THE STATUS AND CONSERVATION OF SHOREBIRD HABITAT IN SOUTH-EAST TASMANIA

by

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fulfilment of the requirements for
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STATEMENT

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university, and to the best of my knowledge contains no copy or paraphrase of material previously published or written by another person, except when due reference is made in the text.

Lisa Parr
University of Tasmania
October 1988.

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Corrigenda

The following minor corrections are to be incorporated into the text:

page	paragraph	line	correction
1	3	5	add: **which were only monitored during the 1980s.**
2	2	2	reference should read: **(ANPWS 1987a).**
3	1	3	insert the text: ...the maintenance of wetland**, as well as non-wetland,** areas for their capacity...
8	2	5	replace relationship with **correlation**
12	5	2	insert the text: (WWF)**, recently renamed World Wide Fund for Nature,** and the...
12	6	7	insert the text: addresses**, among other issues,** the conservation...
32	1	15	insert the word: feeding rate is **inversely** dependent...
74	3	8	insert the text: similar level**, and with a similar distribution**, during...
79	6	4 and 5	homoschedastic should be spelled **homoscedastic**
81	8		insert the heading **Species Richness** before the paragraph
140	1	3	insert the word: **State** Conservation Strategy...
184 and 185			Replace the heading for Breeding Range with the following: **Breeding Range indicates where the populations spending the non-breeding season in Australia originate.**
185	right hand column		Modify the text for Red-necked Stint entry: and some overwinter. **Of those, many winter in Tasmania,** as well as...

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ABSTRACT

Census data from 11 sites of shorebird habitat in South-east Tasmania from the 1960s, 1970s and 1980s were examined qualitatively and by using analysis of variance techniques. The aim was to establish whether the numbers of shorebirds using these sites as feeding, breeding and roosting habitat had changed over that time period, and to establish whether a relationship existed between observed changes in numbers and habitat alteration and loss at the sites.

Of the eight sites monitored intensively during both the 1960s and 1980s sampling periods, the abundance of shorebirds decreased at three sites (Lauderdale, Orielton Lagoon and Sorell), no change in abundance was recorded at two sites (Clear Lagoon and Barilla Bay), and three sites (Pipeclay Lagoon, Calverts Lagoon and South Arm Neck) experienced an increase in shorebird abundance.

At those same eight sites, the number of species present decreased at five sites (Lauderdale, Clear Lagoon, South Arm Neck, Sorell and Barilla Bay) between the 1960s and the 1980s, no change in species richness was recorded at two sites (Pipeclay Lagoon and Orielton Lagoon), and one site (Calverts Lagoon) experienced an increase in species numbers. No clear trends were evident at the remaining three sites.

The reasons for the changes in shorebird numbers at the sites were (1) a shift in site preference and the pattern of site utilization, and (2) a decline in the abundance of some species utilizing the sites. It is highly likely that these changes were related to changes in habitat, although a direct cause and effect relationship could not be proved. Urban pressure was identified as the primary cause of degradation at the sites.

The over-riding management priority was identified as the conservation of the major sites of feeding, breeding and roosting habitat for shorebirds. Secondary priorities included the development of management plans and appropriate levels of management for each site, establishment of wetland conservation policies by the state and local governments, community education of wetland values, involvement of the Bird Observers' Association of Tasmania in an advisory capacity in planning for wetland areas, and the undertaking of ecological research at the sites. The protective reservation of shorebird habitat at Pittwater and South Arm Neck is urgently required.

CHAPTER 1: INTRODUCTION: THE CONTEXT OF THE STUDY

1.1. Introduction

The purpose of this thesis is to review the conservation status of shorebird habitat in South-east Tasmania. To achieve this, the processes altering shorebird habitat at each of the major shorebird sites within the study area of South-east Tasmania have been documented, as has a statistical examination of the changes in shorebird utilization of these sites between two sampling periods 20 years apart. If a significant decline in the use of a site could be correlated to habitat alteration, then the site could be considered to be degraded, in that the changes have made it less suitable as shorebird habitat.

Shorebirds are indicative of the value of wetland areas (Australian National Park and Wildlife Services (ANPWS) 1987). As a natural component of the ecosystems in which they occur, shorebirds act as indicators of the health of those ecosystems. In addition to their ecological role, wetland areas and the shorebirds they support also provide a source of enjoyment and the potential for education and research for people. These functions are diminished when the habitat on which the shorebirds rely is degraded.

If, in this study, a correlation between habitat alteration and changes in the utilization of sites of shorebird habitat by the birds can be shown, then there is strong evidence for immediate action to conserve the habitat, and maintain or improve its utility to shorebirds.

An overview of wetland and shorebird conservation presents the global problems of wetlands destruction and protection of migratory shorebirds, and discusses organizations and actions that deal with the protection and management of shorebirds and their habitat at international, national, Tasmanian and local levels.

The abundance of birds at major shorebird sites in South-east Tasmania has been monitored regularly since 1964. Attempts have been made since that time to obtain protective status for some of these sites. These attempts are documented here to highlight the types of issues and concerns that must be addressed if management actions are to succeed.

For the purposes of this thesis, "shorebirds" refers to the wading species of the order Charadriiformes, specifically those birds of the sandpiper (Scolopacidae), plover (Charadriidae) and oystercatcher (Haematopodidae) families, and will exclude other waterbirds, for example gulls and herons. The term "waders" is synonymous with "shorebirds" in this context. Shorebirds are ecologically dependant upon wetlands and "shorebird habitat" is defined as wetland areas which provide conditions for feeding, breeding or roosting for shorebirds. "Habitat alteration" includes physical changes to the habitat as well as factors which change the utility of a site for shorebirds, such as disturbance. "Conservation of shorebird habitat" should be taken to mean the maintenance of wetland areas for their capacity to support shorebirds.

1.1.1 South-east Tasmania as Shorebird Habitat: The Study Area

Shorebird habitat in Tasmania is a limited resource. In South-east Tasmania there are less than one dozen sites that provide habitat for significant numbers of shorebirds, yet these sites comprise one of the three main shorebird regions in the state. The other two major regions are located in the extreme north-west and the extreme north-east of the state. The South-east region is the study area for this thesis.

The study area is composed of several bays, lagoons and beaches along the Derwent River Estuary and adjacent Pittwater, as well as two near-coastal wetland areas, and an ocean beach with adjacent saltmarsh (Fig. 1.1). The region is at the extremity of a migration route from northern Asia, and is the southernmost location in Australia that supports appreciable numbers of shorebirds.

In a region context, South-east Tasmania is not the last refuge of any endangered species. It does not hold vast numbers of individuals or species, as compared to wetland areas such as the Coorong in South Australia, or the Gulf of Carpentaria in Queensland. It is not the only known breeding area of any species of shorebird. The characteristics that make the shorebird habitat in South-east Tasmania important are more subtle and easier to overlook, and therefore the wetland areas that provide habitat are more vulnerable to unintentional degradation.

The sites of shorebird habitat in South-east Tasmania are similar to the majority of wetland areas in Australia, in that alone they are not outstanding in any of these categories. The importance of these sites is that shorebirds do not rely on individual sites, but rather on components of vast networks of feeding, breeding and roosting habitat on the birds' home ranges and at the extremities of their migratory pathways. The shorebird sites in South-east Tasmania comprise one region of this international network of habitat.

South-east Tasmania provides habitat for migratory shorebirds from breeding grounds in the Palaearctic region, for Double-banded Plovers, which winter in Tasmania from breeding grounds in the glacial river valleys of New Zealand, and for resident species which remain in Tasmania year-round. Some of these resident species, such as Pied Oystercatcher

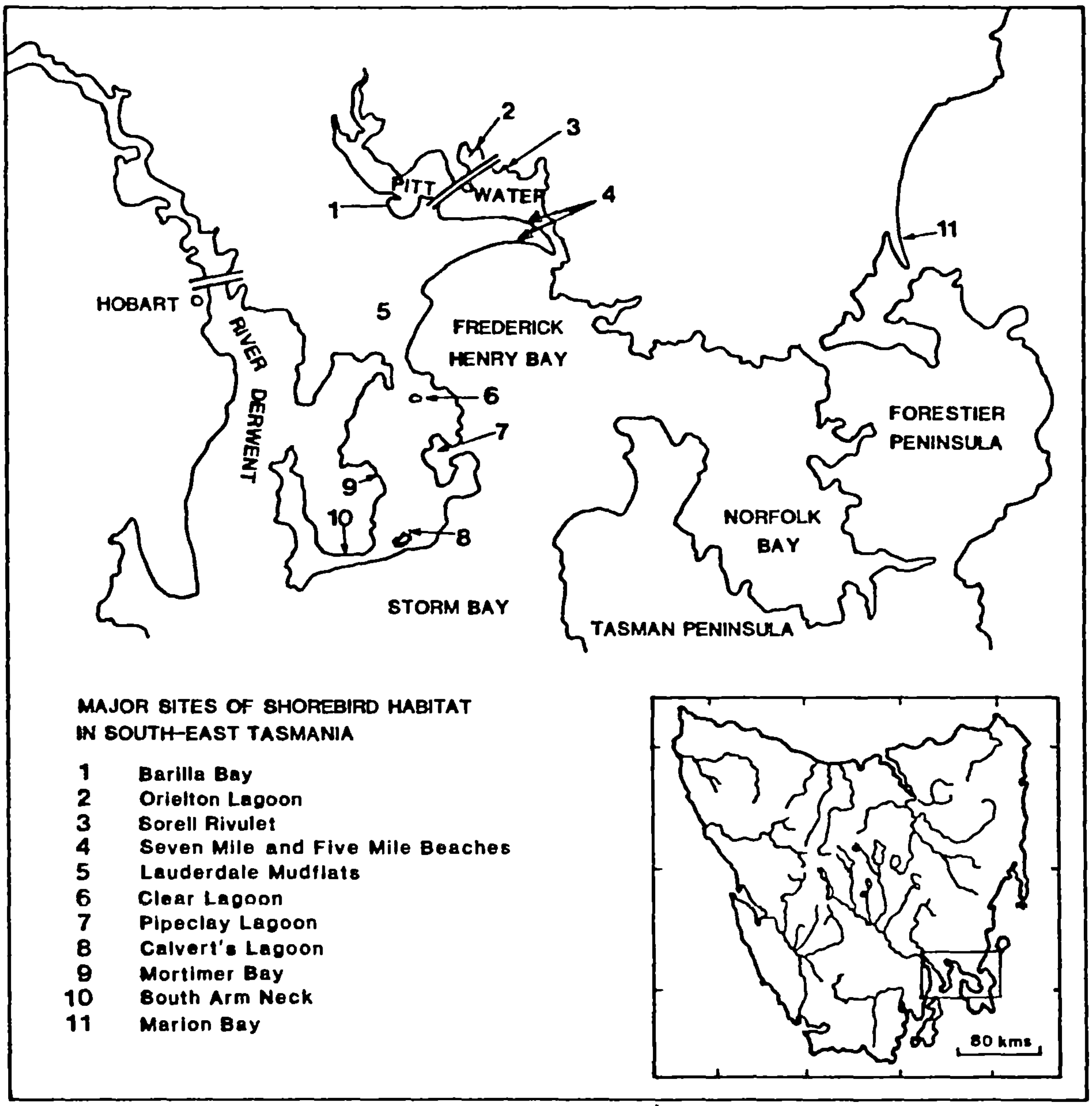

Figure 1.1: The Study Area: illustrating the major sites of shorebird habitat in South-east Tasmania.

