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Methods of Censusing Birds in Australia

Edited by S.J.J.F. Davies

Royal Australasian
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Zoology Section of the ANZAAS and the
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May 17, 1983

Edited by
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An Introduction

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Methods of counting birds accurately are becoming increasingly important. Be it the scientist wishing to follow the effects of climate on the density of birds or the wildlife manager wishing to know the effects of his management policies, a knowledge of the number of birds present in an area is essential. Many techniques have been invented to count birds overseas, ranging from the straight count of individuals to elaborate sampling methods for species that are cryptic and songless. Since the camp out at Campbell Town, Tasmania, in 1969, the RAOU has been involved in the evolution of methods of censusing birds that are appropriate to Australian conditions (Recher, Thomas and Milledge 1971). The 1983 ANZAAS Conference in Perth provided an opportunity for some of those active in this work to gather and compare notes. The symposium, 'Bird Census Work in Australia' was sponsored jointly by ANZAAS Section 11, Zoology, and the Western Australian Group of the RAOU. The Western Australian Department of Conservation and Environment generously agreed to publish the proceedings of the symposium.

The purpose of this bulletin is to provide an up-to-date statement of the state of the art. It should not be seen as a definitive statement on how to count birds in Australia. It is only a basis on which to begin to build such a statement. Because it is intended to help discussion and experimentation, two papers have been included in addition to those given at the symposium. That by Pyke and Recher discusses the results of experimentation with methods of censusing that may be appropriate for Australian woodland and forest birds. Keast's paper discusses the results of a study in New South Wales in which the census technique depended largely on location of the birds by sound and aimed to develop methods of comparing the densities of birds in different types of vegetation.

Two of the papers in the bulletin report work on the non-passerine groups, waders and waterbirds. For these birds the census techniques used to count terrestrial species will not work. Yet counts are essential if places where waders and waterbirds concentrate are to be identified and their populations adequately monitored. The waterbird paper discusses methods of counting by observers on the ground. An earlier publication by the Australian National Parks and Wildlife Service (1979) reviewed progress in methods of assessment of bird numbers from the air. The study of waders in Australia has expanded greatly since the signing of the Australia-Japan Treaty on Migratory Birds. The paper by Minton and Lane reviews methods and presents the first comprehensive statement of the distribution and relative importance of sites where waders congregate in Australia and New Zealand.

Experimentation with methods of counting birds in Australia has shown that some methods generally accepted overseas do not provide reliable estimates of the density of birds in Australia. Some of the results presented have even cast doubt on the validity of these accepted methods under any circumstances.

It is therefore very important that experimentation should continue towards the development of satisfactory methods of censusing birds in Australia. This publication is issued in the hope that it will stimulate further research.

The names of birds used in this publication follow those of Schodde (1978).

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Use Of Bird Census Procedures in Australia: A Review

H.F. Recher — Australian Museum, Sydney

SUMMARY

Counts of Australian birds were first made in 1918, but it is only in the last ten years that Australian ornithologists have made a serious effort to census avian populations. The procedures employed in Australia have been based on methods developed in the northern hemisphere. These have been useful, but each requires modification to account for the ways in which the ecology and behaviour of Australian birds differ from those of their northern counterparts.

INTRODUCTION

During the 1970's there was a tenfold increase in the number of papers based upon censuses of terrestrial avifaunas published in ornithological journals. There are two reasons for this increase. Beginning in the late 1950's, ecological theory focused on community processes with an increased emphasis on quantitative and predictive studies. Simultaneously, there was a heightened concern for our environment and the impact of humans on terrestrial ecosystems.

It was known that birds were sensitive to changes in their habitat and were being affected by DDT and other pesticides which had come into wide use during the 1940's. The effects of these chemicals on the environment was of concern to many biologists and it was reasoned, that birds, as predators positioned near the end of food chains, could be used to gauge the effects of pollution and development on wildlife. Moreover, birds are large, conspicuous and diurnal, attributes that appeared to make them easy to count and hence provide a quantitative base for environmental studies. It was understandable, therefore, that many ecologists selected birds or bird communities to test ecological theory and measure the impact of humans on world ecosystems.

Events in Australia paralleled those in Europe and North America with one major difference. Prior to 1970, little census work had been done in Australia whereas in the northern hemisphere, there was an extensive body of research based on counts of birds and a variety of census methods had been developed and widely tested (see Berthold 1976, and Shields 1979 for reviews). However, based on the results of censuses in south-eastern Queensland, Dwyer (1972) cautioned against the use in Australia of census methods developed in North America and Europe. In support, he cited the high levels of nomadism, asynchronous nesting (prolonged nesting seasons), and prevalence of communal nesting among Australian birds. Dwyer appeared particularly concerned about the apparent lack of uniform distribution in space and time of birds in Australian habitats. His greatest concern was about the timing of censuses and the selection of census plots. Bell (1980) and Recher (1981a) also cautioned against the indiscriminate application of northern hemisphere census procedures in Australia. They argued that asynchronous nesting, communal breeding, vocal mimicry and other behaviour of Australian birds which distinguished them from their northern counterparts could affect census results. Bell considered that year-round censuses might be necessary to monitor Australian avifaunas.

The caution expressed by Dwyer and others requires a careful assessment of the census procedures used in Australia. In what ways, if any, are results affected by the 'distinctive' behaviour of Australian birds? Probably no less careful assessment is required in North Ameria and Europe. However, with no tradition of studies based on the census of birds and the lack of information on the biology of most species, it appears especially important for Australian ornithologists to test census procedures before they are widely applied. Censuses of Australian avifaunas are just beginning and it is a particularly opportune time to review the use of avian census procedures in Australia and evaluate their effectiveness in estimating the numbers of terrestrial birds.

In this paper I review the census of terrestrial bird communities in Australia and comment on the effectiveness of the methods used. In addition, some suggestions are made for ways to improve the accuracy and repeatability of results allowing for the distinctive behaviour of Australian birds. My emphasis is on forests and woodlands, because these habitats are where most of the work has been done. I have not considered studies of individual species which may have included estimates of numbers. In part, this is my own prejudice, but mostly because there are few such studies and censuses were an incidental part of the work.

HISTORY OF BIRDS CENSUS IN AUSTRALIA

The first censuses of terrestrial birds in Australia were carried out by J.B. Cleland in the Pilliga Scrub, New South Wales (Cleland 1919, 1922a, 1922b). By way of contrast, the first recorded census in North America was conducted by Alexander Wilson in 1811. In 1914, the U.S. Bureau of Biological Survey began a 'census of birds in the United States' (Hickey 1981). Cleland's census procedure was to record all the birds seen or heard as he travelled by motor car or walked through the bush. In this way, he censused birds over a distance of 2100 km (1300 miles) between 1919 and 1922 in New South Wales, Queensland and South Australia (Cleland 1922a, 1922b). Cleland (1922a) recognized that his ability to detect birds was affected by the speed of travel ('when walking, the numbers of small birds . . . is increased'), the behaviour and size of the bird and the type of vegetation. When estimating densities (birds per square mile), he therefore adjusted the width of his census transect according to species of bird and density of vegetation. Numbers were also presented as individuals per mile, number of districts and journeys on which a species was recorded, and total individuals. With some refinements, modern census results are commonly reported in the same ways.

Cleland was the first in Australia to encourage others to census birds. His objective was to count birds in a standardized way so that changes in numbers could be detected and monitored through time. Bell (1965) also advocated the need for population counts and particularly sought to encourage amateurs to undertake censuses. According to Bell, population counts had many uses, but the chief interest to amateurs was their value for conservation. Counts were necessary to be certain that areas set aside as national parks or nature reserves were large enough to maintain populations at numbers high enough to ensure the long-term survival of species. Like Cleland, Bell considered there was a need to monitor changes in 'bird life brought about by changes in habitat due to human activity'.

Unfortunately, few ornithologists heeded the advice of Cleland and Bell. After Cleland no censuses were published until Bourke (1949) presented an account of the numbers of birds nesting in a timbered paddock near Cowra in New South Wales. Bourke censused a 14.6 ha (35 acre) plot by mapping the position of all nesting birds. Lamm and Calaby (1950) surveyed the avifauna along the Murrumbidgee River in the Australian Capital Territory over two years from 1947 to 1949. Their transect was 10 km (6 miles) long and confined to the River-oak *Casuarina cunninghamiana* forest along the river's edge. The area censused was approximately 75 ha (180 acres). They presented their data as average number of birds per count (i.e. per 6 miles) and as relative frequency or the per cent of counts on which a species was observed. An adjustment was made for migrating species. This was a method recommended by Serventy (1938).

The next censuses were presented by Bell (1965) and Lamm and Wilson (1966). As an experiment, Bell (1965) counted heathland birds each week from April 1962 to April 1963, weather permitting, along a fixed width transect 1560 m (5200 ft) long and 32 m (105 ft) wide with an area of 4.2 ha (10 acres). Data were presented as average number of birds per count for each month of the census. Bell concluded that limited counts of the kind he conducted were of little value, but that censuses of Australian birds were feasible. If carried out intensively over a number of years, such counts would be useful for the management of bird populations. Lamm and Wilson (1966) combined transect counts with mist netting to estimate the abundance of birds along New Chum's Road in the Brindibella Range near Canberra, Australian Capital Territory. Their objective was to determine the extent of migration in the Brindibellas, but unfortunately they did not compare the numbers of birds sampled by the two methods nor did they present their data fully.

Counting birds became more common from the mid-60's. Kikkawa and his colleagues used species presence/absence data to compare avifaunas from a wide range of habitats in Queensland and northeastern New South Wales (Brereton and Kikkawa 1963, Kikkawa *et al* 1965, Kikkawa and Webb 1967 and Kikkawa 1968). The large number of sites surveyed provided frequency of occurence data which were then used to describe patterns of species diversity (Brereton and Kikkawa 1963), to group habitats by the similarity of their avifaunas (Kikkawa and Webb 1967, Kikkawa 1968), to analyse the structure of bird communities (Kikkawa 1974) and to describe the relation between birds and vegetation structure (Kikkawa and Williams 1971, Kikkawa 1982). Kikkawa and Pearse (1969) used species lists from 121 sites throughout Australia in a numerical analysis of the geographical distribution of land birds. Their results confirmed the zoogeographic regions of Australia derived intuitively by earlier workers.

The use of species presence/absence data and numerical analysis has proved to be a powerful tool in Australian ornithology. It also has been useful in the conservation and management of the continent's wildlife. Webb *et al* (1973) showed how these procedures could be used to identify areas of land for nature conservation. Recher (1975) used presence/absence census data obtained during the 1972 RAOU Field Outing to classify the major avian habitats at Myall Lakes, New South Wales. The results obtained proved valuable in arguing for the reservation of a national park. Association analysis was also used to classify forest habitats in the Eden woodchip district in south-eastern New South Wales (Recher *et al* 1980). The classification assisted in the identification of habitats with the most diverse avifaunas and provided a basis for the development of plans for wildlife management at Eden (Dobbyns and Ryan 1983).

Species abundance data were used by Recher (1969) to compare the diversity of Australian bird communities with those in North America. He concluded that temperate zone forest and shrub communities were equally diverse on both continents and that diversity was determined by the structural complexity of the vegetation. Recher (1969) used fixed width transect and territory mapping procedures to estimate bird numbers. Brereton and Kikkawa (1963) and Holmes (1973) investigated patterns of bird species diversity in temperate and cool temperate rainforests in northern New South Wales. Brereton and Kikkawa based their analysis on species presence/absence data, but Holmes estimated species abundances using a line transect procedure. Dwyer (1972) used similar procedures to census birds in semi-arid habitats in northern Queensland. Dwyer concluded that 'special habitat features', such as rocky outcrops, influenced the distribution and abundance of birds in contiguous habitats. This, he argued, raised doubts about the use in Australia of census techniques developed for north temperate avifaunas and environments where birds and habitats might be more uniform in their distribution.

Census work has also been important in the study of the evolution of island avifaunas. Abbott (1973, 1974, 1975) studied the avifauna of Tasmania and islands in Bass Strait and compared these to mainland communities. He used a mapping procedure and counted birds on small (3 ha) plots to avoid problems with the heterogeneity of habitat. Although his forest plots in Tasmania and on the islands had fewer species than the mainland, total population densities were about the same. Recher *et al* (1971) obtained similar results in a series of censuses conducted during the 1969 RAOU Field Outing. Abbott (1978) compared the number of passerine species breeding on islands around the south-west coast of Australia with mainland assemblages in similar habitats. He again found that the island avifaunas had fewer species and concluded that the difference resulted from the poor colonizing ability of most passerine birds. Recently, Abbott (1980) used mist net captures and Davies (1980) the IPA method (an interval point count procedure; Blondel *et al* 1970) to estimate the relative abundance of birds on islands off the West Australian coast.

The amount of bird census work increased rapidly during the 1970's. Virtually all of this work was related to the management of forests and coastal heaths. Pattemore and Kikkawa (1974) used mist net captures to compare avifaunas in logged and unlogged rainforest in northern New South Wales. Logging and its impact on the abundance of birds in rainforest and wet sclerophyll forest was also studied by Milledge (1980) and Shields *et al* (in press). The effect of integrated logging or clear-felling on birds in eucalypt forest was studied in New South Wales by Recher and his co-workers (Recher *et al* 1980, Smith [in press], Kavanagh *et al* 1984), in Victoria by Loyn (1980), and in Western Australia by Wardell-Johnson (1984). Disney and Stokes (1976), Gepp (1976), Suckling *et al* (1976), Driscoll (1977) and Friend (1982) among others compared populations of birds in exotic pine plantations with those in eucalypt forest. Woinarski (1979) working in Victoria presented data on the abundance of birds in plantations of native trees.

The effects of fire on bird populations were also intensively studied. Cowley (1974) and Christensen and Kimber (1975) reported on the effects of prescribed burning and Smith (pers. comm.) and Recher, Allen & Gowing (in press) on the impact of wildfire on birds of forest. Recher (1981c) also studied the effects of wildfire on birds of heath.

The objectives of these studies were to measure the effect of forestry practices (i.e. logging, clear-felling and establishment of plantations) and fire on the abundance of native birds and to recommend ways to minimize adverse effects. Other workers have sought to establish the effect on the numbers of birds of mining (Collins *et al* [in press]), clearing for power-lines (Bell 1980), clearing for agriculture (Kitchener *et al* 1982; Howe 1981) and die-back (Ford and Bell 1981). Bird census work has also figured importantly in biological surveys (e.g. Broadbent and Clark 1976; Kikkawa and Monteith 1980; Kitchener *et al* 1982) and in the preparation of environmental impact statements (e.g. Recher *et al* 1975; Forestry Commission (N.S.W.) 1981).

Kitchener (1982) and Kitchener *et al* (1982) reported on the adequacy of reserves in the wheatbelt of Western Australia for the conservation of birds and other vertebrates. The reserves had more species than recorded by Abbott (1978) for similar sized islands around the south-west coast. Although reserves as small as 80 ha were important sanctuaries, Kitchener *et al* (1982) concluded that 1500 ha was the minimum area needed to conserve a local avifauna. Reserves of 30,000-90,000 ha were required to contain most of the bird species of the south-west.

The adequacy of a reserve system for the conservation of birds is not only a function of the number of reserves and their size. Allowance must also be made for seasonal changes in abundance and for migration and nomadism. Few studies have attempted to census birds through the year or to monitor changes in abundance from year to year. Recher *et al* (1980) presented data on year to year variation in species number and the abundance of individuals during the breeding season for forest transects in south-eastern New South Wales. They found that the number of species on a plot could differ by 30% between years and that numbers in different types of forest varied independently (Fig. 1). Abundance decreased as the number of species decreased. Ford and Bell (1981) compared summer and winter populations on a plot in woodlands near Armidale, New South Wales. The summer and winter counts were in different years, but apart from marked differences in abundance for some migrants there was little difference in total numbers of birds between seasons.

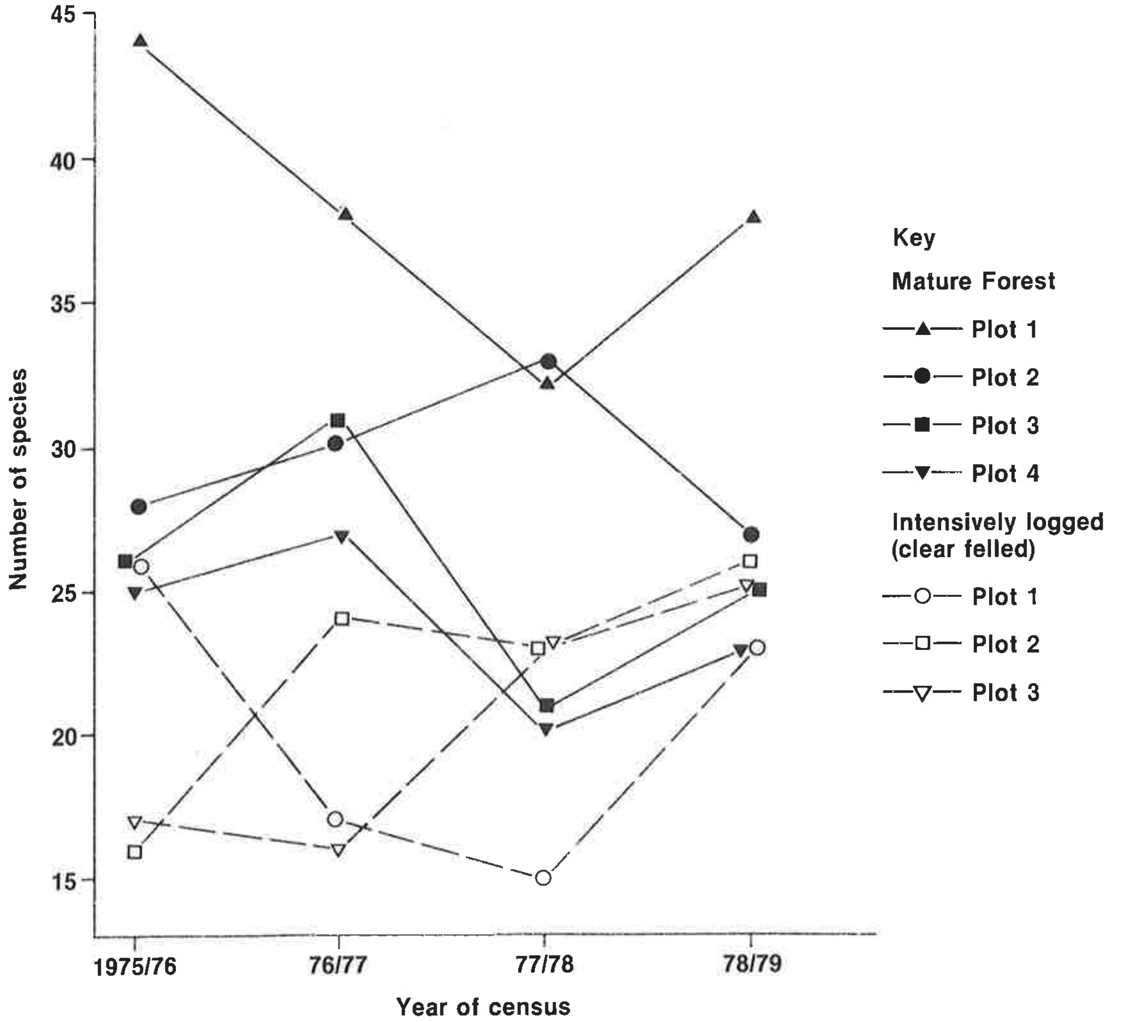

Figure 1: Variation between years in the number of bird species on census transects during the breeding season (October-December) in forests of south-eastern New South Wales. The solid lines represent four plots in mature forest and the dashed lines represent three plots which had been intensively logged (clear-felled). The number of species varied by as much as 30% between years and was accompanied by parallel changes in the total number of individuals. The plots varied independently of each other. (adapted from Recher *et al* 1980).

Bell (1980) working in the Australian Capital Territory and Recher, Gowing *et al* (1983) on the southern tablelands of New South Wales censused birds monthly. Results from the latter's plots in forest and woodland were similar to Bell's. The number of species and the abundance of birds were lowest in winter, increased during spring and summer as migrants returned and declined through late summer and autumn (Fig. 2).

The yearly pattern of abundance in the avifauna on the southern tablelands was correlated with seasonal changes in abundance of insects (Recher, Gowing *et al* 1983). Collins and Briffa (1982) in Western Australia and Ford (1983) in South Australia showed

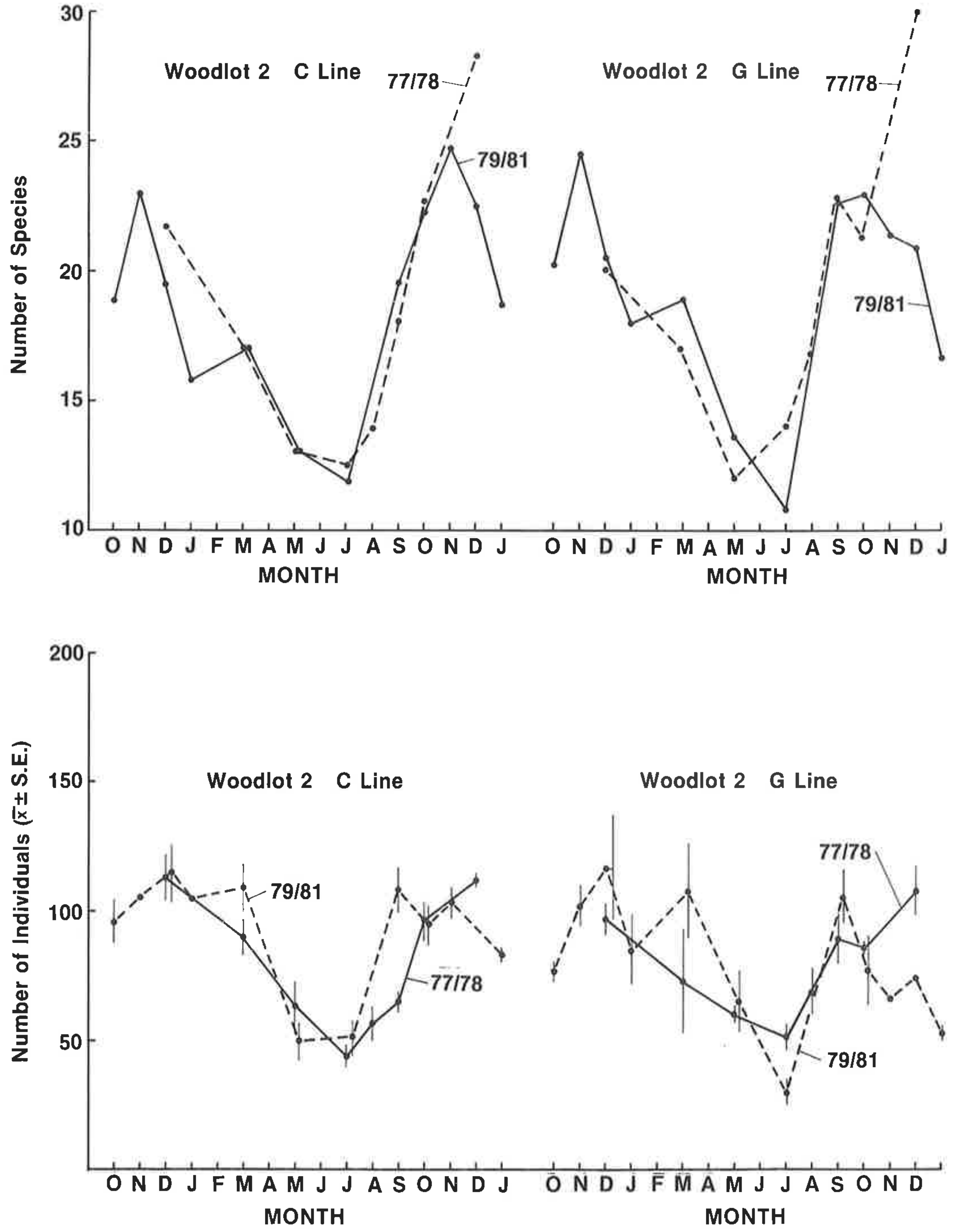

Figure 2: The average number of species and individuals detected in a 2 h count on two 5 ha transects in open forest and woodland near Bombala, New South Wales. Numbers were lowest in winter and peaked in spring as numbers of birds migrated through the region. (adapted from Recher, Gowing *et al* 1983).

that the movements and abundance of honeyeaters was correlated with the abundance of nectar-rich flowers on which the birds fed. However, Pyke (in press a) was unable to show a relationship between the seasonally varying numbers of honeyeaters on heath near Sydney and either the amount of nectar or the abundance of small flying insects. Honeyeaters were absent from open eucalypt forest except at times of substantial nectar production, but peaks of nectar production and honeyeater numbers did not often coincide (Pyke [in press b]). Pyke (pers. comm.) was also unable to relate the numbers of insectivorous birds in the same habitats to seasonal patterns in the abundance of flying insects.

THE ROLE OF AMATEURS

The increased use of census procedures to study populations of birds and to monitor environmental impact in Australia parallels similar increases in America and Europe. However, there has been a much greater involvement of amateurs in bird census work in America and Europe than in Australia. The annual Christmas Bird Count is the largest and oldest count in North America involving amateurs (Bock and Root 1981). The count was inaugurated in 1900 and in 1979 involved 33,022 participants who censused 1320 count units (each unit is a circle 24 km in radius) in North, Central and South America and Hawaii (Drennan 1981). The North American Breeding Bird Survey commenced in 1966 and by 1980 involved more than 1800 volunteer observers (Bystrak 1981). In Europe the British Trust for Ornithology began in the early 1960's to monitor breeding bird populations on farmland in its Common Birds Census with the use of volunteers (Batten and Williamson 1974; O'Connor 1981). By 1980, 300 to 350 sites including farmland, woodland and mixed habitats were sampled annually.

The Common Birds Census uses a mapping method while the North American Breeding Bird Census is based on a point transect system. These counts and others like them are co-ordinated nationally and contribute importantly to an understanding of the abundance of birds in North America and Europe. The counts obtained can be used to monitor long-term trends in the abundance of individual species (e.g. Sen 1981; Geissler and Noon 1981; Marchant 1980). Comparable programmes have been initiated in Australia, but until recently have not been co-ordinated at a national level and have had limited success.

World Bird Day Counts were initiated by the Bird Observers' Club, Melbourne in 1950 when counts were submitted from 99 locations throughout Australia. The number of counts increased to 155 in 1954 (Morgan and Wheeler 1955) with 2 from Western Australia, 37 from Queensland, 13 from New South Wales, 94 from Victoria and 9 from Tasmania. The counts appear to have been conducted on the style of the American Christmas Counts with an element of competition as to where the greatest number of species could be recorded. In 1954 the largest number of species recorded in a single count was 131, at Grafton, New South Wales. Procedures do not appear to have been standardized and the duration of counts, size of area surveyed, and number of observers differed between counts. World Bird Day Counts were published irregularly and ceased in the early 1960's.

