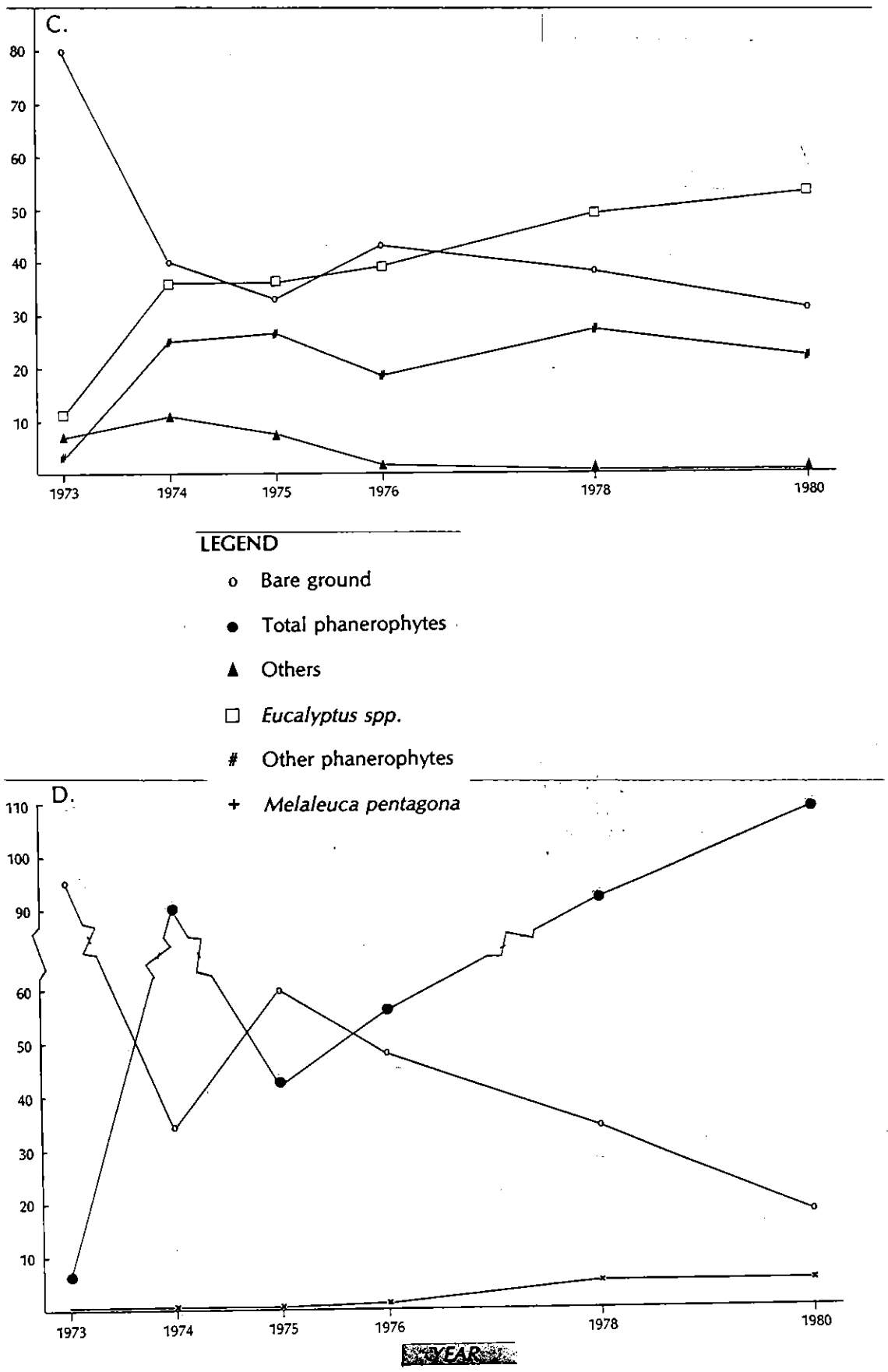
CHAMAEPHYTES												
Carpobrotus virescens	2(1)	2(1)	3(1)	3(1)	12(1)	12(1)	<1	2	2	3	4	7
LIANAS												
Kennedia nigricans	47(2)	30(2)	6(2)	4(2)	2(2)	1(1)	5	27	5	3	5	7
Muehlenbeckika adpressa	171(3)	100(3)	20(3)	9(3)	-	-	12	11	6	3	-	-
GEOPHYTES												
Stackhousia huegelii	1(1)	1(1)	1(1)	1(1)	-	-	+	+	+	+	-	-
Stylidium adnatum	20(2)	23(2)	42(3)	19(2)	43(3)	27(3)	+	2	2	1	1	1
THEROPHYTES												
Crassula	1(1)	-	-	-	-	-	+	-	-	-	-	-
Gnaphalium sphaericum	3(1)	3(1)	11(1)	-	2(1)	-	+	+	+	-	+	-
Poranthera microphylla	2(1)	-	-	-	-	-	+	-	-	-	-	-
Scirpus antarcticus	1(1)	pres(1)	pres(2)	-	10(1)	-	+	+	<1	-	+	-
Senecio	-	-	9(1)	-	2(1)	-	-	-	1	-	+	-
Trachymene pilosa	2(2)	-	-	-	-	5(1)	+	-	-	-	-	+

H PLOTS

SPECIES	TOTAL DENSITY (FREQUENCY)						MEAN COVER %					
	1973	1974	1975	1976	1978	1980	1973	1974	1975	1976	1978	1980
Bare Ground							99	50	72	72	67	48
Total Cover							1	57	38	32	49	67
PHÁNEROPHYTES												
Acacia cyclops	3(2)	2(2)	2(2)	2(1)	2(1)	1(1)	+	<1	1	2	7	13
Acacia rostellifera	-	-	-	1(1)	4(2)	1(1)	-	-	-	+	2	1
Alyogyne hakeifolia	4(1)	pres(1)	7(1)	5(1)	-	-	+	28	17	13	-	-
Eucalyptus angulosa	68(3)	20(3)	7(3)	7(3)	6(2)	6(2)	<1	<1	2	3	12	18
Leucopogon revolutus	-	-	1(1)	1(1)	-	-	-	-	+	+	-	-
Melaleuca globifera	43(3)	40(3)	32(3)	32(3)	24(2)	19(3)	<1	10	10	9	14	16
Melaleuca lanceolata	3(1)	-	-	-	-	-	+	-	-	-	-	-
Pelargonium littorale	1(1)	-	-	-	-	-	+	-	-	-	-	-
Phebalium rude	-	-	1(1)	-	-	-	-	-	+	+	-	-
Pimelea argentea	-	-	-	-	12(2)	2(2)	-	-	-	-	1	3
Pimelea clavata	1(1)	-	-	-	14(3)	26(3)	+	-	-	-	2	12
Pultenaea obcordata	-	-	1(1)	-	-	-	-	-	+	-	-	-
Rhagodia baccata	-	-	-	-	4(1)	-	-	-	-	-	<1	
Spyridium globulosum	-	-	-	-	1(1)	-					<1	