and Hooded Plover, are present in larger numbers in Tasmania than elsewhere in Australia (Lane 1987). In addition, shorebird habitat in South-east Tasmania is important as habitat for young birds competing for preferred feeding sites on the mainland of Australia (Barter, Chairperson, Australasian Wader Studies Group, pers. comm.).

While the focus of this discussion is habitat for shorebirds, it must be noted that they are only one component of a wetland community. A variety of plants, invertebrates, small mammals and other birds also rely on wetland ecosystems, and it is the interaction of all these organisms plus abiotic factors that comprises the stable, functioning ecosystem.

1.2 The Shorebird Habitat Study in Context

Wetland areas perform a number of functions. Wetlands are valuable to humans for their role in flood control, water flow regulation, erosion control, waste-water assimilation, recreation, aesthetics, education and science (Adam 1984). However, World Wildlife Fund (1987) stressed that the most important characteristic of wetlands is their role in maintaining ecosystem function. They act as water purifiers (WWF 1987), are important in energy and nutrient cycling within the ecosystem, accumulate toxic heavy metals, and provide habitat for fish, birds and other organisms (Adam 1984) and are net importers of carbon (Nixon 1980). Central to this study is the importance of wetlands as shorebird habitat.

Wetland areas are, however, increasingly being degraded or destroyed. World Wildlife Fund (1987) estimated that at least one-half of the world's wetlands have been lost to date, mostly during the twentieth century. It cited a 50% reduction in coastal European breeding habitat since World War II, and a 50% reduction in wetlands in the United States since colonial times. Agricultural drainage of estuarine areas in Britain continues to be a primary cause of wetland loss (Prater 1981). Other worldwide threats to wetlands include dam construction, over-cutting of mangroves for firewood, industrial pollution, acid rain and drainage schemes (WWF 1987). Shorebird habitat is destroyed not only by these threats, but also by increasing urban pressure on wetland areas, including the heavy use of beaches and estuaries for recreational pursuits, which causes disturbance of feeding, breeding and roosting shorebirds and the introduction of dogs and predators.

Of all the processes that pose a threat to wetland areas, attrition is the most insidious. Wetlands traditionally have been viewed as useless land best suited to reclamation for developments or disposal sites. The lack of value placed on wetlands has resulted in a creeping destruction of wetland areas. The cumulative effect of numerous small projects has been substantial (Adam 1985).

Attrition has had a particular impact on shorebird habitat, diminishing the amount available across the networks of shorebird habitat previously described. Much of the problem is that the importance of these numerous small sites to shorebirds is seldom recognized, and thus is not considered when planning developmental projects, however small.

There has recently been an increase in interest and concern for protecting and managing wetlands, and the importance of such areas as shorebird habitat is slowly coming to be recognized by some governments and by conservation groups. However, even with international treaties which address wetlands and migratory shorebirds and their habitat, and world and national conservation strategies and policies, constructive action based on these has not been sufficient. The basic problem is that the conservation of shorebirds and their habitat is not currently a high profile issue. Political action to protect and manage wetland areas as shorebird habitat will only come about when more importance is placed on them by the public and politicians, a situation that will result from public education and raising the public profile of the issues.

One priority action described by the International Convention on Wetlands of International Importance is for Contracting Parties to the Convention to undertake a national survey of wetlands in their countries. While this has not yet happened in Australia, the Australasian Wader Studies Group (AWSG) of the Royal Australasian Ornithologists' Union (RAOU) is preparing to undertake a national survey on the status of shorebird habitat throughout Australia. The objectives of the AWSG survey include the documentation of "the threats to shorebirds and their habitats in need of additional protection" and making "recommendations for actions that will ensure the adequate protection of shorebirds in Australia" (AWSG 1987).

The results of this study on the conservation status of shorebird habitat in South-east Tasmania will provide background information available for use for the AWSG survey.

1.3 The Study

1.3.1 Research Procedures and Hypothesis

Habitat alteration and threats to shorebird habitat were documented for the eleven major shorebird sites in South-east Tasmania. Eight of these sites have been monitored since the mid-1960s, and three other shave been regularly monitored only during the 1980s.

Count data from the mid-1960s to the present was obtained in raw form from the Shorebird Study Group (SSG) of the Bird Observers' Association of Tasmania (BOAT). Monthly count data for the eight sites for four consecutive years in the 1960s and four consecutive years in the 1980s were standardized into indices of abundance, species richness and species diversity. Statistical methods were employed to determine whether shorebirds have changed their pattern of site utilization between the two time periods. Data from annual summer wader counts since 1971 and winter wader counts since 1980 were also analyzed. Trends in site utilization observed from these annual counts were compared with trends observed from the statistical analysis of the monthly counts in an attempt to complement information obtained by that method.

Changes in site utilization by the shorebirds were compared to habitat changes and urban pressures at the sites to determine whether the latter was adversely affecting the suitability of the sites for shorebirds. The working hypothesis of this study was that a positive correlation between these pressures and population changes at the sites would be determined. This would present a strong case for immediate action to protect and manage these areas. Irrespective of such a correlation, at the very least this thesis provides a compilation of data on shorebirds and their habitat that will function as a baseline against which future data at the sites can be compared. The thesis also serves to document existing threats to shorebird habitat in South-east Tasmania and proposes management strategies for dealing effectively with these threats, many of which are in use at other similar wetland areas around Australia.

1.3.2 Objectives

The primary objectives of the study were as follows:

a) to document past and current utilization of the shorebird sites in South-east Tasmania by resident and migratory shorebirds and to establish whether the observed patterns of use have changed between the 1960s and 1980s.

b) to document the processes that alter shorebird habitat and their effect on the shorebird sites of South-east Tasmania;

c) to identify any relationships between changes in site utilisation by shorebirds with habitat alteration at the sites;

d) to identify management priorities for the protection and conservation of the important shorebird sites of South-east Tasmania;

e) to draw on management strategies, guidelines and actions used in similar urban wetland areas around Australia to aid in the generation of management priorities and recommendations; and

f) to make the information readily available for use by relevant management and planning authorities.

1.3.3 Scope and Limitations

This study can not definitively prove that habitat alteration, including disturbance, is the causal factor solely responsible for any observed change in the numbers of shorebirds using a site. This study can, however, present evidence to establish whether a relationship exists between habitat alteration and site utilization by shorebirds. The presence of such a relationship would strongly argue that habitat alteration and disturbance was the causal, or at least a contributing, factor to observed changes in utilization of South-east Tasmanian shorebird sites.

1.3.4 Report Structure

Wetland and shorebird conservation and the situation in Tasmania are discussed in detail in Chapter 2. Chapter 3 then examines the shorebird habitat in South-east Tasmania in terms of the habitat requirements of shorebirds and the physical characteristics, protection and land tenure, and land use of the sites. Chapter 4 documents the various factors which impact upon shorebird habitat and the factors which are acting at the sites of shorebird habitat in South-east Tasmania. Chapter 5 discusses the shorebirds using the habitat and their patterns of use of the area, and presents evidence concerning changing site utilization since 1964. The brief discussion and conclusion sections included in Chapter 5 are intended to condense the results of the statistical analysis into a manageable summary and to present some preliminary conclusions before continuing to Chapter 6, and these include conclusions regarding the status of the null hypotheses advanced in Chapter 5. Management and conservation options, many of which have been applied to other Australian wetland regions which are under similar urban pressures, are considered in Chapter 6, as are management priorities for the sites of shorebird habitat in South-east Tasmania. Chapter 7 presents an overall discussion, and Chapter 8 presents conclusions and recommendations.

CHAPTER 2: OVERVIEW OF WETLAND AND SHOREBIRD CONSERVATION

Wetland habitat in estuarine areas is particularly vulnerable to increasing urban pressure due to the intensive utilization of estuaries for human activities. The same story of habitat loss or alteration has been described for wetlands in Britain, Europe, North America and Asia (Prater 1981; Hale 1980; Reffalt 1985; Wallace 1985; and WWF 1987). In South-east Tasmania, the primary sites of shorebird habitat border the estuaries of the Derwent River and Pittwater, adjacent to Hobart and its suburbs. In Australia, this situation is mirrored in almost every other capital city, since most are located on the estuaries and bays which provide port facilities as well as optimum shorebird habitat.

This chapter provides an overview of the conservation of wetland shorebird habitats at the international, national, Tasmanian and local levels in order to provide a wider perspective to the situation in South-east Tasmania.

2.1 International and Australian Perspectives

2.1.1 International Treaties

Australia is signatory to three international treaties that deal with the protection of shorebird habitat. International cooperation is essential when dealing with species such as shorebirds which migrate over long distances across international boundaries.

CONVENTION ON WETLANDS OF INTERNATIONAL IMPORTANCE, ESPECIALLY AS WATERFOWL HABITAT

In 1971 Australia signed the international treaty "The Convention on Wetlands of International Importance, Especially as Waterfowl Habitat", called "Ramsar" after the town in which the Convention was signed. The stimulus for the Convention was a series of meetings convened by the International Waterfowl Research Bureau during the 1960s which attempted to propose an international solution to the global problem of increasing wetland destruction. Ramsar was the first international treaty to specifically address habitat.

