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WETLANDS AND WATERBIRDS OF THE SNOWY RIVER AND GIPPSLAND LAKES CATCHMENT

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Abstract: Wetlands in the Snowy River and Gippsland Lakes catchments were located and categorized using water regimes and salinity; subcategories were determined using differences in vegetation. Fifteen categories and subcategories were recognised within 72,205 ha of wetland surveyed; the study area also contained an additional 32,522 ha of river flats. Most waterbird habitat (68,492 ha, 95%) was contained in 53 wetlands, each larger than 100 ha. Permanent saline wetlands were most extensive (24,766 ha) but open waters of deep freshwater marshes supported more birds, and more species of birds, than other categories. Of the estimated original wetland area (112,265 ha) 7% has been eliminated, and a further 29% (mainly river flats) has been greatly modified since settlement. Drainage and flood control works have been responsible for most alteration. We conclude that reservation of further wetlands is essential if the waterbird resource is to be maintained. Modification of existing areas may also affect nomadic and migratory species originating elsewhere.

INTRODUCTION

Australia is essentially a dry continent and has, over much of its land surface, an unreliable rainfall with varying annual patterns of distribution. Nevertheless, wetlands (areas temporarily or permanently inundated) of varying types have developed and many bird species have adapted to use such habitats for feeding, resting or breeding. Conservation of these dependent species implies preservation of appropriate habitats and presupposes an adequate knowledge of their habitat requirements. In Australia few attempts have been made to determine the various types and the area of wetlands used by the various species of waterbirds. (Whilst many species of birds use wetlands, waterbirds in this context include members of the following families: Podicipedidae, Pelecanidae, Anhingidae, Phalacrocoracidae, Ardeidae, Ciconiidae, Platealeidae, Anatidae, Accipitridae, Rallidae, Gruidae, Rostratulidae, Haematopodidae, Charadridae, Recurvirostridae, Scolopacidae and Laridae.) Studies by Corrick and Cowling (1975), Goodrick (1970), Lavery (1966) and Riggert (1966) are the only surveys of Australian wetlands, and these deal with only relatively small areas. Since many Australian waterbirds are nomadic and use widely separated habitats, additional surveys of more extensive areas are required.

In this paper we present results obtained in the first of a series of surveys designed to provide data on the distribution, water regime, vegetation and abundance of Victorian wetlands, and their utilization by waterbirds.

STUDY AREA

The study area (Fig. 1) is approximately 27,000 km², about 10 % of the area of Victoria. Most lowlands in the area, except regions of poor soil between Lakes Entrance and the Snowy River and deep sands between Stratford and Bairnsdale and south of Sale, are farmed. Even so the population is essentially urban and concentrated in the brown coalfield towns of Moe and Yallourn (population 21,000), Morwell (17,000), and Traralgon (15,000). Rural towns are considerably smaller (e.g. Sale 10,000, Bairnsdale 8500, Warragul 7000, Maffra 3600; data from Bowden 1977).

PHYSIOGRAPHY

Hills (1964) considered that the study area contained three main physiographic divisions, each with a characteristic topography and hence different types of wetland. The Eastern Highlands, an eroded plateau of a Mesozoic peneplain, has steep ridges and narrow valleys. The poor soils support *Eucalyptus* forests, though these have been mostly cleared from alluvial flats. The second division, the South Gippsland Highlands, occupies the southwestern portion of the study area and is an upwarped, faulted and eroded area of Cainozoic sand and mud stones capped in part by basalts. Dissection is mature and deep, and the steep

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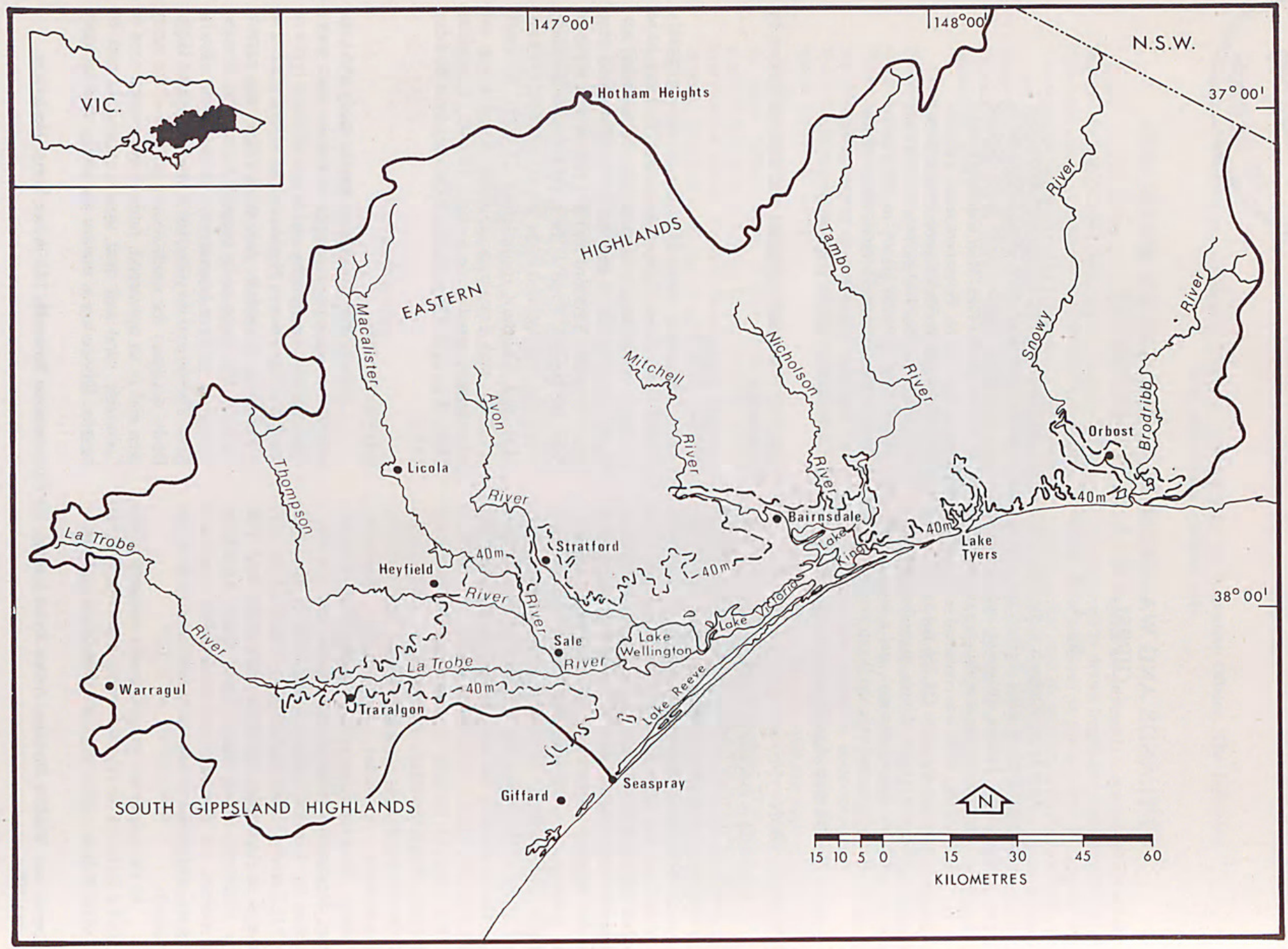


Fig. 1. The study area. The 40 metre contour delimits the East Gippsland Plains.

slopes are rounded. Streams flow within narrow valleys until they reach the third physiographic division, the East Gippsland Plains. Cainozoic sediments overlain by fluviatile sands and gravels and sands of marine origin form the Plains, which extend along the southern edge of the study area (Fig. 1). Lagoons and tidal lakes have formed along the coast.