CHAMAEPHYTES												
Carpobrotus virescens	-	-	1(1)	1(1)	1(1)	1(1)	-	-	+	+	<1	+
LIANAS												
Kennedia nigricans	8(2)	pres(2)	2(2)	-	pres(1)	pres(1)	<1	10	<1	<1	1	2
Muehlenbeckia adpressa	-	pres(2)	pres(2)	4(2)	pres(2)	-	-	3	2	4	<1	-
GEOPHYTES												
Stylidium adnatum	-	-	9(3)	8(3)	73(3)	45(3)	-	-	+	+	3	1
THEROPHYTES												
Gnaphalium indutum	-	-	4(2)	-	2(1)	63(1)	-	-	+	-	<1	
Gnaphalium sphaericum	-	-	5(1)	-	87(2)	-	-	-	+	-	1	
~~Scirpus antarcticus~~ Isolepis marginata	-	-	8(2)	pres(2)	31(2)	-	-	-	<1	+	1	
Senecio lautus	-	-	4(1)	8(1)	10(1)	-	-	-	+	<1	+	
Trachymene pilosa	-	118(3)	>250(3)	-	121(3)	260(3)	-	5	4	-	3	1
Indet seedling	-	-	3(1)	1(1)			-	-	+	+	-	
Hibbertia seedling						1(1)						+


A.
90
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
1980
LEGEND
o Bare ground
● Total phanerophytes
▲ Others
□ Leucopogon revolutus
+ Muehlenbeckia adpressa
B.
90
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
1980
YEAR



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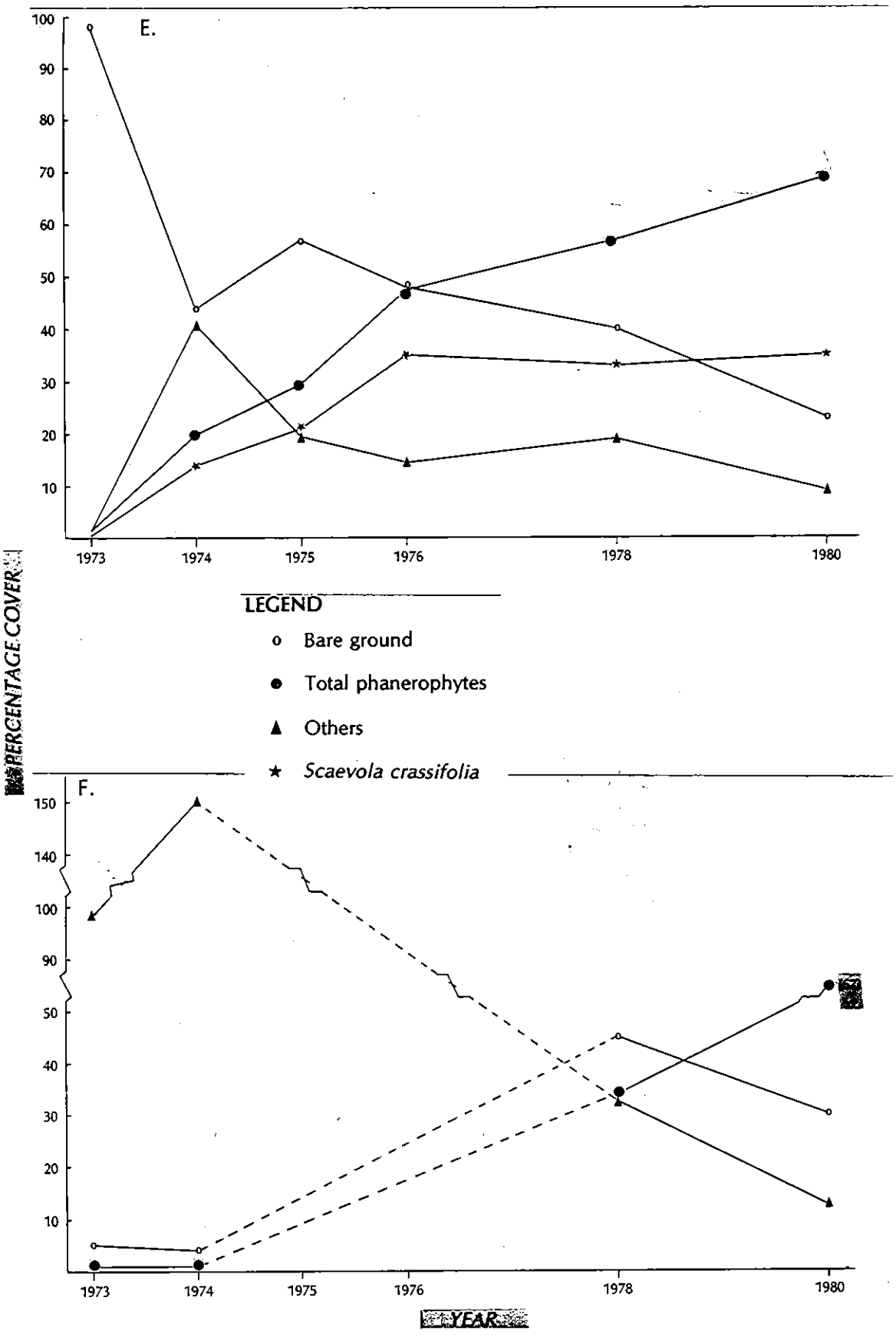
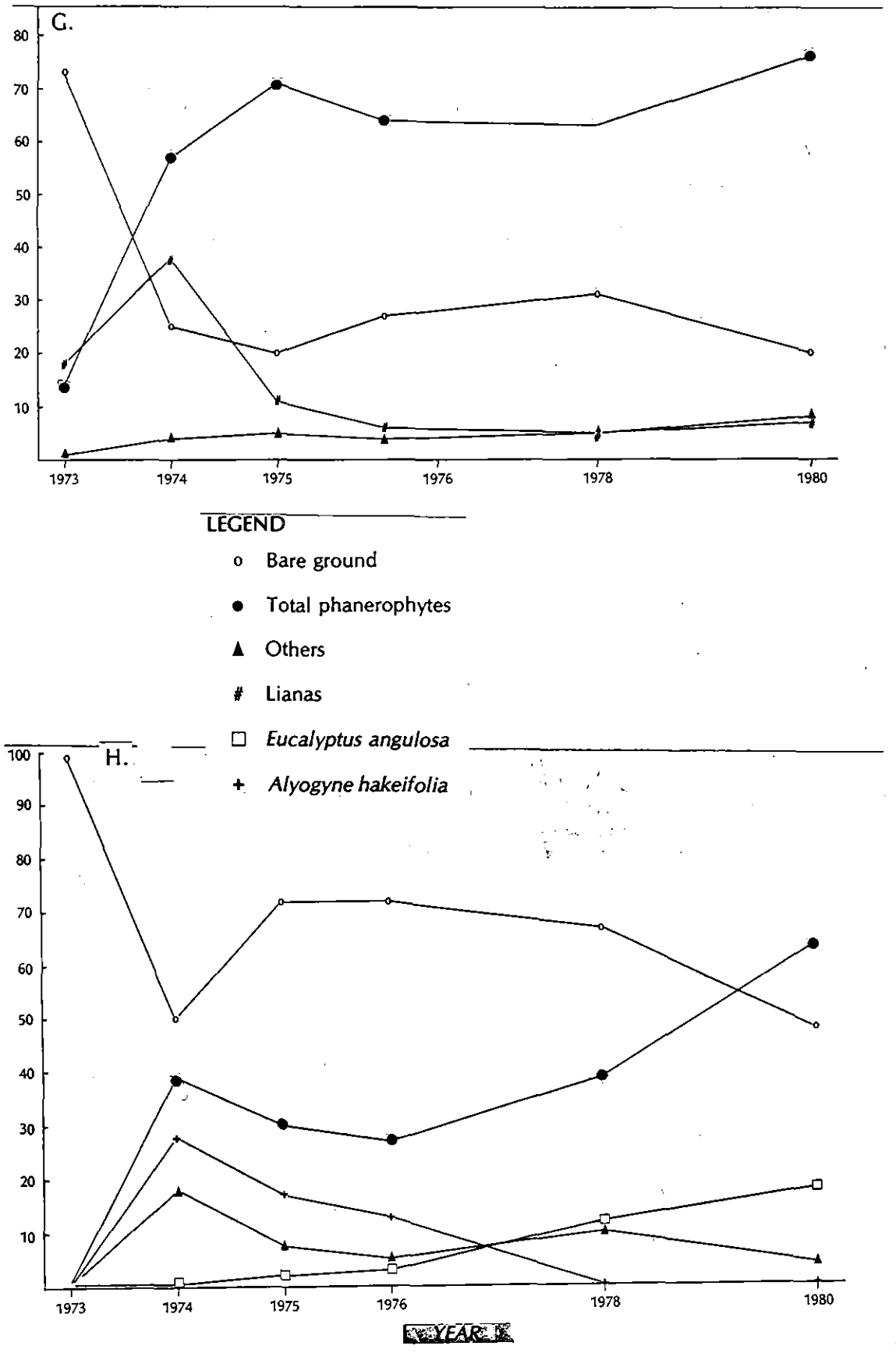