The basic premise of Ramsar is to stop the destruction of wetlands by two mechanisms. The first is to list wetlands considered to be of international importance and to take their protection into account in decision-making regarding land use (Lyster 1985). The second is to promote "the wise use of all wetlands", irrespective of whether they are on the List of Wetlands of International Importance (Ramsar article 3(1)).

Wetlands, under Ramsar, are defined as "areas of marsh, fern, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres". Waterfowl are defined as "waterbirds which are ecologically dependant upon wetlands" (Ramsar article article 2(1)), and thus include shorebirds. A wetland is eligible for the List of Wetlands of International Importance if it meets one or more criteria. These have been revised slightly with successive meetings of the Contracting Parties to the Convention, but the general principles have remained the same. Appendix 1 sets out the criteria in detail.

Under Ramsar, a wetland is considered to be of international importance if it regularly supports 20,000 waterfowl or one per cent of the individuals or breeding pairs of a population of one species or subspecies of waterfowl. A wetland can also be listed for its role in the support of rare or endangered species of plants or animals, maintenance of genetic or ecological diversity, support of endemic organisms or for exceptional exemplification of a specific type of wetland (International Waterfowl Research Bureau 1980). Other criteria include provision of internationally important habitat at a critical stage of the biological cycle for organisms or communities, or support of "substantial numbers of individuals from particular groups of waterfowl indicative of wetland values and productivity or diversity" (Australian National Parks and Wildlife Service (ANPWS) 1987a). Shorebirds are specified as a type of waterfowl which are indicative of wetland values under the Annex to the Conference at Regina, 1987 (ANPWS 1987a).

Each Contracting Party must list at least one wetland at the time of ratification and is encouraged to add more if possible. Wetlands can also be deleted from the list or reduced in size, but if this must be done, alternative additions or replacements are strongly encouraged (Ramsar article 4(2)).

The "wise" use of all wetlands is promoted by the Convention, with emphasis on the establishment of nature reserves on listed and non-listed sites, and the promotion of research, management and training of personnel to further Ramsar's aims (Ramsar article 3(1)). The premise behind the "wise use of wetlands" is to maintain their ecological character for nature conservation as well as sustainable development (International Waterfowl Research Bureau 1980, Recommendation 1.5).

A recommendation to the 1980 Conference of the Contracting Parties at Cagliari was that Parties "prepare inventories of their wetlands and of their resources as soon as possible as an aid to the formulation and implementation of national wetland policies" (Lyster 1985). As of 1984 about one-half of the Contracting Parties had inventoried their important wetlands (Groningen Conference Document C 2.6. paras 103-121; Cagliari Conference Document CONF/3 paras 20-38; Cagliari Conference Document CONF/4 paras 40-45) and few, including Australia, had drafted national wetland policies (Lyster 1985)

Ramsar is based on the concept that "the conservation of wetlands and their flora and fauna can be ensured by combining far-sighted national policies with co-ordinated national action" (Preamble to Ramsar). It places upon the Contracting Parties an "international responsibility for the conservation, management and wise use of migratory stocks of waterfowl" and wetlands (Ramsar article 2(1)). It is not legally binding but is considered "soft law"(Lyster 1985), and is an international commitment on the part of the Contracting Parties. While the treaty does not guarantee protection of sites on the list, inclusion of unprotected areas may make protection under state legislation more likely (Lyster 1985).

Ramsar has a high potential for effectiveness within its framework. Forty-five countries have become Contracting Parties to the Convention, and as of 1987, 357 sites comprising more than 22×10^6 ha had been listed as wetlands of international importance. No sites had been deleted (Groningen Conference Document C 2.6 paras 52-55). Ramsar leans towards a policy of "wise use" rather than "hands off" (Lyster 1985), and since it does not bind Contracting Parties with law, they may be more inclined to list wetlands if it is not seen as an irreversible decision. By signing Ramsar, the Contracting Parties bind themselves to a moral commitment rather than to a legal obligation.

MIGRATORY BIRD AGREEMENTS

Australia is also a signatory to two international agreements dealing with migratory birds. Both cover a number of shorebird species that utilize shorebird habitat in South-east Tasmania. All shorebird species included in the agreements are listed in Appendix 2. In addition, both agreements address the environments of migratory birds, and thus include wetland habitats. The Japan-Australia Migratory Birds Agreement (JAMBA) was signed in 1974 and entered into force in 1981. The China-Australia Migratory Birds Agreement (CAMBA) was signed in 1986 but has not yet entered into force.

The two agreements are nearly identical in content. Both recognize the values of birds and the international concern that exists for the protection of migratory birds and their environments and provide a means of cooperation between the Contracting Parties. The basic premise is to protect migratory birds by controlling hunting, encouraging joint research, establishing sanctuaries for managing and protecting migratory birds, and "taking appropriate measures to preserve and enhance the environment of migratory birds" (CAMBA article IV(b); JAMBA article IV).

Birds which migrate between the two countries involved in each Agreement are listed in annexes to the Agreements. JAMBA puts additional emphasis on the protection of endangered birds, regardless of whether they migrate, and thus Japan and Australia have also annexed a list of each country's endangered birds. CAMBA refers to endangered birds with the statement that "each Contracting Party shall encourage the conservation of migratory birds, especially those in danger of extinction" (article III(3)).

The stimulus for the agreements came with a recommendation, from the 1972 House of Representatives Select Committee on Wildlife Conservation, for bilateral agreements between Japan and Australia, China and Australia, and Papua New Guinea and Australia (Australia, Parliament 1972). An agreement between Australia and Papua New Guinea has not yet eventuated and is not likely to in the near future.

As partial fulfillment of Australia's obligation under the Migratory Bird Agreements, the Australian National Parks and Wildlife Service (ANPWS) funds and coordinates several research projects on birds migrating between Australia and Asia, as well as research projects on non-migratory endangered species.

IMPLEMENTATION OF THE INTERNATIONAL TREATIES

In Australia, the implementation of these three international treaties is the joint responsibility of the states, the territories and the federal government. ANPWS assumes a coordinating role through the Council of Nature Conservation Ministers (CONCOM) Working Group on International Agreements Relating to Migratory and Wetland Birds (ANPWS 1987b). This working group performs the same role for the Convention on Wetlands of International Importance (Ramsar) because of the similar subject matter.

Due to Australia's federal system of government, the states and the Northern Territory are primarily responsible for managing their wildlife and habitat. The Commonwealth government is responsible for these matters only in Commonwealth controlled areas, and also for international wildlife trade and international treaties (ANPWS 1987b).

The result of this division of responsibility is that the individual states and the Northern Territory implement the international treaties within their borders, while the Commonwealth government plays a coordinating role.

2.1.2 Organizations

A number of international organizations are involved with wetland conservation programs. Several of these, such as World Wildlife Fund (WWF) and the International Council for the Preservation of Birds (ICBP), also have Australian branches. The national and international activities of these organizations, which raise public awareness of wetland and shorebird values, influence action taken in Tasmania towards the protection of shorebird habitat.

The ICBP, WWF and International Waterfowl Research Bureau (IWRB) are three sister organizations which grew from the International Union for the Conservation of Nature and Natural Resources (IUCN) to address different conservation issues. The IWRB was formed to deal with wetland and waterbird research and management and with conservation (South Australia, Department of Environment and Planning 1983), and was responsible for the series of meetings which led to the Ramsar meeting in 1971. The ICBP was formed to deal with bird preservation on an international level, and the WWF addresses the conservation of wetland species. All have active branches in Australia (Rounsevell, Department of Lands, Parks and Wildlife, pers. comm.).

The Convention on Wetlands of International Importance is jointly administered by the IUCN and the IWRB. In addition, the IUCN is in the process of preparing a Global Wetlands

Conservation Strategy (South Australia, Department of Environment and Planning 1983), has a continuing program of Wetland Directories (WWF 1987) and, in 1985 and 1986, joined with WWF International to organize an International Wetlands Campaign (WWF 1987).

The major functions of WWF are the funding of research programmes and increasing public awareness of wildlife conservation issues. The WWF provides funding to the IWRB, and pays the IUCN as a technical supervisor for its work on wetland projects (WWF 1987).

The Australian National Parks and Wildlife Service is the primary adviser to the Commonwealth on conservation and wildlife matters. The ANPWS coordinates the implementation of the three international treaties, (Ramsar, JAMBA and CAMBA) with the Council of Conservation Ministers (CONCOM) and with relevant wildlife authorities in each state and territory. The purpose of the ANPWS is the same as the purpose of the various state and territory wildlife agencies, that is to establish reserves and to protect and conserve wildlife. However, the ANPWS is not the parent organization of these agencies, but rather fulfils the same role for the Commonwealth government, cooperates with the states and territories and provides assistance and funding when needed (ANPWS 1987b).

Two other organizations are prominent in shorebird conservation in Australia. Both of these organizations, by their nature, are also directly involved with wetland conservation.

The Royal Australasian Ornithologists' Union (RAOU) was established in 1901 to "advance knowledge and conservation of the birds of the Australasian region" (Blakers et al. 1984). The RAOU is involved in a number of research projects including several funded by ANPWS in partial fulfillment of Australia's obligations under the Migratory Birds Agreements (ANPWS 1987c). These include studies of Australasian waders, banding and wetland utilization studies of migratory waders and on-going monitoring of Australian Bird Populations (ANPWS 1987c).

The Australasian Wader Studies Group (AWSG) is the group within the RAOU which specializes in wading birds. Its stated objectives include the development and coordination of and assistance with Australasian shorebird research and the formulation and promotion of "policies for the conservation and management of waders and their habitat" (AWSG 1987). The RAOU Conservation Committee is the body which deals with conservation matters.

2.1.3 Conservation Strategies

The National Conservation Strategy of Australia (NCSA) and the World Conservation Strategy (WCS), to which Australia is a signatory, both address the conservation of wetland habitat.