The river flats within the Plains are composed of two sections, meander and delta plains (Jenkin 1968). On the meander plains, swamps formed within cut-off meanders range in size from small, simple oxbows to continuous lengths of by-passed stream beds filled only in floods. In contrast, delta plains formed as river deltas with associated natural levees advance into drowned valleys and shallow bays. The extensive swamps formed behind the levees at the mouths of most rivers in the study area (i.e. LaTrobe, Avon, Mitchell, Tambo and Snowy Rivers) represent a major wetland formation within the area.

The other major formation, coastal lagoons, were formed by sand bars enclosing shallow bays and by vegetation which stabilized silt deposited by inflowing rivers (e.g. Bird 1962, 1965 a, b, Jenkin 1968, Nicholson 1972). Elsewhere, and particularly within the Dividing Range, wetlands are restricted to small areas of river flats and infrequent water storages.

CLIMATE

Climatic details for part or all of the study area are available (e.g. Bureau of Meteorology 1975, 1976; Central Planning Authority 1954, 1968; Land Conservation Council 1972; Nicholson 1972) but only rainfall and the negative effects of temperature and evaporation on subsequent run-off will be discussed further.

Rainfall is evenly distributed throughout the year, increasing with elevation and from east to west across the study area (e.g. Hotham Heights 1538 mm p.a., Orbost 839 mm p.a. and Warragul 1051 mm p.a.) although stations in the deeper river valleys and near Sale are affected by rain shadows (e.g. Seaspray 585 mm p.a. and Licola 741 mm p.a.; Bureau of Meteorology 1975). Temperatures are warm to hot during summer and cool during winter and are moderated by proximity to the sea and by increasing and decreasing altitude respectively (e.g. mean maximum and minimum daily temperatures for January at Sale are 25.9 and 12.9°C, Hotham Heights 17.6 and 7.5°C and Orbost 25.4 and 13.1°C and for July at Sale 13.5 and 3.3°C, Hotham Heights 1.2 and −3.3°C and Orbost 14.7 and 4.4°C; Bureau of Meterology 1975).

Although few records are available evaporation ranges between 0.76 and 1.0 m, except in the upper Eastern Highlands, where losses are less than 0.76 m (Bureau of Meteorology 1968). Seasonal differences in temperature and rainfall result in evaporation which exceeds rainfall by 3-4 times during summer, but is equal to or less than rainfall during winter (Bureau of Meteorology 1976). The resulting runoff varies from 25 mm near Sale to about 1 m in the Highlands (Department of National Development 1966).

Droughts are infrequent. For example, droughts of two months or more occur in less than 2% of winters. Droughts of two months or more starting in January are more common (i.e. Giffard 40% of all years, Orbost 16%) but prolonged droughts (of 5 months or more) are less frequent (Giffard 7%, Orbost 1%; Central Planning Authority 1954, 1968; Nicholson 1972). Thus the wetlands throughout the study area are reliably supplied with water.

HYDROLOGY

More than 90% of the water discharged by rivers in the study area flows through the LaTrobe, Thomson, Macalister, Mitchell and Snowy Rivers. Flows are at a maximum during late winter and early spring, decrease as summer approaches and increase again after autumn and winter rains. Floods usually occur between June and October.

The water levels and salinity of the Gippsland Lakes are determined by rainfall, freshwater inflow and exchange of sea water with Bass Strait. The water level is highest, and the water freshest, during winter and spring, but during summer the water becomes increasingly saline and salt water may intrude as far as Lake Wellington (Ducker *et al.* 1977).

River flows are modified by diversion of water for various purposes. Diversions for irrigation from the Macalister and Thomson Rivers total 236,000 Ml per year, about 40% of the mean annual flow in the Macalister River, and since only 20% of diverted water returns to the river system (Melbourne and Metropolitan Board of Works 1975) wetlands dependent on river flows are inevitably affected. Additional water is taken for domestic and industrial purposes, mainly in the LaTrobe Valley (219,000 Ml p.a.), for private irrigation along river flats (60,000 Ml p.a., Ministry for Conservation 1977), and for hydro-electricity generation and irrigation from the upper Snowy River (20% of mean annual flow; Webster and McLennan 1965).

Some wetlands may be maintained or modified by ground water. However, the mechanism is not understood. Harris (1976), who summarised available data, indicated possible problems resulting from increased run-off as a result of changing land-use, from lowering of water tables and from pollution of the aquifers.

METHODS

WETLAND DISTRIBUTION

Wetlands were located from aerial photographs, from topographic maps* or during ground surveys. Each wetland was examined, the water regime was determined and major plant communities identified and delineated on aerial photographs. Pantographic enlargements were made, where appropriate, to help determine areas covered by wetlands and associated communities.

Drained wetlands were generally difficult to locate, particularly in agricultural areas where clearing and cultivation has been extensive. The boundaries of some former wetlands were determined from early maps or photographs. The detailed and extensive river flat surveys (State Rivers and Water Supply Commission 1934-40) showing contour levels and the proliferation of minor drains indicate many original basins. Whilst our survey provided evidence of many former wetlands some smaller drained areas were probably not located.

WETLAND CLASSIFICATION

Several schemes of wetland classifications have been proposed (e.g. Martin *et al.* 1953, Cowardin & Johnson 1973) and local systems for specific areas varying both in size and complexity have been developed (e.g. Frith 1959, Lavery 1966, Riggert 1966, Goodrick 1970, Braithwaite 1975, Corrick & Cowling 1975). Such systems took account of combinations of water regime, salinity, plant species and their abundance and cover, and ratios of emergent vegetation to open water. Most classifications recognise problems associated with the variety of water regimes, and the physical and chemical factors which may occur. However, wetlands have usually been classified by the predominant plant community, even though small, less abundant communities may be more important to the ecology of waterbirds using the wetlands.

In this study wetlands were assigned to categories, based on their water regimes and salinity and subcategories were established using vegetational differences. These categories and subcategories are:—

1. *Flooded River Flats*
2. *Freshwater Meadows*
3. *Shallow Freshwater Marshes*
   - 3.1 *Herb-dominated*
   - 3.2 *Sedge-dominated*
4. *Deep Freshwater Marshes*
   - 4.1 *Shrub-dominated*
   - 4.2 *Reed-dominated*
   - 4.3 *Sedge-dominated*
   - 4.4 *Rush-dominated*
   - 4.5 *Open water*
5. *Permanent Open Freshwater*
6. *Semipermanent Saline Wetlands*
   - 6.1 *Salt pans*
   - 6.2 *Salt meadows*
   - 6.3 *Salt flats*
   - 6.4 *Sea rush-dominated*
7. *Permanent Saline Wetlands*
   - 7.1 *Shallow*
   - 7.2 *Deep*

*Details of photographs and maps used, and locations of individual wetlands are available from the Librarian, Fisheries and Wildlife Division.

CATEGORY 1. *Flooded River Flats*

Included in this category is land temporarily inundated for very short periods after flooding or heavy rain. Inundation is too brief to induce and support true aquatic vegetation, and plant species are determined by agricultural practices.

CATEGORY 2. *Freshwater Meadows*

Wetlands in this category have water-logged soil for up to 3 months each year, but surface water is usually shallow (< 0.2 m) and transient (< 14 days). The plant community which develops is dominated by *Carex appressa* and *Juncus* sp. but other species (e.g. *Paspalum distichum, Eleocharis acuta, Scirpus fluviatilis, Polygonum minus* and *Amphibromus neesii*) may be associated. This vegetation is modified by trampling and grazing by stock, which reduces herbs, and by cultivation which can eliminate tussocks.