E.
100
90
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
1980
LEGEND
o Bare ground
● Total phanerophytes
▲ Others
★ Scaevola crassifolia
F.
150
140
100
90
50
40
30
20
10
1973
1974
1975
1976
1978
1980
YEAR



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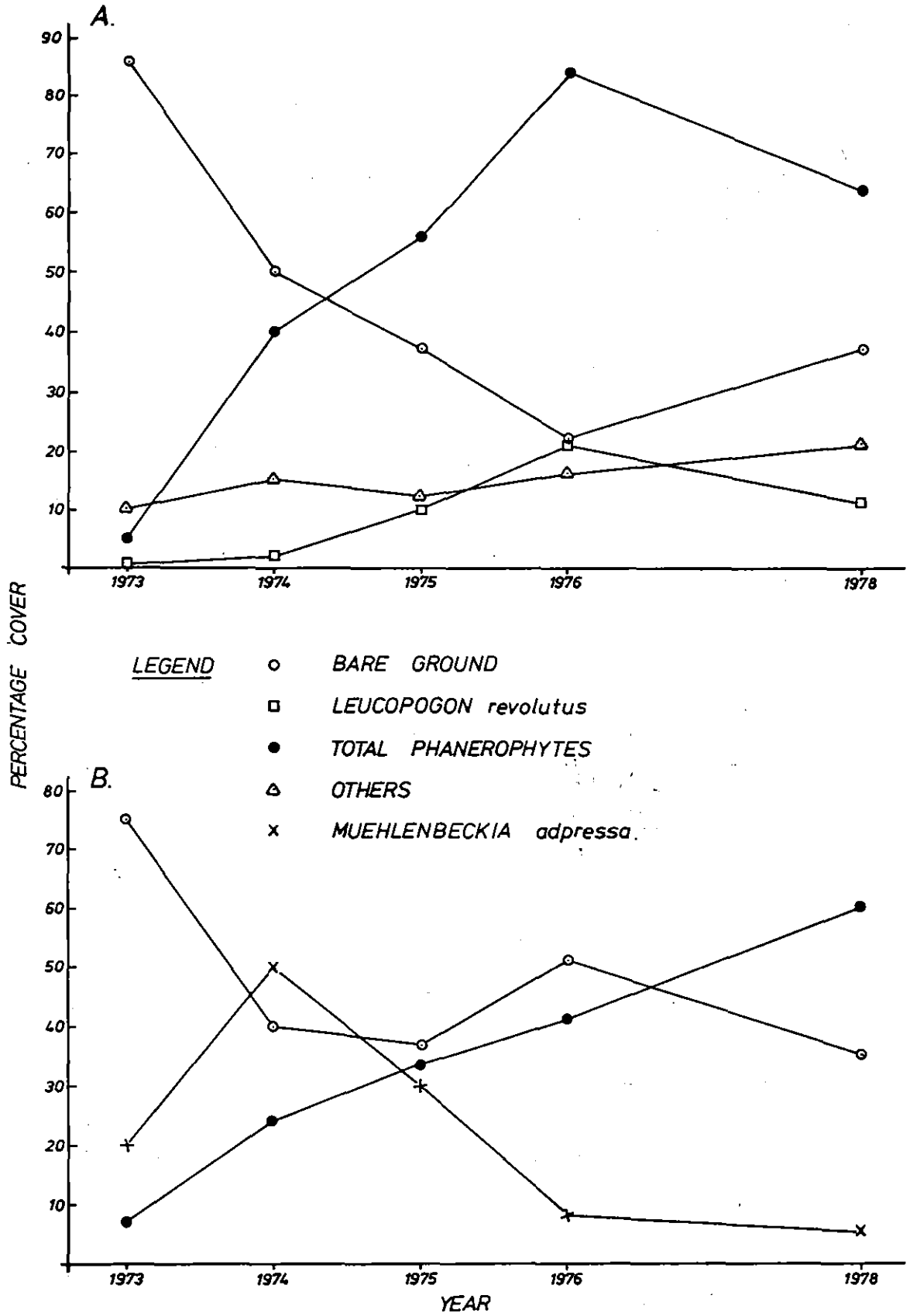
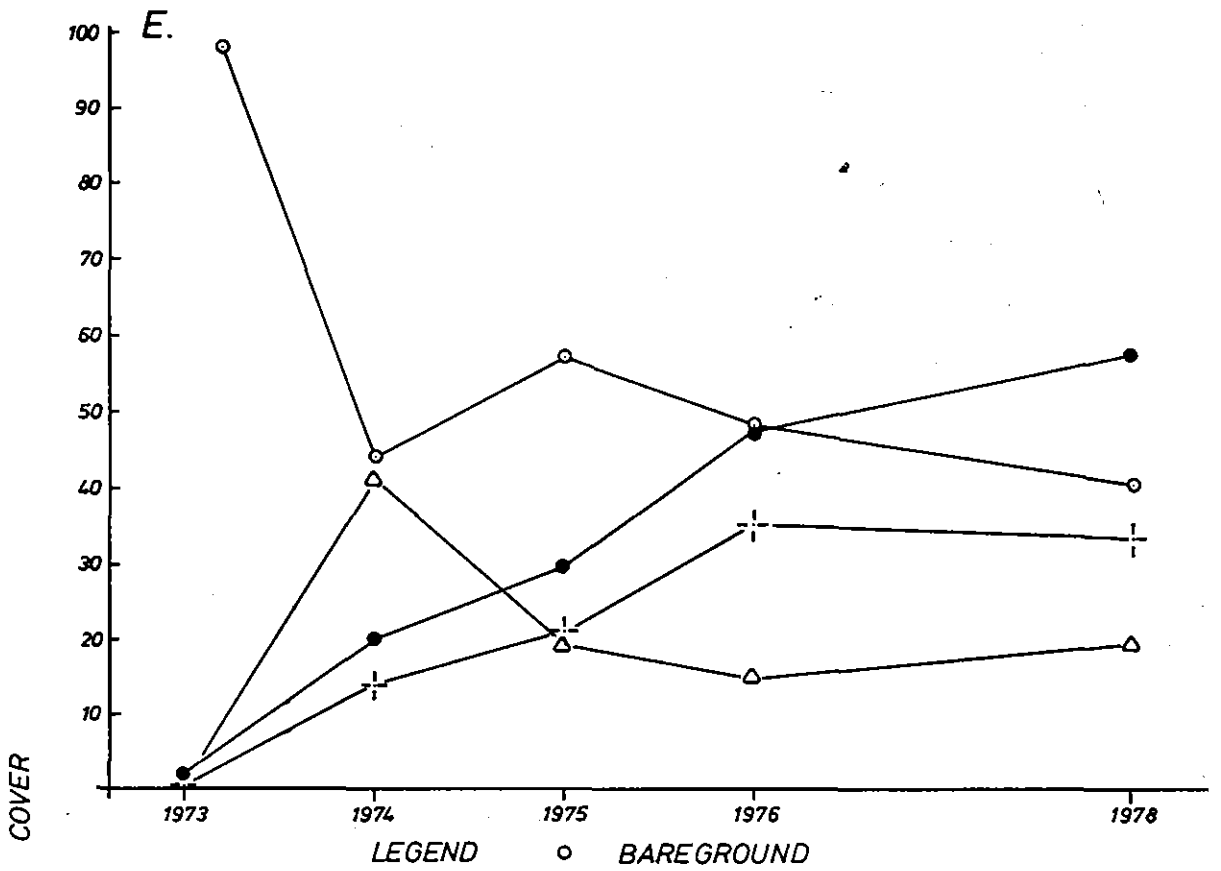