The NCSA was developed in 1983 and was based on the World Conservation Strategy prepared by IUCN in 1980, which recommended that national strategies be prepared. The NCSA (Australia, Department of Home Affairs and Environment 1984) is the basis for a framework for conservation in Australia, and its purpose is "to provide nationally agreed guidelines for the use of living resources by Australians so that the reasonable needs and aspirations of society can be sustained in perpetuity" (Australia, Department of Home Affairs and Environment 1984, para. 4). It "identifies broad strategic measures necessary to bring about properly integrated conservation and development practices in Australia" (para 11). It has adopted the three main objectives of the WCS:

"i) to maintain essential ecological processes and life support systems
ii) to preserve genetic diversity
iii) to ensure the sustainable utilization of species and ecosystems"

(IUCN 1980 section 1.7)
(Australia, Department of Home Affairs and Environment 1984 para 17)

The NCSA recognizes that as a dry continent, Australia's future development is constrained by its water resources, and that many wetlands and water supplies are already very degraded. It also recognizes that many habitats, and particularly coastal and estuarine environments, are under pressure of destruction or alteration. A priority national requirement identified by the NCSA is the management of developmental impact on coastal or aquatic resources and on critical habitats such as wetlands, estuaries, bays and reefs so that their ability to meet conservation and development objectives is not diminished" (Australia, Department of Home Affairs and Environment 1984, para 25 j). In addition, it lists "managing for sustainable yield while protecting life support systems" as a priority national action, with a strong emphasis on establishing research and protecting habitat. It recommends that a national wetland inventory be published, with a set of criteria for conservation evaluation (para 32 m).

Successive meetings of the Contracting Parties to Ramsar also stressed the need for national inventories of wetlands and national wetland policies to promote wise use of wetland areas (ANPWS 1987a). To date, Australia has not carried out a national wetlands inventory, although the Commonwealth Scientific and Industrial Research Organization (CSIRO) published a National Wetland Survey Feasibility Study in 1975 (CSIRO 1975), carried out preliminary studies and drew up a proposal for such a survey (CSIRO 1976). The project did not continue due to lack of funding, but Mitchell and Roberts (1982) reported that various State and Federal bodies are slowly implementing some of the aims of the proposed survey.

Although conservation strategies and national wetlands policies are an essential beginning to ensuring sensitive management of wetland habitat, the political reality is that establishing the policies is the easy part of the process. Coordination between agencies and organizations responsible for wetland areas is vital and appropriate action, rather than policy-making and piecemeal action, is the process which is crucial in the attempt to conserve and protect wetland habitat.

2.2 The Tasmanian Perspective

2.2.1 Agencies and Organizations

In Tasmania, several agencies and organizations may have an interest in a wetland area that provides shorebird habitat. Each may play a role in actions taken to manage the site.

THE DEPARTMENT OF LANDS, PARKS AND WILDLIFE

The Tasmanian National Parks and Wildlife Service (NPWS) and the Lands Department were amalgamated in 1987 and now each is a section within the Department of Lands, Parks and Wildlife (DLPW). NPWS is responsible for the protection of wildlife and its habitats. Under the National Parks and Wildlife Act (Tasmania) 1970, the agency controls the protection of fauna, including shorebirds, and establishes reserves for nature conservation. The Lands section administers Crown reserves and is responsible for the foreshore between Low and High Water Marks, unless specified to the contrary on a title, and for coastal reserves. Coastal reserves generally extend to 30 m above High Water Mark (Tasmanian Conservation Trust 1980).

COUNCILS

Local councils are the agencies responsible for land use zoning. The councils draw up planning schemes that specify land subdivision, zoning and housing densities for land within their municipalities. They cannot designate areas for conservation, as can NPWS, but they can zone an area for no or minimal development based on its conservation value (Douglas, Municipality of Clarence Planning Section, pers. comm.). Crown land is considered within the planning schemes, but the Crown is not bound by the schemes.

NATIONAL HERITAGE COMMISSION

Areas of conservation value in Australia may be placed on the Register of the National Estate. Such listing has no connection with the reserve status of an area and has no implications with respect to ownership. Listing on the Register simply records that the national estate value of a site has been recognized.

The National Estate is:

> **"...those places, being components of the natural environment of Australia, or the cultural environment of Australia, that have aesthetic, historic, scientific or social significance or other special value for future generations, as well as for the present community."**

(Australian Heritage Commission pamphlet, undated)

National Estate status is designed to protect listed areas from adverse affects from developments and alterations, by stipulating that such activities only occur when there is "no feasible or prudent alternative" and that damage to the area is minimized (Australian Heritage Commission pamphlet, undated).

BIRD OBSERVERS' ASSOCIATION OF TASMANIA

The Bird Observers' Association of Tasmania (BOAT) has been an active organization in bird research in Tasmania since the early 1970s. The Shorebird Study Group (SSG) is the group within BOAT which specializes in research and monitoring of shorebirds. The SSG carries out annual summer and winter wader counts and during the early 1980s carried out intensive monitoring of the important shorebird sites in South-east Tasmania. The group is also involved in banding studies of shorebirds to determine local and migratory movements, and individual members of the group are involved in research on various species of shorebirds.

OTHER

Other government and non-government organizations may also be interested parties in wetland areas. The jurisdiction of the Hobart Marine Board is below Low Water Mark. Wetland areas may be present on land administered by the Forestry Commission, and organizations such as the Tasmanian Sea Fisheries, Department of Main Roads, Mines Department and Tasmanian Duck Advisory Council may also have interests in wetland areas. All of these parties have the right to make submissions if an area is proposed for reservation or management, as do local land owners under the public appeal process.

2.2.2 Reserves

Wetland areas in Tasmania are protected mainly by establishing reserves. While Crown reserves are administered by the Lands Department, the various types of wildlife reserves are under the jurisdiction of the NPWS under the National Parks and Wildlife Act 1970. The Act provides for the reservation of land under several categories, and regulates the degree of protection given wildlife and their habitat within these reserves (Part III, section 15).

Under the National Parks and Wildlife Act, land can be set aside as a "Conservation Area", intended for conservation purposes (section 14(1)). Fauna are protected in this type of a reserve and thus shooting and interfering with any form of wildlife is prohibited without permission of the managing authority (National Parks and Reserves Regulations (Tasmania) 1971 section 3(1)).

Types of Conservation Areas include State Reserves and Wildlife Sanctuaries. A Wildlife Sanctuary is a type of Conservation Area in which fauna is protected. A Nature Reserve is a type of State Reserve in which both wildlife and habitat is protected. Under the National Parks and Wildlife Act, an area proposed for a reserve is evaluated by the NPWS, and is subject to inter-departmental review before a proposal is submitted to State Cabinet for final acceptance or rejection.

2.2.3 The Conservation and Management of Shorebird Habitat in South-east Tasmania

STATE ACTION

Tasmania has no wetland policy that stipulates protection for wetland areas or limits the amount of development that can occur on wetland areas. In addition, Tasmania has not signed the National Conservation Strategy of Australia, so is under no obligation to adhere to the guidelines covering wetlands in that document.

The Department of Lands, Parks and Wildlife is the agency responsible for protection and conservation of wildlife and its habitat in Tasmania, but the establishment of reserves to achieve this purpose requires inter-departmental consultation and agreement prior to Cabinet approval.

The extent to which Tasmania has taken action under Ramsar has been limited. Ten of the 28 wetlands which have been listed by Australia on the List of Wetlands of International Importance are in Tasmania. Tasmania's importance for wetlands and waterfowl is clear because of its more reliable fresh water supply available to waterfowl compared to the drier mainland, especially in periods of drought on the mainland. These ten wetlands, however, are outside the State Reserve system, and although they have National Heritage standing, that standing indicates conservation value but does not guarantee protection (Australian Heritage Commission pamphlet, undated). Kirkpatrick and Tyler (1988) consider only the State Reserves to have the long term security required to be successful as reserves.

Action has been taken in Tasmania under the Migratory Bird Agreements. Research on migratory and endangered birds has been funded by ANPWS and WWF to assist in Australia's partial fulfillment of its obligation under the two treaties. This research is being carried out by BOAT, the DLPW and the RAOU (ANPWS 1987c).

LOCAL COUNCIL ACTION

Of the three Municipal Councils with jurisdiction within the South-east Tasmania study area, only Clarence Council takes wetland and shorebird values into account to a large extent in its planning scheme.

Figure 2.1 illustrates the study area and identifies the boundaries of the Clarence, Sorell and Richmond Municipalities.

RICHMOND MUNICIPALITY

Within the study area, the only wetland region under the jurisdiction of Richmond Council is Upper Pittwater, an area of saline mudflats and saltmarsh along the Coal River estuary. This region has been zoned for conservation and forestry, with a planning policy statement objective "to preserve existing wooded areas and skylines to provide a scenic backdrop to the Municipality and a suitable environment for native animals, stabilize slopes and naturally control water runoff" (Richmond Planning Scheme 1976, Schedule 2). The area is zoned for 50 ha minimum lot sizes, with buildings prohibited. Primarily intended for forests and passive recreation, uses such as forestry, active recreation, agriculture, public use and tourism are discretionary uses (Richmond Planning Scheme 1976, Schedule 2).

Most of the land which abuts the wetland area is privately owned pastoral land, and public access is limited. The Upper Pittwater region is utilized by waterfowl, such as ducks, but is not heavily utilized by shorebirds (Park, SSG, pers. comm.).

SORELL MUNICIPALITY

Sorell Council has jurisdiction over the majority of Pittwater, including the shorebird study sites of Orielton Lagoon and Sorell, Marion Bay and Blackman Bay. Two planning documents are in effect within the Municipality of Sorell. The Sorell Planning Scheme 1977 covers the developed areas of Sorell, while the Municipality of Sorell Planning Document #1 1986 covers the rural areas (Cowen, Municipality of Sorell Planning Section, pers. comm.).

Pittwater is zoned under the land use classification "Lakes, Rivers, Waters and Seas" within the rural planning scheme, and the zoning includes everything below High Water Mark. The planning policy statement objective is "to control the use of lakes, rivers, waters and seas to preserve them for recreational pursuits while allowing their development for aquaculture and fishing" (Sorell Planning Scheme 1977 Schedule 2, p. 6). Discretionary uses include aquaculture, boating, dune buggy riding, removal of beach resources and withdrawl of water for irrigation and aquaculture (Sorell Planning Scheme 1977 Schedule 2, p. 6).