CATEGORY 3. *Shallow Freshwater Marshes*

In these wetlands soil is water-logged throughout the year and surface water (< 0.5 m) may be present for 6-8 months. These marshes are usually dry by January and fill in May or June following rains or floods. Two subcategories are recognised:—

Subcategory 3.1 *Herb-dominated*

This subcategory of shallow freshwater marsh occurs on agricultural land. The annual, moist-soil species of plants are succeeded by pasture species as waters recede. Such marshes are typified by a diverse flora which includes *Marsilea mutica, Azolla filiculoides, Carex appressa, C. gaudichaudiana, Eleocharis acuta, Glyceria australis, Paspalum distichum, Scirpus fluviatilis, Potamogeton tricarinatus, Alisma plantago-aquatica, Spirodela oligorrhiza, Polygonum minus, Ranunculus* sp., *Lythrum hyssopifolium, Ludwigia peploides, Rumex bidens, Callitriche stagnalis* and *Cotula coronopifolia.*

Subcategory 3.2 *Sedge-dominated*

This subcategory is typified by a dense cover of *Lepidosperma longitudinale, Cladium articulatum* and *Lepyrodia muelleri; Villarsia reniformis, Utricularia dichotoma* and *Selaginella uliginosa* may also occur.

CATEGORY 4. *Deep Freshwater Marshes*

Deep freshwater marshes (> 1 m) remain inundated during years of average or above average rainfall. Five subcategories are recognised:—

Subcategory 4.1 *Shrub-dominated*

Some areas of deep freshwater marshes are dominated by *Melaleuca ericifolia* whose multiple trunks may be 5 m high. The rootstocks collect soil and litter in which *Phragmites australis, Polygonum lapathifolium, Cotula coronopifolia* and *Urtica incisa* may grow. In deep water floating plants (e.g. *Azolla pinnata, Lemna minor,* etc.) may form dense mats, and submerged *Vallisneria spiralis* occurs. Emergent species (e.g. *Myriophyllum propinquum, Villarsia reniformis, Ranunculus* sp.) are common in shallower waters.

Subcategory 4.2 *Reed-dominated*

Areas of some deep freshwater marshes are dominated by tall, dense stands of *Phragmites australis, Juncus ingens* or *Typha* sp. in which few associated species grow.

Subcategory 4.3 *Sedge-dominated*

Small deep marshes, usually in dune swales, covered by *Lepidosperma longitudinale* are included in this subcategory. Associated species are usually few (mainly *Villarsia reniformis, V. exaltata, Utricularia dichotoma* and *U. australis*) but some (e.g. *Spirodela oligorrhiza, Azolla filiculoides, Eleocharis sphacelata, Myriophyllum propinquum, Potamogeton tricarinatus, P. ochreatus, Vallisneria spiralis, Callitriche stagnalis* and algae) are more numerous in larger marshes.

Subcategory 4.4 *Rush-dominated*

Eleocharis sphacelata dominates some parts of deep freshwater marshes. Associated species include *Myriophyllum propinquum, Pseudoraphis paradoxa, Amphibromus neesii, Otelia ovalifolia, Villarsia reniformis, Potamogeton tricarinatus, P. ochreatus, Ceratophyllum demersum, Ranunculus* sp., *Lemna trisulca, Azolla filiculoides, A. pinnata,* and *Spirodela oligorrhiza.*

Subcategory 4.5 *Open water*

Areas of open water devoid of emergent vegetation occur within deep freshwater marshes. The vegetation of the littoral margin includes *Cotula coronopifolia, Paspalum distichum, Scirpus fluviatilis, Eleocharis acuta, Triglochin procera* and *Potamogeton tricarinatus,* but is much modified by changes in water levels, wave action, turbidity, gradient and grazing.

CATEGORY 5. *Permanent Open Freshwater*

Water storages and natural lakes deeper than 1 m are included in this category. Fluctuations of water-level in storages, together with the generally steep shoreline, restrict the growth of aquatic plants along the shore. In natural lakes *Vallisneria spiralis, Potamogeton ochreatus* and *Lepilaena bilocularis* are found in shallows where turbidity is low.

CATEGORY 6. *Semipermanent Saline Wetlands*

These wetlands are maintained by rainfall and inflows from permanent saline wetlands. Plant associations vary with the periodicity of inundation and four subcategories were distinguished:—

Subcategory 6.1 *Salt pans*

Generally salt pans have little surface water (< 0.5 m) except after winter and spring run-offs or floods. Some aquatic plants (e.g. *Lepilaena cylindrocarpa, L. preissii* and *Ruppia maritima*) are abundant in shallow waters during winter and spring but increasing salinity and temperatures, coupled with decreasing waterlevels, eliminate them during summer.

Subcategory 6.2 *Salt meadows*

Salt meadows are inundated for 3-5 months but are usually dry by January. Such areas are typified by a low ground-cover of *Salicornia quinqueflora* and *Mimulus repens,* and *L. preissii* may occur in the shallows. In grazed areas prostrate species may be reduced by trampling.

Subcategory 6.3 *Salt flats*

Salt flats have surface water only during winter and early spring. Vegetation is low, dense and varied in open areas and usually includes *Wilsonia humilis, W. backhousei, Salicornia quinqueflora, Samolus repens, Arthrocnenium halocnemoides, Distichlis distichophylla, Sporobolus virginicus, Monerma cylindrica, Frankenia pauciflora,* and *Selliera radicans.* Where beds of *Gahnia filum* develop, associated species are fewer.

Subcategory 6.4 *Sea rush-dominated*

Extensive stands of *Juncus maritimus* occur in some salt-affected areas inundated or water-logged for long periods. Such stands, which may occur in areas where *Melaleuca ericifolia* has died after salt intrusion, generally exclude other vegetation.

CATEGORY 7. *Permanent Saline Wetlands*

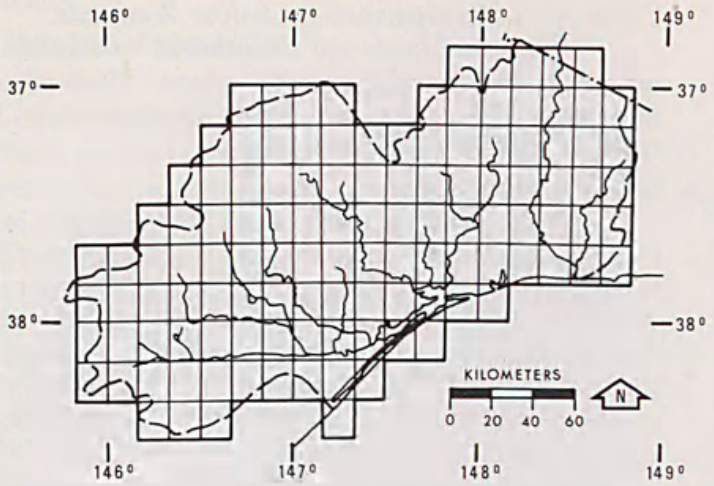
The entrances to most coastal lagoons in the study area are closed, or restricted for most of the year. Tidal influence is restricted or absent, and therefore the presence of shallow water determines waterbird usage. Two subcategories are recognised purely on water depth.