In 1979 the New South Wales Field Ornithologists Club began spring and autumn censuses within 80 km of Sydney to monitor long-term changes in the numbers of birds. In May 1982 the census involved 125 persons who travelled 2080 km (McGill 1982). Apart from the restrictions to remain within 80 km of the Sydney G.P.O., to census in May and November, to report birds on a district by district basis and to keep count of the number of participants, hours and distance, there appear to be no formal procedures. All birds seen and heard are recorded and the data can be expressed as birds per hour or per kilometre of census. A preliminary analysis of the data (G. Pyke, [pers. comm.]) indicates that these counts detect seasonal changes in abundance of species and should detect year to year variation. However, as happened with the World Bird Day Counts, there is a risk that the lack of precise guidelines as to the areas surveyed and census procedures will confuse results and minimize the long-term benefits of the programme.

An effort to co-ordinated censuses at a national level has been made by the RAOU. In 1980, the RAOU proposed a national census programme, the Rolling Bird Survey, to provide quantitative data that could compare temporal changes at any one site (Cullen 1980). The Rolling Bird Survey is based on a point transect system using fixed routes. Species present at each point are recorded over a five minute period, but the number of individuals is not registered. Abundance is calculated on the frequency with which species occur at points. With sufficient participation, the Rolling Bird Survey should provide similar kinds of data to the American Breeding Bird Survey. A resolution was also passed at the 1980 RAOU Congress in Tasmania that the RAOU promote the adoption of standard procedures for the census of birds in Australia.

THE USE OF CENSUS PROCEDURES

Although there are many variations, basically four procedures are used throughout the world to census birds: mapping (including nest searches), line transects, point or quadrant counts and mist net captures (see Ralph and Scott 1981 for comprehensive discussions of census methods). Each of these procedures has been used in Australia. Generally, Australian workers have followed European and American guidelines without testing the validity of the procedures for the different behaviour of Australian birds. Recher (1969), for example, assumed that all birds were territorial and monogamous, that only males sang and that breeding of different species was synchronous (Recher 1981a). As Dwyer (1972) and Bell (1980) have noted, these are not valid assumptions.

Five studies in Australia have compared the estimates of population densities by different methods. Loyn (1980) used standard mapping techniques (IBCC 1970) in eucalypt forest and compared the results to transect counts modelled on the Emlen method (Emlen, 1971, 1977). Loyn found that the estimates of density from the transect counts were lower than results obtained from mapping and considered that the transect procedure failed to detect inconspicuous birds. Hermes (1978) compared estimates of non-breeding bird populations in open forest obtained by transect counts, by quadrant counts and by mapping. He obtained significantly different estimates of density for each method, but concluded that each procedure accurately portrayed seasonal changes in abundance. The methods differed principally in their effectiveness of censusing particular species. Shields and Recher (in press) compared estimates of breeding bird densities in open eucalypt forest and woodland obtained from fixed width line transects to those from mapping, nest searches and mist net captures. The transect method was the only one to sample the entire avifauna. Comparisons of population densities for birds sampled by all four methods were similar to the results obtained by Hermes (1978). Territorial species (e.g. Rufous Whistler *Pachycephala rufiventris*) were best sampled by mapping whereas colonial species (e.g. White-naped Honeyeater *Melithreptus lunatus*) and species with large territories or home ranges (e.g. White-throated Treecreeper *Climacteris leucophaea*) were best sampled by transect procedures. Nest searches, if intensive, gave results comparable to those from mapping, but were of more value when combined with mapping. Mapping was facilitated by individually colour banding resident birds. Mist net captures in these habitats gave the least reliable estimates of numbers and were the most expensive in terms of time and effort. Davies (1982) compared densities of birds in shrub and mallee habitats as estimated by transect counts, by mapping, by point counts using the procedures of the Rolling Bird Survey and the IPA method (Blondel *et al* 1970). Davies found the IPA results were too variable to be used. Higher estimates of species densities were generally obtained from the point counts than from the transects. Mapping sometimes gave higher and sometimes lower estimates of species densities than the point counts. Arnold (1984) compared variable distance point (following Recher 1981b) with transect counts. He found the point counts in woodland missed species and provided lower estimates of numbers than transect counts.

Recher, Milledge *et al* (1983) described a transect method used in forest and woodland habitats in New South Wales. The transect had a fixed width and incorporated a point census for more detailed habitat studies. The procedure gave consistent results and was useful where estimates of relative abundance were adequate and there was a need to sample uncommon species. Kavanagh and Recher (1984) described problems of observer variability with this method and Shields and Recher (1984) compared results with three other census procedures. Pyke (1983) described a method of estimating absolute densities using 'instantaneous counts' of birds within a fixed radius of the observer. Recher (pers. comm.) also used instantaneous counts to estimate numbers of swallows, woodswallows and honeyeaters on heath. In this instance, the counts were made at fixed intervals along a census transect. Pyke and Recher (in press) evaluated the use of a variable distance point count procedure in cool temperate, tall open forest and Harden *et al* (pers. comm.) assessed the use of transect procedures in warm temperate tall open forest. Each of these procedures, as well as the others used in Australia, were affected by weather, time of day, variability of observers, rate of movement, density of vegetation and so forth in the same ways that census results were affected in the Northern Hemisphere (see Ralph and Scott 1981 for reviews). It is worth noting that Pyke (1984), Davies (1982), and

Pyke and Recher (in press) found repulsion of birds by the observer a difficulty with point counts. Apart from these problems, results were not affected in any unusual way by the behaviour or habits of Australian birds (e.g. communal nesting, nomadism).

POPULATION DENSITIES OF EUCALYPT FOREST AND WOODLAND BIRDS

The largest number of censuses which estimate species abundances have been carried out during the spring and summer in forest and woodland habitats in south-eastern Australia. The majority of studies have used transect procedures, but there are some data derived from mapping and nest searches. Although the plots span a wide latitudinal range (32°S to 41°S) and include a variety of forest types, they can be grouped into four structural formations; woodland, low open forest, open forest and tall open forest. Within each group there is a range of estimated densities with open forest having the smallest total densities (Fig. 3). Woodland, low open forest and tall open forest are broadly similar with the greatest densities of birds estimated for tall open forest. The same pattern is shown by counts in forest near Eden, New South Wales (37°S) conducted by Recher and his co-workers between 1975 and 1979 using a standard transect procedure (Recher *et al* 1980; Recher, Milledge *et al* 1983) (Fig. 4). Open forest on ridges and slopes had fewer species of birds and lower total densities than tall open forest along creeks and in gullies. Plots in woodland probably had high densities because of the large number of open country birds (e.g. Australian Magpie *Gymnorhina tibicen*) which occurred with forest birds in these habitats. Due to the abundance of nectar-rich flowers, low open forest had high densities of nectivorous birds which greatly increased the total number of birds (Milledge and Recher [in press]).

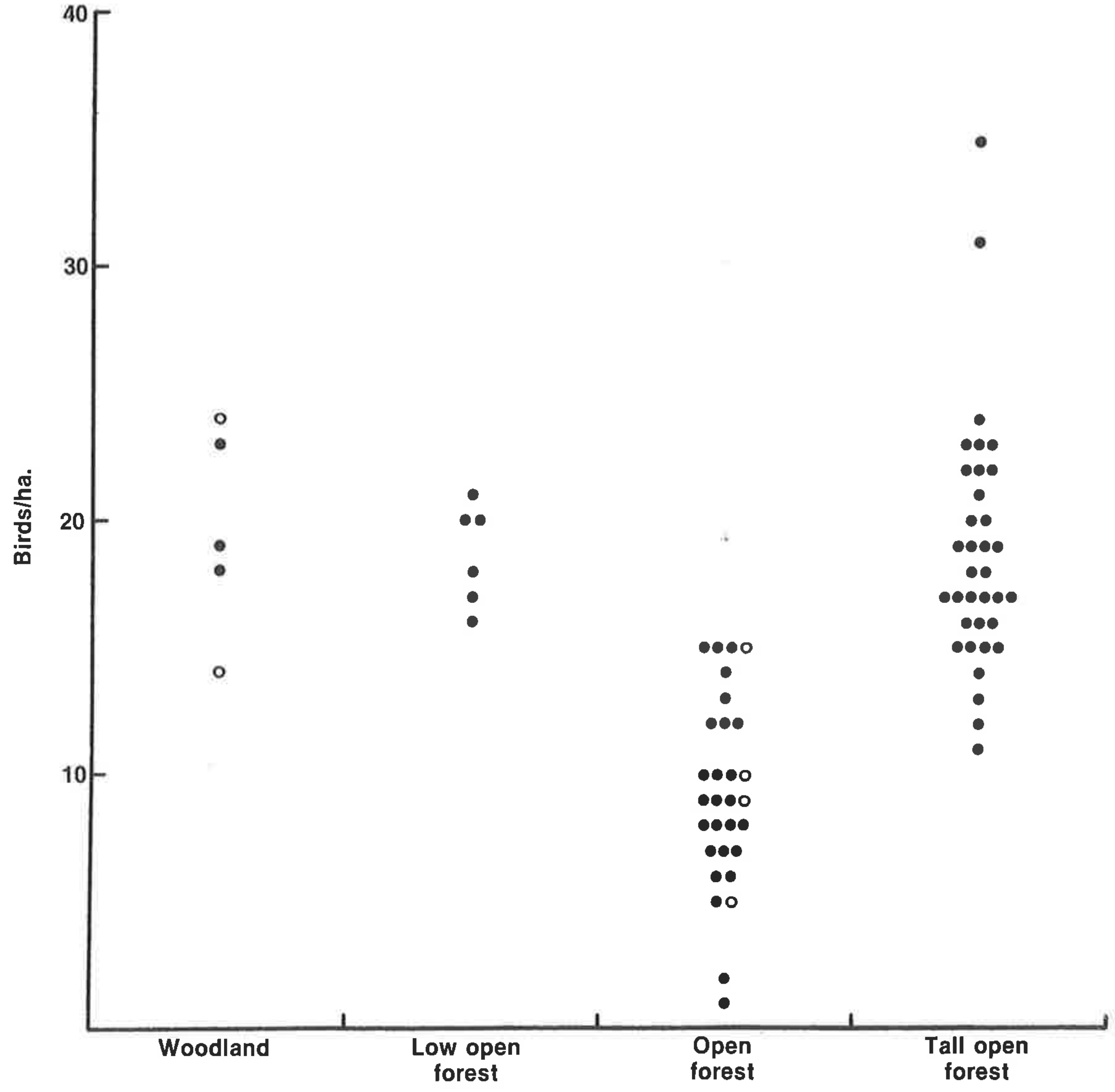

Figure 3: The number of birds per hectare in a variety of forest and woodland plots from Tasmania, Victoria and New South Wales. Plots differed in size and different census procedures were used by the observers who carried out the counts. The open circles counted breeding birds only, but in most instances an attempt was made to count all individuals on the plots. Data were extracted from papers cited in the list of references, but should not be used to represent 'real' densities.

DISCUSSION AND CONCLUSIONS

Because the results obtained from censuses of forest and woodland birds in south-eastern Australia are broadly similar and fit our 'biological intuition' of the likely differences in the numbers of birds between different types of forest, it is tempting to conclude that the censuses accurately measured densities and that the different methods gave similar results. However, none of the methods used by different workers have been calibrated against one another nor are the properties and assumptions of the various methods fully understood (Pyke and Recher 1984). Comparisons of densities estimated by different methods or in different locations may therefore be misleading. The problems inherent in comparing results from different methods is well illustrated by the different results obtained when individual workers have compared methods on the same sites (e.g. Hermes 1978; Loyn 1980; Shields and Recher [in press]).

Although it appears that standard census methods (e.g. mapping, transect counts) are as useful in Australia as in North America or

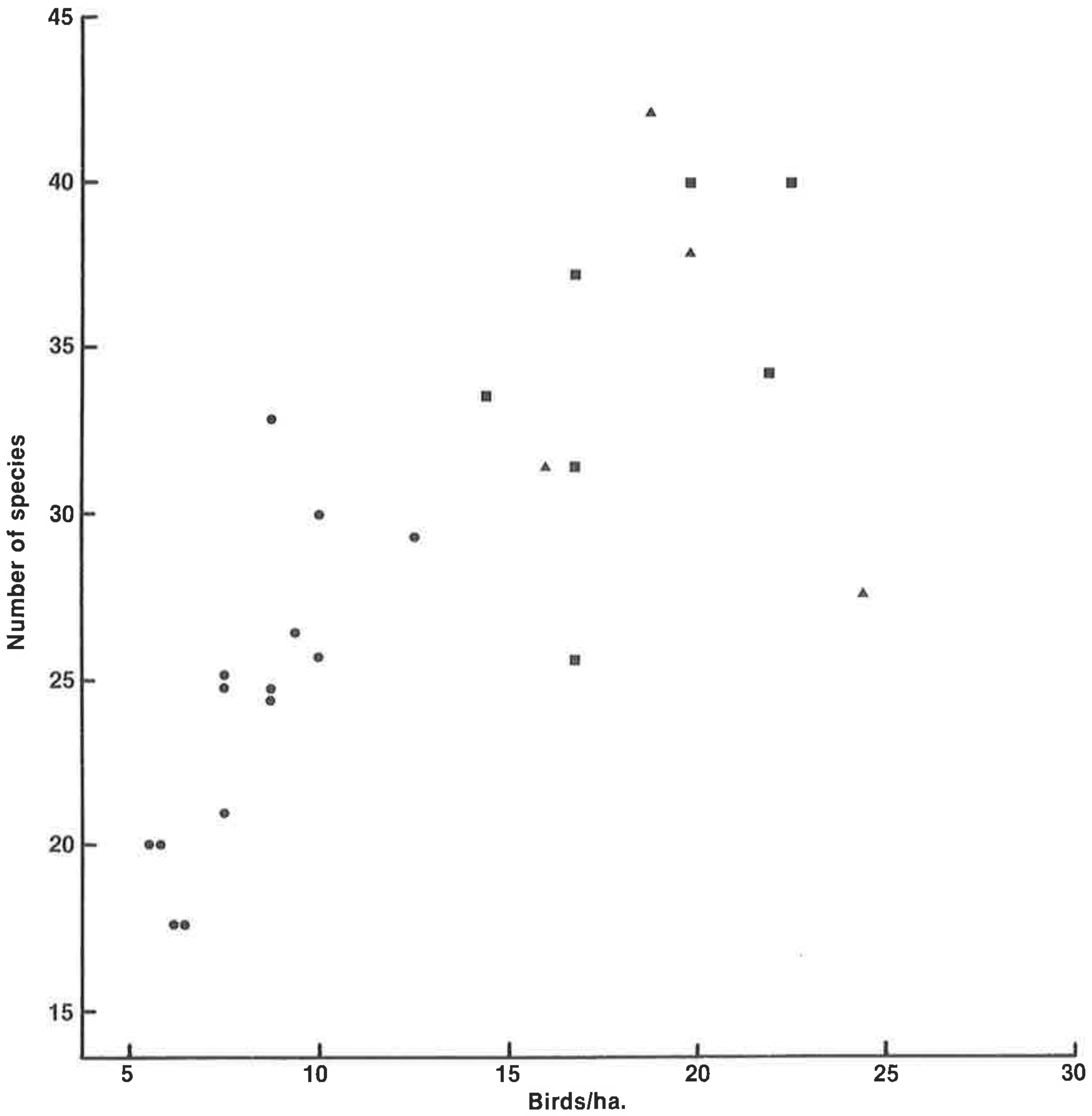

Figure 4: Fixed width transect count of birds in low open forest, open forest and tall open forest were conducted from 1975 to 1978 in forests near Eden in south-eastern New South Wales. The same procedures were used on all counts and results are similar to those derived from the literature and illustrated in Figure 3. Open forest (closed circles) generally had fewer species and individuals than either low open forest (triangles) or tall open forest (squares).

Europe, they are also subject to the same sources of error. The problems inherent in each method are discussed more fully by Pyke and Recher (1984).

It is unreasonable to expect all workers to adopt the same census method. The method chosen will differ according to the objectives of the research proposed and to the type of habitat. However, there is a substantial advantage in standardizing procedures for individual methods. This is especially so in Australia where little work has been done to date and the small numbers of people available to conduct censuses makes the adoption of uniform codes feasible. Standard procedures and methods of data recording and storage would facilitate the comparison of results and in this way greatly extend the value of individual counts.

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Comparison of Numbers and Species of Birds in Wandoo Woodland obtained by Two Census Methods

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SUMMARY

The numbers of birds present in two different plant communities within Wandoo woodland were censused by two methods. Each community was 4 ha, and was divided into hectare blocks using marking tapes. The number of birds was censused ten times by one observer using the RAOU fixed point method, and by two others walking along transects counting birds 12.5 m either side of them. Each site was then censused 10 times by the two methods but by having only one walking observer and thus having an equal amount of time being spent using both methods.

There were significant interactions between method of census and bird species being censused. Equal numbers of birds of noisy, mobile species were recorded by walking and stationary observers even when stationary observation time was only half that of walking observation time. However, the quieter and less mobile the bird species the greater the difference in numbers recorded by the two methods. Over the same time period spent observing a stationary observer recorded only a tenth of the number of robins and wrens that a walking observer recorded.

The RAOU method has a number of serious limitations if it is used to estimate actual numbers of birds in Wandoo woodland. These limitations are discussed.

INTRODUCTION

A modification of the variable circular plot method has been chosen by the RAOU as the standard method of estimating changes in bird density at particular locations surveyed separately. The variable circular plot method was designed, originally, for estimating numbers of birds in tall, structurally complex types of vegetation in rugged terrain (Reynolds *et al*, 1980). In such situations a high proportion of contacts will be by sound only. The distance from the observer standing at a fixed point is estimated, and densities of each species are calculated separately. This is because detectability of different species varies; more birds of the vocally active species will be detected at greater distances from the observer than will birds of species that are quiet and inactive. Thus the circular area for estimating numbers varies with species.

The alternative method usually taken as a standard for assessing census methods is that of spot mapping. In this a fixed area is searched for birds and their locations, estimated either from visual or aural cues, are mapped. The mapping technique is more time consuming so quicker methods like the variable circular plot method have been sought. The question is how accurate are they? Not many comparisons have been made. In coastal scrub in California the variable circular plot technique underestimated the numbers of individuals, but by amounts varying from $<2\%$ to about 70%. For any given species there was a tendency to overestimate a species where it was sparse, and underestimate it where it was dense (Desante, 1981). Frochot *et al* (1977) came to a similar conclusion. On the other hand in various forest communities in Poland Walankiewicz (1977) found that estimates made from listening posts *overestimated* the numbers of a species when their density was high simply because at high densities territories were closer and males sang more frequently.

Certainly all the evidence so far suggests that the two methods give different estimates of the avian community in an area. Svenson (1981) in a five year study in Sweden found that for only three of 27 species were estimates closely positively correlated $(r>0.8)$. For 14 species there was a positive but low correlation, and for 10 species negative correlations of $r=0.0$ to -0.8.

The comparison given here was restricted to two four hectare sites in Wandoo *Eucalyptus wandoo* woodland at Baker's Hill, W.A. On one site there was a uniform stand of mature Wandoo with patches of regrowth and a general understorey of shrubs. The other site was on a creekline, with sheet rock outcrops, Casuarina and Acacia, scattered mature Wandoo and little understorey shrub layer. Thus visibility was much better at the second than at the first site.

METHODS

Census techniques

Each site was 400 m x 100 m (4 ha) and was marked out into strips of 12.5 m x 100 m by coloured plastic tapes. At the centre of each hectare of the sites a steel post was placed to provide a listening post.

First comparison

Each site was censused ten times by two methods simulataneously. Two observers walked slowly along the strips observing 12.5 m either side of them. When necessary the walkers deviated from their line to identify birds. At the same time a third observer was stationed on an observation post and recorded the birds heard and/or seen within a hectare area during five minutes. The fixed point observer was not allowed to move more than 3 m from the observation post to identify birds. The effect of disturbance by the walking observers helping the stationary observer was minimised by having the fixed point observer ahead of the walking observers. This was done by the fixed point observer starting at post 2, then going to 3, 4 and 1. Walking observers started in the first section (hectare) and moved through 2, 3 and 4.

Only birds that could be positively identified were recorded. Identification was by sound, sight or both. If a bird was identified by sound the observers recorded it only if they were certain the bird was within the area they were censusing. To minimise double counting by the walking observers they consulted at the end of each 100 m section about birds that may have been recorded by both of them. The census was completed by the walking and fixed point observers in the same time span, with the fixed point observer spending five minutes at each post. However, this meant that the total observation time for the walking observers was double that of the fixed point observer.

Second comparison

The census was repeated a further ten times but with the fixed point observer spending 10 minutes at each observation post whilst one observer walked the transects. Thus the number of observers and time spent observing was the same for both census methods. In this comparison the method of identification (sound, sight, sound and sight, and estimated distance from the observer were recorded).

RESULTS

First comparison

A similar number of birds was seen at each site although there were some differences in the species present. Almost twice as many birds were recorded by walking observers than by stationary ones ($P<0.001$), but the relative difference in numbers varied considerably (Table 1). Parrots, Rufous Whistlers and Striated Pardalotes were recorded in equal numbers by the two methods, but for all other groups or species walking observers produced higher counts. The extreme difference was that only about a tenth of the number of Splendid Fairy-wrens and Scarlet and Red-capped Robins were recorded by observers standing at a fixed point as observed by walking observers.

The smaller number of observations recorded by stationary observers was due to both fewer sightings and, often, fewer birds seen per sighting, especially with the small passerines like Weebills. Stationary observers recorded an average of 2.4 birds of this type per sighting compared with 3.5 birds per sighting by walking observers.

Second comparison

When both stationary and walking observers spent the same amount of time recording birds there were still significant differences in numbers of certain groups or species recorded, i.e. thornbills, Splendid Fairy-wrens, robins and fantails ($P<0.001$). Fewer honeyeaters and Weebills were recorded by stationary observers, but the differences were not significant (Table 1).

Walking observers identified 45% of birds by sound alone, 11% by sound and sight and 44% by sight alone. Stationary observers identified 69% of birds by sound, 9% by sound and sight and 22% by sight.

DISCUSSION

Preston (1979) calculated that reasonably skilled observers will miss 50% of the objects in a census area be they birds, asteroids or caterpillars when they are observing alone, but miss only 13% of the objects when observing in three person census parties. The fraction of species missed similarly drops from 15% to 5% as the party size increases from one to three. Preston describes this mathematically as number seen is proportional to nk, where n = the number of observers, k varies from 0 for conspicuous birds such as ducks on a sheet of water, to 1 for very inconspicuous birds in thick reeds, bush or forest.

The results of this comparison broadly substantiate Preston's conclusions, but show that the value of k for a bird species may differ with census method as is shown in Fig. 1. Some species of birds were so 'conspicuous' that equal numbers were recorded by stationary and walking observers even when unequal time was spent in observation. These were those that were primarily detected by sound (Rufous Whistler, Striated Pardalotes and Port Lincoln Ringnecks.

The less conspicuous species such as Western Gerygones and Tree Martins conformed to Preston's general thesis — doubling the time spent resulted in nearly equal numbers being seen by stationary and walking observers.

At the other extreme stationary observers even when they spent double the RAOU recommended time at a post recorded only half the number of wrens and robins recorded by walking observers. In terms of using a census to determine population density of these species the standard RAOU method probably results in less than 10% of the true numbers being recorded. This conclusion is based on Preston's evidence and the results of the first comparison. Assuming that two walking observers record 75% of the robins and wrens actually present then the ratio of recordings by stationary observers to numbers really present is 0.09.

The problem is that frequently robins make no calls; their calls are not loud at any time, and they don't move around as rapidly as other species. First contact with robins was by sound on only three out of 34 sightings. Wrens are readily audible but often do not make any noise; 40% of first contact with Splendid Fairy-wrens by walking observers

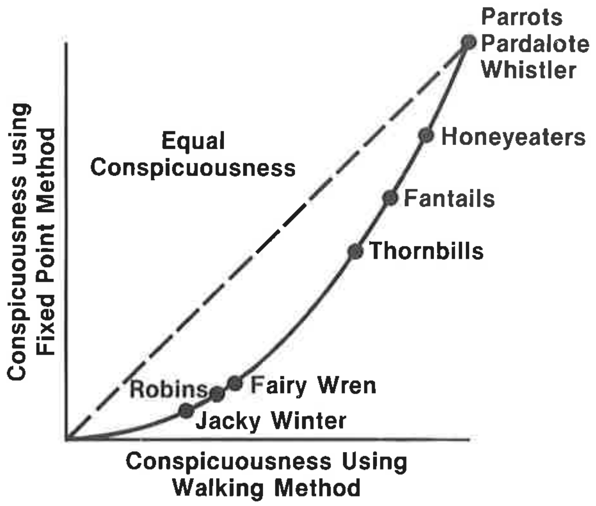

Figure 1: A comparison of the 'conspicuousness' of various birds using two different census techniques. For further details see text.

TABLE 1

Comparisons of numbers and birds recorded using two census methods

	First comparison			Second comparison		
Species or group	Fixed Point	Walk	Ratio FP/W	Fixed Point	Walk	Ratio FP/W
Number of species	23	23	1.00	20	21	.95
Total number of birds	281	559	.51	399	555	.72
Numbers of:						
Thornbills *Acanthiza* spp.	42	119	.35	60	95	.63
Weebills *Smicrornis brevirostris*	41	72	.57	78	90	.86
Western Gerygones *Gerygone fusca*	18	28	.64	19	21	.90
Fantails *Rhipidura* spp.	25	58	.43	46	66	.70
Honeyeaters	27	45	.60	65	77	.84
Robins	4	34	.12	8	29	.28
Splendid Fairy-wrens *Malurus splendens*	2	18	.11	9	20	.45
Rufous Whistlers *Pachycephala rufiventris*	22	22	1.00	27	27	1.00
Striated Paradalotes *Pardalotus striatus*	15	9	1.67	12	10	1.20
Tree Martins *Cecropis nigricans*	35	70	.50	24	23	1.04
Parrots (including Port Lincoln Ringneck *Barnardius zonarius*)	37	38	.97	50	49	1.02

was by sight. The same sort of argument applies to fantails which move around quickly, but in dense vegetation where the observer can see only 10-20 m they may go undetected.

Whilst the walking observation method may have a bias towards over-counting very mobile species its great advantage is that the observer can search dense vegetation when necessary, and move into a favourable position to identify particular birds.

The fixed point method has obvious bias, favouring noisy, mobile bird species. The heavy reliance on identification by sound poses problems in a windy environment like that of south-western Western Australia. Soft sounds will not be heard and loud ones may be 'carried' into the area. Experience with the method is necessary — particularly development of judgement of how far away birds of each species are when they call. The three observers who did this study found that uncertainty of whether to include a bird increased sharply with distances over 30 m. When birds form small parties it is extremely difficult to estimate numbers in the parties just by sound.