Some areas along the coast, for example a narrow strip bordering the entire length of Marion Bay beach, the Spit and the mudflats and saltmarsh behind the Spit, have been zoned public open space, a classification which reserves land for public enjoyment. The Sorell rural planning document does not specifically zone wetland areas for protection based on their

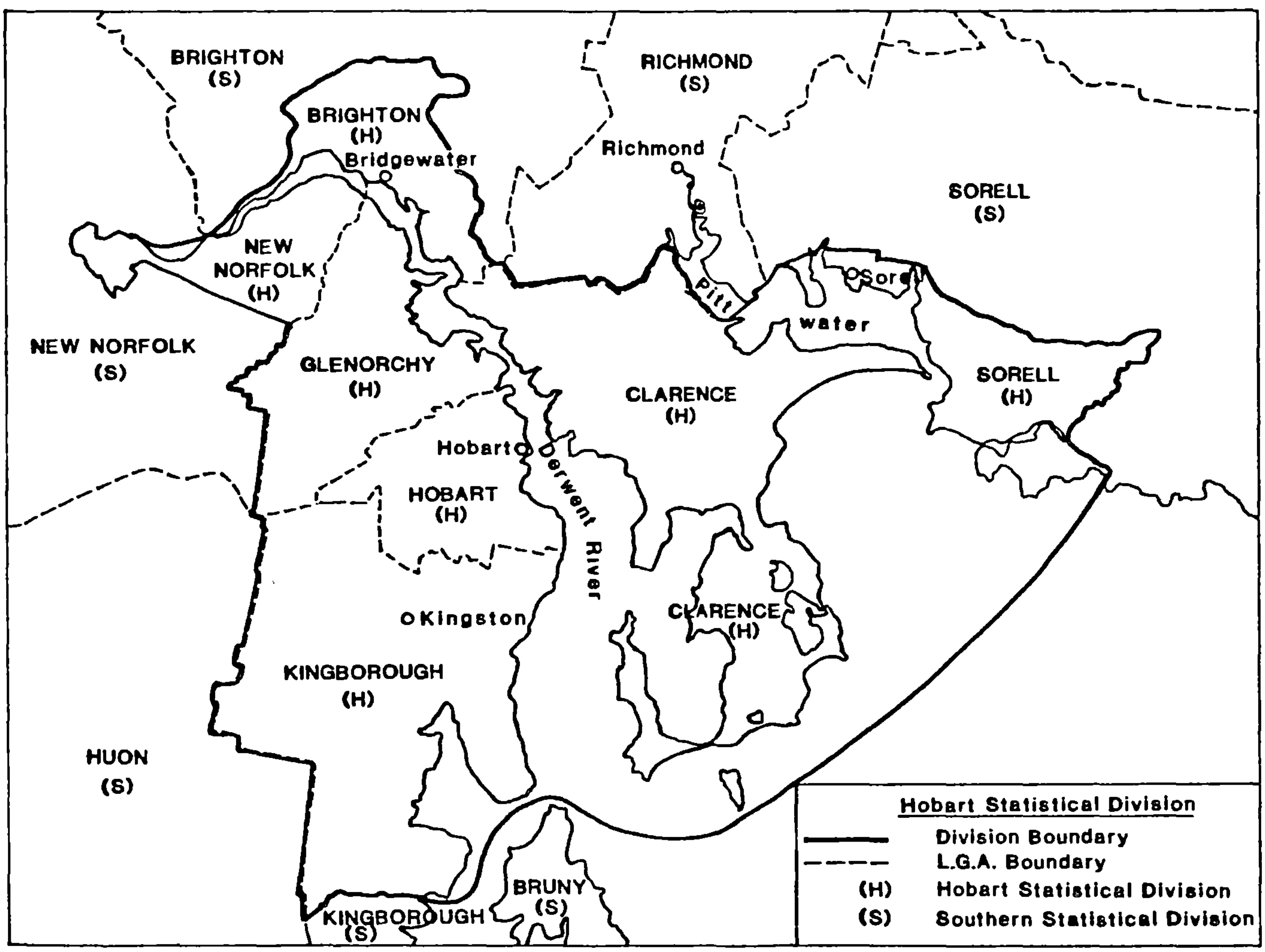

Figure 2.1: The Study Area: identifying the boundaries of the Municipalities of Clarence, Richmond and Sorell. Source: Australian Bureau of Statistics 1985.

value as wetlands or as shorebird habitat (Cowen, Municipality of Sorell Planning Section, pers. comm.).

CLARENCE MUNICIPALITY

The six shorebird sites on the South Arm Peninsula, Seven Mile Beach, Five Mile Beach and Barilla Bay are under the jurisdiction of the Clarence Council. Of the three councils involved within the study area, Clarence Council and the proposed rural planning scheme takes wetland and shorebird values into account to the greatest extent.

The planning scheme for urban areas of Clarence Municipality does not specifically zone for wetlands at all. Rather, it provides for public open space along the coast, typically in the form of foreshore reserves.

The Eastern Shore Planning Scheme 1986 (unpublished), for rural areas, has been drafted, but will not be made public until it has been approved by the Town and Country Planning Commission (Douglas, Municipality of Clarence Planning Section, pers. comm.). Although the plan is not yet in effect, the planners take the main points of the scheme into account in their decision making, with a view to the eventual adoption of the scheme.

The Eastern Shore Planning Scheme deals specifically with areas of conservation interest, including wetlands, and plans in advance the desired outcome and feeling for each region under the scheme. Areas of conservation quality, such as habitats, are dealt with in a section of special provisions.

None of the councils can actually designate areas for conservation, but they can zone an area for no or minimal impact in accordance with its conservation significance. For example, the Eastern Shore Planning Scheme has zoned the South Arm Neck and southern Pittwater areas in accordance with their recognized importance to shorebirds, and they are zoned appropriately for future reservation of the areas by the DLPW.

The shorebird sites of Lauderdale, Clear Lagoon, Mortimer Bay, Calverts Lagoon, Pipeclay Lagoon, South Arm Neck and Pittwater are specifically noted within the planning scheme for their importance to shorebirds, and their values are retained within the planning scheme (Douglas, Municipality of Clarence Planning Section, pers. comm.). A working paper leading up to the Eastern Shore Planning Scheme (Municipality of Clarence unpublished) noted specific problems mentioned in a BOAT report to Council (based on BOAT (1982)) and considered these in relation to the planning study.

ACTION BY OTHER ORGANIZATIONS

Two studies have been undertaken which deal with coastal land within the study area for this thesis, and are therefore relevant to this discussion.

During the late 1970s, the Tasmanian Conservation Trust, funded by the State Government, carried out a coastal survey which compiled a data base on the Tasmanian coast

(Tasmanian Conservation Trust 1980). The study made management recommendations for the coastal zone in general as well as for specific coastal units. While some of the recommendations have been addressed, the majority of the recommendations relevant to this thesis have not. For example, recommendations concerning the management issues of grazing and off-road vehicles at Marion Bay have not been followed up, the wetland areas at Pittwater-Orielton Lagoon still do not have protected status and Nature Conservation areas have not been developed for wildlife habitat within Ralphs Bay or Pipeclay Lagoon although these were actions recommended by the coastal study.

In 1985, Hepper, Marriot and Associates prepared a Derwent River Management Plan for the Hobart Metropolitan Councils' Association (Hepper et al. 1985). The plan detailed a management policy and enhancement opportunities for 61 Foreshore Management Units along the Derwent River. Three important South-east Tasmanian shorebird sites were included in the plan: Lauderdale, Mortimer Bay and South Arm. The Municipality of Clarence has incorporated ideas presented in the Derwent River Management Plan into the Eastern Shore Planning Scheme 1986 (unpublished). Again, protected status, as recommended in the plan for some sites, can only be conferred by the Department of Lands, Parks and Wildlife. The plan stressed that implementation of the recommendations "will be gradual and require community support, political will and the re-direction of resources" (Hepper et al. 1985).

2.2.4 Proposed Reserves

A few attempts to reserve areas of shorebird habitat in Tasmania have been made. Three proposals have proceeded as far as Cabinet submissions. The two proposals for Conservation Areas within the South-east Tasmania study area were rejected.

This section reviews the proposals for the protective reservation of Pittwater and South Arm Neck, the concerns raised during the consideration of the proposals, and their current status. The objective is to provide background information as a case study of past reservation attempts, and to identify management issues that would need to be considered in future attempts to reserve or manage similar areas.

BOUNDARIES AND LAND TENURE

For both the proposed Pittwater and South Arm reserves, all land involved is Crown Land. The boundary lines are illustrated on Figures 2.2 and 2.3, and the original and modified proposed boundaries are shown for Pittwater. The proposed Pittwater Nature Reserve would encompass approximately 2000 ha, and the South Arm Wildlife Sanctuary 400 ha (Rounsevell, Department of Lands, Parks and Wildlife, pers. comm.). The boundary line for each is High Water Mark, although at South Arm some areas of adjacent Crown land are included.

When land is subdivided, a coastal reserve extending to 30 m above High Water Mark is usually created (Tasmanian Conservation Trust 1980). When a coastal reserve has been created in this way, in order to allow access for the public and recreation, this land cannot be included in a State Reserve and thus the State Reserve can only extend to High Water Mark.

PROPOSED PITTWATER NATURE RESERVE

Pittwater (Figure 2.2) was first considered for protective reservation in the early 1970s. Residents of Midway Point and the Sorell Council approached the Tasmanian National Parks and Wildlife Service with complaints of excessive shooting over Orielton Lagoon, and proposed that the Lagoon be made a Wildlife Sanctuary, and there was strong support for this suggestion (Mercury, 15 October 1970). By 1973, duck-shooting had been prohibited on the Lagoon and steps were being taken towards protective reservation of Orielton Lagoon.

Before the proclamation was finalized, however, support began to waver. A skeet range was proposed for a site nearby within the Sorell Municipality, and it was considered inappropriate to site this development adjacent to a Conservation Area (SSG pers. comm.). In addition, the prohibition on duck-shooting on the Lagoon had satisfactorily ended the duck-shooting problem. The Sorell Council withdrew its proposal and instead additions were made to the Wildlife Amendment Regulations (Tasmania) (No. 2 and No. 4 of 1973) to provide for the protection of all wildlife on or over the Lagoon.