Subcategory 7.1 *Shallow*

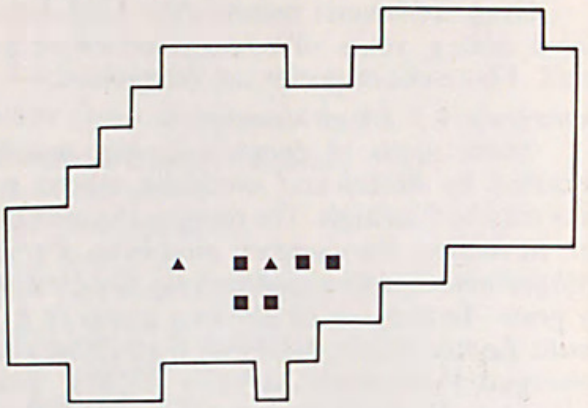
Zostera sp., *Ruppia maritima* and algae (Ducker *et al.* 1977) are common in these shallow (< 2 m) areas. Shorelines are sandy or rock-covered, but *Juncus maritimus* may grow in more sheltered locations.

Subcategory 7.2 *Deep*

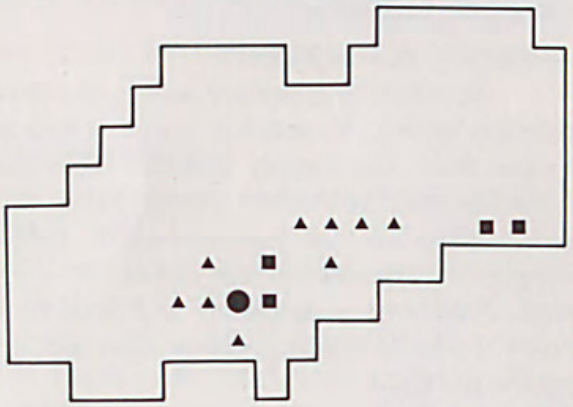
The subcategory includes deeper (> 2 m) waters which may support *Ruppia maritima, Zostera* sp. and algae depending on the turbidity and depth of water.



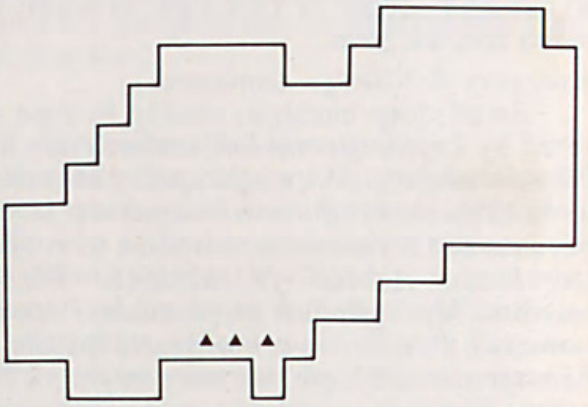
Freshwater meadow 2.



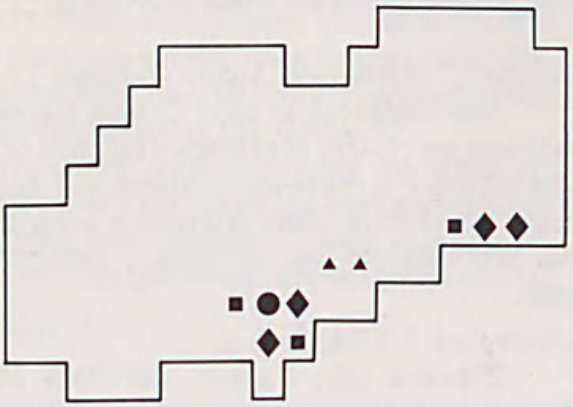
Shallow freshwater marshes 3.1 Herb dominated



Shallow freshwater marshes 3.2 Sedge-dominated



Deep freshwater marshes 4.1 Shrub-dominated



Deep freshwater marshes 4.2 Reed-dominated

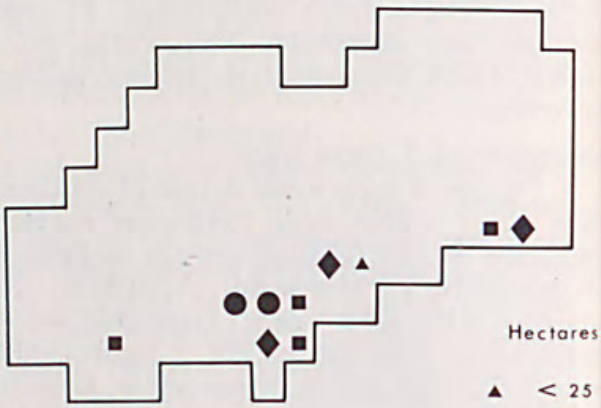
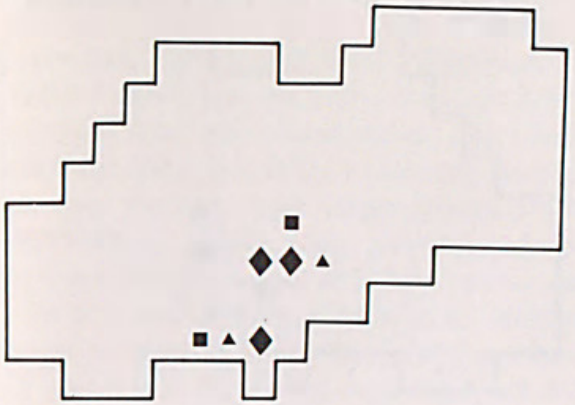
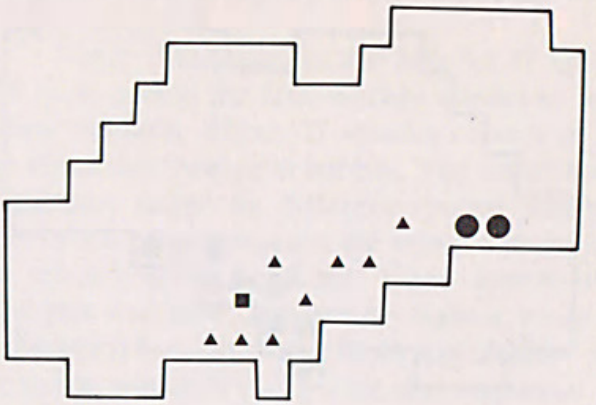


Fig. 2. The distribution (plotted on a 10′ grid) of the area (ha) of each wetland category and subcategory of the study area.

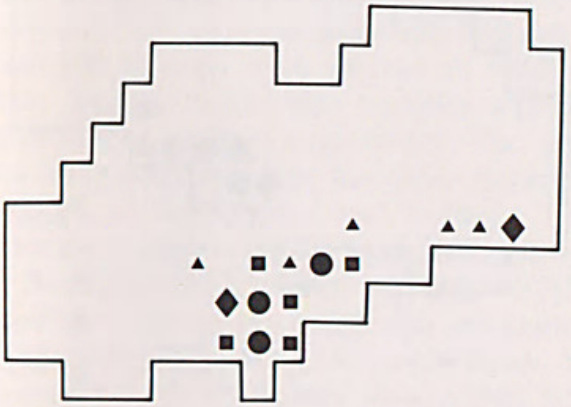
Deep freshwater marshes 4.3 Sedge-dominated



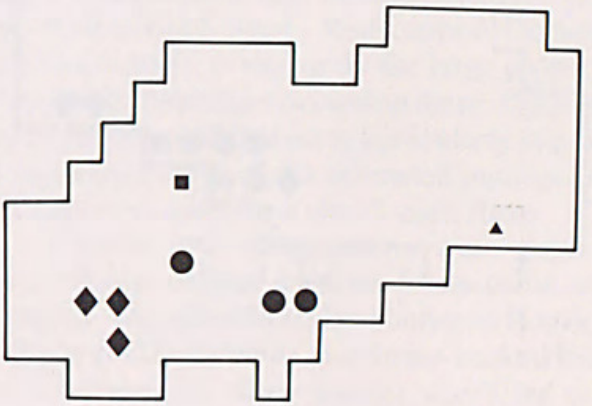
Deep freshwater marshes 4.4 Rush-dominated



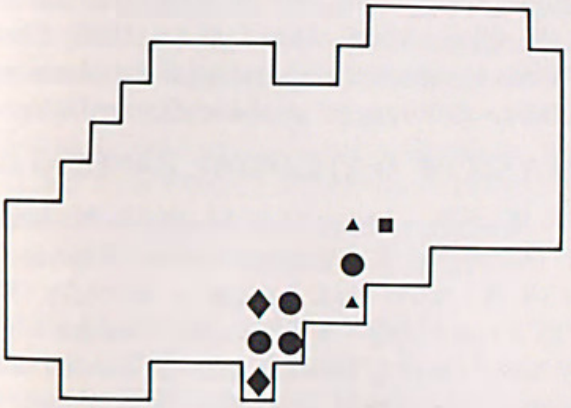
Deep freshwater marshes 5.5 Open water



Permanent open freshwater 5.