In terms of efficiency of use of time and area covered the walking method also has advantages. This is because the area estimated varies between species, depending on their conspicuousness. For inconspicuous species only a small area around the observer is, in fact, 'covered'. The walking observer 'covers' a much larger area than a stationary observer in any given time.

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Assessment of Community Composition and Species Richness in Contrasting Habitats

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SUMMARY

A general method for comparing bird numbers in dissimilar habitats (rainforest, woodland, woodland savannah) is developed based on the plot census technique. Both song and visual sightings were incorporated. Tests were run to determine the optimum times of day for conducting the counts, and the optimum count period.

For the open forest and woodland situations of Australia counts should be limited to 2½-3 hours per day, beginning about an hour after sunrise. At this time song is most sustained and the birds are localized as they feed. Duration of the count period should be between 10 and 15 minutes. On this basis 12-15 single plot counts are possible per day, provided that travelling time between the plots be minimized.

Some of the problems associated with making bird counts in dissimilar habitats are reviewed.

INTRODUCTION

A major problem in the study of bird populations is developing comparative data for dissimilar habitats. Yet such is basic to determining species richnesses, centres of abundance, relative importance of different habitats to individual species and, ultimately, instituting conservation measures. The present paper investigates this for an Australian situation.

In open woodland birds are highly visible, in closed rainforest minimally so. In the former most individual birds can be located without relying on song. In rainforest many species and individuals will be missed unless calling individuals are incorporated into the counts. Yet it is 'difficult and probably impossible' to determine if an unseen songster is actually within a count plot Pyke and Recher (pers. comm.). Counts based on visual sightings are seen by them as the only valid and truly quantitive method.

These, and other problems, have been reviewed in comprehensive recent literature on the making of bird counts, e.g. Ramsey and Scott (1979), Reynolds *et al.* (1980), Dawson (1981), Recher *el al.* (1983), Pyke and Recher (pers. comm.), and in the other papers in this volume. Of special importance are the relative merits of the 'plot' relative to the 'strip count' method, and biases introduced by the length of the count period (Scott and Ramsey 1981). Some observers now see the 'variable-sized plot' as the best method, i.e. counts are made relative to circles of increasing size outwards from the observer. A problem of the plot method is that birds are mobile and some may move in and out of the plot during the course of the count. 'Instantaneous' counts are desirable but not possible, short of aerial photography. They can, in fact, only be approached by use of the strip count method, where the observer keeps moving forward. (Emlen 1971).

The pilot study outlined here preceded a more comprehensive one on the avifauna of the Hunter Valley. Requirements were those of the first paragraph above. The Hunter study, in addition, had the objective of using birds as monitors of 'habitat quality', i.e. of documenting which habitats had the richest avifaunas, and the responses of individual species to changed or degraded habitats. The work was developed within the framework of the 11 basic types of vegetation occurring in the valley, as detailed in the 1963 CSIRO vegetation map.

The studies were based on the assumption that:

(a) the plot method of making counts was best for discriminating between minor differences in habitat and hence was appropriate;

(b) both visual sightings and calls must be used and the method incorporate both;

(c) many plots would have to be counted in a limited time, and each plot could only be counted once.

PROBLEMS AND METHODS

Within the framework defined two basic methodological aspects manifested themselves. These were: (a) the best time of day for making counts, (b) the optimum duration of the count period. These variables assume special importance in the open habitats of Australia. Here song and general

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activity is greatly curtailed during the hotter parts of the day. Associated with low carrying capacity various species have feeding territories in excess of the 10,000 sq m of the standard 'count plot'. Obviously counts must be limited to times of 'maximum detectability'. Duration of each count must be sufficiently long to record all the individuals immediately associated with the particular plot but not so long as to include wanderers from outside.

The study reviewed here was carried out in a community in open woodland at Ebenezer near Windsor, Hawkesbury River, New South Wales. The early part of the breeding season (October 1-15, 1982) was chosen. Comparative studies must be focussed on breeding habitats for the birds are then making the greatest demands on the environment. They are then also localized, most vocal, and easiest to count.

A standard sized plot of 10,000 sq m (radius of 57 m) was marked out on the top of a small escarpment, the site being sufficiently open to permit the observer, centrally placed, to locate the birds within circles of 40 m and 57 m. Markers indicated the limits of the circles.

DURING WHAT TIMES OF THE DAY SHOULD BIRD POPULATION COUNTS BE MADE?

Birds call most frequently in the early morning; then also, since they are feeding, they are most obvious visually. Because calls were to be used as the main means of locating birds, the frequency of singing was measured at different times of day. The study was preceded by a survey of the species present in the area. The measurements recorded the number of species that called in the first five minutes from time zero, those additional ones that called in the second five minutes, and so on, for 25 minutes. Results were expressed as percentages of total species present. Measurements were made at the following times: 0545 (45 minutes after sunrise), 0630, 0730, 0830, 0930, 1100, 1200, 1300, 1400, 1500, 1600, and 1730 hours. The last was three-quarters of an hour before sunset.

Results obtained on successive days closely replicated each other. Data for one day (October 8) are shown in Fig. 1. These show that:

(a) During the time of maximum morning song (0730 and 0830 hours) 55% of the 22 species called in the first five minutes. At the end of 10 minutes 75% had called, at 15 minutes 85%, and 20 minutes, 90%. The Laughing Kookaburra *(Dacelo novaeguineae)*, Superb (Blue) Fairy-wren *(Malurus cyaneus)*, and Red-browed Firetail *(Emblema temporalis)*, that either do not, or only rarely, call during the day (see later) did not call, and these partly account for the absent 10%.

(b) Outside of this optimum period the 75% figure was achieved as follows: 0630, 15 minutes; 0545, 20 minutes; 0930 and 1730, 25 minutes. At other times of the day the figure was not achieved.

What proportion of total species were detected within the first *five minutes*, the time commonly used in population assessments? This ranged downwards from 55% at 0730 and 0830, to 50% at 0545 and 0630, 40% at 0930 and 1730, 13% at 1200, and 8% at 1500.

If song alone is used as a means of assessing bird numbers counts should be limited to about 2½-3 hours in the morning. Reasonable counts can also be gained over a brief period in the afternoon.

The incorporation of visual sightings obviously improves these results. They lift the figure for percentage recorded per unit time from, say 75% at 15 minutes to closer to 100%. They obviously also permit some slight reduction in the count time, e.g. to 12 minutes.

THE DURATION OF THE COUNT PERIOD

The second major variable, the movements of individuals relative to the edge of plots, was investigated during the time of maximum song. The observer, again located centrally, recorded the position of calling birds at successive five-minute intervals over a 30-minute period. In this a map was used. Following the course of calling individuals in feeding parties proved to be easy. The results of one such test, carried out from 0730-0755 on October 10, is shown in Fig. 2.

Much mobility relative to the 10,000 sq m plot was indicated. Only one species, the Spotted Pardalote *(Pardalotus punctatus)*, called from within the confines of the plot for the full 25 minutes. Individuals of four species, Grey Fantail *(Rhipidura fuliginosa)*, Rufous Whistler *(Pachycephala rufiventris)*, Silvereye *(Zosterops lateralis)*, Yellow-faced Honeyeater *(Lichenostomus [Meliphaga] chrysops)*, sang from within the plot during four of the five-minute periods. Five species were present over 15 minutes, four over 10 minutes, and two called from within it during only one of the 5 minute periods (Table 1). The fact that they did not call did not mean, of course, that these individuals were not present. A couple of species were recognisable as visitors, a White-naped Honeyeater *(Melithreptus lunatus)* that visited a flowering *Eucalyptus*, and a Red-whiskered Bulbul *(Pycnonotus jocosus)*. An Australian Magpie-lark *(Grallina cyanoleuca)*, Australian Raven *(Corvus coronoides)* and Black-faced Cuckoo-shrike *(Coracina novaehollandiae)*, that alighted only temporarily were excluded.

These results suggest that, for this habitat and time of year, it was appropriate to use a count period of 10 minutes but that beyond 15 minutes the quality of results was reduced by the movement of the birds.

Subsequent studies of this type gave comparable results. Variation was, however, sufficiently marked to indicate that observers, contemplating plot counts, should run tests before starting to census at any site. An assessment in tall open eucalypt woodland on the Williams River, a site rather more richly vegetated than the Hawkesbury River one, with taller trees, and some shrubby substratum, showed a high degree of localization of five species during the whole morning feeding period (Table 1). A feeding assemblage of Striated Thornbills *(Acanthiza lineata)*, two Brown Thornbills *(A. pusilla)*, a Spotted Pardalote, two Grey Fantails, and a Yellow-faced Honeyeater, were present in the plot, or remained immediately adjacent to it, for periods of half an hour, or more. On the other hand a Leaden Flycatcher *(Myiagra rubecula)*, White-throated Treecreeper *(Climacteris*

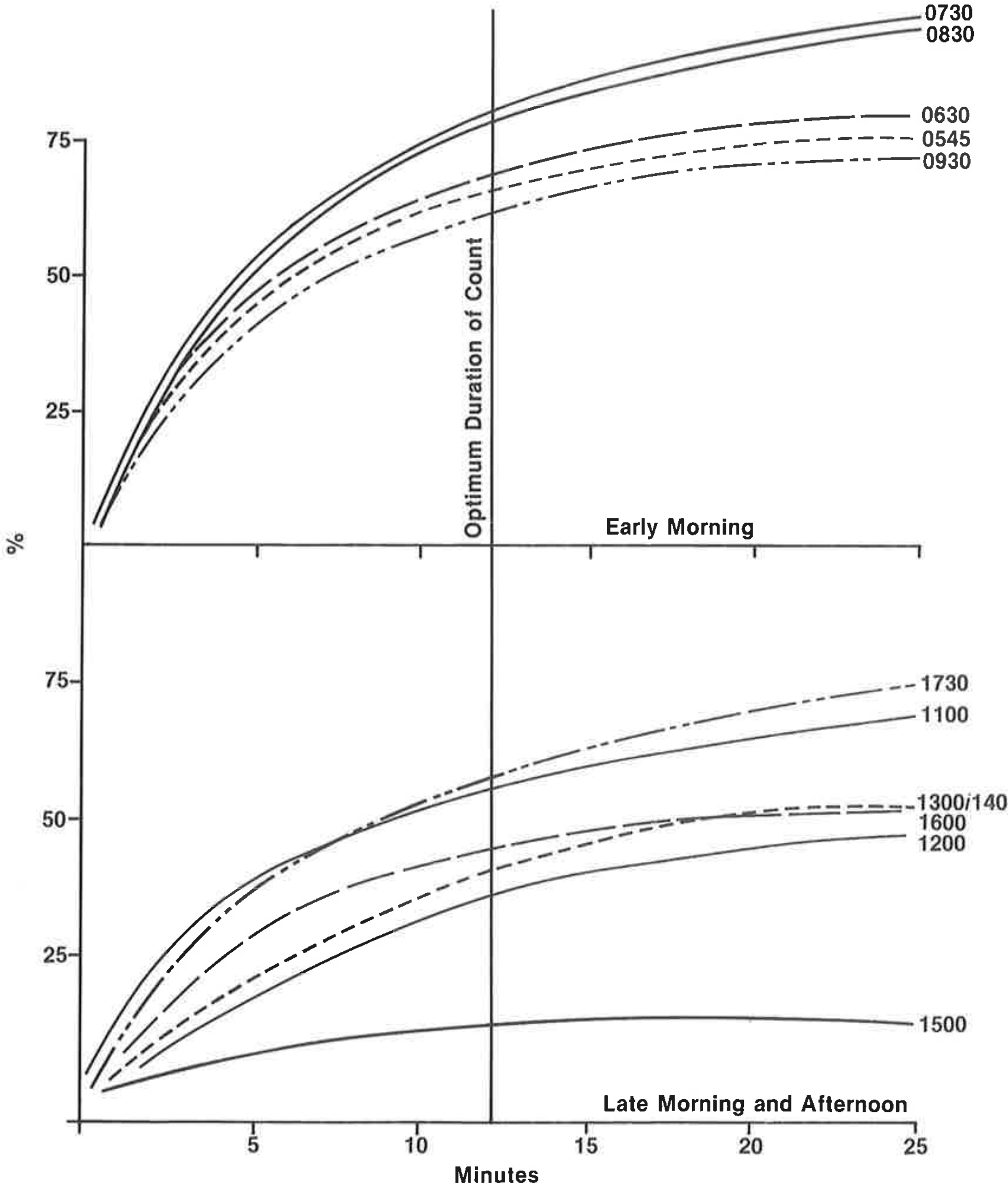

Figure 1. Recording of presence of species of birds on the basis of calling, cumulative, successive five-minute intervals, up to 25 minutes, at different times of day; dry sclerophyll woodland, Ebenezer, near Windsor, N.S.W., October 10, 1982.

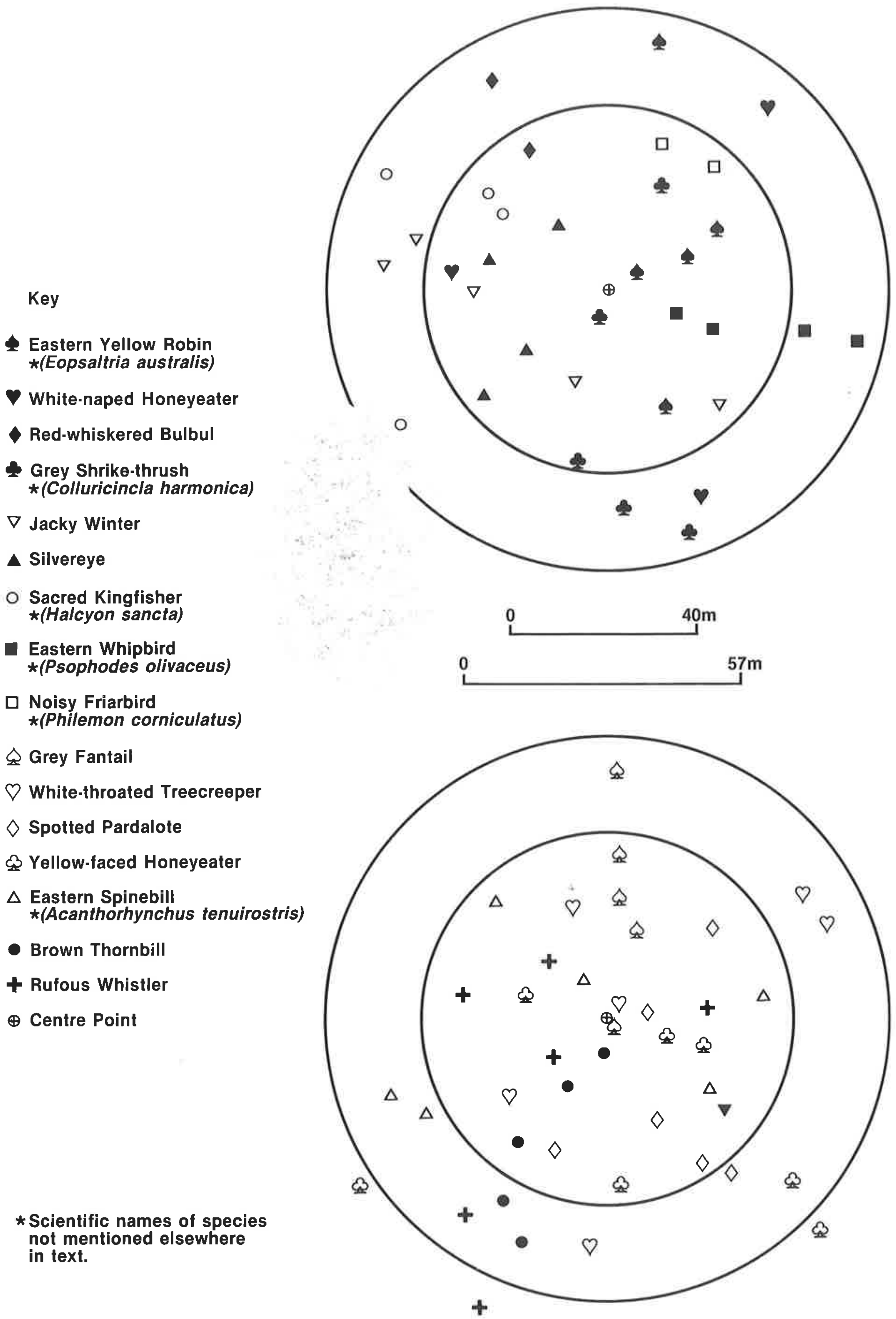

Figure 2 Movements of calling individuals of 16 species of birds; dry sclerophyll woodland, Ebenezer, near Windsor, N.S.W., October 10, 1982, 25-minute period (0730-0755), representing time of maximum feeding and song. Inner circle has radius of 40 m (and represents a 5,000 sq. m plot), and outer circle a radius of 57 m (10,000 sq. m).

leucophaea), and a Willie Wagtail *(Rhipidura leucophrys)*, each spent 10-15 minutes within the plot in the course of wandering around the general area. Species that entered the plot for short periods included the Australian Magpie *(Gymnorhina tibicen)*, Australian Magpie-lark, and Crimson Rosella *(Platycercus elegans)*.

Survey of the dry and avifaunally impoverished 'woodland savannah' near Merriwa in the Goulburn River Valley showed a clumping of species in areas of denser trees and/or where there was some shrubbery. In one such place a pair of Superb Fairy-wrens, Jacky Winters *(Microeca leucophaea)*, and a party of Yellow-rumped Thornbills *(Acanthiza chrysorrhoa)*, were local over a couple of hours. Other plots, by contrast, were utilized mostly by "transients". Striated Pardalotes *(Pardalotus striatus)* occurred regularly. Brown Treecreepers *(Climacterus picumnus)* wandered through several plots in the course of an hour. Territorial Rufous Songlarks *(Cinclorhampus mathewsi)* displayed from exposed trees over several hundred metres. Galahs *(Cacatua roseicapilla)*, Australian Magpies, Australian Magpie-larks, Laughing Kookaburras, and Grey Butcherbirds *(Cracticus torquatus)*, ranged widely, alighting in specific plots from time to time. In this open savannah it was obvious that count periods of as short as five minutes were appropriate but that plots as small as 10,000 sq. m were inappropriate.

TABLE 1

Cumulative increase in species recorded by calls, successive 5 minute intervals, 0730-0755 (sunrise plus 2 hrs 30 mins to 2 hrs 55 mins), October 10, 1982, Ebenezer near Windsor, N.S.W.; Upper Williams River, same hours, December 4; and site near Merriwa, Goulbourn River, N.S.W., November 1982. Occurences within 10,000 sq. m plot

	Ebenezer, dry sclerophyll forest	Upper Williams River tall eucalypt forest	Merriwa, tree savannah
No. bird species	16	15	9
No. 5 min. intervals present	species no.	species no.	species no.
5	1	5	3
4	4	2	1
3	5	3	1
2	4	2	2
1	2	3	2

DISCUSSION

Assumptions and problems of the plot method of estimating bird populations have been outlined by Reynolds *et al* (1980). Considered are the 'best' counting period (to minimize the counting of an individual at two or more sites), and 'best' distance between sites (it being important to keep the counts statistically independent). Results of the above tests at the Hawkesbury River site indicate that count periods of 12 minutes are appropriate. This period also had general applicability in woodland and tall forest sites in the Hunter Valley.

A wide separation of count plots to achieve 'independence' as recommended by Reynolds *et al* (1980) was found to involve two problems, excessive travelling time between plots, and loss of the chance to get information on calling birds in adjacent plots. Noting the occurrence of a species just beyond the plot boundary both helped improve accuracy of the next count and gave information on movements relative to the plot boundary. In the Hunter study the writer, accordingly, used pairs of adjacent plots.

A 'recording period' of 12 minutes permitted the counting of five plots per hour, if travelling time between plots could be kept down to a couple of minutes. Allowing that it is appropriate to make counts for 2½-3 hours meant that 12-15 plot counts could be made per day.

Because the Hunter Valley study involved covering many habitats and a wide geographic area the procedure was adopted of using the middle of the day for travel, selecting study sites, and marking out plots. Following the latter the structural and vegetative characteristics of each plot were recorded. This freed the following morning for making the counts.

In all counts of the numbers of birds there is the problem of relative visibility/audibility. Combination of the two methods is certainly appropriate under the open forest and woodland conditions of Australia. It gives considerable confidence that all, or virtually all, the individuals in a plot are counted. Yet some 'adjustment' must still be made for the fact that in many species the male is highly vocal and hence is immediately recorded whilst the female might be secretive. The Scarlet Honeyeater *(Myzomela sanguinolenta)* is an example. A decision has to be made in such cases as to whether the counts are to be based only on males, or both. During the breeding season it is very likely, of course, that a female will also be present. Less problem surrounds species like the Striated Thornbill that occurs in noisy foraging parties: here all individuals can quickly be counted. A few Australian species are most vocal before dawn and rarely call subsequently. These can only be recorded visually. The Laughing Kookaburra and Superb Fairy-wren are examples. The latter, of course, commonly reveals its presence by scolding the observer.

The method outlined here obviously lends itself to further development. Confidence will be increased when we have a better knowledge of territorial sizes in the different bird species, and data on relative detectabilities of females relative to males. Ultimately, of course, the procedures will vary with the specific objectives of the study. Reynolds *et al* (1980) notes that the 'best' counting method will vary with species, reproductive status, age of the birds, season, and so on. What was sought by the writer was a generalized, all-purpose method for comparing dissimilar habitats.

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The Effectiveness of a Variable Circular-Plot Census Procedure for Estimating Bird Density in the Karri *Eucalyptus diversicolor* F.V. Muell. Forest of South-Western Australia

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SUMMARY

A variable circular-plot census procedure was used to obtain estimates of density of birds in karri forest in south-western Australia in spring 1982 and summer 1983. Birds were also mistnetted and colour-banded to help interpret census results in the four study sites.

Five resident species (White-breasted Robin, White-browed Scrub-wren, Inland Thornbill, Grey Fantail and Red-winged Fairy-wren) dominate the understorey of the forest, although their densities were over estimated. Slash-lines and tracks may have attracted these species thus changing the micro-distribution of the birds within the dense understorey. Estimates of density of species living in the overstorey but not forming flocks were consistent between sites. Tracks are unlikely to affect the censusing of these species.

Differences in estimates of density between seasons may be due to seasonal changes in activity by some species and by a response to the disturbance caused by the construction of the census lines. Some compaction of these sites occurred during summer. Differences in the estimates of density between sites are more likely to be due to site characteristics that affect the census procedure than to real differences. A comparison of diversity indices and density distance curves between sites suggests that the bird communities of the four sites are similar.

INTRODUCTION

Concern has been expressed about the possible negative effect of various forestry management practices on the fauna within the karri forest (Routley and Routley, 1975). The avifauna is the most obvious and probably the most sensitive to gross changes in the structure of the habitat. The practices likely to be of greatest consequence to the avifauna within that part of the karri forest managed by the Forests Department are cutting and burning. Clear felling (removal of all trees in a stand of forest and regenerating the area by planting or by seed from trees cut in the clearing operation) was the method of cutting practised prior to the 1940s and since 1967. Group selection cutting (removal of small groups of mature trees from a stand of forest) was employed between the 1940s and 1967. A prescribed burning programme was introduced in the karri forest in the early 1970s to enable the control of wildfires and to reduce the likelihood of damage to regeneration by fire (Bradshaw and Lush, 1981). A study has been established to examine the effects of these three operations on the avifauna of the karri forest. A knowledge of the density of the bird species in the community and their variability between sites is required prior to the implementation of the operations.

This paper reports on the use of a variable circular-plot procedure (Reynolds *et al*, 1980) in the censusing of birds in two seasons during the first of two years prior to the implementation of operations. Birds were mistnetted and colour-banded to assess the accuracy of this census procedure in the karri forest. Bird detections and detectability were used to assess the similarity of the avian communities of the four study areas.

AREAS AND FIELD METHODS

The four study sites are situated within tall, open, unlogged karri forest, 32 km south west of Manjimup (34°18′, 115°49′) in Gray Forest Block.

The karri forest in the area of this study has two major components (Fig. 1), a dense understorey up to 10 m in height (depending on the time since previous burn) and an open overstorey of sparsely foliaged trees to 70 m in height. A minor component of the forest in this area is a secondary storey of karri saplings ranging in height from 10-35 m.

The dominant understorey of the study area is in two age classes (7 and 15 yeas). Fifteen year old understorey is dominated by one or both of two species, *Bossiaea laidlawiana* Tovey and Morris (netic) and *Trymalium spathulatum* (Labill.) Ostf (hazel), leading to a characteristic but homogenous structure of the understorey of the sites. Different understorey types within the karri forest are consistent in their structure for a given age class (Sneeuwjagt, 1971). The understorey of study site 1 is dominated by open (30-70% cover) 15 year old hazel, site 2 by dense (>70% cover) 15 year old hazel and netic, and site 3 by dense (>70% cover) 15 year old hazel. Site 4 exhibits a range of dense (>70% cover) understorey types in two age classes (7 and 15 years).

The overstorey is dominated by two species, karri and marri *Eucalyptus calophylla* R.Br. ex-Lindl occurring in approximately equal proportions. Karri by virtue of its height is the dominant element in all sites. Fig. 1 shows a profile diagram for study site 2. This represents the structural components of the forest typical of the four study sites.

A variable circular-plot procedure was used to census birds eight times in spring 1982 from 18 points in each nine-hectare site. The census stations were established in a grid to maintain the maximum distance from the edge of planned operations. Points are 120 m apart in lines 60 m apart. Points are 85 m diagonally between lines. Lines include hand slashed and bulldozer tracks. Points are located at the edge of these lines to enable sighting of birds within the overstorey.

Two teams of two people made the census, one person observing and one recording. Observers in the teams alternated between sites to prevent personal bias from influencing the total counts. Various aspects of the birds behaviour when first detected were also recorded although are not discussed in this paper. Each bird seen or heard during a 5 minute interval at each point was counted and the horizontal distance to its location when first encountered was estimated within one of six distance categories (0-50 m, 5-10 m, 10-20 m, 20-30 m, 30-60 m, over 60 m). All counts were carried out within four hours after sunrise.

A second census was carried out in February 1983 to assess the seasonal effects of the marri and some karri flowering within the sites. Five counts were made over a two week period using 9 of the 18 points used in the spring counts.

Results of the counts were analysed using the methods explained by Ramsey and Scott (1981). This method of analysis is easily used and does not preclude accurate estimation of population density in cases of birds reacting to the presence of an observer (Ramsey and Scott, 1981). Estimates of density were derived by plotting the cumulative number of detections against the cumulative area surveyed. The basal radius (Reynolds *et al*, 1980) for each species was determined as the distance from the points where the density (slope of cumulative curve) was highest. The density was then calculated from the total number of birds within the circles of basal radius.