BOAT became involved with the issue at this time and strongly recommended that the whole of Pittwater should be reserved, recognizing its importance to migratory shorebirds. BOAT has continued to push for the proclamation of the area as a Nature Reserve up to the present day.

In 1974, Pittwater was added to the List of Wetlands of International Importance. It was listed for its importance to large populations of waterfowl, as a drought refuge for waterfowl, for its inclusion of saltmarsh communities not well reserved in the state, for its large concentration of the endemic viviparous sea star, Patiriella vivipara, and for its importance as an extensive wetland near Hobart easily accessible for education and research (Tasmania, National Parks and Wildlife Service unpublished). In addition, the characteristic which is most significant on an international scale is the area's importance to migratory waders. It was estimated at the time of listing that about 15% of the non-breeding wading birds wintering in Tasmania could be found within the proposed reserve area (Tasmania, National Parks and Wildlife Service 1981). In 1982, Pittwater was also placed on the Register of the National Estate (Park 1983).

Several studies have been undertaken at Pittwater and provide further evidence for the need for protective reservation of the area. Members of BOAT regularly counted shorebirds using Pittwater between 1964 and 1988 (SSG pers. comm.). Buttermore (1977) reported on eutrophication of the area and Kirkpatrick and Glasby (1981) documented the distribution, community composition and conservation of Tasmanian saltmarshes, including those within Pittwater. In addition, in their role in the reservation process, Tasmanian National Parks

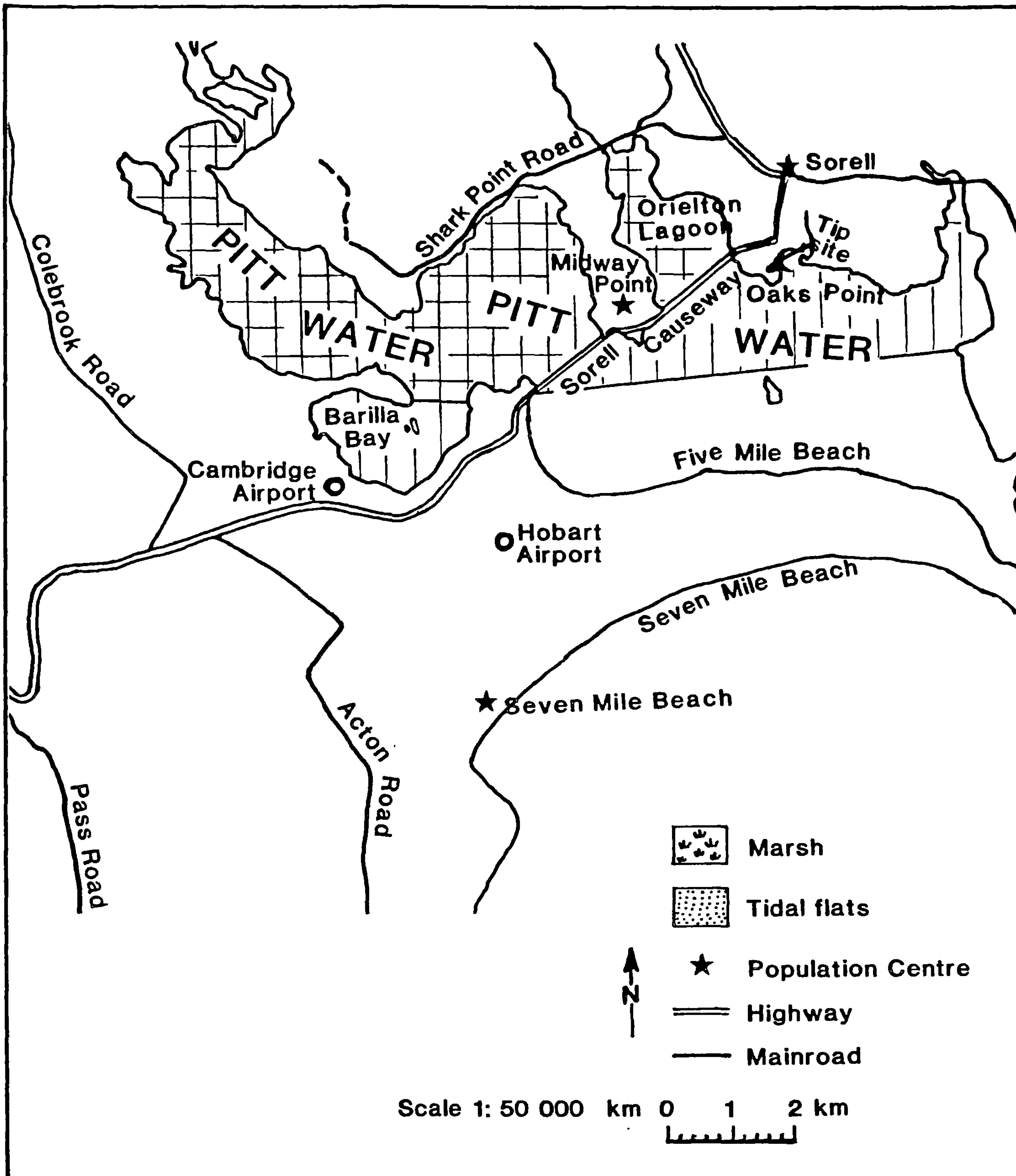

Figure 2.2: Pittwater: the extent of the original proposed Pittwater Nature Reserve is shown with vertical hatching and the current proposal with horizontal hatching.

and Wildlife Service has undertaken investigations of the area (Rounsevell, Department of Lands, Parks and Wildlife, pers. comm.).

As part of the inter-departmental consultation associated with the proposal procedure, some of the agencies asked for comment included the Clarence, Sorell and Richmond Councils, the Town and Country Planning Commission, the Marine Board of Hobart, Lands Department, the Department of the Environment, the Department of Health Services, the Tasmanian Department of Sea Fisheries and the Tasmanian Duck Advisory Council.

Concerns raised by these agencies were reflected in changes made to the Pittwater proposal. Barilla Bay was excluded from the proposal because of the site's proximity to the airport, and there was the fear that there could be an increased incidence of bird strikes by aircraft if nearby habitat were improved to support more birds. The major conflict was that if a future extension of the Hobart Airport were to be approved, the infilling of Barilla Bay for runway extension would be required and this is an option that the airport managers want to keep open should the need arise. Such infilling would destroy the Barilla Bay mudflats, an important feeding area for shorebirds.

The area to the south of the Sorell Causeway, including the shorebird site on the mudflats at the mouth of the Sorell Rivulet, has also been excluded from the proposal. The concern in this case was that the reservation of the area would restrict recreational activities including shooting and the exercising of horses and dogs, aquaculture, and that property values might decrease if adjacent land comprised a Reserve and that private property owners might be required to fence land adjoining the Reserve , thus incurring an expense (BOAT 1985).

All of these potential conflicts had to be addressed before a submission could be sent to Cabinet, and in the most recent proposal, the area to the south of the Sorell Causeway has been excluded, as has Barilla Bay (Rounsevell, Department of Lands, Parks and Wildlife, pers. comm.). A circular was published by NPWS in 1981 outlining and explaining the proposal and the management details. Off-road vehicles would be prohibited. Existing rights such as to aquaculture leases would continue. Recreational activities such as fishing, sailing and boating would continue and passive recreational activities like birdwatching would be encouraged. Fencing to exclude stock would possibly be necessary at some stage, but would not be required immediately (NPWS 1981). Hunting would be prohibited on the reserve, but restricted duck shooting would be permitted in an area in upper Pittwater (Rounsevell, Department of Lands, Parks and Wildlife, pers. comm.). There are already specific areas in the region that allow dog and horse exercising (Municipality of Clarence 1988). BOAT (1985) pointed out in a submission to the Sorell Council that a Nature Reserve could have a positive effect on property values as an attraction to home owners.

The Pittwater Nature Reserve proposal went before State Cabinet in 1986 but was rejected.

PROPOSED SOUTH ARM WILDLIFE SANCTUARY

In 1983 the South Arm Wildlife Sanctuary in lower Ralphs Bay (Figure 2.3) was first proposed. The area was already well recognized locally for its importance to migratory shorebirds but the impetus for the proposal was excessive shooting in the area (Brown, Department of Lands Parks and Wildlife, pers. comm.), a problem which culminated with the 1982 shooting of two Bar-tailed Godwits (BOAT files). The NPWS initiated a reserve proposal with strong support from BOAT. Reservation was also intended to decrease disturbance to birds from human activities and to decrease competition for food between shorebirds and people collecting crustaceans for food.

A number of studies have been carried out at the South Arm shorebird site. In addition to investigations undertaken by the NPWS in their role in the reserve proposal process, inter-tidal ecology was studied by Guiler (1953), shorebird feeding studies were carried out by Thomas and Dartnall (unpublished) between 1968 and 1970, and the shorebirds at the site have been monitored by BOAT regularly since 1964.

As with the Pittwater Nature Reserve proposal, a large number of interested parties were approached for comment on the proposed reserve, including Clarence Council, the Marine Board of Hobart, the Department of the Environment, the Town and Country Planning Commission, the Tasmanian Department of Sea Fisheries and the Tasmanian Duck Advisory Council. The Mines Department also had an interest because of sand mining operations in the area.

This proposal was not as contentious as the Pittwater proposal for several reasons. Residents were happy with the proposal from the start as a means of controlling shooting on the Bay (SSG pers. comm.). The Clarence Council also gave its support and has zoned the area for its conservation potential in its proposed Eastern Shore Planning Scheme 1986, (Douglas, Municipality of Clarence Planning Section, pers. comm.). This zoning allows sand mining on the south side of the neck to continue. Because South Arm has been proposed as a Wildlife Sanctuary rather than as a Nature Reserve, there are fewer restrictions and prohibitions that might create a conflict between interested parties. Since a Wildlife Sanctuary deals with the fauna but not the habitat, activities such as mining, fishing and aquaculture are not restricted. Also, while shooting is prohibited, it can be allowed on consent of the managing authority, and limited shooting on a permit basis would be permitted under Sanctuary status.

This proposal went to State Cabinet in 1986, but was also rejected.