Semipermanent saline wetlands 6.1 Salt pans



Semipermanent saline wetlands 6.2 Salt meadows

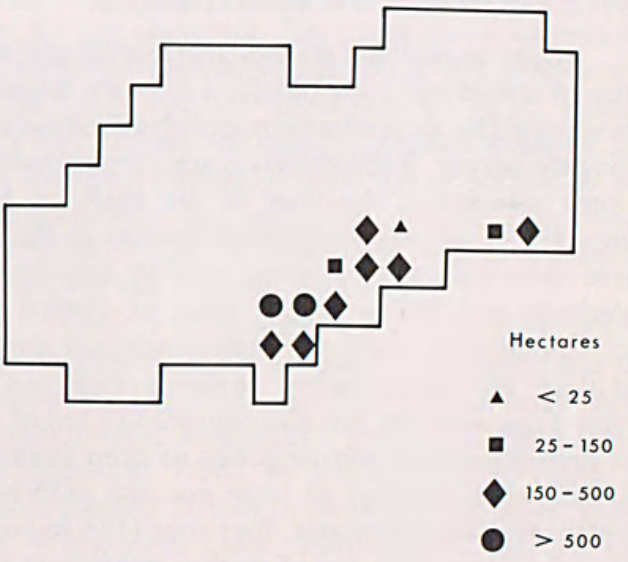


Fig. 2 *(continued)*

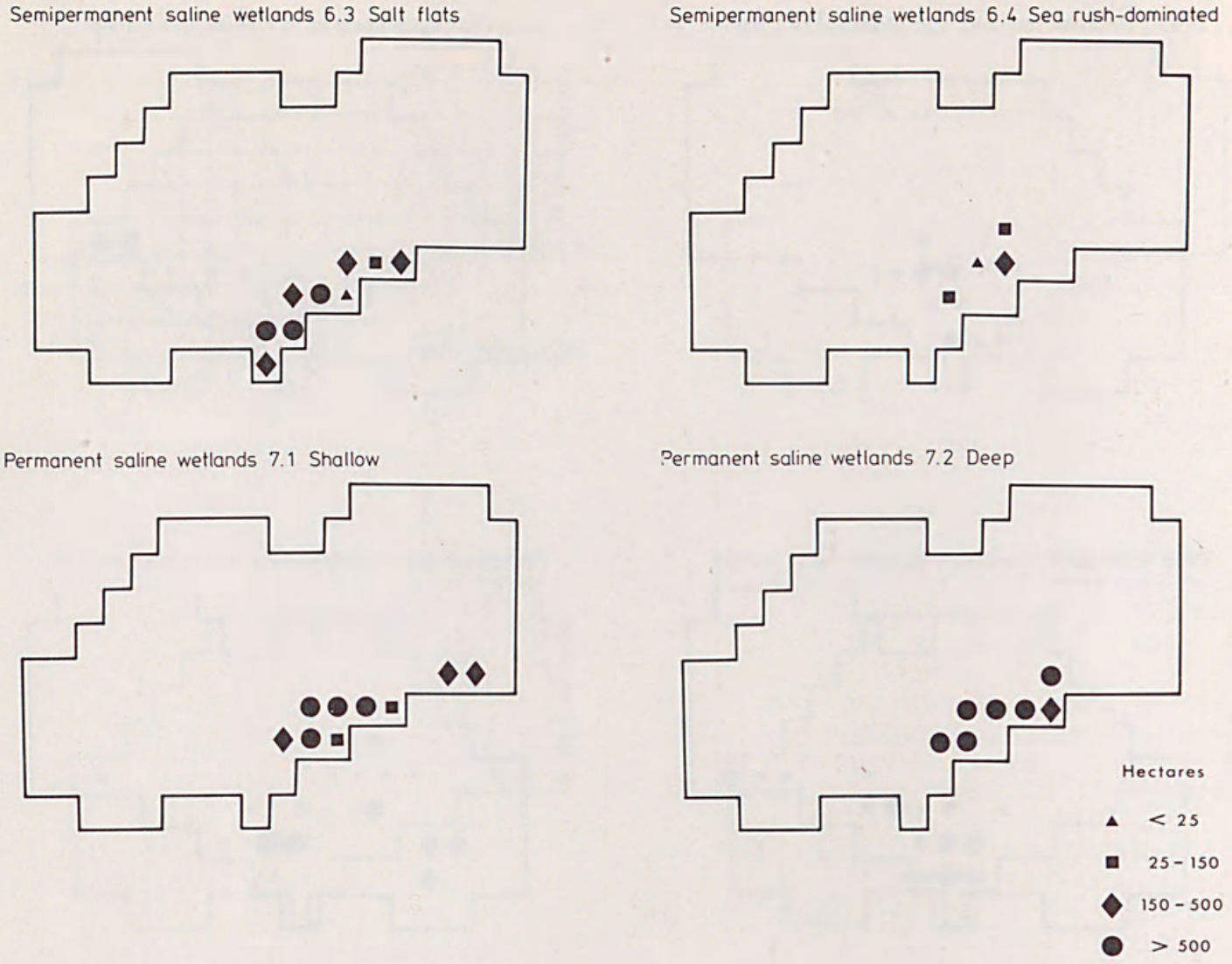


Fig. 2 *(continued)*

WETLAND USAGE BY WATERBIRDS

Data on past and present distribution and abundance of waterbirds were obtained from the literature, lists supplied by local observers and observations made during the survey. Four-weekly counts were conducted at sites selected at the start of the study as being representative of major waterbird habitats in the area. These sites were in areas most used by non-breeding waterbirds and also included areas of cleared river flats, agricultural land and ocean beach; salt meadow and deep permanent saline wetlands were not surveyed. Four sites (66 ha) and one site (33 ha) of open and rush-dominated subcategories of deep freshwater marshes were sampled as were one site (135 ha) of permanent open freshwater, four sites (174 ha) of salt pan and six sites (757 ha) of shallow permanent saline wetland. Roadside counts were also made over 1880 ha of river flats and 2554 ha of agricultural land between Sale and Traralgon. Counts were made at the same time of day on each visit, using binoculars and telescope. No doubt biases are inherent in this method (e.g. McClure 1945, Diem & Lu 1960, Eberhardt 1968) but it satisfied requirements for obtaining data on relative differences in abundance and usage.

ANALYSIS OF WATERFOWL BANDING DATA

Waterfowl have been banded in Victoria since 1951 (McNally & Falconer 1953, Norman 1973). Most (81%) have been banded at Serendip (38°01'S 144°25'E) and only 1.8% have been banded within the study area. During hunting seasons banded birds are recovered throughout Australia. The number of recoveries within the study area is compared with those from elsewhere and the distribution of recoveries in the study area, was plotted on a 10' grid of the area.