Plots of the derived functions of bird detections (per 45 point counts) versus distance from the observer were used to guage the relation between the sites and the two seasons' counts. This density should decline with increasing distance because the ability to detect birds declines with distance. Observer interaction, behavioural changes or other factors may cause these functions to vary between sites or seasons and to have a low value close to the observer.

Table 1 lists all species recorded during the two seasons' surveys in each site. Tables 1 and 2 provide a list of total numbers of detections in each site in each season. A chi squared test was used to test the significance of the differences in the numbers of bird detections within 60 m of the observer for species between sites for spring and summer.

Mist nets were set in cleared areas at six points, 60 m apart in each of the two central lines in each study site. Two mist nets (13 m long, 2.5 m high in three shelves) were operated at each of the twelve points for two consecutive mornings. Due to inclement weather three consecutive mornings were used for sites three and four in February. Nets were unfurled for five hours from dawn. All netted birds were banded under the Australian Bird Banding Scheme, weighed, measured and released at the capture point.

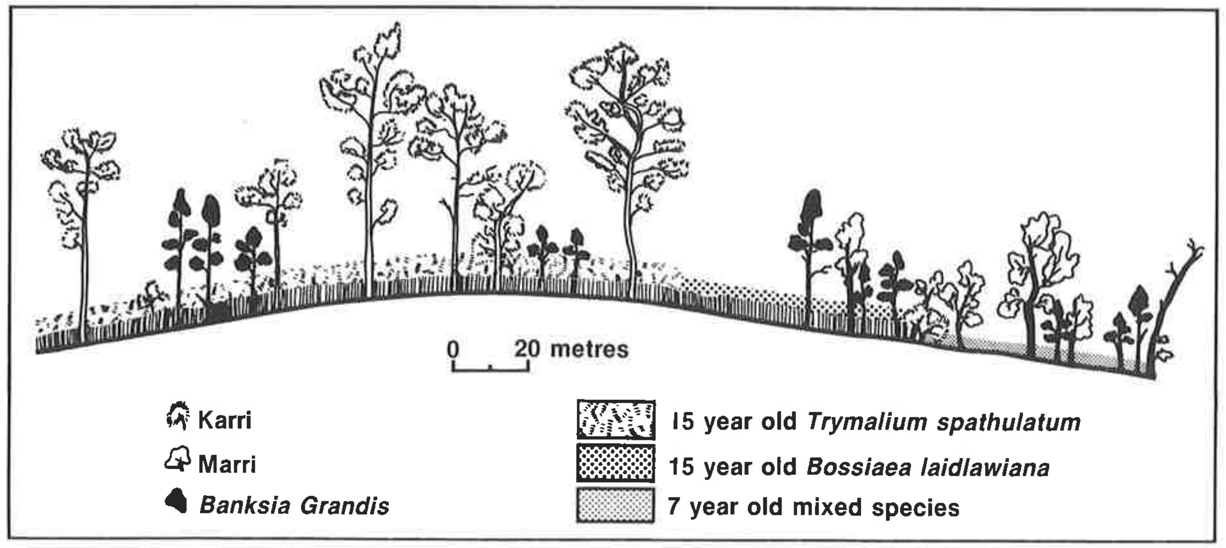

Figure 1: A profile drawing of Karri forest in study site 2 in Gray Forest Block near Manjimup, Western Australia.

TABLE 1

Number of bird detections during 144†, 5 minute point census counts in Spring 1982 within each of 4 study areas in karri forest in Gray Forest Block

SPECIES	SITE 1	SITE 2	SITE 3	SITE 4
Whistling Kite *(Haliastur sphenurus)*				2
Brown Goshawk *(Accipiter fasciatus)*		1		
Collared Sparrowhawk *(Accipiter cirrhocephalus)*	1			
Wedge-tailed Eagle *(Aquila audax)*		1		
Common Bronzewing *(Phaps chalcoptera)*			2	
Red-tailed Black-Cockatoo *(Calyptorhynchus magnificus)*	+	8		
White-tailed Black-Cockatoo *(Calyptorhynchus baudinii)ns*	28	22	17	18
Purple-crowned Lorikeet *(Glossopsitta porphyrocephala)*	9	3	4	5
Red-capped Parrot *(Purpureicephalus spurius)*	10	20	16	12
Western Rosella *(Platycercus icterotis)ns*	37	33	21	32
Port Lincoln Ringneck *(Barnardius zonarius)ns*	18	15	8	22
Fan-tailed Cuckoo *(Cuculus pyrrophanus)ns*	27	25	26	16
Horsfield's Bronze-Cuckoo *(Chrysococcyx basalis)*	1		1	+
Shining Bronze-Cuckoo *(Chrysococcyx lucidus)*	4	12	4	+
Southern Boobook *(Ninox novaeseelandiae)*	+			
Laughing Kookaburra *(Dacelo novaeguineae)*	6	11	2	12
Sacred Kingfisher *(Halcyon sancta)*	+			
Tree Martin *(Cecropis nigricans)****	40	18	48	21
Black-faced Cuckoo-shrike *(Coracina novaehollandiae)*	13	9	13	16
Scarlet Robin *(Petroica multicolor)*	+	+		
White-breasted Robin *(Eopsaltria georgiana)****	37	91	78	52
Crested Shrike-tit *(Falcunculus frontatus)*	+	1		
Golden Whistler *(Pachycephala pectoralis)ns*	53	72	63	60
Grey Shrike-thrush *(Colluricincla harmonica)ns*	14	20	22	13
Restless Flycatcher *(Myiagra inquieta)*	2	3	1	2
Grey Fantail *(Rhipidura fuliginosa)ns*	58	68	48	54
White-browed Babbler *(Pomatostomus superciliosus)*	10	3	26	14
Red-winged Fairy-wren *(Malurus elegans)ns*	62	56	48	43
White-browed Scrub-wren *(Sericornis frontalis)ns*	61	70	69	69
Western Gerygone *(Gerygone fusca)****	26	17	3	8
Inland Thornbill *(Acanthiza apicalis)**	14	35	21	29
Western Thornbill *(Acanthiza inornata)*				
Rufous Treecreeper *(Climacteris rufa)*	3	+	10	6
Red Wattlebird *(Anthochaera carunculata)*	12	19	17	9
Little Wattlebird *(Anthochaera chrysoptera)*		3		
White-naped Honeyeater *(Melithreptus lunatus)ns*	161	158	142	134
New Holland Honeyeater *(Phylidonyris novaehollandiae)**	57	31	52	39
Western Spinebill *(Acanthorhynchus superciliosus)*				
Spotted Pardalote *(Pardalotus punctatus)ns*	47	56	56	60
Striated Pardalote *(Pardalotus striatus)ns*	90	84	92	79
Silvereye *(Zosterops lateralis)*	5	28	1	15
Red-eared Firetail *(Emblema oculata)*	1	+	+	
Dusky Woodswallow *(Artamus cyanopterus)*	5	5	5	7
Australian Raven *(Corvus coronoides)*	5	9	2	5
Diversity Index; 144 point counts (H)	1.27	1.30	1.26	1.28
Diversity Index; 45 points counts (H)	1.17	1.21	1.24	1.25

Chi square test for numbers of detections for species between sites within 60 m of observer for total counts.

ns not significant
* $P<0.05$
** $P<0.01$
*** $P<0.001$
\+ species detected during census but not from above counts
† 128 counts were conducted at site 4.

TABLE 2

Number of birds detections during 45, 5 minute point census counts in Summer 1983 within each of 4 study areas in karri forest in Gray Forest Block

SPECIES	SITE 1	SITE 2	SITE 3	SITE 4
Red-tailed Black-Cockatoo		3		
White-tailed Black-Cockatoo*	51	25	7	8
Purple-crowned Lorikeet**	37	24	67	40
Red-capped Parrot *ns*	4	9	2	8
Western Rosella *ns*	89	56	55	38
Port Lincoln Ringneck**	10	4	1	6
Fan-tailed Cuckoo *ns*		3		1
Laughing Kookaburra	6			1
Tree Martin***	15	5	23	56
Black-faced Cuckoo-shrike	2			
White-breasted Robin**	16	38	28	42
Golden Whistler***	2	12	4	18
Grey Shrike-thrush	5	1	1	1
Grey Fantail**	49	27	9	14
White-browed Babbler	11		4	3
Red-winged Fairy-wren *ns*	14	30	19	17
White-browed Scrub-wren *ns*	7	5	11	8
Western Gerygone	3	4	2	
Inland Thornbill*	2	9	4	5
Western Thornbill				1
Rufous Treecreeper	3	17	3	4
Red Wattlebird***	41	29	21	66
Little Wattlebird *ns*	97	64	64	63
White-naped Honeyeater *ns*	31	50	44	52
New Holland Honeyeater *ns*	134	123	173	125
Western Spinebill	1	4	3	
Spotted Pardalote**	8	17	25	16
Striated Pardalote		5		
Silvereye		2		
Red-eared Firetail	4		1	1
Dusky Woodswallow	8	1		
Australian Raven	6	1		
Diversity Index ($\hat{H}$)	1.12	1.17	1.02	1.11

Chi square test for numbers of detections for species between sites within 60 m of observer for total counts.

ns not significant
* $P<0.05$
** $P<0.01$
*** $P<0.001$

Banding studies were carried out as a check of the estimates of density for species dwelling in the understorey. The White-breasted Robin was chosen for study because of high numbers of captures in mist nets and because it is one of the more easily observed bird species dwelling in the understorey. A standard capture/recapture formula (Loyn, pers. comm.) has been used to provide an estimate of the population of White-breasted Robins impinging on the mist nets in each site in each season;

$$p = \frac{\Sigma wx^2}{\Sigma xz}$$

where p = population
w = number caught on any one day
x = cumulative total of birds marked at the end of that day
z = the number of birds caught on that day which had already been marked.

A separate estimate of the population impinging on the mist nets was derived based on mist net captures only and using mist net captures combined with colour-band observations. An approximate guide to the area of mist net coverage for White-breasted Robins during the February mist net session was made. The percentage of birds sighted with colour-bands was plotted against distance from the mist net line. It was assumed that;

(1) The effective area surveyed by the mist nets was the same in all areas.
(2) The numbers of White-breasted Robins with colour-bands declined as a linear function with distance from the mist net lines.

Diversity Indices were used to examine the similarity of the bird communities in the four study sites. Diversity of each of the bird communities was calculated using the Shannon Diversity Index

$$(\hat{H} \text{ where } \hat{H} = \frac{\Sigma}{J} \frac{Ni}{N} \log 10 \frac{Ni}{N}).$$

Diversity was calculated for all sites using all detections within 60 m of the observer in each of the spring and summer counts. Diversity was also calculated from 45 point counts in spring to enable a direct comparison between spring and summer data. A measure of the diversity of birds in the understorey was derived by using the first capture of each individual in each mist net session as the input data.

RESULTS

Species Dwelling in the Understorey

Tables 3 and 4 show high total estimates of density in both seasons. They are consistently highest in spring. Much of this high estimate is accounted for by five species of passerines dwelling within the understorey. Estimates of density are high for the Grey Fantail, White-breasted Robin, Inland Thornbill, White-browed Scrub-wren and Red-winged Fairy-wren in all sites during spring. All species dwelling in the understorey had consistent densities between sites. Estimates of density in summer (Table 4) for the Grey Fantail, Inland Thornbill and White-browed Scrub-wren although high are considerably lower than spring estimates. Few other passerines were recorded in the understorey and none of these were found to have high estimates of density.

Table 5 shows that the same five passerines found in the census to have high estimates of density are the most frequently netted and recaptured species. Mist netting however does not support the census results of lower densities in summer of Inland Thornbills, Red-winged Fairy-wrens and White-browed Scrub-wrens. Capture rates of each of these five dominant passerines are consistent between seasons. However mist netting supports the census observations that low numbers of other species living in the understorey are present within the study sites. Mist netting did not detect any species not recorded by censusing.

TABLE 3

Densities of birds per ha derived from 144, 5 minute point census counts in Spring 1982 within each of 4 study areas in karri forest in Gray Forest Block

SPECIES	SITE 1	SITE 2	SITE 3	SITE 4
Red-tailed Black-Cockatoo	-	1.11	-	-
White-tailed Black-Cockatoo	.39	-	.11	.11
Purple-crowned Lorikeet	.44	.07	.10	.08
Red-capped Parrot	.33	.25	.33	.51
Western Rosella	1.77	.88	1.55	1.76
Port Lincoln Ringneck	1.76	.20	.20	.63
Fan-tailed Cuckoo	.66	.24	.88	.13
Horsfield's Bronze-Cuckoo	-	-	.02	-
Shining Bronze-Cuckoo	.07	.17	.09	-
Laughing Kookaburra	.02	.09	-	.19
Tree Martin	2.43	.88	5.31	4.04
Black-faced Cuckoo-shrike	.66	.17	.22	.42
White-breasted Robin	6.19	9.06	8.40	7.58
Crested Shrike-tit	-	-	.22	-
Golden Whistler	1.77	1.99	1.71	2.78
Grey Shrike-thrush	.10	.12	.37	.14
Restless Flycatcher	.22	.06	.02	.01
Grey Fantail	5.53	9.73	6.19	3.54
White-browed Babbler	.50	.66	1.10	.20
Red-winged Fairy-wren	7.07	6.63	3.98	4.80
White-browed Scrub-wren	6.41	6.41	8.84	8.84
Western Gerygone	.54	.44	.05	.25
Inland Thornbill	1.77	4.42	2.65	4.04
Rufous Treecreeper	.11	.44	.33	.06
Red Wattlebird	.44	.27	.27	.06
Little Wattlebird	-	.06	-	-
White-naped Honeyeater	6.19	4.20	5.97	6.06
New Holland Honeyeater	6.19	.94	2.43	1.77
Spotted Pardalote	1.11	4.42	1.25	2.02
Striated Pardalote	4.42	3.54	2.65	2.02
Silvereye	.88	.72	.06	2.27
Red-eared Firetail	.22	-	-	-
Dusky Woodswallow	.06	.07	.22	.25
Australian Raven	-	.22	.22	-
Total Density (Birds/ha)	58.25	58.46	55.74	54.56

Observations of colour-banded birds in summer 1983 showed that 56.7% (37) of sightings of White-breasted Robins along the mist net lines were of colour-banded birds. Of sightings in adjacent lines (60 m distant), 16.7% (4) were of colour-banded birds. The effective area surveyed was calculated to be 10.81 ha. Table 6 shows that estimates of density of White-breasted Robins derived from observations of colour-banded birds combined with recaptures in mist nets are considerably less than those obtained through censusing.

TABLE 4

Densities of birds per ha derived from 45, 5 minute point census counts in Summer 1983 within each of 4 study areas in karri forest in Gray Forest Block

SPECIES	SITE 1	SITE 2	SITE 3	SITE 4
Red-tailed Black-Cockatoo	-	.06	-	-
White-tailed Black-Cockatoo	.28	.35	.04	.47
Purple-crowned Lorikeet	1.73	.35	3.71	1.49
Red-capped Parrot	.08	.14	.04	.35
Western Rosella	2.12	1.26	3.54	2.12
Port Lincoln Ringneck	.24	-	-	.35
Fan-tailed Cuckoo	-	.04	-	.08
Tree Martin	.88	.24	.86	2.59
Black-faced Cuckoo-shrike	.08	-	-	-
White-breasted Robin	1.95	3.54	5.66	6.37
Golden Whistler	.04	.31	.31	.86
Grey Shrike-thrush	1.41	.02	.02	-
Grey Fantail	.71	2.12	.47	1.41
White-browed Babbler	.63	-	2.83	2.30
White-browed Scrub-wren	.71	.53	1.24	1.06
Western Gerygone	.08	.08	.04	-
Inland Thornbill	.16	1.41	.71	.88
Western Thornbill	-	-	-	.02
Rufous Treecreeper	.16	2.12	-	-
Red Wattlebird	.86	.63	.31	1.65
Little Wattlebird	1.65	1.02	2.04	1.26
White-naped Honeyeater	1.65	1.89	2.52	2.67
New Holland Honeyeater	10.61	4.48	9.90	5.42
Western Spinebill	.02	1.41	.53	-
Spotted Pardalote	.04	.20	.37	.39
Striated Pardalote	-	.08	-	-
Red-eared Firetail	2.12	-	.08	.08
Dusky Woodswallow	.31	.02	-	-
Australian Raven	.02	-	-	-
Total Density (Birds/ha)	29.78	25.84	35.3	32.06

Species Dwelling in the Mid and Upper Storeys

High estimates of density were obtained for two species of Honeyeater (White-naped and New Holland) in both spring and summer. Estimates are consistently higher for the New Holland and lower for the White-naped Honeyeater in summer than in spring. Data from mist netting support these estimates of density for honeyeaters. White-naped Honeyeaters were caught more often than New Holland Honeyeaters in November and vice-versa in February. No nectar-eating species were detected by mist netting and not by censusing. Those species which were detected were found to be abundant. Wattlebirds (Red and Little) were found to be confined to the upper storey canopy and gave high estimates of density in summer. Populations of two other species, the Western Rosella and Purple-crowned Lorikeet were more dense in summer than in spring. Both inhabit the upper storey.

Most species occurring in the mid and upper storeys gave higher spring than summer estimates of density. Golden Whistler, Spotted and Striated Pardalotes, Western Gerygone and Port Lincoln Ringneck all have consistently higher estimates of density in spring than in summer.

Several species dwelling in the upper storey, White-tailed Black-Cockatoo, Purple-crowned Lorikeet and New Holland Honeyeater are active flocking species. The Tree Martin and White-browed Babbler are active communal species. All five species gave variable estimates of density between sites.

TABLE 5

Mist net bird capture data [Total captures; total recaptures (individuals recaptured)] from 240* net hrs in each of 4 study areas in karri forest in Gray Forest Block November 1982 and *February 1983*

SPECIES	SITE 1		SITE 2		SITE 3		SITE 4	
Western Rosella	1	*2*				*1*		
Fan-tailed Cuckoo	1		1	*1*	2	*21(1)*	1	
Shining Bronze-Cuckoo			1				1	
Tree Martin		*1*				*1*	2	
Scarlet Robin								*1*
White-breasted Robin	14;3(3)	*12;2(2)*	19;4(4)	*16;5(3)*	40;7(5)	*34;20(14)*	40;17(11)	*31;15(10)*
Crested Shrike-tit			1			*1*		
Golden Whistler	6	*5;2(2)*	6	1	11;1(1)	*2;1(1)*	20;1(1)	*7;2(2)*
Grey Shrike-thrush		*2*			1			*1*
Grey Fantail	4	*5;1(1)*	7	*10;1(1)*	10;1(1)	*9*	11;1(1)	*9;2(2)*
White-browed Babbler		*2*		*6*			5	
Red-winged Fairy-wren	3	*8*	7;1(1)	*4;1(1)*	7	*10;3(3)*	3	*12*
White-browed Scrub-wren	21;3(3)	*3;1(1)*	11	*11;4(3)*	16;2(1)	*19;7(6)*	25;5(4)	*19;8(7)*
Inland Thornbill	7;1(1)	1	5	*2*	8	*4;2(1)*	4	*8*
Western Thornbill								*1*
Rufous Treecreeper							2	*1*
White-naped Honeyeater	17;1(1)		8		6	*13*	21;1(1)	*9;3(3)*
New Holland Honeyeater	16;1(1)	*17*	2	*6*	3	*27*	7	*44;4(4)*
Western Spinebill								1
Spotted Pardalote	2		3		5		3	
Striated Pardalote	4	*3*	7	*2;1(1)*	3		5	
Silvereye	3		19;1(1)		5		10	
Red-eared Firetail		*2*	2			*1*		*7*
Dusky Woodswallow					2		2	
Diversity Index (H)	.99	*.96*	1.04	*.90*	.98	*.94*	1.05	*.95*

* 360 net hrs in sites 3 & 4 *February 1983*

TABLE 6

Density per area surveyed of White-breasted Robins dervied from mistnet data (supplemented with colour-band observations) within 4 study sites in karri forest in Gray Forest Block

	SITE 1	SITE 2	SITE 3	SITE 4
Spring	26.45	26.94	101.07	74.90
Summer		28.29 (19.05)	37.39 (30.63)	30.58 (24.66)
Summer Population Estimate (birds/ha)		2.62 (1.76)	3.46 (2.83)	2.83 (2.28)

Seasonal and Site Differences

Thirty-nine species of birds were detected in the 144 point counts of the spring census (Table 1). Thirty-two species were detected from 45 point counts in summer (Table 2). Fewer species were found to have significant differences in numbers of detections between sites in spring, than in summer. The spring data collected from the 9 points used during the summer census were extracted and compared with the summer data. Thirty-two species were detected during these counts. Five species were recorded in each season which were not recorded during the other season.

Estimates of total density were consistently high in all sites in both seasons despite lower detection/densities within 5 m of the observer (Fig. 2). The detection/density curves for total bird detections were consistent between sites but not between the two seasons despite being low close to the observer in both seasons. The detection/density curves reached a maximum value farther from the observer in summer than in spring.

The detection/density curves for individual species were also inconsistent between seasons. Many species dwelling in the overstorey (e.g. White-naped Honeyeater and Striated and Spotted Pardalotes) had highest detection/densities within 5 m of the observer in spring and 10 m of the observer in summer. Grey Fantails are one of the few species dwelling in the understorey which consistently had the highest detection/densities within 5 m of the observer in spring. No species dwelling in the understorey and few others had highest detection/densities within 5 m of the observer during summer.

Indices of diversity were similar for each site within seasons. Indices of diversity differed between seasons being higher in spring than summer for each site (Tables 1 and 2). Indices of diversity in the understorey derived from mistnetting were similar both within and between seasons.

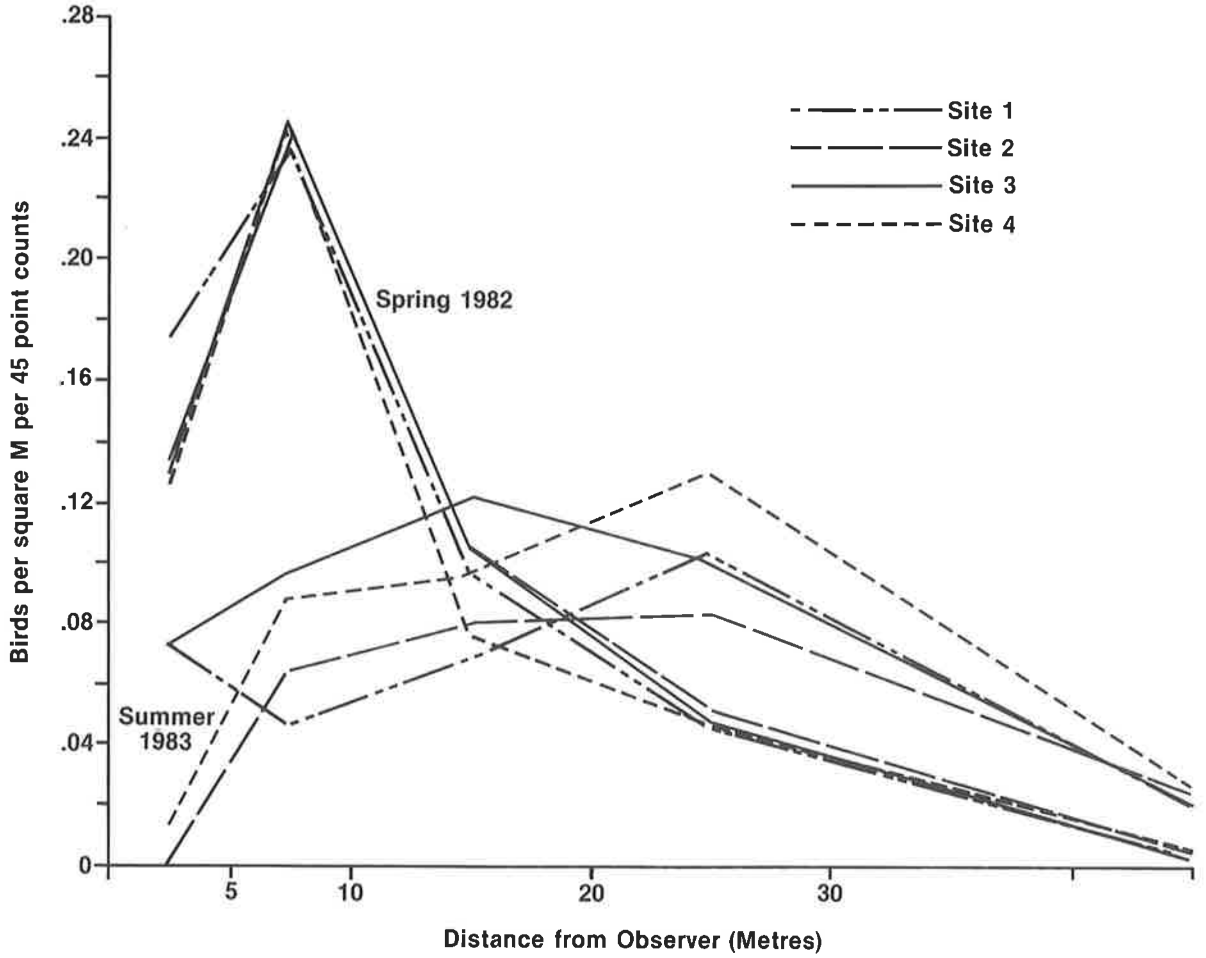

Figure 2: The density/distance functions for bird detections per 45, 5 min. point census counts in Spring 1982 and Summer 1983 within each of 4 study sites in Karri forest in Gray Forest Block.

DISCUSSION

Species Dwelling in the Understorey

Five resident passerines dominate the understorey in each of the study sites. White-breasted Robin, White-browed Scrub-wren, Inland Thornbill, Red-winged Fairy-wren and Grey Fantails account for much of the estimate of total density for each of the study sites, particularly in spring. Few other passerines are resident within the understorey. Nevertheless it is likely that the densities of each of these species has been considerably over-estimated, particularly in spring despite low detection/densities within the closest census band (0-5 m). Mistnetting results suggest little variation in population levels of species dwelling within the understorey between spring and summer. Variable estimates of density between spring and summer obtained through censusing suggest either changes in activity of the birds or stabilization of the tracks. These results suggest that censusing from newly constructed lines or tracks leads to changes in the micro-distribution of the species in the community and hence affects the estimation of density for these species. The line of sight created by tracks may also preclude reliable estimates of density for species dwelling in the understorey.

The White-breasted Robin because of the nature of its feeding strategy (aerial perch, ground prey) and social behaviour (ill defined territories) is likely to be the species most favoured by small openings created by slash lines and tracks. Estimates of density (particularly those including observations of colour-banded birds) of White-breasted Robins obtained through mistnetting are likely to be close to the actual density of this species in each site. Although reliable knowledge of densities has been derived only for White-breasted Robins, the residential status of other species dwelling in the understorey with variable estimates of density between seasons suggest that the total estimates of density obtained in summer are more accurate (despite being more variable) than those obtained in spring. The differences in total estimates of density between the seasons is largely due to the estimates of density of species dwelling in the understorey.