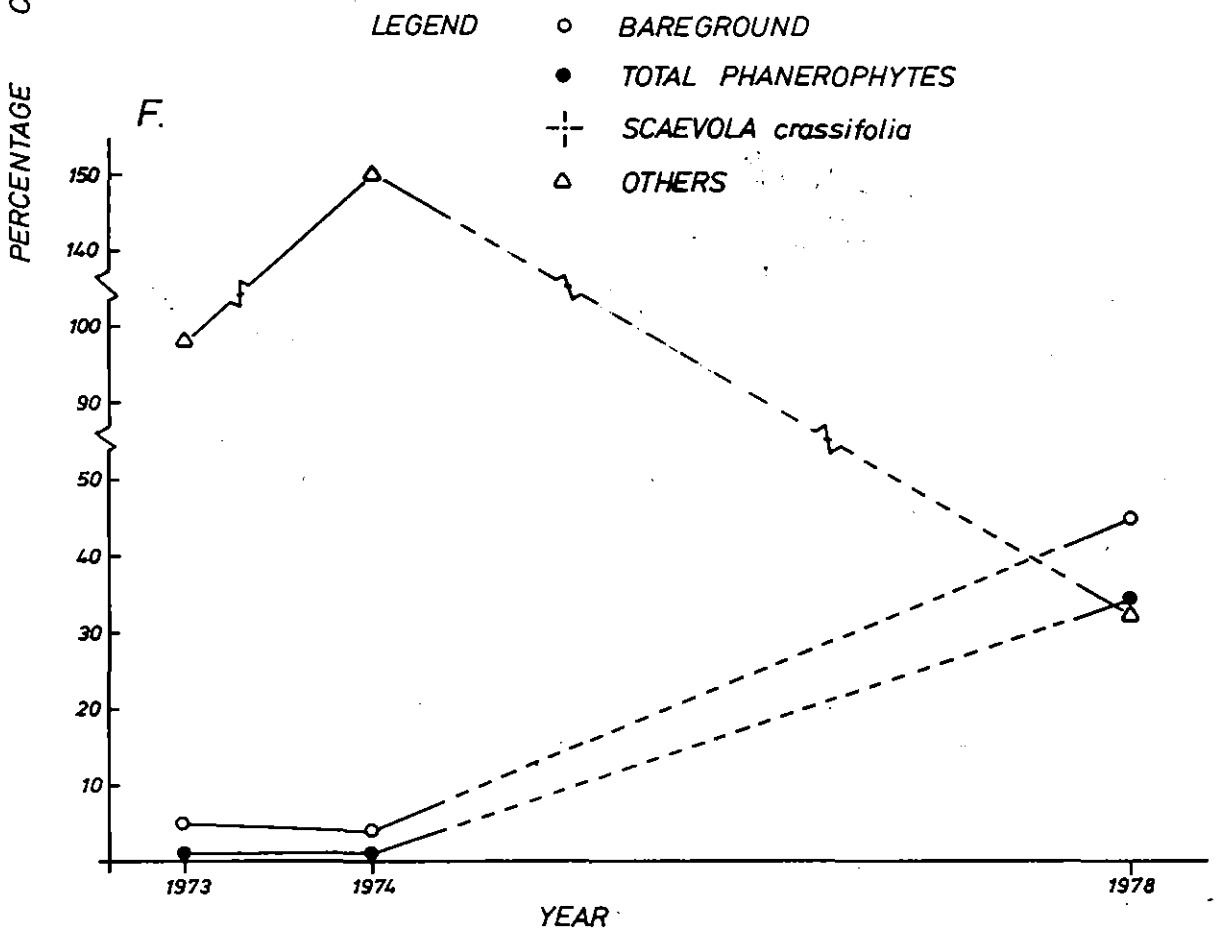
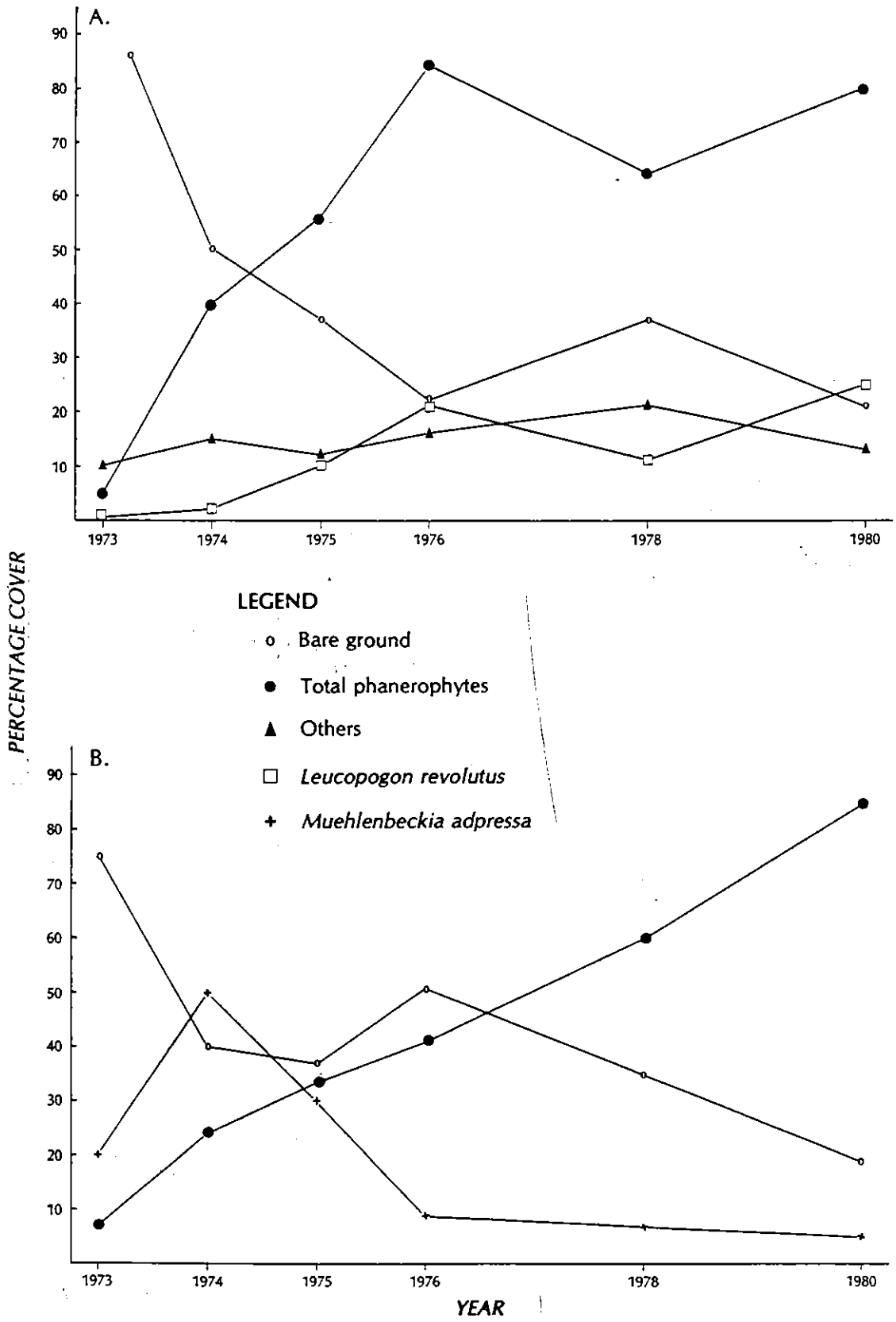
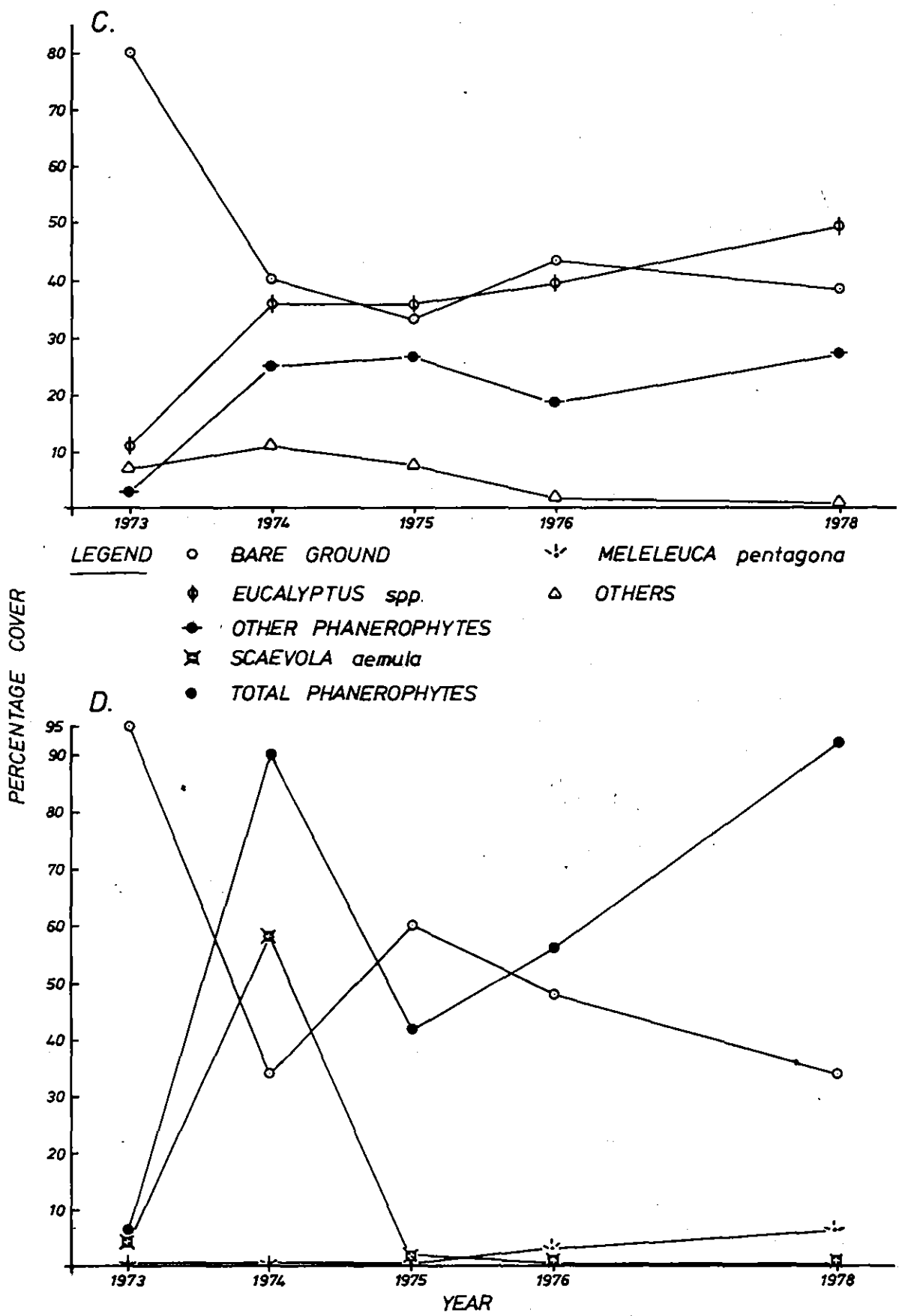
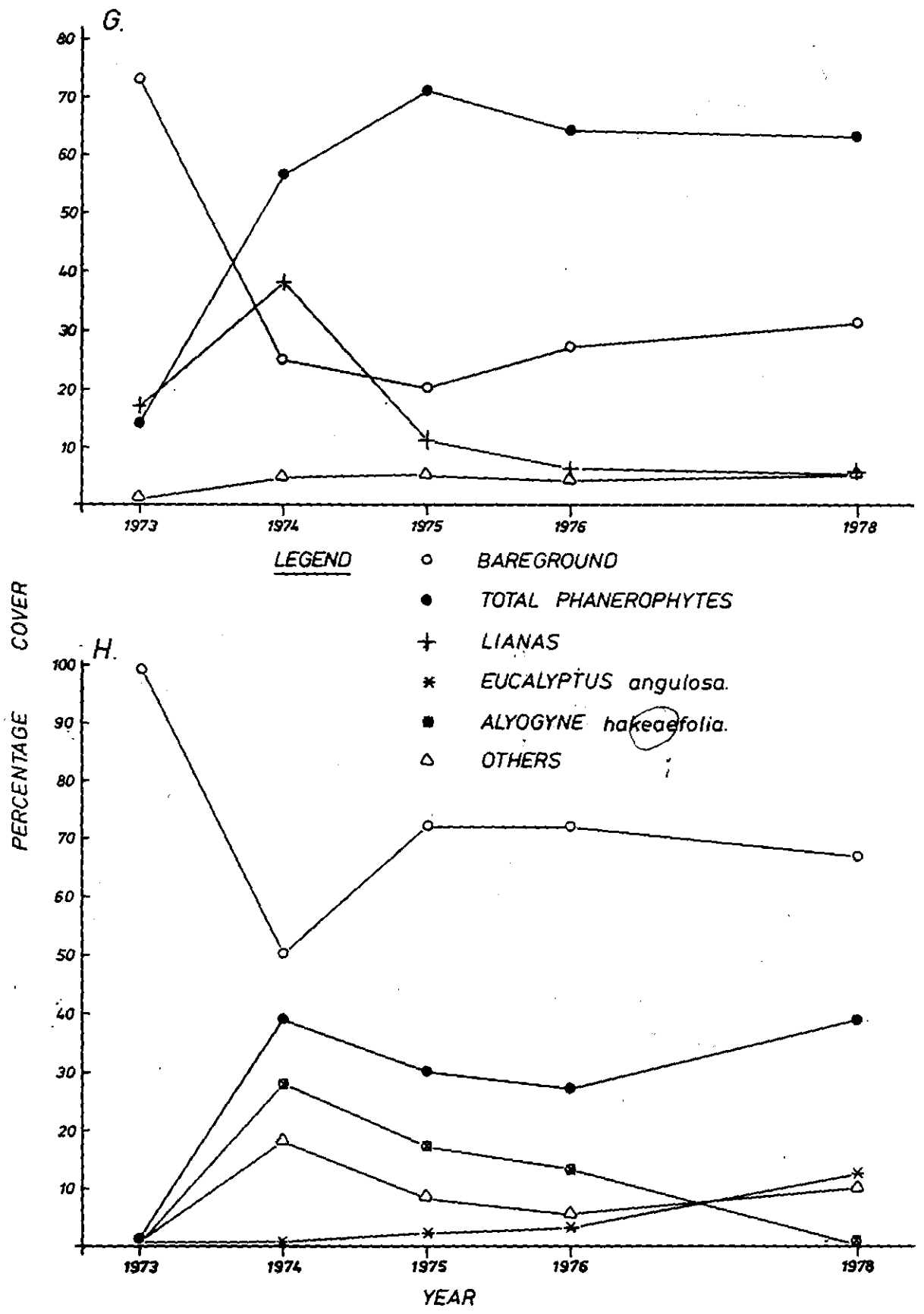