RESULTS

WETLAND DISTRIBUTION

Fig. 2, which summarises the distribution of wetlands in each category and subcategory in each 10'

square, emphasises the abundance of wetlands around the Gippsland Lakes, and the scarcity of wetlands in the mountainous Eastern and South Gippsland Highlands. Indeed, other than the rivers there are few wetlands upstream from the coastal plains. The restricted distributions of saline wetlands, found only around salt lakes or near the sea, and sedge-dominated deep freshwater marshes, which occur only between Stratford and Bairnsdale and south of Sale, is also evident.

The area and number of individual wetlands of each category examined during the survey are shown in Tables 1 and 2. Of 72,205 ha examined, 68,492 ha (95%) are within the 53 wetlands which exceed 100 ha; the remaining 3,713 ha is comprised of 167 small wetlands.

Drainage works have eliminated 27 wetlands (of 5,625 ha) and reduced the surface area of another 18 (by 1,913 ha). Deep freshwater marshes have been most affected; 7181 ha (34%) have been lost and 140, 476 and 540 ha have been altered to freshwater meadow, shallow freshwater marshes and semipermanent saline wetland respectively. The area of shallow freshwater marshes has been reduced by 329 ha (25% of original area) and 28 ha (< 1%) of semipermanent saline wetlands have also been lost.

In addition to individual wetlands, 32,522 ha of river flats occur in the study area distributed as follows: LaTrobe River, 8740; Thomson River, 5200; Macalister River, 8100; Mitchell River, 5340; Snowy River, 5142.

These river flats are flooded briefly each year but contain many small wetlands (not recorded individually) which provide valuable waterbird habitat. Since settlement, clearing, cultivation, flood control works and drain construction have all modified the habitats provided by the flats, particularly by reduction of the area and duration of inundation of shallow basins. All river flats along major rivers have been modified to the detriment of most waterbirds. Thus of the 112,265 ha of wetland, including river flats, which previously existed in the study area, 36% (40,060 ha) have been eliminated or greatly modified.

WETLAND USAGE BY WATERBIRDS

The waterbirds recorded in each wetland category and subcategory are listed in Appendix 1. The open waters of deep freshwater marshes and shallow permanent saline wetlands had the most diverse avifauna (55 and 53 species respectively) although shallow freshwater marshes and salt pans also provide habitat for 40 species. In contrast only 3 species used salt flats and 2 the rush-dominated semipermanent saline wetlands. Shallow freshwater marshes and the shrub and reed-dominated subcategories of deep freshwater are the most important breeding habitats. Few species have been recorded breeding in saline wetland categories.

Table 3 summarises the data for 27 species of birds seen during the four-weekly counts in selected wetland habitats. These 27 species consist of the 10 most abundant from each habitat. The table shows the comparative usage by different species within each category and also compares the relative abundance of each species in each habitat. Open waters of deep freshwater marshes showed the highest usage (27.3 bird/ha/visit) but salt pans (12.4) and shallow permanent saline wetlands (5.4) were also important. In all surveyed habitats relatively few species (e.g. Coot, Black Swan, Grey Teal, Silver Gull, Crested Tern, Swamp Hen and ibis) accounted for most of the total usage. The importance of certain wetland habitats to particular species, e.g. Crested Grebe, White-necked Heron, Musk, Black and Mountain Duck, Chestnut Teal, Red-necked Stint, Red-capped Dotterel and Black Cormorant, is shown by the large proportion of their estimated numbers occurring there. Open areas of deep freshwater marshes were particularly important in that more than 40% of the estimated numbers of 8 of the 27 species listed in Table 3 used them.

Counts and observations were made on a variety of non-wetland habitats likely to be used by waterbirds. On agricultural land between Heyfield and Traralgon (Table 3) White and Straw-necked Ibis were more common than those species which fed in water (Coot and Black Swan). On cleared areas in the Eastern Highlands, where waterbird habitat was restricted to farm dams and river courses, Wood Duck, White-faced Heron and Masked Plover, which feed away from water, were most common; Little Grebe, Black Duck, Grey Teal and several species of cormorant were far less abundant. The numbers of waterbirds in the Highlands appeared to be much less than the totals of the same species occurring on large wetlands elsewhere. Along the coast waterbird usage of some sites is higher because of roosting or resting by birds which normally feed out to sea; at Lake Tyers Beach, for example, 75% of the usage was contributed by Silver Gull and Crested Tern (Table 3).

There was considerable seasonal variation in both the habitats used by many waterbirds, and their occurrence. Migratory species were present during summer (snipe, sandpipers, godwit, Eastern Curlew and Common Tern) or winter (Cattle Egret and Double-banded Dotterel). However, nomadic species (e.g. White-eyed Duck, Pink-eared Duck and Grey Teal) may be present at any time throughout the year. Of the species which breed in the study area only the Little Tern is known as a regular migrant (absent between February and September); other breeding species (e.g. Pied and Little Pied Cormorant, Royal Spoonbill,

TABLE 1.
AREA OF WETLAND CATEGORIES AND SUBCATEGORIES IN EACH WETLAND SIZE RANGE
(CATEGORY 1, RIVER FLATS, IS OMITTED).

Category/subcategory	Area (ha) in wetlands of the following size ranges:					Total area (ha)	
	<5	6–10	11–25	26–100	>100	Subcategory	Category
2 Freshwater meadow	10	25	46	177	104		362
3 Shallow freshwater marshes							988
.1 Herb-dominated	16	47	166	143	581	953	
.2 Sedge-dominated	19		16			35	
4 Deep freshwater marshes							13725
.1 Shrub-dominated		10	5		3108	3123	
.2 Reed-dominated			1	25	3769	3795	
.3 Sedge-dominated	181	166	242	179	46	814	
.4 Rush-dominated	17	10	88	15	1422	1552	
.5 Open water	21	37	113	82	4188	4441	
5 Permanent open water			34		16880		16914
6 Semipermanent saline wetlands							15450
.1 Salt pans	7	18	94	387	5220	5726	
.2 Salt meadows	41	29	198	570	5534	6372	
.3 Salt flats	4	32	120	179	2771	3106	
.4 Sea rush-dominated			4	52	190	246	
7 Permanent saline wetlands							24766
.1 Shallow			42	45	9008	9095	
.2 Deep					15671	15671	
Total area :	316	374	1169	1854	68492		72205

TABLE 2.
NUMBER OF WETLAND CATEGORIES AND SUBCATEGORIES IN EACH WETLAND SIZE RANGE (CATEGORY 1, RIVER FLATS, IS OMITTED).

Category/subcategory	Number in wetlands of the following size (ha) ranges					Total number	
	< 5	6–10	11–25	26–100	>100	Subcategory	Category
2 Freshwater meadow	2	3	2	3	1		11
3 Shallow freshwater marshes							
.1 Herb-dominated	5	7	8	3	2	25	
.2 Sedge-dominated	7		1			8	
Number of wetlands	12	7	9	3	2		33
4 Deep freshwater marshes							
.1 Shrub-dominated		1	2		13	16	
.2 Reed-dominated			1	1	13	15	
.3 Sedge-dominated	66	24	15	4	1	110	
.4 Rush-dominated	6	2	7	1	2	18	
.5 Open water	8	5	8	4	15	40	
Number of wetlands	75	30	25	7	17		154
5 Permanent open water			2		5		7
6 Semipermanent saline wetlands							
.1 Salt pan	4	3	8	20	14	49	
.2 Salt meadows	17	6	16	20	18	77	
.3 Salt flats	2	6	10	6	4	28	
.4 Sea rush-dominated			1	2	4	7	
Number of wetlands	19	12	26	26	20		103
7 Permanent saline wetlands							
.1 Shallow			3	1	8	12	
.2 Deep					6	6	
Number of wetlands			3	1	8		12
Total number	108	52	67	40	53		320

TABLE 3.