Species Dwelling in the Mid and Upper Storeys

Many species dwelling in the upper storey show consistent estimates of density between sites during spring. Consistent estimates are likely for such species provided they do not flock because slash lines or tracks used for censusing aid in the census of them without affecting their behaviour. Estimates of density appear to be most variable for species living in the upper storey and forming flocks. This may explain high and variable estimates for the Purple-crowned Lorikeet and New Holland Honeyeater during February. The lower number of counts in summer than in spring may also have led to greater variability in estimates of density and numbers of detections in summer. Fewer counts in summer led to fewer species being recorded.

High estimates of densities and total numbers of detections suggest that several itinerant species living in the upperstorey are supported at times by flowering of either the marri or karri. The high estimates of density for the wattlebirds, lorikeets and honeyeaters during summer coincided with flowering in the upper storey. Reduced summer populations of White-naped Honeyeaters may be due to a competitive advantage of the New Holland Honeyeater and the two species of wattlebird at the time of flowering of the upper storey trees. Censusing and mist netting results suggest that both of these honeyeaters have high resident populations. The high estimates of density of Western Rosellas during summer are likely to be due to the hazel seeding at this time.

Seasonal and Site Differences

A high proportion of detections during spring were of resident species dwelling within the understorey. This accounts for much of the skew in the detection/density functions at the 5-10 m interval. Many understorey dwelling species were attracted to the edges of the small openings created by the tracks and slash lines during spring. Some stabilization of the tracks and slash lines may have led to a lowering of the estimate of density during summer for some species. Defence of territory associated with breeding activity was found to be highest in spring. Hence edge effects and observer interaction are also likely to be greatest in spring during periods of highest activity.

The greater skew in the density/distance functions during summer may be caused by less attraction of understorey birds to tracks and a high proportion of detections being of active flocking species in the overstorey. There may be some difficulty in assigning the correct distance category to detections of these species.

Caution is required in making seasonal comparisons between estimates of density where density/distance functions vary between seasons. Nevertheless the technique of density estimation used in this paper can account for variable detectability between different species or sites (Ramsey and Scott, 1981). Hence the detection/density curves need not be highest closest to the observer. However one needs to distinguish between actual detectability and errors in the determination of distance.

The similarity of diversity indices and density/distance functions between sites during seasons suggest that overall, the avian communities are similar within each of the four study sites. The differences in diversity indices between seasons may be partially explained by the different density/distance functions. In addition a few species living in the overstorey were found to dominate counts during February. The low indices of diversity in the understorey may be due to the dominance of this storey by a few species. The close correspondence of indices of diversity in the understorey between seasons is likely to be due to a high proportion of the birds within this storey being of resident species.

The two main vegetation layers forming the forest in the study area provide different environments and support different communities of birds. Censusing the two storeys may therefore be best done on separate occasions or at separate sites. Slash lines and tracks appear to be suitable sites from which to census species living in the overstorey but have led in this study to over-estimates of some of those living in the understorey. Sites within undisturbed forest adjacent to current census points may be suitable for the censusing of birds dwelling in the understorey. If observations made over two or more years from such sites are compared, the extent to which tracks or slash lines modify sites for censusing birds dwelling in the understorey can be determined. The extent to which small openings affect the behaviour of the birds of the karri forest may also be determined. This will aid in the understanding of the effects of forest operations on the bird communities of the karri forest.

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Censusing Waterbirds using South-West Wetlands

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SUMMARY

Little is known of the appropriateness of census methods for waterbirds used overseas by amateurs and in Australia by scientists. Investigations by the RAOU in the South-West of Western Australia have shown that amateurs can apply a number of useful techniques to the varied waterbird census conditions encountered. However no one standard procedure seems to be applicable to all situations. Observers should strive to be thorough and systematic in attempts to census waterbirds, preferably devising procedures which can be repeated during each visit to the wetland that they are surveying.

Recommended techniques can be applied to censusing different types of wetland and species of waterbird. The most important of these involve close investigation of dense vegetation in wetlands and familiarity with distinctive calls of cryptic species of waterbirds.

INTRODUCTION

Waterbirds may be defined as those species of bird dependent on wetlands for major parts of their life cycles and include representatives from the grebe, cormorant, heron, duck, rail, wader and tern families (see list in Table 2). This definition sometimes includes raptors such as the Marsh Harrier and passerines such as the Clamorous Reed-Warbler.

Wetlands are affected by a great diversity of man-induced disturbances including reclamation of land, diversion of water, chemical pollution and salinization. The prime reason for undertaking censuses of waterbirds could therefore be to prevent, halt or gauge the effects of disturbances to wetlands and consequently waterbirds.

Waterbirds are conspicuous organisms and in many cases, total populations can be observed at concentrations in summer. As a result, substantial volumes of census data can often be collected for waterbirds.

In the United Kingdom, the Wildfowl Trust has conducted monthly counts of ducks, geese and swans since 1947 and has established an index of abundance for waterfowl from this scheme (Salmon 1981). Censuses of waterbirds in the United States have relied heavily on aerial surveys by the U.S. Fish and Wildlife Service (e.g. Bellrose 1978).

In Australia, the CSIRO has conducted local intensive studies of game ducks e.g. Barrenbox, NSW (Frith *el al.* 1969), and of all waterbirds e.g. Lake Cowal, NSW (Vestjens 1977). In several states, groups and individual amateurs have undertaken local or regional census work from time to time (e.g. Hunter and Richmond floodplains, N.S.W.: Gosper 1981).

Few large scale census programmes have been organised in this country: one exception has been the regional wetland and waterbird surveys of the Victorian Fisheries and Wildlife Division, progressively covering the state since 1979 (e.g. Western District: Corrick 1982). In fact, no large scale survey of waterbirds by amateurs has been tackled in Australia and no major assessment has been made of the applicability to Australian conditions of census methods used overseas.

Although our present knowledge of movements by some waterbirds is poor (e.g. rails), we do know that many species of waterbird (especially ducks and waders) exhibit strong nomadic or migratory tendencies within Australia. Consequently proper management of waterbirds for conservation in Australia must be at a national level, with the assistance of census work on the same scale. That is, waterbird populations in any local district or region cannot usually be managed in isolation.

The RAOU has been interested in establishing a national census of waterbirds for some years. When fieldwork for its Atlas of Australian Birds finished in 1981, it was hoped that the Union's large force of amateur observers (built up during the Atlas) could take up a census of waterbirds at the national level. Unfortunately, funding could not be secured at the time.

However, the RAOU was aware that the Western Australian Department of Fisheries and Wildlife required management data for its south-western wetland nature reserves. The Union therefore offered its voluntary observer force in WA to the Department, to achieve that need. The study which was subsequently established (The South-West Waterbird Project), was to be in part a pilot study which would better equip the RAOU for tackling a future national census.

THE SOUTH-WEST WATERBIRD PROJECT

Funding for this project will total more than $100,000 over the five year period 1981-1985 and a large portion has been budgetted to employ a full-time Field Officer. The Field Officer's role is essentially to co-ordinate collection of data by the amateur observers, to organize data processing and analysis, to provide feedback to participants and to conduct research into techniques of censusing waterbirds. Travel allowances and computing costs are the largest project expenses besides salary.

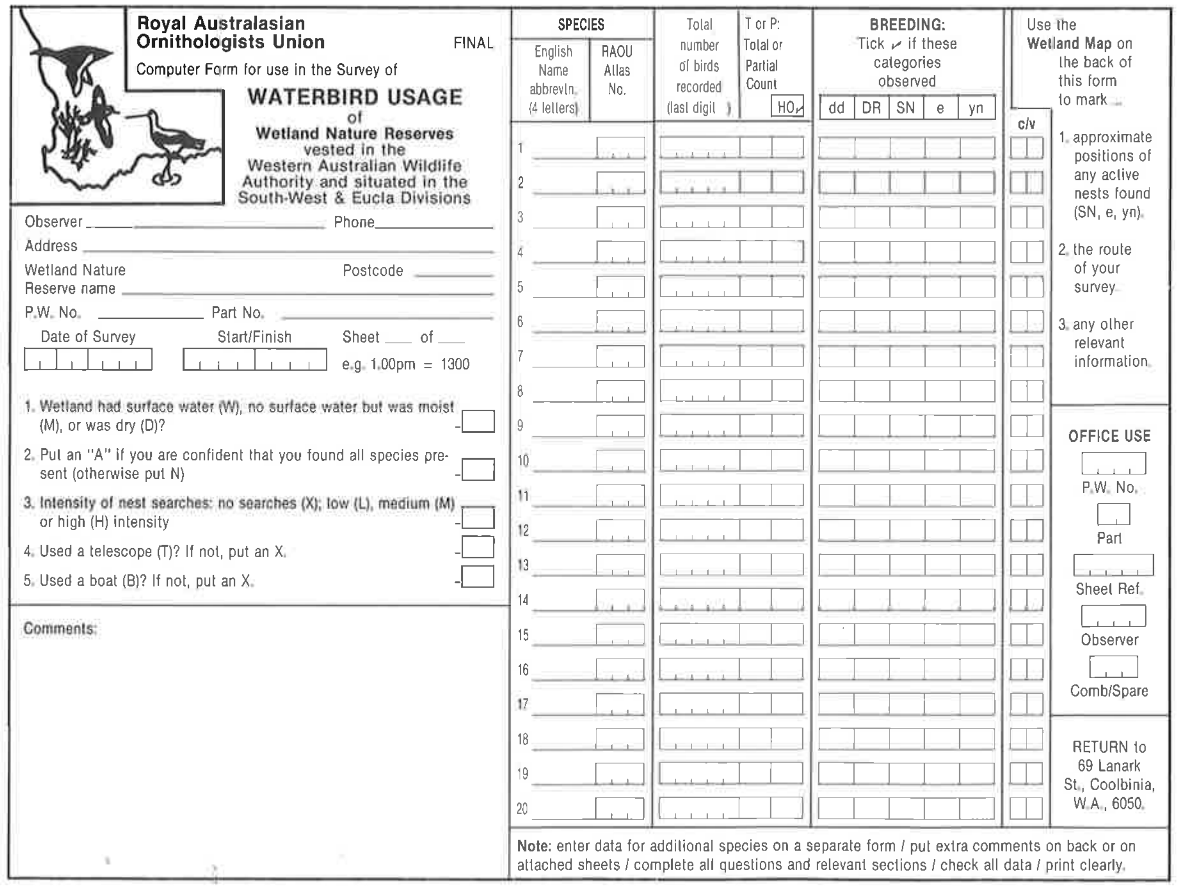
The project aims are:

1. to obtain *information on waterbird usage* to help in the management of wetland nature reserves and in the resolution of conflicts between different uses;
2. to assess the *role and importance* of the Wetland Nature Reserve System in the conservation of waterbird population in the South-West;
3. to assess the efficiency and practicability of various *census methods* for waterbirds, under Australian conditions; and
4. to provide appropriate *experience for future monitoring* of waterbird populations in WA and Australia.

The use of amateurs in this waterbird census has presented a few problems in data collection. Careful consideration of the amount and complexity of information to be gathered (see data form, Fig. 1), and its subsequent application, has ensured that a large volume of readily usable data has arisen from the Project.

Deployment of more than one observer at some wetlands has enabled both co-ordinated simultaneous surveys (for large or complex areas) and comparisons between observers to be made. Surveys are made at least once every two months within preferred nine day periods. Extra surveys are made at peak periods such as when lakes begin to dry out. Rubber waders, canoes, tripod-mounted telescopes and printed field notebooks are widely used and have greatly facilitated fieldwork.

Initial checking and editing of data is done by the Field Officer but all other computing is handled by a commercial programmer. Data are compatible with the W.A. Depart-



Royal Australasian Ornithologists Union FINAL

Computer Form for use in the Survey of

WATERBIRD USAGE
of
Wetland Nature Reserves
vested in the
Western Australian Wildlife
Authority and situated in the
South-West & Eucla Divisions

Observer ______ Phone ______
Address ______
Wetland Nature Reserve name ______ Postcode ______
P.W. No. ______ Part No. ______
Date of Survey ☐ Start/Finish ☐ Sheet ___ of ___ e.g. 1.00pm = 1300

1. Wetland had surface water (W), no surface water but was moist (M), or was dry (D)? -☐
2. Put an "A" if you are confident that you found all species present (otherwise put N) -☐
3. Intensity of nest searches: no searches (X); low (L), medium (M) or high (H) intensity -☐
4. Used a telescope (T)? If not, put an X. -☐
5. Used a boat (B)? If not, put an X. -☐

Comments:

	SPECIES		Total number of birds recorded (last digit)	T or P: Total or Partial Count HO✓	BREEDING: Tick ✓ if these categories observed					c/v
	English Name abbrevln. (4 letters)	RAOU Atlas No.			dd	DR	SN	e	yn	
1										
2										
3										
4										
5										
6										
7										
8										
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Use the **Wetland Map** on the back of this form to mark ...

1. approximate positions of any active nests found (SN, e, yn).
2. the route of your survey.
3. any other relevant information.

OFFICE USE

P.W. No. ☐
Part ☐
Sheet Ref. ☐
Observer ☐
Comb/Spare ☐

RETURN to
69 Lanark
St., Coolbinia,
W.A., 6050.

Note: enter data for additional species on a separate form / put extra comments on back or on attached sheets / complete all questions and relevant sections / check all data / print clearly.

Figure 1: Observers sheet used in the south-west waterbird project.

ment of Fisheries and Wildlife water depth and quality data and are summarized in detailed quarterly printouts by wetland and species. Feedback to participants is achieved through posting out of relevant parts of the printouts, a large quarterly newsletter and by personal contact.

The principal limitations of the Project's data stem from incomplete surveys and an inherent inability to devise a single standard census technique for all water birds and wetland conditions.

RESULTS

The project statistics listed in Table 1 show that many wetlands have not been monitored in the first two survey years. However, the wetlands presently under close scrutiny are a good representative sample of types of wetland within the system of reserves and include most of the known 'good waterbird spots'. It has been particularly pleasing to see a strong network of country-based observers established. These people comprise over half of the total number of participants.

Predictably, the wetlands which have been surveyed most often are closest to Perth and they also have the highest number of species recorded. Unfortunately, the most important wetland for breeding (Toolibin Lake) is slowly being degraded by saline inflows, while the wetland with the largest aggregate of birds in any month so far (Peel Inlet), is subject to severe eutrophication.

Ninety-six waterbird species have been recorded in the Project to date (83% of potential), 42 of them being found breeding (see Table 2). Concerted training of observers in locating cryptic species (rails, bitterns), has led to an encouraging volume of data for these birds, although there are few records of breeding by cryptic waterbirds. Several rare and vagrant species have been sighted (e.g. Broad-billed Sandpiper, Oriental Pratincole), but others have not yet been encountered (e.g. Black Bittern). The most widely recorded species have been the Grey Teal, Australian Shelduck, Pacific Black Duck, Black Swan and White-faced Heron: these same species also have many breeding localities (see Table 2). Distribution information has largely mirrored the findings of the Atlas of Australian Birds (1977-81).

As might be expected, the topmost species in monthly aggregates for the whole study area have been the Grey Teal (24,252 birds), Banded Stilt (20,526 birds) and Australian Shelduck (17,246 birds). Many species including the Straw-necked Ibis, Chestnut Teal, Dusky Moorhen, Sharp-tailed Sandpiper and Whiskered Tern, have proportionately much smaller populations in south-western Australia in comparison with numbers encountered in wetland systems of south-eastern and central-eastern Australia (pers. obs.). On the other hand, Little Bitterns,

TABLE 1

Project Statistics for the period 1 July 1981 — 30 June 1983

1. Number of *active participants* at 30/6/83	=	101	(56 based in country districts)
2. Number of wetland nature *reserves being covered* (either regularly or occasionally) by participant observers	=	91	
3. Number of *wetlands being monitored* for waterbird usage (some reserves include more than one wetland)	=	144	
4. Number of wetlands being monitored on at least a *two-monthly basis* (unless dry)	=	96	
5. Total number of wetlands *to be surveyed* (at least once) during the duration of the Project	=	382	
6. Number of *data sheets* received	=	1,104	
7. Number of *surveys* of waterbirds for which these sheets present data	=	964	
8. Number of waterbird *species* recorded in the study	=	96	
9. Of these, number that have been recorded *breeding* at wetlands under study	=	42	
10. The *most frequently surveyed* wetland has been Thomsons Lake	=	68	surveys
11. The wetland with the *most species* recorded has been Forrestdale Lake	=	57	species
12. The wetland with the *highest number of species found breeding* has been Toolibin Lake	=	17	species
13. The wetland with the *largest bird aggregate* (all species) for any month has been Peel Inlet	=	41,157	birds in November, 1982

TABLE 2

South-West Waterbird Project
Waterbird Species Recorded (most recent data available)

Species	No. of Wetlands Recorded From	No. of Wetlands Breeding In	Largest Concentration (at one wetland)	Largest Monthly Aggregate	Month of Largest Aggregate
Great Crested Grebe *Podiceps cristatus*	12	3	36	59	Nov
Hoary-headed Grebe *Poliocephalus poliocephalus*	48	2	800	1,849	Nov
Australasian Grebe *Tachybaptus novaehollandiae*	39	2	524	667	Jun
Australian Pelican *Pelecanus conspicillatus*	32	0	455	473	Jul
Darter *Anhinga melanogaster*	15	1	12	28	Mar
Great Cormorant *Phalacrocorax carbo*	21	0	137	162	May
Pied Cormorant *Phalacrocorax varius*	16	0	519	519	Jun
Little Black Cormorant *Phalacrocorax sulcirostris*	34	0	285	648	Jul
Little Pied Cormorant *Phalacroorax melanoleucos*	51	2	716	880	Jul
Pacific Heron *Ardea pacifica*	24	1	(200	200	Nov)
White-faced Heron *Ardea novaehollandiae*	92	9	131	494	Jan
Cattle Egret *Ardeola ibis*	1	0	2	2	Jan
Great Egret *Egretta alba*	42	2	(182	258	Feb)
Little Egret *Egretta garzetta*	5	(1	12	13	Apr)
Rufous Night Heron *Nycticorax caledonicus*	18	1	31	48	Feb
Little Bittern *Ixobrychus minutus*	(4	1	1	3	sev)
Australasian Bittern *Botaurus poiciloptilus*	15	0	5	8	Sep
Glossy Ibis *Plegadis falcinellus*	5	0	24	29	Mar
Sacred Ibis *Threskiornis aethiopica*	24	1	80	155	Jan
Straw-necked Ibis *Threskiornis spinicollis*	24	1	1,090	1,278	Nov
Royal Spoonbill *Platalea regia*	2	0	6	6	Mar
Yellow-billed Spoonbill *Platalea flavipes*	22	2	45	74	Jul
Black Swan *Cygnus atratus*	83	35	3,500	7,326	Nov
Freckled Duck *Stictonetta naevosa*	11	2	(500	506	Dec)
Cape Barren Goose *Cereposis novaehollandiae*	2	0	8	8	Mar
Australian Shelduck *Tadorna tadornoides*	100	33	12,000	17,246	Nov
Pacific Black Duck *Anas superciliosa*	94	16	3,500	7,067	Jan
Grey Teal *Anas gibberifrons*	101	25	8,230	24,252	Dec

Table 2 (contd)...

Species	No. of Wetlands Recorded From	No. of Wetlands Breeding In	Largest Concentration (at one wetland)	Largest Monthly Aggregate	Month of Largest Aggregate
Chestnut Teal *Anas castanea*	26	1?	320	431	May
Australasian Shoveler *Anas rhynchotis*	58	5	2,000	2,485	Jan
Pink-eared Duck *Malacorhynchus membranaceus*	45	10	2,500	6,254	Jan
Hardhead *Aythya australis*	44	6	2,000	2,887	Jan
Maned Duck *Chenonetta jubata*	25	1	540	579	May
Blue-billed Duck *Oxyura australis*	23	1	(370	370	Jul)
Musk Duck *Biziura lobata*	53	3	160	409	May
Osprey *Pandion haliaetus*	3	0	2	2	sev
White-bellied Sea-Eagle *Haliaeetus leucogaster*	2	0	1	1	sev
Marsh Harrier *Circus aeruginosus*	37	1	4	22	Sep
Buff-banded Rail *Rallus philippensis*	5	0	7	9	Dec
Baillon's Crake *Porzana pusilla*	3	1	5	7	Jan
Australian Crake *Porzana fluminea*	5	1	20	26	Jan
Spotless Crake *Porzana tabuensis*	12	3	22	30	Jan
Black-tailed Native-hen *Gallinula ventralis*	33	7	117	356	Sep
Dusky Moorhen *Gallinula tenebrosa*	11	1	232	232	Apr
Purple Swamphen *Porphyrio porphyrio*	23	8	80	195	Jan
Eurasian Coot *Fulica atra*	70	27	5,000	9,922	Jan
Pied Oystercatcher *Haematopus longirostris*	1	0	2	2	Mar
Banded Lapwing *Vanellus tricolor*	4	0	14	14	Jan
Grey Plover *Pluvialis squatarola*	6	NB	101	101	Nov
Lesser Golden Plover *Pluvialis dominica*	1	NB	1	1	Nov
Red-kneed Dotterel *Erythrogonys cinctus*	18	1	27	55	Sep
Hooded Plover *Charadrius rubricollis*	17	0	393	473	Feb
Little Ringed Plover *Charadrius dubius*	(1	NB	1	1	Dec)
Large Sand Plover *Charadrius leschenaultii*	1	NB	4	4	Oct
Red-capped Plover *Charadrius ruficapillus*	46	15	3,000	4,795	Mar
Black-fronted Plover *Charadrius melanops*	43	1	32	109	Mar

Table 2 (contd)...

Species	No. of Wetlands Recorded From	No. of Wetlands Breeding In	Largest Concentration (at one wetland)	Largest Monthly Aggregate	Month of Largest Aggregate
Black-winged Stilt *Himantopus himantopus*	56	5	2,750	7,301	Jan
Banded Stilt *Cladorhynchus leucocephalus*	36	0	10,000	20,526	Sep
Red-necked Avocet *Recurvirostra novaehollandiae*	33	0	2,000	2,119	Mar
Ruddy Turnstone *Arenaria interpres*	2	NB	24	25	Nov
Eastern Curlew *Numenius madagascariensis*	2	NB	2	2	Nov
Whimbrel *Numenius phaeopus*	2	NB	2	2	Nov
Wood Sandpiper *Tringa glareola*	(6	NB	30)	32	Apr
Grey-tailed Tattler *Tringa brevipes*	4	NB	5	5	May
Common Sandpiper *Tringa hypoleucos*	17	NB	8	15	Jan
Greenshank *Tringa nebularia*	35	NB	112	173	Mar
Marsh Sandpiper *Tringa stagnatilis*	7	NB	20	22	Mar
Terek Sandpiper *Tringa terek*	3	NB	2	3	Nov
Black-tailed Godwit *Limosa limosa*	3	NB	12	19	Mar
Bar-tailed Godwit *Limosa lapponica*	3	NB	22	22	Dec
Red Knot *Calidris canutus*	7	NB	542	542	Oct
Great Knot *Calidris tenuirostris*	3	NB	98	153	Feb
Sharp-tailed Sandpiper *Calidris acuminata*	21	NB	2,119	2,460	Jan
Pectoral Sandpiper *Calidris melanotos*	(6)	NB	2	4	Jan
Red-necked Stint *Calidris ruficollis*	25	NB	10,000	14,174	Feb
Long-toed Stint *Calidris subminuta*	(7)	NB	26	28	Mar
Curlew Sandpiper *Calidris ferruginea*	20	NB	2,804	3,338	Jan
Sanderling *Calidris alba*	1	NB	1	1	sev
Broad-billed Sandpiper *Limicola falcinellus*	2	NB	1	1	Nov
Ruff *Philomachus pugnax*	(2	NB	5	5	Feb)
Oriental Pratincole *Glareola maldivarum*	1	NB	1	1	Jan
Australian Pratincole *Stiltia isabella*	(1	0	2	2	Nov)
Silver Gull *Larus novaehollandiae*	41	1	2,864	4,049	Jan
Whiskered Tern *Chlidonias hybrida*	16	0	280	284	Sep
White-winged Tern *Chlidonias leucoptera*	2	NB	5	5	May

Table 2 (contd)...

Species	No. of Wetlands Recorded From	No. of Wetlands Breeding In	Largest Concentration (at one wetland)	Largest Monthly Aggregate	Month of Largest Aggregate
Gull-billed Tern *Gelochelidon nilotica*	4	0	2	2	sev
Caspian Tern *Hydroprogne caspia*	4	0	16	16	Jun
Roseate Tern *Sterna dougallii*	1	0	2	2	Jul
Fairy Tern *Sterna nereis*	3	0	5	7	Jan
Crested Tern *Sterna bergii*	4	0	12	16	Sep
Clamorous Reed-Warbler *Acrocephalus stentoreus*	22	2	99	175	Dec
Little Grassbird *Megalurus gramineus*	18	2	51	96	Jul

Explanation

1. "wetland/s" refers to wetlands under study in this project — i.e. we are only looking at a sample of all South-West wetlands.
2. "largest concentration" refers only to our field data, not to all available historical data.
3. "largest monthly aggregate": aggregates for each month of the Project are compiled by summing totals from each wetland; the largest of these aggregates to date is a minimum size for the population of the species in the study area (South-West of W.A.)
4. where several months produced the (same) peak aggregate, the entry has been given as 'sev'.
5. figures are given in brackets where data received recently (but not processed) have significantly exceeded data already processed.
6. 'NB' indicates that the species does not breed in Australia.

Blue-billed Ducks, Spotless Crakes, Wood Sandpipers and Long-toed Stints seem to be well represented in the south-west corner of Australia (pers. obs.).

Particularly important findings have included the first recorded breeding of Little Egrets (one pair) in southern WA, flocks of up to 500 Freckled Ducks, and concentrations of more than 300 Hooded Plovers on one coastal lake near Esperance (less than 500 known in all of Victoria).

A variety of other interesting results has been appearing. These include the following:

1. peaks in abundance e.g. for three cormorant species, numbers peak in winter (these results have often confirmed previous findings or suspicions);
2. possible migratory species, not really suspected previously e.g Pacific Heron and Baillon's Crake appear to be largely absent from the south-west from February to September;
3. changes in distribution and status e.g Sacred Ibises are now more widespread and abundant than ten years ago (these are conspicuous birds);
4. unusual breeding patterns e.g. Pink-eared Ducks found breeding in almost every month of the year, partly due to unseasonal floods in 1982;
5. unexpected behavioural patterns e.g. Black-fronted Plovers found in concentrations of up to 32 birds whereas they usually keep to pairs or family groups.

*The summary printout by species can be used to plot graphs showing changes in abundance of a species at a wetland over a twelve month period (see Fig. 2). This can then be interpreted in terms of trends in water depth and quality.