A.
90
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
PERCENTAGE COVER
LEGEND
BARE GROUND
LEUCOPOGON revolutus
TOTAL PHANEROPHYTES
OTHERS
MUEHLENBECKIA adpressa.
B.
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
YEAR


E.
100
90
80
70
60
50
40
30
20
10
COVER
1973
1974
1975
1976
1978
LEGEND
BAREGROUND


TOTAL PHANEROPHYTES
SCAEVOLA crassifolia
OTHERS
F.
PERCENTAGE
150
140
100
90
50
40
30
20
10
1973
1974
1978
YEAR


A.
90
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
1980
LEGEND
Bare ground
Total phanerophytes
Others
B.
Leucopogon revolutus
Muehlenbeckia adpressa
PERCENTAGE COVER
YEAR


C.
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
LEGEND
BARE GROUND
EUCALYPTUS spp.
OTHER PHANEROPHYTES
SCAEVOLA aemula
MELELEUCA pentagona
OTHERS
TOTAL PHANEROPHYTES
D.
PERCENTAGE COVER
95
90
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
YEAR


G.
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
LEGEND
BAREGROUND
TOTAL PHANEROPHYTES
LIANAS
EUCALYPTUS angulosa.
ALYOGYNE hakeaefolia.
OTHERS
PERCENTAGE COVER
H.
100
90
80
70
60
50
40
30
20
10
1973
1974
1975
1976
1978
YEAR

ASW

PART VII

THE TAMMAR WALLABY : HABITAT PREFERENCES

by A. Tingay and S.R. Tingay

INTRODUCTION

The Tammar Wallaby, Macropus eugenii (Demarest) is a small macropod which occurs in south-western Australia and in South Australia. In Western Australia it is found on Middle Island and four other offshore islands, and in eight isolated mainland localities (Table 1). The principal wild mainland populations occur in reserves in wheat growing districts and for the purposes of management these may be considered as ecological islands (Main 1961, Main and Yadav 1971). Studies of the population ecology of the species on actual islands can, therefore, provide considerable information for the selection and management of mainland reserves.

Prescribed burning of sections of these mainland reserves is currently practised as a fuel reduction measure, and it has been suggested that regenerating vegetation, particularly of Casuarina formations, provides necessary habitat for Tammars (Ride 1974). However, Main and Yadav (1971, p.129) from considerations of island populations, stated that the species has "...considerable ecological tolerance ...due to non-specific habitat requirements together with an ability to survive on poor food and to drink sea water." The ability for the Tammar to survive on sea water has been documented by Kinnear et al. (1968).

Table 1

This article details the distribution of Tammars on Middle Island and includes a quantitative assessment of relative use of five vegetation types by analysis of abundance of faecal pellets. This method has been used in mainland Australia by Caughley (1964) for two other species of Macropod, by Johnson (1977) in Tasmania for macropod and possum populations, and in New Zealand by Riney (1957) for several species of mammals.

METHODS

Physical and biological aspects of the Middle Island environment have been described in detail in other parts of this publication. Terminology in this paper is consistent with that used in those parts.

Data on the Tammar were collected as part of a vertebrate fauna survey of the island carried out from 5 to 16 November 1976 (se Part IV of this publication). Sightings of Tammars, and notes on the occurrence of faecal pellets in different plant associations, were made. Two associations, Melaleuca lanceolata low open forest and Eucalyptus platypus open forest, were sampled for quantitative assessment of droppings. The sampling of burnt and unburnt areas of each association gave a total of four standardised quantitative samples.

The unburnt sites had a sparse understorey with little shrub cover and good visibility (Figs. 1 & 2), while the burnt sites were very dense to a height of about two metres and had very

restricted visibility even at ground level (Figs. 3 & 4). The burnt sites were approximately equal in density of vegetation, but the unburnt Melaleuca lanceolata site had a lower and more closed canopy than the unburnt Eucalyptus platypus site.

In each of the four sample sites, twenty one metre square quadrats were laid out. The first quadrat at each site was selected randomly and subsequent quadrats occurred at ten metre intervals along a line transect. The leaf litter in each of these was carefully sifted and all faecal pellets were collected and counted regardless of age. The absence of other mammals on the island meant that there were no identification problems.

A fifth sample was collected in a dense unburnt Melaleuca lanceolata closed scrub - sand dune heath association on the promontory between Cormorant and Coverdale Coves on the north coast. This vegetation unit was only large enough for ten quadrats. No comparable burnt association was located for sampling. Data were collected according to the standard method described above.

RESULTS

Sightings of Tammars or their faecal pellets were made in all plant associatoins and on the bare granite of Flinders Peak and the sandy baches of the northern coastline. Daylight sightings were most frequent in the dense, regenerating associations. At night, the Tammars appeared to disperse widely from dense cover. This subjective impression of a diurnal pattern of dispersion may, however, be

inaccurate as concealment of observers is naturally more difficult in the less dense associations.

Tammars may have visited Flinders Peak and the beaches to obtain water from the shallow pools on the granite or from the sea.

Results of the quantitative samples of faecal pellets are summarized on Table 2. The data from the four main samples were analysed using a two-factor analysis of variance with replication (Zar 1974), the results of which are summarised on Table 3. Data from the fifth sample (Melaleuca lanceolata closed scrub - sand dune heath association) were not included in the analysis because of the different sample size. There is no interaction effect of vegetation type and fire history ($F = 0.679$; $0.50 > p > 1.00$). There is a significant difference between the number of droppings in Melaleuca forest association types and in the Eucalyptus forest types ($F = 14.1$, $1' < 0.05$) but there is no difference between burnt and unburnt samples of these associations ($F = 3.9-$; $0.05 > p > 0.10$): The last comparison is significant at the 0.10 level and may be considered as an important trend.

DISCUSSION

Tammar wallabies are distributed throughout Middle Island and make some use of all plant associations and of open granite and sandy beaches. They have an apparent preference for relatively dense vegetation as shown by the high numbers of faecal pellets recorded in the very dense low coastal heath and in regenerating vegetation. Denser vegetation may provide better daytime cover and/or relatively greater diversity or quantity of food.