CURRENT STATUS OF RESERVE PROPOSALS

The proposals for reservation of Pittwater and South Arm were both rejected by State Cabinet in 1986. The Bird Observers' Association of Tasmania sought clarification of the reasons for the rejection of the proposals. The organization received a letter from the Minister for Lands, Parks and Wildlife stating that further information detailing degradation of the

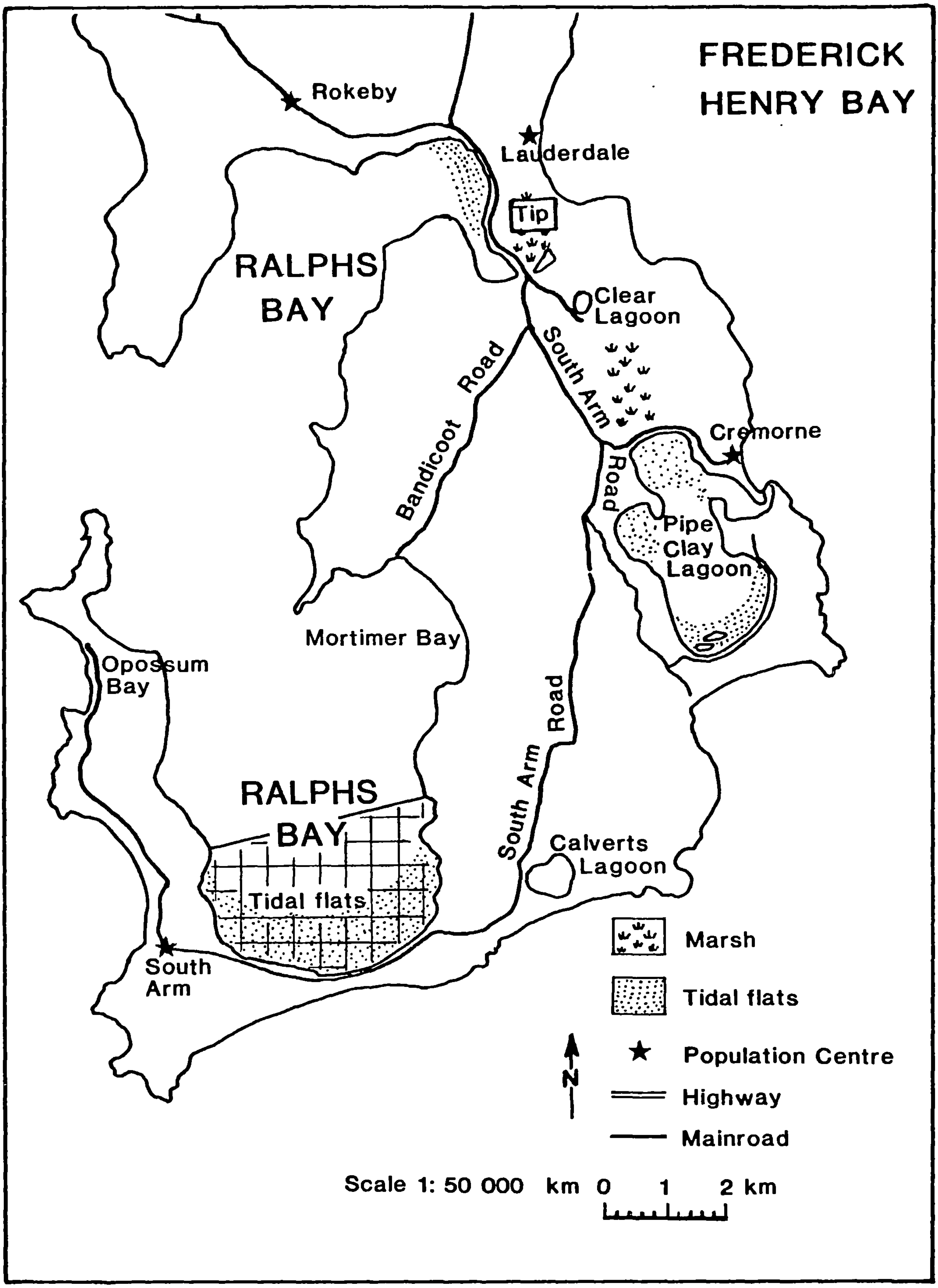

Figure 2.3: South Arm: the extent of the proposed South Arm Wildlife Sanctuary is shown with hatching.

areas and increased threats to the shorebirds since 1970 was required. BOAT has prepared a submission which has been forwarded to all members of State Cabinet for their consideration, (BOAT 1988a). Reconsideration of the proposals by State Cabinet is expected in the near future.

CHAPTER 3: SHOREBIRD HABITAT IN SOUTH-EAST TASMANIA

This chapter describes the types of habitat required by shorebirds and possible effects of shortage of these habitats. It also describes the 11 sites of important shorebird habitat in the South-east Tasmania study area in terms of human demography, physical characteristics, and current land tenure and land use management.

3.1 Habitat Requirements of Shorebirds

Shorebirds require habitat for breeding, feeding and roosting. In Tasmania, resident species such as oystercatchers and some of the small plovers rely on the region for suitable habitat year-round, including the breeding season. Palaearctic and New Zealand migrants breed overseas and migrate to wintering areas in Tasmania. Plates 1, 2 and 3 show representative examples of shorebird habitat in South-east Tasmania. The selection of wintering habitat is based primarily on food availability, requiring a supply adequate for sustaining birds during their non-breeding season and their return migration to the breeding grounds. The wintering areas must also provide an undisturbed roost (Hale 1980). Lack (1944) and Salmonson (1950) explained the dispersal of bird populations to various wintering areas as an adaptation to decrease competition for food. For example, some populations which breed in the Northern Hemisphere migrate to Britain, others to South Africa, South America or Australia. Shorebirds migrate between breeding and wintering grounds to exploit rich seasonal food supplies (Hale 1980).

The specific habitat requirements of shorebirds vary by species, but some general characteristics of shorebird habitat can be identified, and potential effects of habitat shortage can be discussed.

3.1.1 Feeding Habitat

A variety of factors interact to comprise suitable feeding habitat. The particle size of the mudflats is an important factor determining the availability of food for invertebrates, and thus the availability of prey for shorebirds. Fine particles, but not fine enough to clog respiratory and feeding systems of the invertebrates, or to become waterlogged and anoxic, have a higher organic and nutrient content from adherent plants and micro-organisms than do larger particles. The tidal flux in an area determines the accessibility of feeding and roosting habitat, and transports detritus to the invertebrates from the ocean and the saltmarshes. The density and distribution of invertebrates is also affected by temperature, oxygen and salinity concentrations in the region. Intertidal flats adjacent to saltmarshes or mangroves are also excellent feeding grounds for shorebirds, because invertebrate prey must remain relatively close to the surface to have access to oxygen and food (O'Connor 1981).

Plate 1

Mudflats: example of shorebird habitat (Lauderdale).

Plate 2

Saltmarsh vegetation and mudflats at near-coastal lagoon: example of shorebird habitat (Calverts Lagoon).

Plate 3

Ephemeral wetland: example of shorebird habitat (Clear Lagoon).

Three types of coastal wetlands, rocky shores, beach and dune shores, and intertidal flats, provide feeding habitat for shorebirds (Davies 1972). Some shorebirds are adapted to feeding on the prey available on rocky and sandy shores, such as invertebrates which graze on algae-covered rocks, or insect larvae in aerated soils, but intertidal flats are the richest in invertebrates and thus provide the richest food source for shorebirds (Lane 1987).

Lack of disturbance is another essential factor in determining feeding habitat. The amount of time that shorebirds can spend feeding is dictated by tides and the accessibility of the feeding grounds, by frequency of disturbance from humans or predators, and by prey availability and the energy requirements of the birds (Lane 1987). Feeding time is more critical for smaller shorebirds (Dann 1987), possibly because larger birds feed and store fat more efficiently (Calder 1974), and Lane (1987) stressed that "frequent disturbance can make an area unsuitable for these species", because it denies them crucial feeding time.

3.1.2 Roosting Habitat

Shorebirds roost at high tide, resuming feeding on the ebb of the tide. For the period of time that the tide is too high for feeding, the shorebirds are dependent on roosting areas which, Hale (1980) stressed, are traditional sites and "not just the nearest point of dry land". A variety of locations may be used for roosting, including saltmarshes, islands, fields and man-made structures, and in the absence of suitable sites, the last resort is to "roost" on the wing, flying around the feeding area until the tide has subsided enough for feeding to resume. (Prater 1981) noted this behaviour in some British estuaries where there was high disturbance and no alternative roosting sites available. The energetic expenditure of such an activity, especially for small species living close to their energy limits, would suggest that eventually the birds would have to move to a less disturbed area (Prater 1981).

3.1.3 Breeding Habitat

Lack of disturbance, shelter and absence of predators are particularly important factors in the determination of breeding habitat. Incubating birds are vulnerable to attack by cats, dogs and, outside Tasmania, foxes. When breeding birds are pushed off their nests their chicks and eggs are left open to damage and attack. A reliable food supply close by is also essential to support adults and offspring throughout the breeding season.

3.2 The Effects of Habitat Shortage

A close relationship between bird density and food availability suggests that food is the major factor in shorebird distribution (Goss-Custard et al. 1977). However, little is known regarding how closely the shorebird numbers approach the carrying capacity of their wintering grounds.

Pressure on the habitat, in the form of a decrease in habitat or an increase in competition for feeding habitat, can have several effects; for example, it has been found that shorebirds have preferred feeding areas, and that an increase in the density of shorebirds in these areas cause additional birds to move to less preferred areas (Zwarts 1974; Goss-Custard 1977). Research has also shown that intensive feeding on an area by shorebirds does not deplete the food resource, but lowers food availability to a level below which it is no longer efficient to feed. At such low prey densities, energy expended in capturing prey is not offset by energy intake (Evans et al. 1979). Goss-Custard (1977) suggested that a decrease in size of an available feeding area would probably cause birds to shift to other sites, hence straining those resources, with the eventual outcome of the shorebirds abandoning a heavily used area entirely. This hypothesis was based on evidence that increasing density of shorebirds on preferred feeding grounds resulted in a shift to less preferred feeding grounds. An increased difficulty in obtaining prey, plus an increase in bird density would possibly result in decreased prey abundance (Horwood and Goss-Custard 1977). There is also evidence that feeding rate is density dependent in species that hunt visually or that "take foods that are responsive to bird behaviour", and an increase in bird density was linked to decreased foraging success (O'Connor 1981). Hale (1980) commented that the effect of habitat loss would vary with the species, and that species existing closer to the carrying capacity of an area would be more seriously affected than would those species far below it.