RECOMMENDED CENSUS METHODS FOR WATERBIRDS

While many wetlands are convenient for counting birds (e.g. small salt lakes, drying lagoons), others present a host of obstacles which prevent comprehensive results being obtained. Difficulties include poor accessibility (deep inundation), poor visibility (distance, haze), safety hazards (deep mud, spikey reeds) and dangerous creatures (snakes). These all hinder attempts to standardize census procedures for waterbirds, but none more so than inconsistent wetland conditions, month to month and year to year.

Cryptic bird species and birds that call infrequently are difficult to locate, but 'super abundant' species such as the Coot can also be difficult in that all individuals can rarely be accounted for at any one wetland. Large dense mixed-species flocks are particularly daunting but can be dealt with satisfactorily by using a systematic approach.

It seems that no one standard procedure can at present be recommended for all waterbird censusing. Nevertheless, methods can be suggested for different situations and these may eventually become standard. Some are briefly outlined here.

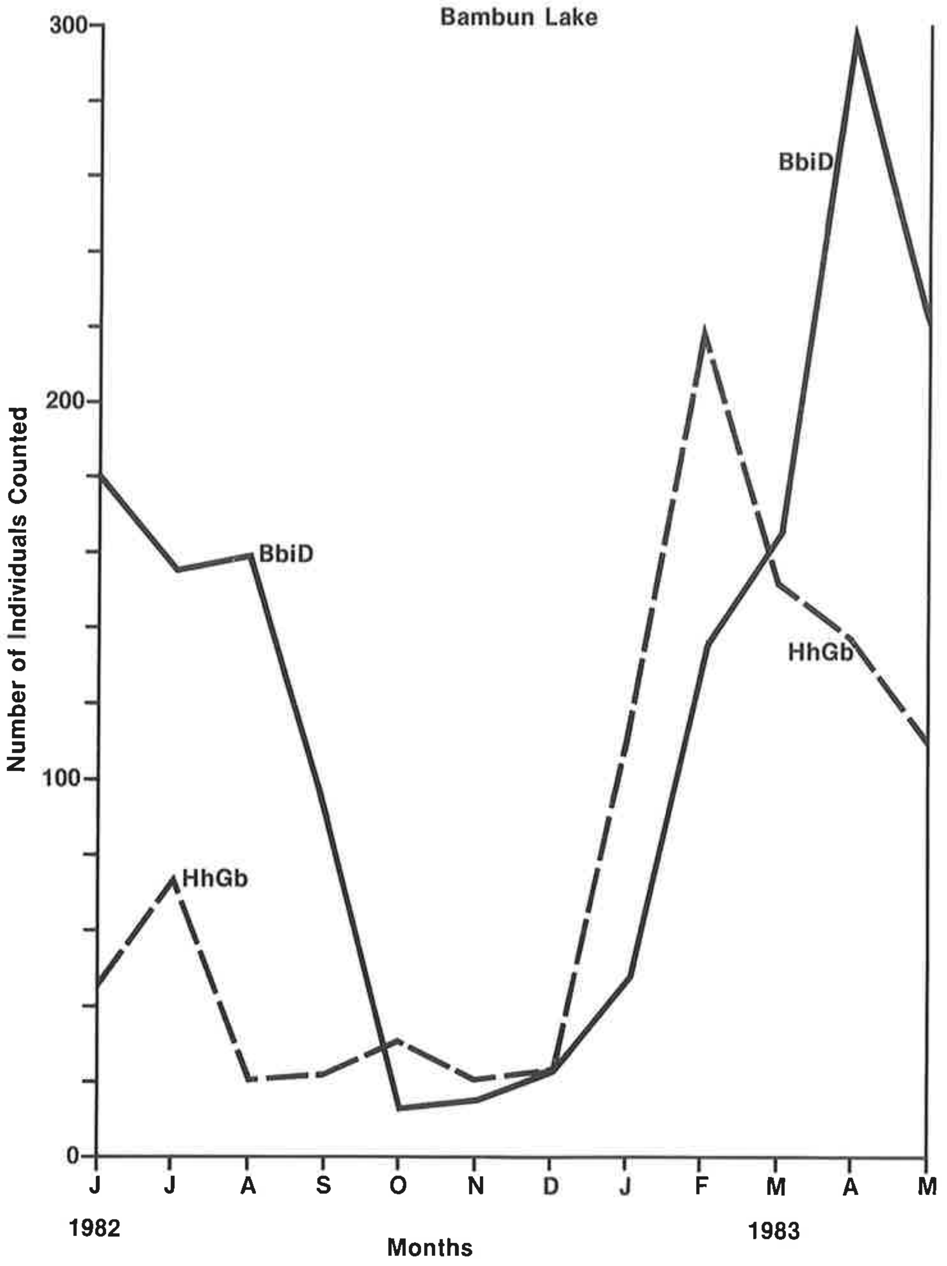

Figure 2: Fluctuation in numbers of Blue-billed Duck (BbiD) and Hoary-headed Grebe (HhGb) at Bambun.

General suggestions

1. *Coverage.* Observers should strive to maximize survey effort (area covered), repeatability (use the same route each time), and effectiveness (use suggested methods for conditions prevailing).
2. *Finding and indentifying waterbirds.* Investigate all habitat types and familiarize with references on species likely to be encountered.
3. *Counting.* Work in pairs to compare estimates and avoid double-counting by being systematic. Count individuals where possible but for large mixed-species flocks, obtain a total count as soon as possible and then use a 'segment and percentage' approach to sort out species counts. Review estimates as often as possible. Counts of birds in flight can also be helpful.

Methods for different wetland types

1. *Estuaries*. Count at high tide when birds are less scattered, unless roosts are inaccessible.
2. *Dense reed-swamps*. Count birds by noting calls or flushing them from cover; sample along transects.
3. *Wooded lakes*. Maximize area covered: try using some type of circular weave route (e.g. four leaf clover) within the lake.

Approaches for particular waterbird groups and species

1. *Small grebes and other diving species*. Count at least three times to account for submerged individuals.
2. *Australasian and Little Bitterns*. Listen for calling males at dusk and dawn in spring.
3. *Freckled Ducks*. Cover all potential loafing sites: these birds can often be secretive, reluctant to leave cover.
4. *Duck mobs in flight*. Scan systematically and anticipate the movements of the mob. Choose a viewing position with the least interrupted view.
5. *Crakes and rails*. Tape record calls and play back to attract birds into the open where they can be seen. Patiently scan shadowy, muddy edges of dense cover.

SUPPLEMENTARY TECHNIQUES

Subject to funding, aerial surveys are the only effective means of obtaining useful data from vast flooded basins and large wetland complexes. Aerial work is not suited to small wetland patches though, and does not record cryptic species. Special survey techniques are needed: aerial census are best done by professionals or trained amateurs.

The presence of crakes and rails may be confirmed and some breeding data obtained (i.e. runners found), by trappng these birds with drift-lines and walk-in traps, set within dense cover. This type of operation requires permits from state wildlife authorities.

CONCLUSION

The volume of information amassed in the RAOU's South-West Waterbird Project is evidence that amateurs can effectively participate in waterbird census work. Application of appropriate methods for specific conditions and particular waterbirds, should assist waterbird censusing. The most important considerations though, are consistency and adoption of a systematic approach.

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Counting and Banding Waders in Australasia

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SUMMARY

Studies of waders in Australasia have escalated as a result of the RAOU Wader Studies Programme. Fifteen sites in Australia and twelve in New Zealand are now known annually to support concentrations in excess of 10,000 birds. Other concentrations may be located as the study progresses. The importance of Australia as a wintering ground for northern hemisphere waders is great. Most of the world's population of Eastern Curlew spend their non-breeding season here; there are also larger concentrations of Black-tailed Godwits, Great Knots and Large Sand Plovers in Australia than are known elsewhere. The coast of eastern Asia is thought to be the most important route by which waders travel to and from Australia but little detailed information is yet available from it. Preliminary estimates of the total numbers of waders in Australia exceed one and a half million and in New Zealand a quarter of a million. Details of counts and banding results are given for individual species but it is stressed that this paper represents only the preliminary findings of the RAOU Wader Studies Programme.

INTRODUCTION

The object of this paper is to review the current status of studies of wading birds in Australia and New Zealand. It will cover knowledge which has been gained to date as well as describing work which is planned or needs to be done in the future.

WADER STUDIES WORLD-WIDE

Before considering Australasia in detail it is helpful to consider the international and historical background to recent research.

Wader studies in the non-breeding season essentially comprise the following:

a) counts to establish distribution and numbers;
b) banding studies to collect basic biological/biometric information and establish migration routes;
c) studies of feeding ecology.

Some of the earliest concentrated studies were carried out in Scandinavia, during the late 1940's and early 1950's, where extensive banding of migratory waders took place. The first comprehensive wader counting programme was the British 'Birds of Estuaries Enquiry' which began in 1969 with monthly counts of all major wader habitats over five years (Prater 1981). Banding studies also expanded greatly in Britain at this time. Subsequently, special banding and counting expeditions were made to more remote locations such as Iceland, Greenland, Morocco and Mauritania which are visited by waders when on migration or wintering in western Europe.

The most intensive wader banding in North America was carried out in the mid-1960's when the Smithsonian Institute caught Ruddy Turnstones on migration through the Pribilof Islands off Alaska (Thompson 1973). An intensive banding programme by the Canadian Wildlife Service of waders on southward migration at James Bay (Morrison and Spaans 1979) followed. More recently, extensive surveys of the distribution of waders in North America and much of South American has been carried out (Morrison [pers. comm.]).

In the Asian region, counting of waders on spring and autumn migration has been undertaken in Japan for a number of years. Some wader banding has also taken place by the Bird Migration Research Centre of the Yamashina Institute for Ornithology. Wader banding also took place as a part of the Migratory Animals Pathological Survey financed by the United States Army (McClure 1974) in a number of south-eastern Asian countries concentrating on Malaysia. Three years ago, the Bombay Natural History Society started banding waders at a number of localities on the Indian Coast.

Fig. 1 shows the current known distribution of waders outside the breeding season. As can be seen there are comparatively few locations with high concentrations of waders (>10,000). With the majority breeding in arctic regions and migrating long distances to evade the Northern Hemisphere winter, land masses in the Southern Hemisphere are naturally particularly important. Thus it might be expected that Australasia has a very important role in the world-wide distribution of waders outside the breeding season. It is this, in conjunction with the spur provided by recent threats to wader habitats in

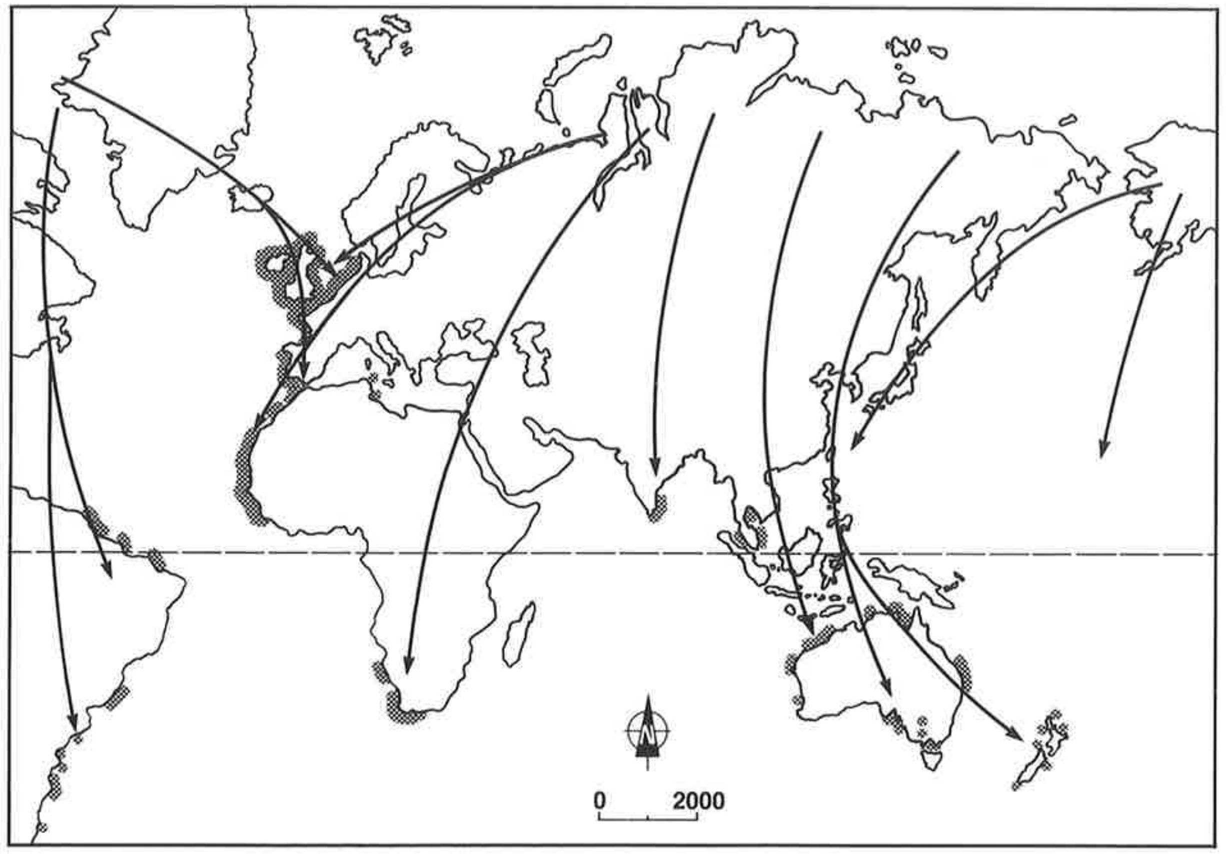


Figure 1: Known major (>10,000) non-breeding areas for Arctic-breeding waders are shown shaded. Probable migratory paths are indicated by arrows.

Australasia which has lead to the increase in the level of study of waders here in recent years. If conservation issues are to be properly evaluated and appropriate protection measures put forward, **facts** are needed.

AUSTRALASIAN WADERS

There is a marked contrast between the relative significance of waders in the avifauna of Australia and New Zealand (Table 1). Although almost the same number of species have occurred in both countries (Australia 70, New Zealand 57) there are nearly three times as many migrant species occurring **regularly** in Australia (30 versus 11). Both countries have similar numbers of resident species of waders.

The number of species of birds occurring in Australia is approximately 2½ times that of New Zealand. Waders form 19% of the New Zealand avifauna compared with only 9% of that in Australia.

In view of the above it is not surprising therefore that intensive studies of waders began in New Zealand well before they did in Australia. For example, regular summer and winter counts have taken place every year since 1960 of the wader populations in Manukau Harbour and the Firth of Thames areas near Auckland (Veitch 1977, 1978). Furthermore, detailed studies of many of New Zealand's resident species have taken place — particularly on their breeding grounds — over the last 20 years.

In Australia, regular small scale wader counts took place from 1948 to 1951 in Hobart (Wall 1953) and in the mid-1950's in the Brisbane area (Amiet 1957). In the mid-1960's Thomas (1973) continued Wall's work. Westernport Bay in Victoria has also been counted regularly since 1973, early results being presented by Loyn (1978). A comprehensive national counting programme was commenced under the auspices of the RAOU in 1981. This involves twice yearly National Wader Counts at as many habitats as possible throughout the country in February and July. These aim to assess the relative importance of habitat areas for waders on a national scale. As well, a number of regular (monthly or more frequent) counts have been conducted at selected localities. The preceeding work was funded from 1980 to 1982 by the RAOU, and since June 1982 by the Australian National Parks and Wildlife Service. Most parts of northern Australia have been surveyed at least once during the spring and summer months by aerial surveying and in the Broome-Port Hedland area by ground based expeditions. Money for specific expeditions and surveys is provided by participants in these activities, as well as donations from private individuals, companies and state governments.

TABLE 1

Wader Species in Australasia

	Residents	Regular Migrants	Small No.s/Vagrants
Australia (70)	16	30	24
New Zealand (57)	13	11	33
		% Avifauna	
	Waders	Seabirds	Landbirds/Others
Australia (736)	9%	11%	80%
New Zealand (307)	19%	33%	48%

RESULTS

Wader Counts

Data are now available on wader numbers for most of the Australian coastline. Due to difficulty of ground access however, two areas remain uncounted; Broad Sound/Shoalwater Bay on the Queensland coast and the Arnhem Land coast between Darwin and Millingimbi. A small part of the Shark Bay area in Western Australia has been visited on the ground, but the total number of waders using that region is not known. Due to difficulty of ground access, the entire Gulf of Carpentaria has only ever been counted from the air. Aerial surveying does not allow species identification and a substantial proportion of the known wader numbers have not yet been assigned to species. Fig. 2 shows the current best estimate of the summer wader distribution in Australia and highlights the location of high concentrations of waders in Australia. From this it can be seen that 14 coastal and 2 inland wetland complexes hold the vast majority of Australia's waders. Moreover, these occur in three main parts of Australia; the north-west, the Gulf of Carpentaria and the south-east.

Concentrations of waders in coastal areas correlate with a number of factors, the most important being the presence of intertidal sand and mud flats. In the northern Australian coastline, where waves usually have low energy, these are most extensive in areas of high tidal range backed by a hinterland of low relief and with an open shore (e.g. Broome-Port Hedland area and south-eastern corner, Gulf of Carpentaria). On the southern Australian coastline where wave energy is often high, intertidal flats usually occur behind barrier complexes (e.g. Peel Inlet, W.A.; The Coorong, S.A.; Corner Inlet, Victoria and Hervey Bay and Moreton Bay, Queensland) or in marine embayments surrounded by a hinterland of low relief (e.g. St. Vincent and Spencer Gulfs, S.A. and Port Phillip Bay, Victoria), rather than on the open shore. This contrasts with the European situation where storms generally prevent the formation of barriers, mangroves do not fringe the coast and most intertidal flats are found in true estuaries. In Australia, modification by man such as the construction of saltworks and sewage farms particularly if near existing intertidal areas has probably made habitat even more suitable.

The presence of substantial numbers of waders at the inland sites in Victoria demonstrates the need for more work at other inland areas, particularly wetlands associated with the Murray-Darling drainage system.

Fig. 3 shows the location of wader concentrations in New Zealand. These are predominantly on the eastern coast, as the western coast is very exposed and generally lacks major embayments or estuaries. Again, waders occur in high numbers where intertidal mudflats are present in marine embayments (e.g. Manukau Harbour) or associated with barrier complexes (e.g. Farewell Spit). There are only 12 locations which hold large numbers of waders (Veitch [pers. comm.]).

In Australia some 30 species of wader are regular migrant visitors, whereas in New Zealand only 11 species fall into this category. This reflects the less diverse nature of New Zealand intertidal areas, the smaller total area of habitat and perhaps most importantly, the relative remoteness of New Zealand from major world migration paths.

Table 2 summarises information on the known numbers of each species of wader in Australia. Table 3 gives the information for New Zealand. The geographical range of species in Australia differs, so that at any one place no more than five or six species will constitute over 90% of wader numbers. In New Zealand, Red Knot and Bar-tailed

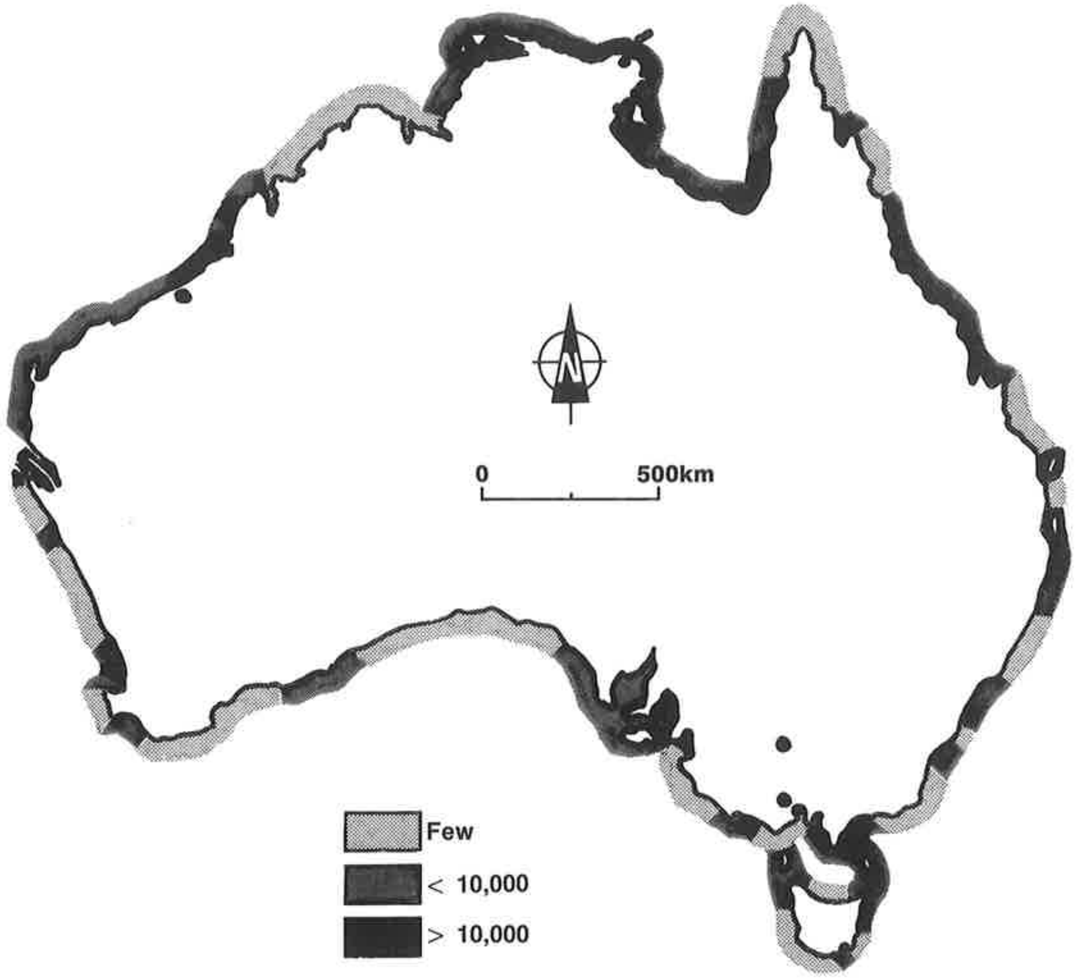
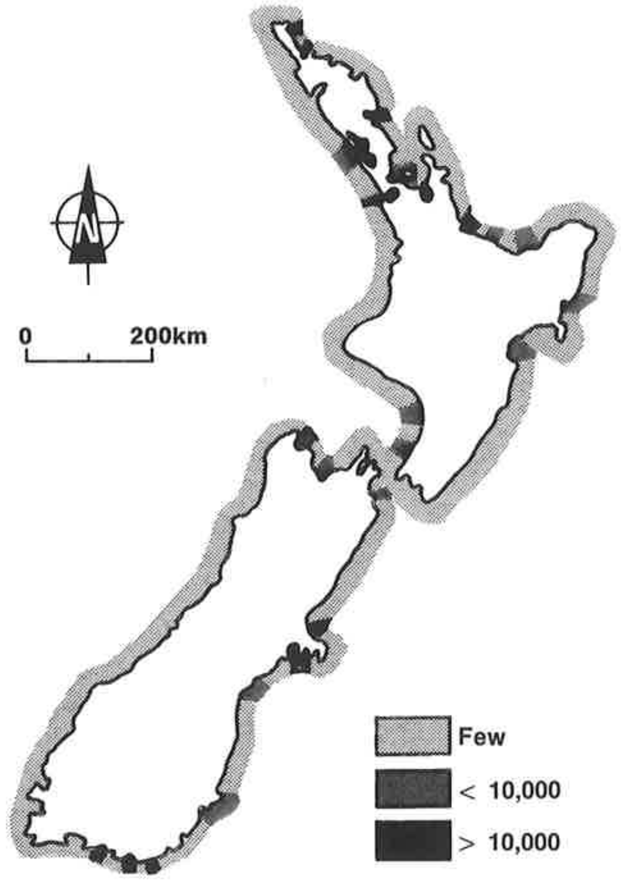


Figure 2: Areas in Australia known to hold concentrations of waders (>10,000, <10,000 and a few) for at least some time each year.



Godwit dominate most areas with the exception of sites in Southland that hold substantial numbers of Ruddy Turnstones.

North-western Australia is dominated by Red and Great Knots, Large Sand Plovers, Bar-tailed Godwits, Curlew Sandpipers and Red-necked Stints. The north-eastern coast waders are made up predominantly of Bar-tailed and Black-tailed Godwits, Great Knots and Mongolian Plovers. Southern Australia holds Red-necked Stints, Curlew Sandpipers, Sharp-tailed Sandpipers and the resident Banded Stilts in largest numbers. Northern Australia tends to be dominated by larger species of migratory wader whilst southern Australia is predominated by smaller species. Numbers of Great Knots, Large Sand Plover and Black-tailed Godwits that have been discovered as a result of the RAOU Wader Study Programme represent the largest numbers yet discovered anywhere in the world and highlight the significance of the northern Australian coast for waders. Southern Australia holds the bulk of the world population of the Sharp-tailed Sandpiper and Red-necked Stint.

As well as these abundant species there are a number of waders which occur in small numbers confined to only a few widely separated places. These include the Eastern Curlew (almost entire population of which spends the non-breeding months in Australia) and the Grey Plover. The Ruddy Turnstone is more widespread but at lower densities than the more abundant waders.

TABLE 2

Estimates of Wader Numbers in Australia, 1983

Red-necked Stint *Calidris ruficollis*	291,000
Curlew Sandpiper *Calidris ferruginea*	179,000
Sharp-tailed Sandpiper *Calidris acuminata*	126,000
Great Knot *Calidris tenuirostris*	105,000
Banded Stilt *Cladorhynchus leucocephalus*	99,000*
Bar-tailed Godwit *Limosa lapponica*	85,000
Large Sand Plover *Charadrius leschenaultii*	69,000
Red Knot *Calidris canutus*	59,000
Black-tailed Godwit *Limosa limosa*	53,000
Red-capped Plover *Charadrius ruficapillus*	38,000*
Oriental Plover *Charadrius veredus*	22,000
Red-necked Avocet *Recurvirostra novaehollandiae*	19,000*
Black-winged Stilt *Himantopus himantopus*	15,000*
Grey-tailed Tattler *Tringa brevipes*	13,000
Masked Lapwing *Vanellus miles*	12,400*
Greenshank *Tringa nebularia*	11,435
Eastern Curlew *Numenius madagascariensis*	9,647
Grey Plover *Pluvialis squatarola*	7,022
Mongolian Plover *Charadrius mongolus*	6,250
Double-banded Plover *Charadrius bicinctus*	5,685
Ruddy Turnstone *Arenaria interpres*	5,347
Little Curlew *Numenius minutus*	5,188*
Terek Sandpiper *Tringa terek*	4,331
Sanderling *Calidris alba*	4,278
Pied Oystercatcher *Haematopus longirostris*	4,128*
Lesser Golden Plover *Pluvialis dominica*	3,438*
Oriental Pratincole *Glareola maldivarum*	3,000*
Whimbrel *Numenius phaeopus*	1,885*
Marsh Sandpiper *Tringa stagnatilis*	1,722
Banded Lapwing *Vanellus tricolor*	1,379*
Sooty Oystercatcher *Haematopus fuliginosus*	1,355
Red-kneed Dotterel *Erythrogonys cinctus*	1,312*
Black-fronted Plover *Charadrius melanops*	898*
Hooded Plover *Charadrius rubricollis*	720*
Latham's Snipe *Gallinago hardwickii*	232*
Broad-billed Sandpiper *Limicola falcinellus*	218*
Common Sandpiper *Tringa hypoleucos*	173*
Asian Dowitcher *Limnodromus semipalmatus*	130*
Unidentified	307,000
TOTAL	1,572,173

* Underestimates.