However, the number of faecal pellets recorded in both types of Melaleuca associations were significantly higher than in either of the Eucalyptus associations even though burnt Eucalyptus association is apparently denser than unburnt Melaleuca association. This indicates a preference for particular types of vegetation independent of density of cover. Furthermore, within each type of plant association there was no difference between burnt and unburnt samples (at the generally accepted 0.05 level of significance).
On Middle Island, therefore, type of plant association, seems to be more important to Tammers than does density per se. Regeneration of preferred habitats after burning apparently does not significantly increase their attractiveness but there is a trend toward the burnt samples.

The generality of these findings to mainland habitats is unknown. It is possible that on Middle Island the determining factor is habital preference is the type and availability of food items rather than habitat density.

In the previous study (Bakkeer and Weston - Section VIIA) selective grazing or food preference in regenerating vegetation is described. This was not related to water or nitrogen requirements. The authors suggest that palatability in terms of quality of food items may have been the cause. The indication of both studies of the Tammar Wallaby on Middle Island is that preferred food items of the species occur differentially in vegetation associations. In some cases regenerating food species may be more palatable. These factors

result in population concentrations.

Further studies were planned to include a wider range of plant associations but the island suffered a disastrous fire in January, 1977 which burnt most of the previously unburnt area. Future work, perhaps on other islands, should include more plant associations together with studies of diet as a basis for intensive examination of the reasons for differential habitat use. Middle Island could be used to study use of vegetation at various stages of regrowth. The technique may be applicable to studies of mainland reserves provided positive identification of faecal pellets could be made.

ACKNOWLEDGEMENTS

We would like to thank Angas Hopkins of the Western Australian Fisheries and Wildlife Department for inviting us to accompany him on his 1976 visit to Middle island. He, Arthur Weston and Malcolm Trudgen provided information on the plant associations and information on Tammar wallabies.

We thank them also, together with Dr S.J.J.F. Davies, for reading and criticising the manuscript.

Table 3. Analysis of Variance Summary Table of Data Summarised on Table 2.

Source	SS	DF	MS	F values
Total	27226.4	79		
Cells	5359.8	3		
Factor A* ~~(Vegetation)~~	4047.0	1	4047.0	14.067
Factor B ~~(Fire history)~~	1117.5	1	1117.5	3.884
Interaction	195.3	1	195.3	0.679
Error	21866.6	76	287.7	

* ~~Significant value~~
Factor A - Plant Associations
Factor B - Fire History

Table 2. Number of Tammar Faecal Pellets in Samples Sites

Vegetation Type	Sample Size (No. $1m^2$ quadrats)	Mean ± S.E.	Range
Eucalyptus platypus			
open forest			
unburnt	20	9.8 ± 1.78	1-30
burnt	20	14.5 ± 2.49	0-44
Melaleuca lanceolata			
low open-forest			
unburnt	20	20.9 ± 3.09	4-54
burnt	20	31.5 ± 6.22	5-103
Melaleuca lanceolata			
closed scrub - sand	10	1.38 ± 37.28	24-356
dune heath			- -

(8) make this VII

PART ~~VIII~~ Studies of the Tammar Wallaby

A. THE TAMMAR WALLABY: THE INFLUENCE OF GRAZING ON SECONDARY PLANT SUCCI

by H.R. Bakker and A.S. Weston

INTRODUCTION

The effects of grazing by indigenous mammals on the regeneration of native vegetation after fire have received relatively little direct attention, though some authors have noted apparently increased grazing in recently burnt areas (e.g. Christensen and Kimber 1975).

A recent study by Leigh and Holgate (1979) has highlighted the considerable significance of selective grazing by predominantly native mammal herbivores on pyroseres in dry sclerophyll forest and woodland vegetation in New South Wales. They found, for example that grazing exerted profound effects on species compositions of plant communities as well as on their structural attributes.

Of the few published studies concerning these effects in Australian ecosystems, all have been undertaken in stands of vegetation that either include significant components of alien annuals or are subject to grazing by introduced mammals or both. In a few studies, the size of the burnt patches was to small to be representative.

The fire on Middle Island in the summer of 1972/73 provided an opportunity to study some of these effects under more optimal conditions. The fire was severe and extensive, burning about half the vegetated portion of the island (see Part I of

this publication). One mammal herbivore, the Tammar wallaby (Macropus eugenii), was present in low to moderate densities, and alien plants were relatively rare on the island (see Part II of this publication). A brief investigation of post-fire grazing was carried out in November 1974 in conjunction with ongoing studies of the regeneration of the burnt vegetation (see Part V of this publication). The aims of the investigation were twofold: to enumerate the species of plants subjected to heavy grazing during the early stage of the pyrosere, and to determine the importance of the grazed species in the diets of the herbivores.

STUDY SITE

A detailed description of Middle Island and its vegetation is included in Parts I and III of the present publication.

The site chosen for detailed study of the grazing was a completely burnt stand of Melaleuca globifera forest on the south-eastern side of the granite outcrop immediately west of Lake Hillier. At the time of the study, twenty months after the fire, the site was largely covered with a variety of shrubs and vines to a height of 50 cm. In terms of density, cover and biomass, the most important species were Anthocercis genistoides, Muehlenbeckia adpressa, Kennedia nigricans and Alyogyne hakeifolia. All four of these species were rare or absent from the island before the fire. Flowering plants of Rulingia cygnorum and Pelargonium littorale and seedlings of Melaleuca globifera, Leucopogon revolutus were also common.

METHODS

During random traverses through the study area, consistently heavily-grazed species of plants were noted. Samples of these species were collected for subsequent analysis for water and nutrient content. The analyses were performed at the Zoology Department, University of Western Australia. Water content in the plants was determined by drying to constant temperature at 105°C. Nitrogen determinations were made using the Kjehdahl Method (Willits, Coe & Ogg, 1949).

Tammars were captured in circular net traps baited with anise oil and small pieces of bread. These traps were placed in the study area and nearby at the edge of a dense, unburnt Leucopogon revolutus shrub community.

Immediately after an animal's capture, a blood sample was taken. Subsequently, urine and faecal samples were collected, and total bodywater of each animal was determined by the injection-of-tritiated-water technique described by Bakker & Main (1979).

The diet of the Tammars was inferred from visual observations of grazing animals and from records of grazed plants. These observations were substantiated by identification of plant epidermal material in the Tammar faecal pellets (see Storr 1964).

RESULTS

Three of the most important pioneer species in the study area, Anthocercis genistoides, Kennedia nigricans and Muehlenbeckia adpressa, showed signs of heavy grazing. Two less abundant species, Rulingia cygnorun and Pelargonium littorale, were also heavily grazed. Rootstocks on resprouting

Acácia cyclops plants nearby, were partially excavated by Tammars to permit grazing of additional new shoots. Epidermal tissue of the first three species was predominant in the faecal pellets. The dominant species of the plant association, Melaleuca globifera and Leucopogon revolutus, were abundant as small seedlings, but they apparently were not grazed.

Table 1 gives the water and crude protein contents of the three most important grazed species, together with two species, Alyogyne hakeifolia and Anthocercis viscosa, that did not seem to form part of the Tammar's diet.

Table 1. Water and Crude Protein Content (C.P.C.) of five selected plant species on Middle Island. Sample material was collected in November 1974. Protein content is expressed as % dry weight.