THE OCCURRENCE AND PERCENTAGE ABUNDANCE INDICES OF WATERBIRDS RECORDED IN SELECTED HABITATS IN THE STUDY AREA. THE TEN MOST ABUNDANT SPECI ON EACH HABITAT ARE INCLUDED.

Species	Occurrence [a] (and percentage abundance indices [b]) of species recorded in:							
	Wetland category and subcategory					Other areas		
	4.4	4.5	5	6.1	7.2	River flats	Farmland	Beach
Great Crested Grebe				* (1)	2 (99)			
Hoary-headed Grebe		2 (34)	7 (36)	1 (12)	2 (15)	2 (1)	1	*
Australian Pelican		* (30)	1 (25)	* (23)	1 (15)	2 (7)	1	*
Little Pied Cormorant	* (*)	1 (24)	* (4)	1 (17)	4 (53)	1 (2)	1	3
Black Cormorant		* (8)	* (5)	* (1)	5 (86)	* (1)	2	1
Little Black Cormorant		* (31)	1 (33)	* (5)	1 (30)	* (1)	*	*
White-necked Heron	4 (40)		* (49)	* (8)		* (2)		
White-faced Heron	8 (3)	* (3)	* (2)	3 (77)	* (5)	6 (11)	7	*
White Ibis		1 (43)	1 (7)	* (*)	* (1)	24 (49)	26	*
Straw-necked Ibis		* (12)				11 (88)	39	
Black Swan	45 (1)	10 (26)	6 (4)	27 (38)	39 (31)	5 (*)	10	
Mountain Duck		1 (27)		5 (72)	* (1)	1 (1)	*	
Black Duck		7 (84)		2 (13)	* (1)	3 (1)	1	
Grey Teal		17 (64)		16 (35)	1 (1)	7 (1)		
Chestnut Teal		2 (19)	* (*)	10 (54)	8 (26)	* (*)	*	
Musk Duck		* (5)	1 (53)	* (11)	1 (30)	* (1)		
Swamp Harrier	3 (13)	* (73)	* (14)	* (*)		* (*)		
Dusky Moorhen		3 (94)	* (*)			5 (6)	1	
Swamphen	35 (3)	10 (97)	* (1)			6 (2)	1	
Coot		37 (46)	75 (23)	27 (18)	31 (11)	23 (1)	7	
Masked Plover		3 (82)	* (1)	1 (12)	* (3)	2 (2)	2	
Red-capped Dotterel		* (2)		1 (98)			*	8
Red-necked Stint				2 (100)				1
Silver Gull		1 (13)	* (*)	12 (74)	4 (13)	(*)		26
Pacific Gull				* (4)	5 (96)			
Little Tern			2 (58)	* (15)	1 (27)			3
Crested Tern			* (6)	* (3)	1 (91)			49
% of total usage	95	94	95	99	99	98	86	96
Additional species	1	15	7	8	13	15	9	14
Total all species (birds/ha/visit.)	0.6	27.3	1.8	12.4	5.4	1.8	0.6	6.5

a For each species, the number of individuals/ha/visit expressed as a percentage of the total number of individuals of all species/ha/visit for each habitat.

b For each species, the estimated number of individuals in a particular habitat (N) expressed as a percentage of the estimated number of individuals of that species on all the surveyed habitats. N is calculated as the average number of individuals/

ibis, Chestnut Teal and Wood Duck) may move throughout coastal south-eastern Australia or far inland on a less predictable basis, but probably in response to varying seasonal conditions.

ANALYSIS OF WATERFOWL BANDING DATA

The distribution of band recoveries, plotted on a 10′ grid over the study area (Fig. 3), shows that Chestnut Teal were recovered from 25 10′ grid squares, Black Duck from 31 and Grey Teal from 48. 45% of the Chestnut Teal recoveries came from wetlands close to Lakes Wellington and Victoria while only 21% of Black Duck and 27% of Grey Teal recoveries came from the same area. The importance of the study area to Chestnut Teal is shown by the higher proportion (32%) of recoveries of this species which have come from within the study area (c.f. Grey Teal 8% and Black Duck 12%, see Table 4).

DISCUSSION

Coastal wetlands of southeastern Australia not only support local breeding populations of waterbirds but also provide drought refuges for species which breed inland, and non-breeding habitat for migratory species. The study area is of considerable importance to waterbirds since it contains almost as much wetland habitat (47,439 ha), within comparable categories, as does the entire coast of New South Wales (53,198 ha) (see Goodrick 1970). Nevertheless, our survey shows that the wetland area has so declined that of about 112,200 ha present during the early stages of settlement some 40,000 ha (36%) have been eliminated or greatly modified. This reduction is similar to those reported by Riggett (1966) and Goodrick (1970), who found a loss of some 32 and 38% of wetland habitat in study areas in the south of Western Australia and coastal New South Wales. Deep freshwater marshes have suffered most losses, and river flats have been greatly modified. Since existing deep freshwater marshes are of high value as breeding or feeding habitat, so presumably were those which have been lost. Changes in river flats, which before settlement were probably complex systems of shallow wetlands, *Melaleuca* thickets, and red gum woodland with deep cut-off lagoons, have been more difficult to evaluate. Modifications may have been detrimental to some species, but beneficial to others such as White Ibis, Wood Duck, White-faced Heron.

This study shows that some wetlands receive more usage than others but that most species use a variety of wetland types. Presumably such variation reflects the habitat requirements of individual species. Consequently further loss or modification of wetland habitat will affect many species of waterbirds, and future changes in land-use or water-diversion should

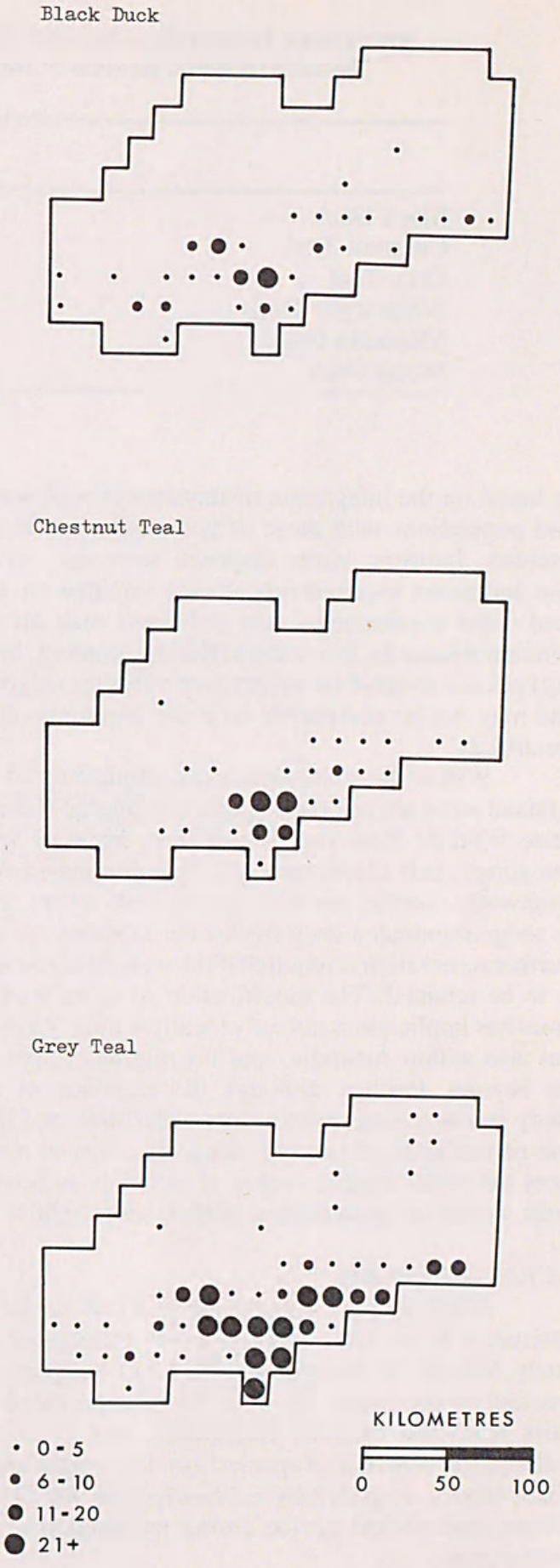


Fig. 3. The distribution (plotted on a 10′ grid) of the recoveries of banded ducks shot in the study area during open seasons between 1953 and 1973. Only those species with more than 100 recoveries in the study area are shown.