TABLE 3

Wader Numbers in New Zealand

Bar-tailed Godwit *Limosa lapponica*	100,000
South Island Pied Oystercatcher *Haematopus ostralegus*	60,000*
Red Knot *Calidris canutus*	50,000
Pied Stilt *Himantopus leucocephalus*	15,000*
Wrybill *Anarhynchus frontalis*	4,500
Ruddy Turnstone *Arenaria interpres*	4,000
Lesser Golden Plover *Pluvialis dominica*	1,000
Others	unknown
TOTAL c	250,000

* Underestimates.

Wader Banding

Wader banding is conducted in Australasia under the auspices of the CSIRO Australian Bird Banding Scheme and the New Zealand Wildlife Service. Banding provides an opportunity to study the individual wader in the hand to collect data on biometrics, moult and weight. Over the longer term it provides comparative information on mortality and population turnover at a particular site. It provides information on the movements of waders between sites in Australia and New Zealand and between Australasia and the breeding grounds in Siberia and Alaska. These data, particularly those on moult, weight and onward movements enable the full significance of sites to be determined. They reveal how the birds are using the areas in a wider context, that of their strategy of international migration.

Table 4 details the numbers of waders that have been banded in Australia showing that Red-necked Stints, Curlew Sandpipers and Sharp-tailed Sandpipers dominate. This reflects their abundance and the fact that most banding of waders is undertaken in southern Australia where these species are most abundant. Table 5 gives New Zealand banding totals. Compared with Australia, over 70% of the waders banded in New Zealand are resident species. This reflects the fact that resident species constitute a higher proportion of the waders of New Zealand, but also that most wader banding has concentrated on locally breeding species. The numbers of Red Knots banded results from work conducted mostly in the last three years in the Auckland region.

Almost half the migratory waders banded in Australia have been banded in the last two years, showing the impetus given by the RAOU Wader Studies Programme and the more widespread use of cannon-netting techniques for catching waders on roosts.

Although 43,000 migratory waders have been banded in Australia, only 29 have ever been recovered overseas (see Table 6). Of these, 11 have been found in Japan, demonstrating that the two countries have a joint responsibility for the conservation of waders and justifying the treaty which exist between the two countries. Only 15 waders banded elsewhere in the world have been recorded in Australia (see Table 6). This is a very low recovery rate and compares with for example Britain where one in every 100 birds caught is foreign banded and two in every 100 birds banded gets recovered elsewhere. This reflects the population density of countries to Australia's north (generally much lower than Europe). As well, there are language differences which possibly prevent Australia being notified of recoveries (bands are written in English only). Hunting pressure throughout Asia is much less than in Europe so that the incidence of recoveries due to this is much lower. Efforts are being made by the Australian Bird Banding Scheme through the Australian foreign service and Radio Australia to improve the potential for recoveries.

Figs. 4, 5 and 6 map international recoveries of Red-necked Stints, Curlew Sandpipers and all other waders respectively. From this it can be seen that waders have been recovered over a considerable spread of longitude. These maps also highlight the significance of the Chinese coast as a migratory stopover. The dates of recoveries up the East Asian coast are between mid-April and late May, with one exception. This corresponds to the time of northward migration. Interestingly, the dates get later further north (see later). The Malaysian and Indian recoveries of Curlew Sandpipers have been in August, during southward migration.

In New Zealand, recoveries are limited to two inward and two outward movements of Red Knots, and one inward movement of a Bar-tailed Godwit (see Fig. 7). The movements of Red Knots suggest that the New Zealand Knots pass through Australia on migration.

As well, there have been seven movements between Australia and New Zealand of Double-banded Plovers. The Double-banded Plovers serve to illustrate the value of another technique used in banding; colour-marking studies. This involves marking waders with coloured plastic leg bands and/or brightly coloured plumage dyes. There have been no actual recoveries of this species between the two countries, only resightings.

The colour-dyeing of 4000 waders in the Broome-Port Hedland area during the 1982 wader studies expedition there in August/September has resulted in 19 resightings elsewhere in Australia. This represents a much higher rate of data generation compared to actual recoveries between banding sites within Australasia. This technique has also resulted in one resighting, in Hong Kong, of a Red-necked Stint colour-dyed in Victoria.

Migratory waders require fuel in the form of sub-cutaneous and peritoneal fat to undertake their long-distance movements. Banding studies of waders in Australasia are producing data on weights of birds prior to departure in March and April. This gives an indication of the amount of fat deposited prior to departure, a figure which can be used to calculate flight range. Table 7 gives the weight increases shown by a number of species caught in southern Australia, and their potential non-stop flight range under ideal conditions. The formula used to calculate this is that of Nisbett and Drury (1965), and approximates to 1% of total body weight consumed per hour of flight. Using this, migratory waders leaving southern Australia are capable of a non-stop flight of between 2000 and 5000 kilometres. Compared with their counterparts elsewhere in the world, Australian waders put on more weight prior to departure. For example, the Ruddy Turnstones are the heaviest yet recorded. With the exception of the Red-necked Stint and Sharp-tailed Sandpiper, most waders in southern Australia are depositing enough fat to fly beyond the north coast of the continent in one leg. The Red-necked Stint and Sharp-tailed Sandpiper have enough fat to reach the northern parts of Australia. Sharp-tailed Sandpipers depart southern Australia before most waders, and may move north to undergo a major pre-migratory fattening on wetlands resulting

TABLE 4

Waders Banded in Australia

Migratory Species	
Red-necked Stint	23,878
Curlew Sandpiper	8,196
Sharp-tailed Sandpiper	4,719
Red Knot	1,483
Bar-tailed Godwit	927
Great Knot	828
Double-banded Plover	766
Terek Sandpiper	547
Others	2,245
TOTAL 33 species	43,589
Resident Species	
Masked Lapwing	3,940
Red-capped Plover	2,291
Banded Lapwing	1,051
Black-fronted Plover	732
Red-kneed Dotterel	648
Others	1,651
TOTAL 17 species	10,313
TOTAL All species	53,902

TABLE 5

Waders Banded in New Zealand

Migratory Species	
Red Knot	892
Double-banded Plover	763
Bar-tailed Godwit	58
Others	15
TOTAL 7 species	1,728
Resident Species	
Wrybill *Anarhynchus frontalis*	1,967
South Island Pied Oystercatcher *Haematopus ostralegus*	1,020
Masked Lapwing *Vanellus miles*	587
Pied Stilt *Himantopus leucocephalus*	396
New Zealand Shore Plover *Thinornis novaeseelandiae*	270
Variable Oystercatcher *Haematopus unicolor*	194
New Zealand Dotterel *Pluvialis obscura*	171
Others	342
TOTAL 13 species	4,947
TOTAL All species	6,675

TABLE 6

Australian Wader Recoveries

	Banded in Aust./ Recovered Overseas	Banded Overseas/ Recovered in Australia	Total Recoveries
Red-necked Stint	7	4	11
Curlew Sandpiper	7	1	8
Grey-tailed Tattler	3	3	6
Latham's Snipe	1	4	5
Red Knot	2	1	3
Sharp-tailed Sandpiper	3	–	3
Eastern Curlew	2	–	2
Terek Sandpiper	1	1	2
Ruddy Turnstone	1	–	1
Bar-tailed Godwit	1	–	1
Large Sand Plover	1	–	1
Lesser Golden Plover	–	1	1
	29	15	44

TABLE 7

Weights and Flight Ranges of Some Waders

	Fat Free (gm)	Take Off (gm)	Addition	Range
Curlew Sandpiper	53	88	66%	3600 km
Knot	120	175	46%	3600 km
Great Knot	155	267	72%	
Ruddy Turnstone	100	172	72%	5600 km
Grey Plover	230	380	65%	
Bar-tailed Godwit (male)	290	416	43%	
(female)	350	520	48%	
Mongolian Plover	70	106	51%	
Lesser Golden Plover	127	177	39%	
Double-banded Plover	57	76	33%	2100 km
Red-necked Stint (mean)	29.5	37.7	28%	1800 km
(maximum)		42	42%	2400 km
Sharp-tailed Sandpiper	64	75	15%	1100 km

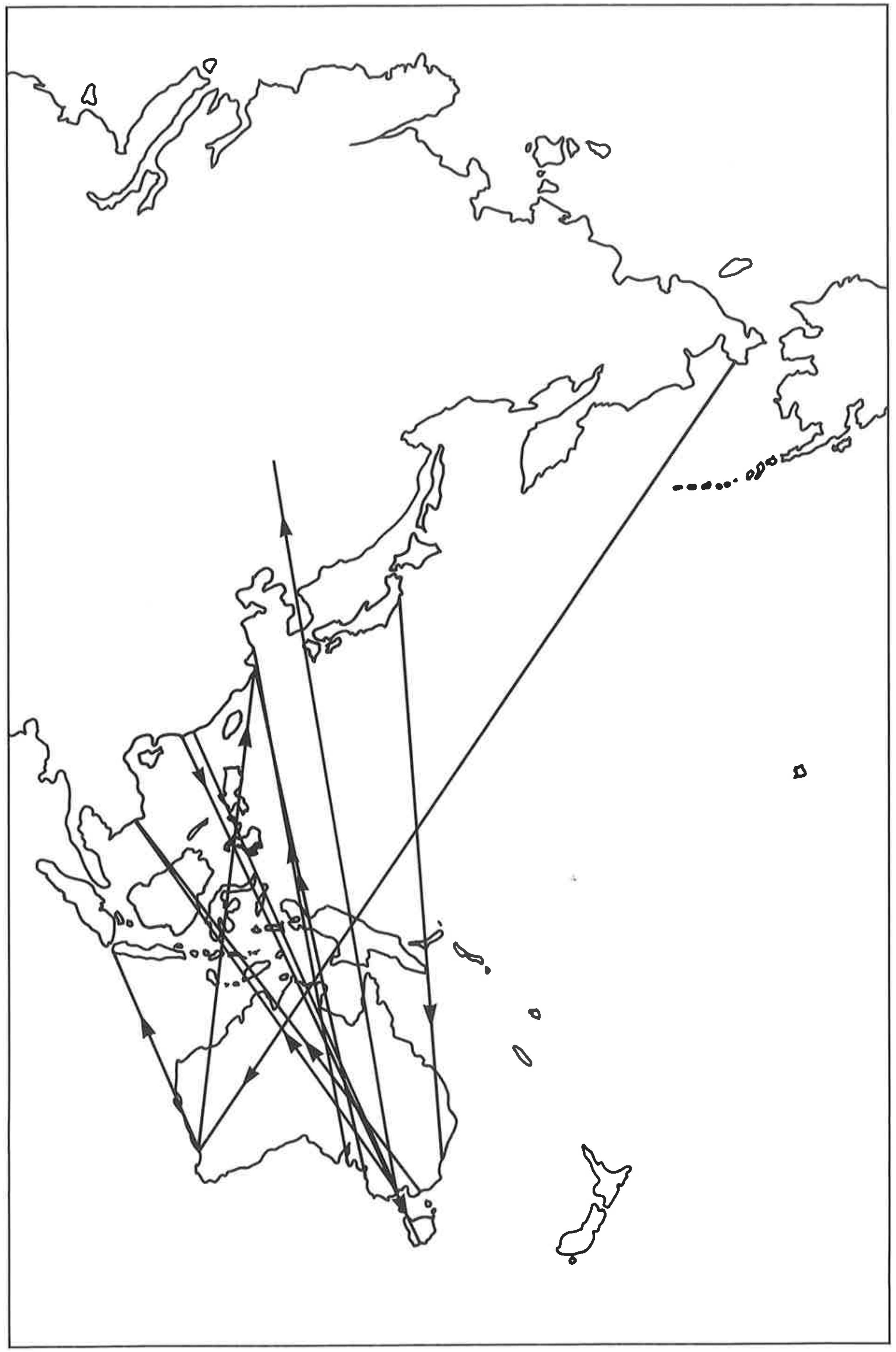


Figure 4: Recoveries of banded Red-necked Stints, showing banding and recovery sites. Arrows indicate direction of movement.

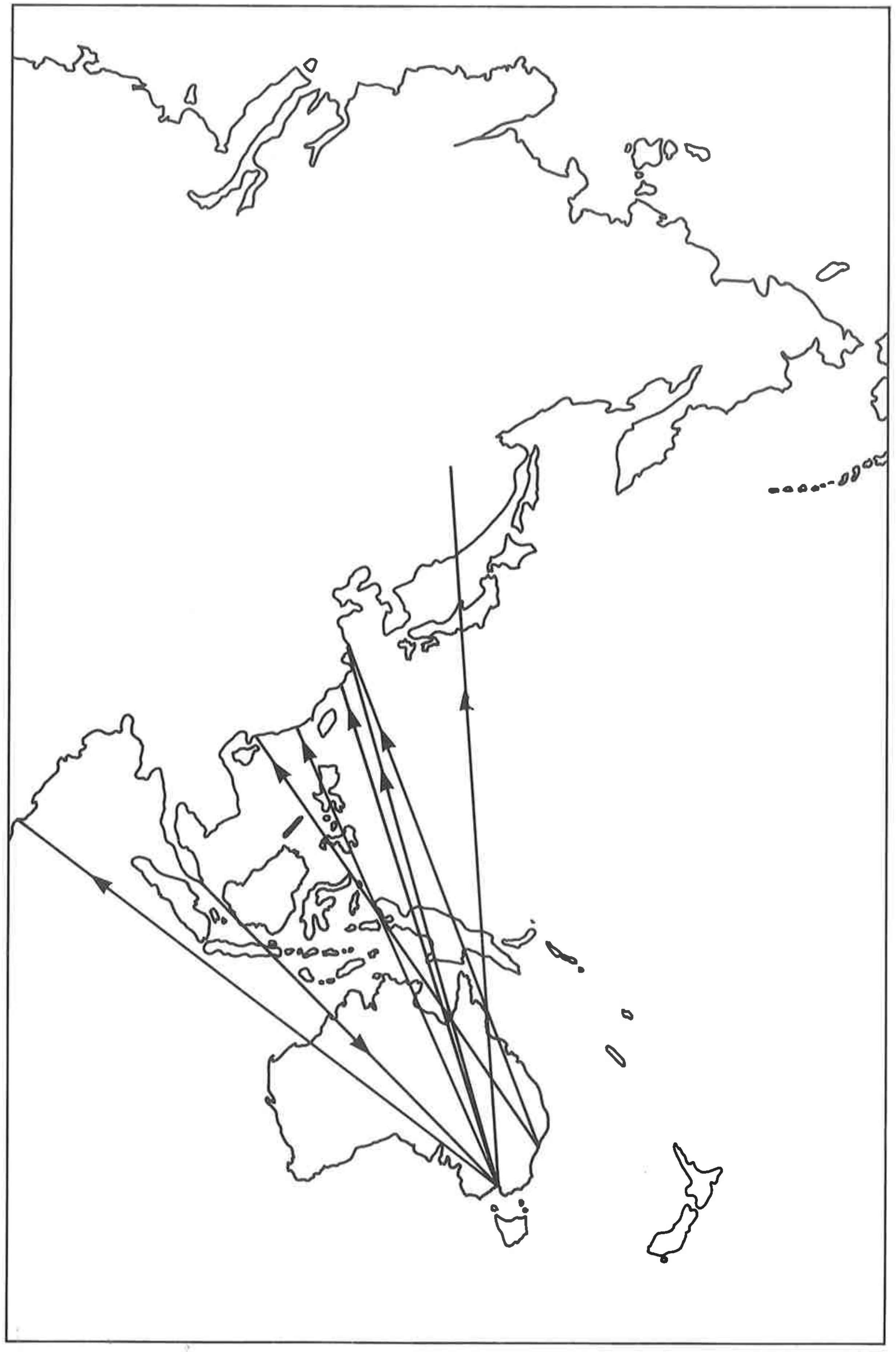


Figure 5: Recoveries of banded Curlew Sandpipers showing banding and recovery sites. Arrows indicate direction of movement.

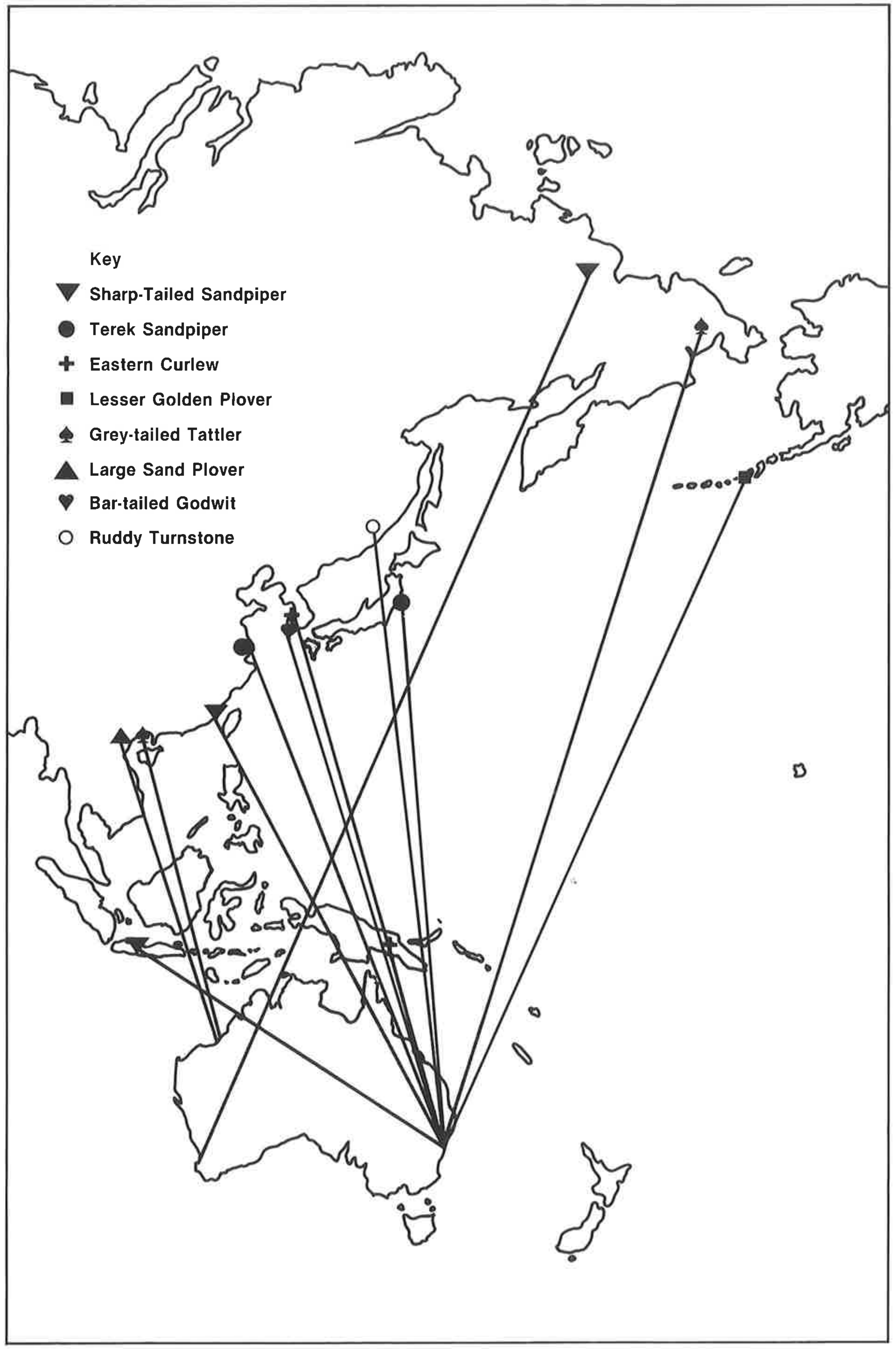


Figure 6: Recoveries of banded Sharp-tailed Sandpiper, Terek Sandpiper, Eastern Curlew, Lesser Golden Plover, Grey-tailed Tattler, Large Sand Plover, Bar-tailed Godwit and Ruddy Turnstone showing banding and recovery sites: see legend.

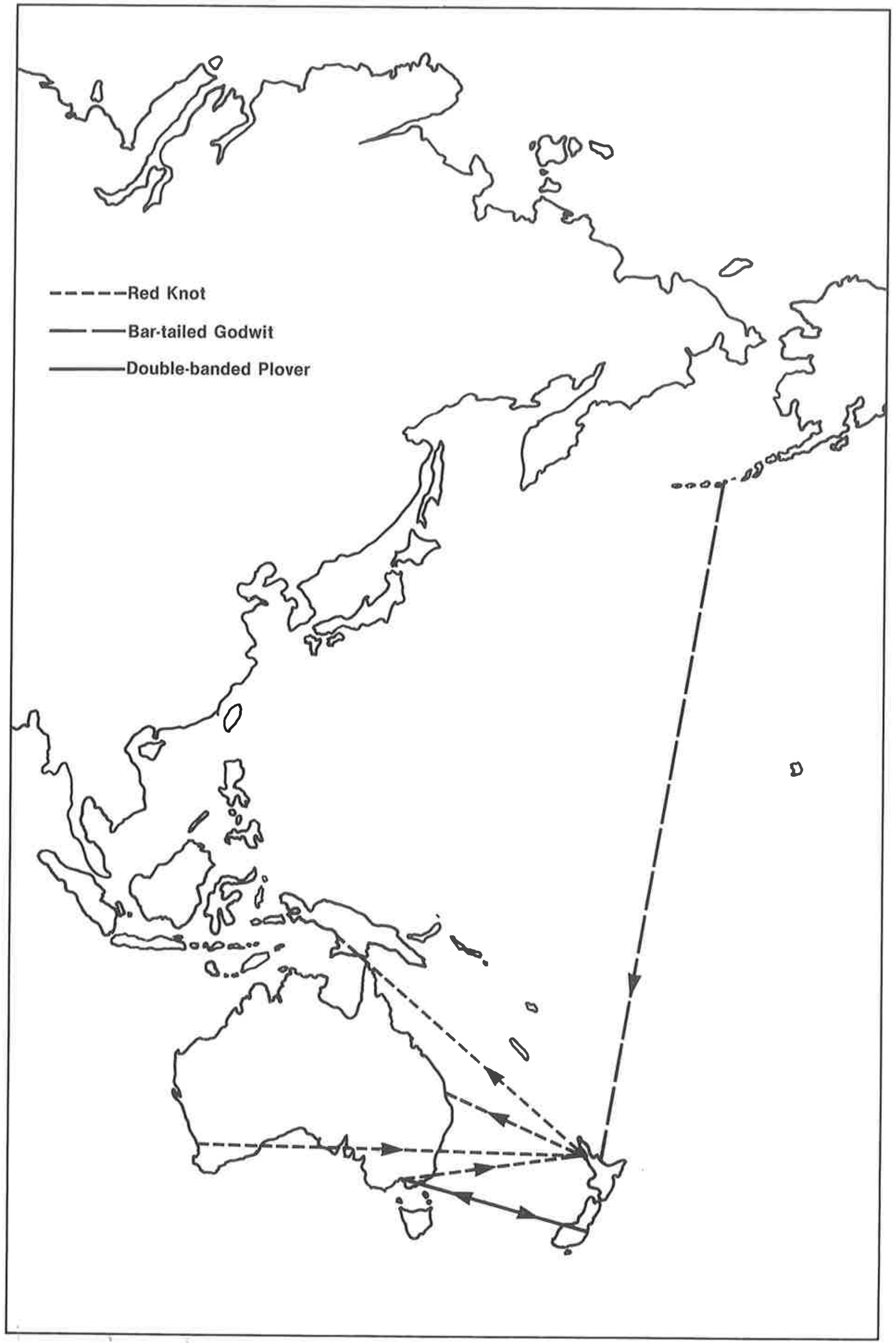


Figure 7: Recoveries of banded Red Knot, Bar-tailed Godwits and Double-banded Plover showing banding and recovery sites: see legend. Arrows indicate direction of movement.

from the tropical wet season in Northern Australia.

Data for individual birds show that they increase from fat-free to take-off weight in the space of two to three weeks. It therefore seems likely that birds undertake their migration as a series of long flights between suitable habitats up the Western Pacific. They stop for two or three weeks between flights to "refuel". This would require four or five steps for a migration from southern Australia to Siberian breeding grounds, and would take about ten weeks. This is confirmed by the timing of recoveries in Asia. Birds depart Australia in March and early April. Southern Chinese recoveries have been in late April and early May, those in northern China and southern Russia in late May and most waders are known to arrive on the Siberian breeding grounds in early June (Dement'ev and Gladkov 1967).

THE FUTURE

In Australia and New Zealand waders are an important component of the avifauna. They are concentrated in small areas and it is thus important that these are preserved. We have a responsibility not only to ourselves — for the resident species — but also to those other countries in which the migrants breed or through which they pass on migration. We are responsible for these migrants for eight months of the year and in many cases for the first eighteen months of their life.

We need comprehensive facts for conservation assessments and for the proper preparation of a case for conservation action. To obtain this the following is required:—

a) continuity of comprehensive bi-annual counts for a period to allow coverage to be completed and to enable an understanding of normal variations to be obtained. Comprehensive simultaneous counts are required in New Zealand;
b) banding to delineate more clearly migration routes between the breeding and non-breeding areas. This will also highlight particular "steeping stones" on the migration and help clarify movements within Australia and New Zealand;
c) studies of feeding ecology of waders in the principal habitats are required to indicate reasons for the distribution and numbers found by counts. This is also essential data to assess the likely ability of habitats to accommodate changes. Further information could be produced from such studies on the relation between population level and food supply, information critical to determining the carrying capacity of areas.

CONCLUSION

Through the efforts (mostly voluntary) of many hundreds of keen, amateur birdwatchers, much information is being gathered on the status and biology of waders in Australasia. The results presented here are only preliminary and much more work needs to be done before a full picture of wader numbers, distribution and migration will emerge. The RAOU Wader Studies Programme has federal funding until mid-1985 and in this time will attempt to fill gaps in our knowledge of numbers and distribution. Banding studies must continue beyond this date if worthwhile results are to emerge. The RAOU will continue to support wader studies to ensure the wise conservation of Australasia's internationally significant waders.