	C.P.C.	% water
Alyogyne hakeifolia	10.8	79.7
Anthocercis viscosa	8.3	79.4
Anthocercis genistoides	8.9	73.7
Kennedia nigricans	14.0	72.0
Muehlenbeckia adpressa	7.8	81.8

No quantitative data on grazing were collected as this would have necessitated the use of exclosures as part of a long term study. It was obvious from field observations, however, that the rates of spread and projective foliage cover increase of the two lianas, K. nigricans and M. adpressa, were substantially reduced by the grazing. Anthocercis genistoides was kept pruned to a small compact shrub.

Only seven animals were captured. All of them two adult males, four adult females and one juvenile male appeared to be in good condition. The average weight of adult males was 5.53 ± 0.08 kg and of the females 3.75 ± 0.03 kg. Total bodywater content was 74.7 ± 1.04% per animal. Faecal swabs analysed for Salmonella gave negative results.

DISCUSSION AND CONCLUSIONS

Aspects of dietary and habitat preference of Tammars have been studied in a number of other Western Australian localities (Storr 1965, Kelsall 1965, Kinnear 1970, Bakker 1973). The species shows an apparent preference for shrub communities with dense canopies from two to four metres in height, with fairly open ground storey. Dietary preference varies from place to place, but Kelsall (1965) and Kinnear (1970) reported that Tammars are capable of existing on diets with very low nitrogen levels without ill-effects. Kinnear (1970) noted heavy grazing of Mirbelia ramulosa on East Wallabi Island. This Fabaceous shrub species had a water content of from 35% (mid-summer) to 57-71% (mid-winter) and crude protein content (% dryweight) of 6.9% (mid-summer) to 11.6 - 15.3% (mid-winter). None of these earlier studies involved areas of vegetaiton regenerating after a fire.

The results of the present study seem to indicate that the animals caught were in good condition as a result of the availability of high quality food and sufficient water. Water content of the plant species was much higher than both the summer and winter levels recorded for Mirbelia ramulosa on East Wallabi Island, and free water was also available in rock pools. This probably reflects the

fact that Middle Island experiences an annual rainfall which is about 50% higher than that of East Wallabi Island. The low total bodywater figure for the Middle Island Tammars is indicative of their good condition, as this measure is inversely related to animal condition (Main and Bakker 1979).

In November 1974 the Tammars in the study area did not seem to graze selectively for either water or nitrogen. With regard to water this is not surprising since, as mentioned above, free water was still available. The nitrogen levels of the plant species analysed were sufficiently high and similar to be unimportant in respect to the Tammars' food selection activities.

The Tammars displayed a definite preference for species which were important in the early stages of the pyrosere, while seedlings of species dominating the climax plant association received little attention. It may be that, as postulated by Cates and Orians (1975) and Otte (1975), these early succession species are more palatable to the generalist herbivore; certainly the foliage is less sclerophyllous. Avoidance of unpalatable species may be an important factor. For example the bitter, sticky, external covering on the leaves of Anthocercis viscosa may deter potential grazers. Alternatively, as has been suggested by Westoby (1974), large herbivores may select an optimum mix of nutrients, available in a variety of species.

The heavy grazing pressure on the three early succession species appeared sufficient to affect significantly the course of plant succession and it is suggested that this pressure could increase with the advance of the dry season. However, Carpobrotus and Disphyma were not recorded as

being grazed on Middle Island at any time; the former genus was grazed on other islands by Tammars (Kinnear 1970) and Quokkas (Setonix brachyurus) (Storr 1964) at times of physiological stress. A few Pimelia argentea shrubs were noted as being ringbarked in a nearby area in May 1977, after the second fire, at the end of the dry season.

The dominant species of the association, Melaleuca globifera and Leucopogon revolutus, appeared to be advantaged by the heavy grazing pressure on the pioneer species, at least in the short term. In particular, the removal of the dense lianas provided gaps in the canopy to which slower-growing seedlings responded favourably.

In the long term, however, the effect may not be so pronounced, as most of the pioneer species showed a decline in importance by the third of fourth year after the fire (Part V of this publication). The findings of this study are supported by results of Leigh and Holgate (1979) from the Southern Tablelands of New South Wales, and Taylor and Weston (unpublished data) for the University of Western Australia Marsupial Breeding Station at Jandakot, near Perth.

An indirect effect of grazing upon pioneer species was the considerable reduction in their reproductive capacity. Although a large proportoin of the affected plants survived the grazing, many did so in a stunted form, with production of fewer flowers. A consequent reduction in seed production could extend the effects of this epidsode of grazing to future generations.

It was not possible during the course of this study to determine the effect of the fire and the

post-fire food resource on the Tammar population. However, it is suggested that this latter effect would be slight, as Tammar populations are slow to respond demographically to sudden increases of short durations in food resources.

The results of this study highlight the importance of grazing during the process of plant regeneration after fire. The selective grazing of pioneer species by a native mammal herbivore species appears to facilitate the return of the sclimax community, and to influence the course of plant succession in not only the contemporary generation but also future generations.

REFERENCES

Bakker, H.R. (1973). 'The Hormonal Control of the Water and Electrolyte Metabolism of the Tammar (Macropus eugenii)'. Ph.D. Thesis, Uni. of Western Australia.

Bakker, H.R. and Main A.R. (1979). Condition, Body composition and total body water estimation in the quokka (Setonix brachyurus) MSS in preparation. Aust. J. of Zoology.

Cates, R.G. and Orians, G.H. (1975). 'Successional Status and the Palatability of Plants to Generalised Herbivores'. Ecology 56 : 410-418.

Christensen, P.E. and Kimber, P.C. (1975). 'Effect of Prescribed Burning on the Flora and Fauna of South-West Australian Forests.' Proc. Ecol. Soc. Aust. 9 : 85-106.

Kelsall, J.P. 1965). 'Insular Variability in the Tammar (Protomnedon eugenii) of Western

Australia.' Ph.D. Thesis, Uni. of Western Australia.

Kinnear, J.E. (1970). 'Nitrogen Metabolism of Macropods with Special Reference to the Tammar (Macropus eugenii)'. Ph.D. Thesis, Uni. of Western Australia.

Leigh, J.H. and Holgate, M.D. (1979. 'The Responses of the Understorey of Forests and Woodlands of the Southern Tableland to Grazing and Burning'. Aust. J. Ecol. 4 : 25-45.

Main, A.R., and Bakker, H.R. (1979). Adaptation of Macropod Marsupials to Aridity. In A. Keast (Ed.) ' Ecological Biogeography in Australia'. (In press).

Otte, D. (1975). 'Plant Preference and Plant Succession : A Consideration of Evolution of Plant Preference in Schistocerca'. Oecologia 18 : 129-144.

Storr, G.M. (1964). 'Studies on Marsupial Nutrition IV. Diet of the Quokka, Setonix brachyurus (Quoy & Gaimard), on Rottnest Island, Western Australia'. Aust. J. Biol. Sci. 17 : 469-481.

Storr, G.M. (1965). 'The Physiography, Vegetation and Vertebrate Fauna of the Wallabi Group, Houtman Abrolhos'. Proc. Roy. Soc. W. Aust. 48 : 1-14.

Westoby, M. (1974). 'An Analysis of Diet Selection by Large Generalist Herbivores'. Amer. Natur. 108 : 290-304.

Willits, C.O., Coe, M.R. & Ogg, C.L. (1949). 'Kjelvahl determinations of nitrogen in refractory materials'. J. Assoc. Offic. Agric. Chemists 32 : 118-127.