TABLE 4.
RECOVERIES, DURING OPEN SEASONS 1951-73, OF DUCKS BANDED IN VICTORIA. THE SMALL NUMBER OF BIRDS BANDED IN THE STUDY AREA ARE NOT INCLUDED IN THE TABLE.

	NUMBER BANDED	NUMBER RECOVERED IN VICTORIA	NUMBER RECOVERED IN STUDY AREA	(%)
Black Duck	6223	1168	137	(11.7)
Chestnut Teal	4056	484	156	(32.2)
Grey Teal	60491	8972	719	(8.0)
White-eyed Duck	420	27	2	(7.4)
Mountain Duck	3812	652	52	(8.0)
Wood Duck	1513	168	2	(1.2)

be based on the integration of requirements of waterbird populations with those of potentially conflicting interests. Industry, waste disposal, sewerage, irrigation and urban requirements already impinge on wetland water requirements, and pollutants may present additional hazards. Recreation (fishing, boating, hunting) place a demand on wetlands of various categories, and may not be compatible with the requirements of waterbirds.

Within the study area, only about 20% of the wetland areas are reserved as part of National Parks or State Wildlife Reserves. Whilst large areas of some categories such as salt pans and rush-dominated deep freshwater marshes are well represented, others, such as sedge-dominated deep freshwater marshes are not. Further reservation is required if the waterbird resource is to be retained. The modification of more wetland areas has implications not only locally within Victoria, but also within Australia, and for migratory species, far beyond. Further, although the emphasis of this study has been directed towards waterbirds and their use of wetlands of varying categories, this is not to deny the wider intrinsic value of wetlands as ecosystems worthy of preservation in their own right.

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APPENDIX 1.

Waterbirds recorded in wetland categories and subcategories in the study area. X present, not recorded breeding; B present, recorded breeding; S present, but utilizing shallow areas (shores) only and ( ) very few records (irregular visitors, vagrants, unusual breeding habitat etc.).

Species	Records of waterbirds in each of the following categories and subcategories:														
	1	2	3	4.1	4.2	4.3	4.4	4.5	5	6.1	6.2	6.3	6.4	7.1	7.2
Great Crested Grebe								X	X	X				X	X
Hoary-headed Grebe			B				B	X	X	X				X	
Little Grebe			B				B	X							
Australian Pelican								X	X	X				X	X
Darter								(X)	(X)						
Black-faced Cormorant														(X)	
Pied Cormorant				B				X	X					X	X
Little Pied Cormorant			X	B		X	X	X	X					X	
Black Cormorant				(X)				X	X	X				X	X
Little Black Cormorant			X	B			X	X	X	X				X	X
White-necked Heron	X	X	X				X	S							
White-faced Heron	X	X	X				X	S			X	X		S	
Cattle Egret	X							(S)							
Large Egret	X	X	X	B			X	S		X	X				
Little Egret								S		X	X			S	
Plumed Egret			(X)												
Nankeen Night-heron			X					S							
Little Bittern					(X)										
Brown Bittern					X		X	S							
Glossy Ibis	X		X					S							
White Ibis	X	X	X	B	B			S			X			S	
Straw-necked Ibis	X	X	X	B	B										
Royal Spoonbill			X	B				S		X	X			S	
Yellow-billed Spoonbill			X	B			X	S		X					
Plumed Tree-duck	(X)							(X)							
Black Swan	X		X	(B)	B		B	X	X	X	X			X	X
Freckled Duck								(X)		(X)	(X)				
Mountain Duck	B	X	X					X	X	X	X	X	X	X	
Black Duck	X	B	B	B	B		X	X	X	X	X			X	
Mallard								(X)						(X)	
Grey Teal		X	B				X	X	X	X	X			X	
Chestnut Teal			B	B	X			X	X	X	X			X	
Shoveler			X					X	X	X	X			X	
Pink-eared Duck			X					X							
White-eyed Duck			X				X	X	X						
Wood Duck	X	X	X					X							
Blue-billed Duck							B	X	X	(X)					
Musk Duck						X	X	X	X	X				X	
White-breasted Sea-eagle				B			X	X	X	X				X	X
Swamp Harrier	X		X		B	B	X	X		X	X				
Land Rail		X	X		X										
Water Rail		X	X		X										
Marsh Crake		X	X		X										
Spotted Crake		X	X		X										
Dusky Moorhen	X	X	X	X			B	X							
Swamphen	X	X	X	X	B	B	B	X							
Coot	X	X	X			B	B	X	X	X				X	
Painted Snipe		(X)	(X)												
Pied Oystercatcher														(S)	
Sooty Oystercatcher														(S)	
Masked Plover	B		B					S	S		X	X	X	S	
Banded Plover	B							S							
Grey Plover										(X)				(S)	
Eastern Golden Plover										(X)				(S)	
Red-kneed Dotterel			B					S			B				
Hooded Dotterel														(S)	
Double-banded Dotterel								(S)		X	X			S	
Red-capped Dotterel								S		B	X			S	
Black-fronted Dotterel			X					S	S						
Pied Stilt			X					S		X	B				
Banded Stilt								(S)		(X)					
Turnstone										(X)				S	
Eastern Curlew										(X)				S	
Whimbrel										(X)				(S)	
Grey-tailed Tattler														(S)	
Common Sandpiper														S	
Greenshank								S		X	X			S	
Japanese Snipe	X	X	X					(S)		X	X			(S)	
Bar-tailed Godwit										X				S	
Black-tailed Godwit														(S)	
Knot										X				S	
Great Knot										(X)				(S)	
Sharp-tailed Sandpiper			X					S	(S)	X	X			S	
Red-necked Stint								S	(S)	X	X			S	
Curlew Sandpiper										X	X			S	
Silver Gull	X		X					X	X	X	X			X	
Pacific Gull									X					X	
Whiskered Tern			X					X	X					(S)	
White-winged Black Tern								(X)	(X)						
Gull-billed Tern								(X)	(X)					(X)	
Caspian Tern									X	X				X	X
Common Tern									X					X	X
White-fronted Tern														(X)	(X)
Little Tern									X	X				X	X
Fairy Tern														(X)	
Crested Tern									X					X	X
Common species Non-shorebirds	19	17	38	13	12	5	20	26	25	31	23	3	2	22	11
Shorebirds								19	2					16	
Uncommon species Non-shorebirds	1	1	2	2	1			6	3	10	1			5	1
Shorebirds								4	2					11	
Breeding species (included in above groups)	3	1	7	12	6	3	7				2				
Total Species	20	18	40	15	13	5	20	55	32	41	24	3	2	54	12