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Censusing Australian birds: A summary of procedures and a scheme for standardisation of data presentation and storage

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SUMMARY

A variety of methods for censusing birds have been employed in Australia (Recher, 1984). With few exceptions (e.g. Pyke, 1984; Pyke & Recher [in press]), the properties of these methods have not been explored nor have these methods been calibrated against one another. Consequently the usefulness of each method is poorly known and it is difficult to compare estimates of the densities (i.e. numbers per unit area) of birds obtained by different methods or in different locations. This situation will only be remedied when a standard set of procedures is adopted, when the properties of these procedures are carefully evaluated and when the results of these procedures are compared for the same locations. It may also be necessary for individual observers to be calibrated against one another. The purpose of this paper is to outline the nature of the problem of estimating the density of birds, to summarize a set (not necessarily complete) of census procedures, to discuss briefly the kinds of analyses used to obtain estimates of density and any biases inherent in each procedure and to present a scheme for standard presentation and storage of results.

INTRODUCTION

It is difficult to estimate density because birds are mobile, cryptic and affected by the presence of an observer. The mobility of birds makes it difficult to avoid counting the same bird more than once and leads to a continual accumulation of detected birds with increasing time spent observing an area. Because of this, counts that span intervals of time may be more a reflection of the movement of birds through an area than of the density at any instant.

The decline in our sensory acuity with increasing distance makes the likelihood that a bird is detected decline with increasing distance from an observer. The nature of this decline varies between species, habitats and observers (see Ralph and Scott 1981 for reviews) and it is therefore necessary to estimate the relationships between the probability of detection at different distances and these other parameters. It is possible to estimate these relationships if the distances between observer and bird are accurately estimated (Burnham *et al.*, 1980; Pyke & Recher [in press]).

An observer may attract or repulse birds and in other ways affect their behaviour, thereby increasing or decreasing the probability of detection. Accurate estimation of the density of birds therefore requires determination of the magnitude of these effects. However, it has proved impossible to do this because the numbers of birds detected at a particular distance results from an interaction between the number of birds present, which may have been affected by the observer's presence, and the unknown ability of the observer to detect a bird at that distance (e.g. Pyke, 1983).

Attraction or repulsion of birds should be minimized. This may be possible by judicious choice of clothing and using care in the movements and location of the observer. The behaviour of observers should also be adjusted so as to render birds maximally detectable so long as other sources of error are not thereby introduced. For example, some species may only be detected when flushed.

CENSUS PROCEDURES

Procedures for censusing birds may be divided initially into six categories:

- point counts;
- area counts;
- transect counts;
- mist net counts;
- mapping counts; and
- presence-absence counts.

During point counts an observer, located at a point, surveys the surrounding area for birds. Transect counts are obtained by an observer traversing some distance while surveying to the side for birds. Mist net counts are based on the numbers of birds captured in mist nets over some period of time. Mapping counts are obtained by mapping observed locations of birds (and/or nests) and assigning clusters of points (and/or each nest) to a bird or a group of birds. In presence-absence counts an observer records whether or not a species is present at each of several points. As the following summary will show, in some cases these categories may be further subdivided on the basis of differences in the methods employed.

INTERVAL POINT COUNTS

Procedure:

An observer, located at a point, surveys the surrounding area for some period of time and records the species (and sex and age if appropriate) and distance of birds detected. An attempt is made to avoid counting individuals more than once.

Variables:

a) *Time spent at a point (i.e. the census interval);* the most commonly used time intervals are 5 and 10 minutes.

b) *Number of points;* points are usually spread uniformly through the area of interest, often at regular intervals along a line.

c) *Method of detection;* birds may be detected by sight or sound or both. Distances may be recorded separately for sight and sound detections with two distances recorded for an individual if it is heard and then seen. Birds that are heard after first being seen are usually ignored.

d) *Number of counts;* in general the greater the number of counts the more accurate will be any estimates of abundance. However, the number of counts is often limited by the number of observers and the time available for the cenus.

e) *Distance categories employed;* distances might be recorded to the nearest metre or in distance categories (e.g. 0-5 m and so on). Distances beyond some point may be excluded.

Problems and suggested correction procedures

a) *Movement of birds;* movement of birds makes it difficult to avoid counting individual birds more than once and leads to a continual accumulation of birds with increases in the time spent at a point. Initial detections will include birds present at the beginning of a census interval as well as birds that arrive during the interval; later detections will increasingly include new arrivals.

The effect of movement on census results can be minimized by limiting the duration of the count to the minimum time needed to detect and register the individuals present in the area of the count at the instant of time the count begins. As the time required for counts may differ from place to place or change from season to season, the count interval should be determined at the start of each census in a new habitat or at a different time of the year. One way of estimating the optimal count interval for censuses is as follows. Divide the census interval into one-minute sub-intervals and record detections separately for each sub-interval. A graph of the average cumulative number of birds (and/or species) per point detected versus the length of the census interval in one minute increments increases rapidly at first and then slows as the time increases. As the curve flattens, a count interval can be chosen so that the average rate of increase in detections relative to the number of birds detected drops to some previously selected level (e.g. 5%, 1%). Alternatively, if the curve continued to rise linearly, the census interval might be extended so that the number of detections made after a set time (say 5 or 10 minutes) could be used to estimate the number of new arrivals during the first part of the census interval (that is, in the first 5 or 10 minutes). This requires observations to be recorded separately for two sub-intervals of time and assumes that the final slope of the curve provides an estimate of the rate of arrival of birds into the survey area. The estimated number of birds present at the beginning of the census interval is the number detected during the first sub-interval minus the estimated number of new arrivals during that period.

b) *Detection versus distance;* the cryptic behaviour of some birds and the decline of sensory acuity of observers with distance will result in a decline in the probability of detection of birds with distance from the observer. Observers will also differ in their ability to see or hear birds at a distance.

The problem of declining detectability with distance and differences in sensory acuity between observers can be corrected by accurately recording the distance from the observer to each bird registered. Ideally distances should be recorded to the nearest metre but small sample size often discourages this and distances are lumped with the nearest category employed being something like 0 to 5 m. Densities may then be calculated if the following assumptions are satisfied (see Burnham *et al*, 1980; Pyke & Recher, [in press]):

(i) all birds are detected near to the observer (i.e. the probability of detection is one in the nearest distance category);

(ii) the density of birds is not affected by the presence or behaviour of the observer (i.e. attraction or repulsion does not occur);

(iii) distances to detected birds are estimated accurately;

(iv) movement by birds is negligible.

Under these assumptions, the relation between density of detected birds and distance from the observer provides an estimate of the relationship between the probability of detecting a bird and its distance. An estimate of bird density may be obtained by combining the numbers of birds detected at each distance or in each distance category with this estimate of detectability versus distance and the number of point counts. The mathematical analysis involved is discussed in Burnham *et al* (1980) and will not be further discussed here. However, the following desirable properties of this analysis are worthy of note:

(i) the effective area surveyed is less when the detection probability declines rapidly than when it declines more slowly (cf. Emlen, 1971);

(ii) so long as all observers are certain of detecting all near birds, other differences between observers in terms of detectability of birds versus distance should not affect the density estimates (Burnham *et al*, 1980).

The accuracy of distance estimation appears to depend on the detection method employed. We have found that there is much error inherent in estimation of distances to birds that are heard but not simultaneously seen (Pyke & Recher, [in press]). With a little practise or with calibrated binoculars (acting as range-finders) distances to birds that are sighted can be estimated quite accurately (Pyke & Recher, [in press]). We therefore recommend that estimates of density be based on sight detections (i.e. birds initially seen and birds heard then seen). We realize that this will lead to lower total numbers of detections and further recommend that sampling effort be increased in habitats with difficult visibility. If some species are similarly detectable by sight then they may be combined to produce an estimate of density of the group of species and an estimate of the density of each species obtained on the basis of its proportion in the group (Pyke & Recher, [in press]).

c) *Attraction or repulsion of birds;* the presence of an observer may attract or repulse birds relative to the observer's position (e.g. Pyke, 1984).

Disturbance of birds and possible attraction or repulsion can be minimised by moving quietly between points, wearing clothes that blend with the vegetation, avoiding sudden movements and by not making unnecessary sounds during counts. After arriving at a point, the observer should remain still for some minutes before beginning the count so as to allow birds disturbed by the observer's movement between points to resume normal activities. The length of this pause will be a matter of judgement, but 5 minutes is recommended as a minimum period in forest habitats.

Instantaneous point counts

Procedure:

An observer, located at a point, scans the surrounding area (or part of the surrounding area) every x minutes where x is any constant. This should be adjusted to allow time to record observations. We have found a one-minute interval to work well. In principle scans could be visual or auditory or both and distances could be recorded separately for sight and sound detections. Visual scans are analogous to radar and contact with all individuals seen on the area during the scan is assumed to be instantaneous. Auditory scans are awkward to use because it is difficult to decide whether or not a bird has called at the precise instant of the scan. On each scan the observer records the species (and sex and age if appropriate) and distance of birds that are detected. Individuals may be counted more than once and may be registered repeatedly on successive scans so long as they remain detectable and within the census area. A scan may be restricted to a semi-circle or a quadrant rather than the entire circle around the observer. The number of scans per visit to a point and their distribution to different parts of the circle should be chosen so that all possible directions around the observer are sampled equally. If, for example, each scan covers half the circle then half the scans should be allocated to one semi-circle and half to the other.

Variables:

a) *Height above ground of observer*
b) *Fraction of circle scanned each time*
c) *Time interval between scans*
d) *Number of scans per visit to a point*
e) *Number of points*
f) *Total number of visits to all points*
g) *Method of detection*
h) *Distance categories employed*
i) *Total number of 360° scans.*

This is the product of the fraction of a circle scanned each time, the number of scans per visit to a point and the total number of visits made to all points.

Problems and suggested correction procedures:

a) *Movement of birds;* since this census method involves counts that are effectively instantaneous it should lead to results that are independent of the rate at which birds are moving about.
b) *Detection versus distance;* this procedure is subject to the same problems in detecting birds at a distance as interval point counts. The method of analysis as discussed above for interval point counts can be used.
c) *Attraction or repulsion of birds;* see discussion under interval point counts.

Searching area counts

Procedure:

The observer searches an area for birds and attempts to avoid counting individuals more than once. Detections of birds are based on sight and sound.

Variables:

a) *Total size of area sampled*
b) *Number of observers*
c) *Time spent searching per unit area*

Problems and suggested correction procedures:

a) *Movement of birds;* movement of birds makes it difficult to avoid counting individual birds more than once and leads to the continual accumulation of birds as more time is spent searching.
b) *Cryptic behaviour;* the observer will fail to detect some individuals and species that are present in the census area during a search. There appears to be no way to estimate the number of individuals that are missed. Species that are missed may be censused by adjusting procedures to account for their behaviour. For example, nocturnal birds can be counted by visiting the area at dark and owls can be located by playing recordings of their calls (Johnson *et al*, 1981). Other birds such as Mallefowl *Leipoa ocellata* might be scored on the basis of nest mounds or other evidence of their presence.
c) *Attraction or repulsion;* it is not clear what effects attraction or repulsion of birds would have. It is likely that any effects would be small so long as the area searched was large. In this case birds would seldom be attracted or repulsed across the boundary of the area. Repulsion would, however, reduce the probability of detecting particular individuals or species.

Instantaneous area counts

Procedure:

A stationary observer counts those birds that are present in an area at a particular instant in time. Counts may be repeated. Detections are based on sight and sound.

Variables:

a) *Size of area censused per count*
b) *Number of observers*
c) *Total area censused.*

This is the product of the area censused per count and the total numbers of counts.

Problems and suggested correction procedures:

a) *Movement of birds;* this procedure is instantaneous and movement of birds will not affect the results.
b) *Cryptic behaviour of birds;* some individuals and species that are present during a count will not be detected.
c) *Attraction or repulsion;* an area must be small for an instantaneous survey. Consequently repulsion of birds will reduce the numbers of birds detected while attraction will increase them. If the area can be surveyed from a distance, attraction and repulsion will not be problems.

Transect counts

Procedure:

An observer traverses a chosen route counting birds detected on either side and recording the distances of the birds from the centre line of the transect. The observer moves at a constant rate and attempts to avoid counting individual birds more than once.

Variables:

a) *Length of transect;* the transect need not be linear but if it curves the areas censused on each side of the transect line might not be equal and calculations of density would have to take this into account.
b) *Traverse mode;* transects may be traversed by walking, automobile, plane, horseback, etc.
c) *Traverse speed*
d) *Method of detection*
e) *Distance categories employed*

Problems and suggested procedures for correction:

a) *Movement of birds;* movement of birds makes it difficult to avoid counting individual birds more than once and leads to a continual flux of birds through the census area. The estimates of numbers and densities should increase with increases in the average speed of movement of birds but should decrease as the observer's speed increases. Ideally the speed that the observer moves at should be fast relative to average speed of the movement of birds. However, this may lead to considerable repulsion of birds and to a decline in ability to detect birds.
b) *Cryptic behaviour of birds;* the probability that a bird is detected should decrease with increasing distance of the bird from the centre-line of the transect. However, this does not matter so long as birds that are near the centre-line are certain to be detected. This might be a reasonable assumption if birds did not move. In the case of bird movement, however, it is difficult to know how to interpret the number of birds detected near the centre-line of the transect as some birds may move through this region and others will move into and out of this region ahead of the observer without being detected. In principle, if the observer — bird distance were also recorded, it should be possible to estimate the probability of detecting a bird as a function of the perpendicular distance from the centre-line and the distance of the bird from the observer. The probability of detection near the observer would then have an unambiguous meaning. However, the mathematics necessary for this have not been determined (Burnham *et al*, 1980).

The ability of an observer to detect birds that are not near the centre-line of the transect should decrease with increases in the speed of the traverse. The faster an observer travels the less attention can be given to areas away from the observer. So long as birds are stationary and all near birds are detected, estimates of density will be unaffected by this phenomenon. However, even if birds are stationary, the number of birds detected along a transect should increase as the speed of the traverse decreases.

The difficulty of accurately estimating the distance to birds that are detected through sound is at least as great with transect counts as with point counts. Movement of observers may make it even more difficult to focus on a sound and estimate its distance. We recommend that estimates of density be based on sight detections.
c) *Attraction or repulsion;* the continual movement of the observer may attract some birds and repulse others. This will cause error in the estimation of numbers and may render it impossible to apply the methods of analysis of Burnham *et al* (1980).

Mist net counts

Procedure:

Birds caught in mist nets are counted. Individuals that are captured more than once during the same morning or afternoon should be counted only once. However, birds that were caught on a preceding day during consecutive days of netting are recounted when recaptured.

Variables:

a) *Net length*
Large nets should catch more birds than small nets.
b) *Number of nets*
c) *Duration of netting per day*
d) *Constancy of net locations*
Position of nets may remain fixed for several days or may be changed regularly.
e) *Number of days spent netting*

Problems and procedures suggested for corrections:

a) *Movement of birds;* mist nets do not capture stationary birds and the number of birds caught (per m of net per hour) should increase with increases in the average speed and frequency of movement of birds.
b) *Susceptibility to capture;* different sexes, ages, or species of birds may not be equally susceptible to capture. For example, birds that tend to move about high off the ground are less likely to be caught than those moving near the ground.
c) *Response to capture;* birds that are captured (or observe other birds being captured) may learn the locations or appearance of mist nets and thereafter tend to avoid recapture. Successive

periods of netting in the same area may consequently provide more a measure of flux of new birds through the area than the instantaneous density of birds present in the area. To some extent this problem can be minimized by changing net position and orientation frequently.

d) *Time of netting;* nets may be in position for only part of the day or left open from dawn to dark. As birds behave differently during the day, capture rates may differ significantly between times of the day. Netting should therefore be done at the same time of day relative to sunrise and for the same length of time each day. The time of day that individuals are caught can be recorded and capture rates compared for the same times of day.

Mapping counts

Procedure:

Mapping is one of the oldest and most widely used census procedures for breeding birds in the Northern Hemisphere (Williams, 1936; Kendeigh, 1944; Shields, 1979). Standard procedures have been adopted in North America (Hall, 1964) and Europe (I.B.C.C., 1970) which recommend minimum size areas for census and the number of visits or hours required for an acceptable count. Census results are commonly expressed in pairs of breeding bird per 40 ha (100 acres) or per km^2 (100 ha).

The general procedure is for the observer to search an area plotting the location of birds on a map and recording the kinds of behaviour exhibited (e.g. singing, chasing, at nest). Different notations (or different colours) are used to denote species and their behaviour. Lines and arrows can be used to show direction of movement and to distinguish between individuals of the same species. Clusters of points indicate individuals, pairs or groups and interactions (e.g. fights, simultaneous singing) can be used to plot boundaries between territories. This is much easier to do if birds are individually colour-banded.

Variables:

a) *Size of area*
b) *Searching period each day*
c) *Number of days*
d) *Total search time*
e) *Birds individually identified* — yes or no.

Problems and suggested correction procedures:

a) *Behaviour of species;* mapping will only record the number of resident, breeding individuals. Because of their less conspicuous behaviour non-breeding individuals may not be detected or will be confused with nesting birds. Mapping is also unsuitable for transients or birds with territories or home ranges much larger than the census area. In Australian forests fewer than 50% of species can be censused by mapping (alone or in combination with nest searches) (Shields and Recher, [in press]).

b) *Size of groups;* some members of a group may go undetected. In some species, for example Flame Robin *Petroica phoenicea*, the number of males in an area may be easy to determine on the basis of conspicuous territoriality whereas females may be inconspicuous and not easy to detect. In such cases it may be incorrect to assume that each male has exactly one mate. The prevalence of communal nesting creates special problems in Australian habitats.

c) *Protracted nesting season;* mapping is most effective when birds are nesting and the movements of individuals are restricted to a relatively small area around the nest site. In Australia the breeding season may extend over a number of months with asynchronous nesting of species (e.g. Marchant 1980; Recher *et al*, 1983). To correct for this, censuses need to be at intervals throughout the breeding season or scheduled to coincide with favourable nesting conditions (e.g. after rain in the arid zone). Alternatively censuses can be done at the same time each year and counts restricted to species which nest at that time.

Presence-absence counts

Procedure:

This is a modification of the Interval Point Count census method. A stationary observer surveys the surrounding area for a period of time and records all species detected. The Rolling Bird Survey (Cullen, 1980) is an example of this census method. In this case the observer stops once each day at each point along a selected route and records the species of birds seen or heard irrespective of distance from the observer. Neither the number of individuals nor their distance from the observer is recorded. Points should be spaced at least 200 m apart. The route can be traversed on foot or by vehicle. Ten is an appropriate number of points along a route corresponding to about two hours of census time on each visit. The same observer makes at least five counts along the route visiting the same points in a three month period. Ideally surveys are repeated at different seasons throughout the year and the same routes are re-visited each year over a number of years. Counts at each point are for five minutes and are conducted at about the same time of day.

Variables:

a) *Method of detection*
b) *Duration of each count*
c) *Maximum distance*
d) *Number of points*
e) *Number of counts.*

Problems and procedures suggested for correction:

a) *Movement of birds;* the greater the average speed of movement of birds the higher will be the number of species detected per count and the greater will be the fraction of counts in which any particular species is detected.

b) *Cryptic behaviour of birds;* the number of one species may be same as of another, but the more cryptic species will be recorded less often during a count. For example, a species that tends to call every minute or has a loud, penetrating call will tend to be recorded more often than another species that calls less often or more softly.

DATA PRESENTATION

Comparison of estimates of bird density obtained by different observers using different methods in different places will only be possible if all relevant information is recorded and will be much easier if data are presented in standard ways. We therefore recommend the following schemes for presentation of census results.

For all census procedures the following data should be recorded:

1. *Area* e.g. Brisbane Water National Park
2. *Habitat* e.g. Open forest
3. *Location* e.g. North side of road from Pearl Beach to Patonga, 4 km from Patonga
4. *Site* e.g. 1976 — burn area
5. *Latitude and longitude to nearest minute*
6. *Dates* e.g. 12/5/83 to 15/5/83
7. *Period of time during the day* e.g. 0545 to 0815
8. *Names of observers*
9. *Weather conditions* e.g. wind, cloud cover, rain, low temperature, high temperature
10. *Census procedure* e.g. Interval point counts
11. *Method of detection* e.g. Sight only

Additional data presentation would depend on the particular census method. We recommend that data be presented according to the formats shown in Table 1.

DATA ANALYSIS

For most of the census procedures data analysis is straight forward. The total number of birds recorded is divided by the total area censused for searching and instantaneous area counts and for mapping counts. For presence-absence counts the abundance measure for each kind of bird is the proportion of counts during which that kind of bird was recorded.

Data analysis is more complicated when distances between birds and the observer or the transect centre line are recorded. In these cases each distance category must first be converted into an area category. For example, for point counts the distance categories 0-5 m, 5-10 m, 10-20 m correspond to area categories 0-78.5 sq. m, 78.5-314.2 sq. m and 314.2-1,256.6 sq. m. For 1 m of transect the distance category x to y m corresponds to the area category 2x to 2y sq. m, assuming that both sides of the transect are censused. Consequently a point count with distance categories 0-5 m, 5-10 m, 10-20 m etc. is analogous to a transect of length 1 m and distance categories 0-39.3 m, 39.3-157.1 m, 157.1-628.3 m etc. (i.e. half the corresponding area categories). If n point counts are made then the census is analogous to a transect of length n metres. Consequently the results of point and transect counts can be expressed in terms of the length of an equivalent transect, the cut-off points for the equivalent distance categories and the number of birds recorded for each distance category. At this stage various methods exist for the estimation of bird density (see Burnham *et al*, 1980). We follow Burnham *et al* (1980) in recommending that the relationship between density of detected birds and distance be used to estimate the relationship between the probability that a bird is detected and its distance. The latter relationship should be assumed to be non-increasing and should be estimated by the least squares Fourier series (see also Pyke & Recher, [in press]). Using this method an estimate of bird density in numbers per unit area and the associated standard error can be derived using a computer programme ('Transect') developed by Burnham *et al* (1980). This estimate of bird density is an unbiased estimate of absolute bird density so long as the following assumptions are valid:

i) The distribution of birds is unaffected by the presence of the observer;

TABLE 1

Formats for presentation of data from different census methods

A) **Interval Point Counts**	B) **Instantaneous Point Counts**	C) **Searching Area Counts**	D) **Instantaneous Area Counts**	E) **Transect Counts[1]**	F) **Mist Net Counts**	G) **Mapping Counts**	H) **Presence-absence Counts**
Number of points Number of observers Number of days Duration of each count Total number of counts Species, Age, Sex, Distance Categories (m) e.g. 0-5, 5-10, 10-20, etc. e.g. New Holland Honeyeater (Numbers of each kind of bird recorded in each distance category)	Number of points Number of observers Number of days Total number of 360° scans Species, Age, Sex, Distance Categories (m) e.g. 0-5, 5-10, 10-20, etc. (Numbers of each kind of bird recorded in each distance category)	Number of observers Number of days Total area searched Total time spent searching area (in person hours) Species Number (Number of each kind of bird recorded in search area)	Number of observers Number of days Size of area censused per count Total area censused Species, Age, Sex, Number (Numbers of each kind of bird recorded during counts)	Number of observers Number of days Total transect length Total duration of transect counts (in person hours) Traverse mode Traverse speed Species, Age, Sex, Distance Categories (m) e.g. 0-5, 5-10, 10-20 etc. (Numbers of each kind of bird recorded in each distance category)	Net lengths e.g. 10 m; 20 m Numbers of each net length e.g. 5; 4 Total net length e.g. 130 m Number of days Total netting duration (hours) Constancy of net locations (Constant or Changed m times every n days) Total sampling effort (in m of net x hours) Species, Age, Sex, Number (Numbers of each kind of bird caught)	Number of observers Number of days Total search time (hours) Species, Age, Sex, Group, size 1, 2, 3, etc. (Numbers of each size of group for each kind of bird)	Number of census points Number of observers Number of days Duration of each count Maximum distance Total number of counts Species, Number of counts (Numbers of counts during which each species recorded as present)

(1) If the observer also records observer-bird distance then a more complicated scheme will be required to present the data.

ii) all observers are certain of detecting a bird within the closest distance category;

iii) distances are measured or estimated without error;

iv) movement of birds is negligible (Burnham *et al*, 1980).

If these assumptions are satisfied then other differences between observers and differences between habitats, times etc. do not introduce any biases into the density estimates and these estimates can be used for any comparisons among such factors as habitat, species, time etc. If these assumptions are not satisfied then this method, or indeed any other method, will not provide a valid basis for such comparisons. Biases due to movement of birds may be removed by employing instantaneous counts.

DISCUSSION

No census procedure is perfect and the method used will depend on the objectives of the study, the habitat being surveyed, the time available and the skill or preference of the observer (cf. Emlen, 1981). Although standard procedures have been accepted for some census methods (e.g. mapping) and proposed for others (cf. Recher, 1981), most methods have not been tested widely enough for international standards to be adopted. The issue of standard census procedures is particularly difficult to resolve in Australia where little censusing of birds has been done and few studies have tested methods against each other in the field or sought to determine their properties (see Recher 1984 for a review of the use of census procedures in Australia). Although broad guidelines can be set, it is not possible to provide a set of rules for determining which method(s) to use or what procedures (in detail) to follow. Nevertheless certain problems are common to all or most methods and it is possible to structure census work to avoid or account for the worst of these difficulties.

If there is significant movement of birds then only the instantaneous point or area count procedure can provide an estimate of the absolute densities of birds. This assumes negligible repulsion of birds. On the other hand, if it is sufficient to have measures of relative bird densities (e.g. for comparisons between species, habitats, times of year), then other procedures *may* be just as good. For this to be the case it is necessary that any bias in the data (e.g. repulsion or attraction of birds) occur equally across whatever comparison is being made. However, before this is taken for granted it needs to be rigorously tested.

It is also possible to reduce errors in the data collected by adopting certain simple procedures. Observer error and differences between observers can be controlled or corrected for by pre-census training and calibration (Kepler and Scott, 1981; Kavanagh and Recher, 1984). Problems associated with the movement of birds are best handled by minimizing the duration of counts or increasing the rate of movement of an observer along a transect or through an area. In many habitats (e.g. heaths, open forest and woodland) counts can be restricted to visual detection of birds (Pyke and Recher, [in press]). This reduces errors in identification and improves the accuracy of estimates of distance between the observer and the bird.

Each census method has disadvantages and advantages according to the objectives of the census, the habitat to be surveyed and the resources (people and time) available. We expect a variety of methods to be used in Australia (see Recher 1984) and consider it important that each be used in fairly precise ways. That is, that observers adopt some standard procedures for each method and that the same kinds of data be recorded and in similar ways for each census. Only in this way will it be possible to compare results or for other workers to repeat surveys so as to test results or monitor changes in the avifauna.

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