Loss of roosting habitat could also have serious repercussions. Lack of roosting areas may result in "roosting on the wing", as previously discussed. Hale (1980) pointed out that the effect of insufficient roosting areas may not be immediately obvious, noting that movement of birds between estuaries in Britain could actually be different groups of shorebirds moving into an area, not finding a suitable roost and passing on. He stressed that the data could be misinterpreted, where "an estuary may appear to be supporting numbers of birds which are, in fact, part of a transient population" (Hale 1980).

3.3 Shorebird Sites in South-east Tasmania

3.3.1 Location

Less than one dozen coastal sites bordering the Derwent River Estuary and Pittwater constitute the most important shorebird habitat in South-east Tasmania (Figure 3.1). These are the only sites in the region where substantial numbers of shorebirds occur consistently on an annual basis. Figure 3.1 should be referred to for the location of each site in the following descriptions.

3.3.2 Shorebird Habitat Systems

In this paper, the 11 shorebird sites in South-east Tasmania are discussed as separate entities. This approach is entirely artificial, for the sites actually are part of several large

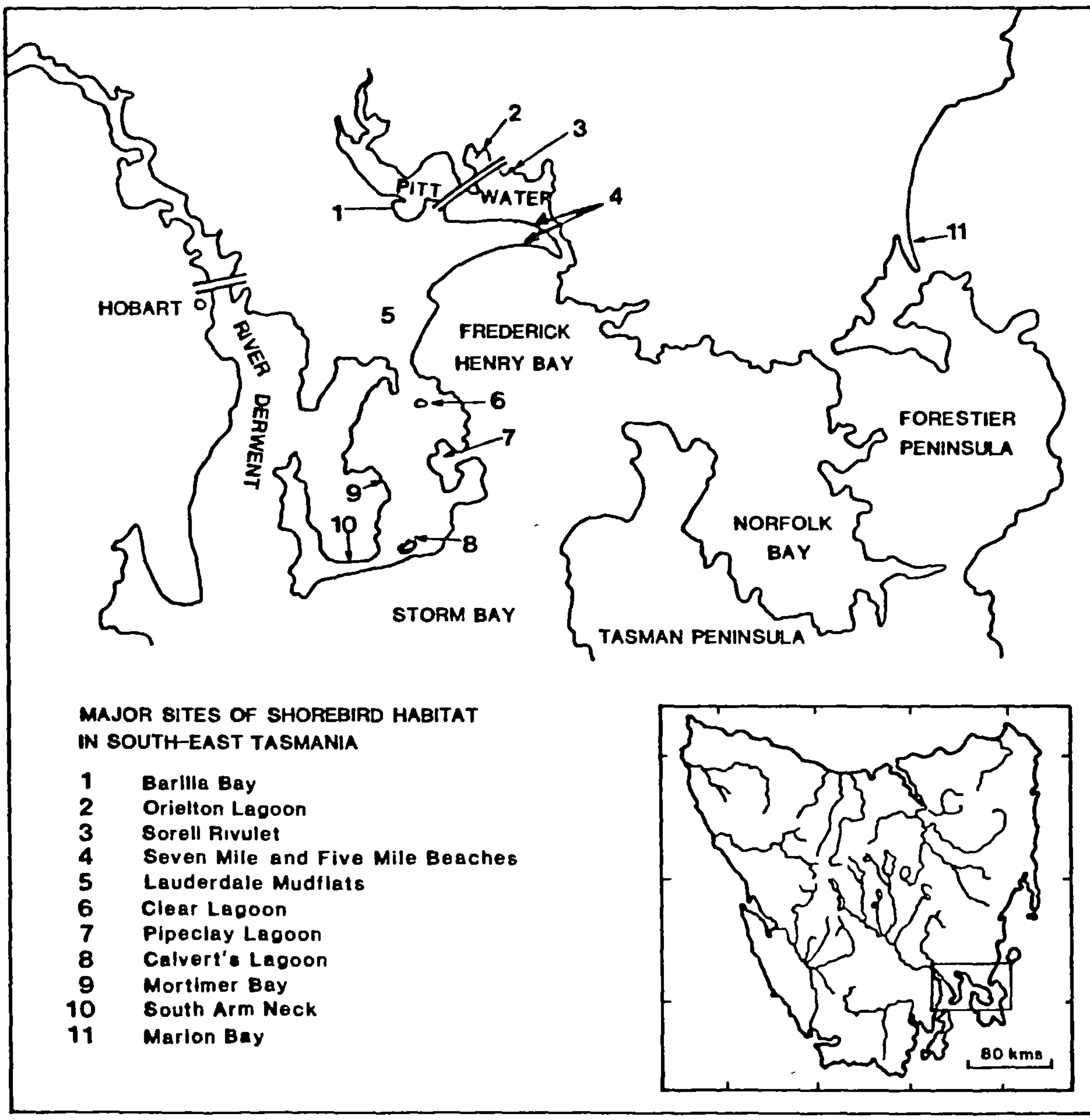

Figure 3.1: The Study Area: illustrating the major sites of shorebird habitat in South-east Tasmania.

systems of shorebird habitat. The birds use various sites within a system for breeding, feeding or roosting, and their movements between sites are a function of tidal and climatic conditions and disturbance at the sites.

The basis for this artificial approach is that the monitoring of the major sites within the systems has been divided among observers to facilitate coverage of the areas. The availability of data over two decades allows analysis of changes in site utilization and habitat alteration at each site.

Two of the main shorebird systems in South-east Tasmania are South Arm and Pittwater. Marion Bay is a separate system, but more data are needed to understand how Marion Bay "fits in" with the other systems. The South Arm system is composed of the shorebird sites on the South Arm Peninsula: Lauderdale, Clear Lagoon, Pipeclay Lagoon, Calverts Lagoon, Mortimer Bay and South Arm Neck. Mortimer Bay is primarily important as breeding habitat for resident species, and huge flocks of shorebirds do not move in and out of the area from other sites. The Pittwater system is composed of Orielton Lagoon, Sorell, Barilla Bay and Seven and Five-Mile Beaches. Patterson (1982) believed that Barilla Bay may be considered the nearest thing to a third discrete system, as movement of birds from adjacent Pittwater does occur, but the area attracts and supports a large shorebird component of its own.

3.3.3 Tidal Regime

The Derwent and Pittwater Estuaries are tidal in nature, although the tidal range is small; for example, in the Derwent Estuary in 1985, the predicted monthly tidal range was a maximum range of 1.44 metres and a minimum range of 1.11 metres. The salinity, degree of flushing and stability of foreshore ecosystems are all influenced by the tidal regime (Hepper et al. 1985).

The tidal cycle in South-east Tasmania is very irregular, and does not follow a consistent pattern. At times there may be two periods of low tide during a day, but at others, only one. Also, a number of days may pass during which feeding habitat for shorebirds is underwater even at low tide. The implication of this irregular tidal regime is that alternate feeding and roosting sites, such as near-coastal lagoons, are essential for shorebirds. They provide dry roosting space, and allow shorebirds to feed for a sufficient amount of time to obtain their daily energy requirement, when preferred feeding and roosting sites are inaccessible.

3.3.4 Previous Studies

The 11 shorebird habitat sites have been the foci of several studies relevant to this thesis. A list of the studies undertaken is listed here for reference.

Glasby (1976), Kirkpatrick and Glasby (1981), Kirkpatrick and Harwood (1981) and Kirkpatrick and Tyler (1988) dealt with saltmarsh vegetation, its distribution and its conservation status.

Smith (1981) discussed the invertebrate community of Calverts Lagoon in relation to its parasites, and Woodward (1985) studied the intertidal fauna of Pipeclay Lagoon. Guiler (1953) carried out invertebrate studies on several Tasmanian intertidal areas, including a major study at Pipeclay Lagoon and a minor study at South Arm. Thomas and Dartnall (unpublished) carried out feeding studies on shorebirds and sampled intertidal invertebrates at most of the major sites of shorebird habitat in South-east Tasmania. Richardson and Woodward (unpublished) surveyed the intertidal fauna of Mortimer Bay during the 1980s.

Low-level monitoring of the avifauna in South-east Tasmania was begun by Wall in 1948, and has continued since that time at various levels of intensity. Thomas and later BOAT carried out shorebird studies in the region, and these will be considered in more detail in later sections.

Blackhall (1986) described the vegetation, limnology and surrounding land use of Clear Lagoon with the purpose of making management recommendations for the areas as waterfowl habitat.

Water quality samples are taken regularly by the Tasmanian Department of the Environment at several locations in the Derwent Estuary, and at Barilla Bay, and a study to determine the sources of nutrients which contribute to the eutrophication problem at Orielton Lagoon was carried out by that department in 1986 and 1987 (Tasmania, Parliament, Department of the Environment 1987, various dates). Buttermore (1977) documented the problem of eutrophication in Orielton Lagoon. Bloom (1975) undertook extensive studies on the problem of heavy metal pollution in the Derwent Estuary.

3.3.5 Demographic Information

Figure 3.2 shows the main census collectors' districts that are relevant to the study area. For each of these collectors' districts and for the Hobart Statistical Division and the State of Tasmania, Table 3.1 gives figures for population and numbers of dwellings at the 1971 and 1986 censuses. The table also gives the percent increase in population and number of dwellings during that time period (Australian Bureau of Statistics, Hobart Office).

Increases in population and numbers of dwellings were much greater in all regions within the study area than within the Hobart Statistical Division or the State of Tasmania as a whole. Even the increases in population and dwellings for the Marion Bay area, a rural region, were greater than the state or Hobart Statistical Division increases.

The Australian Bureau of Statistics has found that Tasmania's population has shifted from primarily rural regions toward the urban areas of the state, including Hobart (Australian Bureau of Statistics 1985). The rapid growth in the Hobart urban area, particularly as

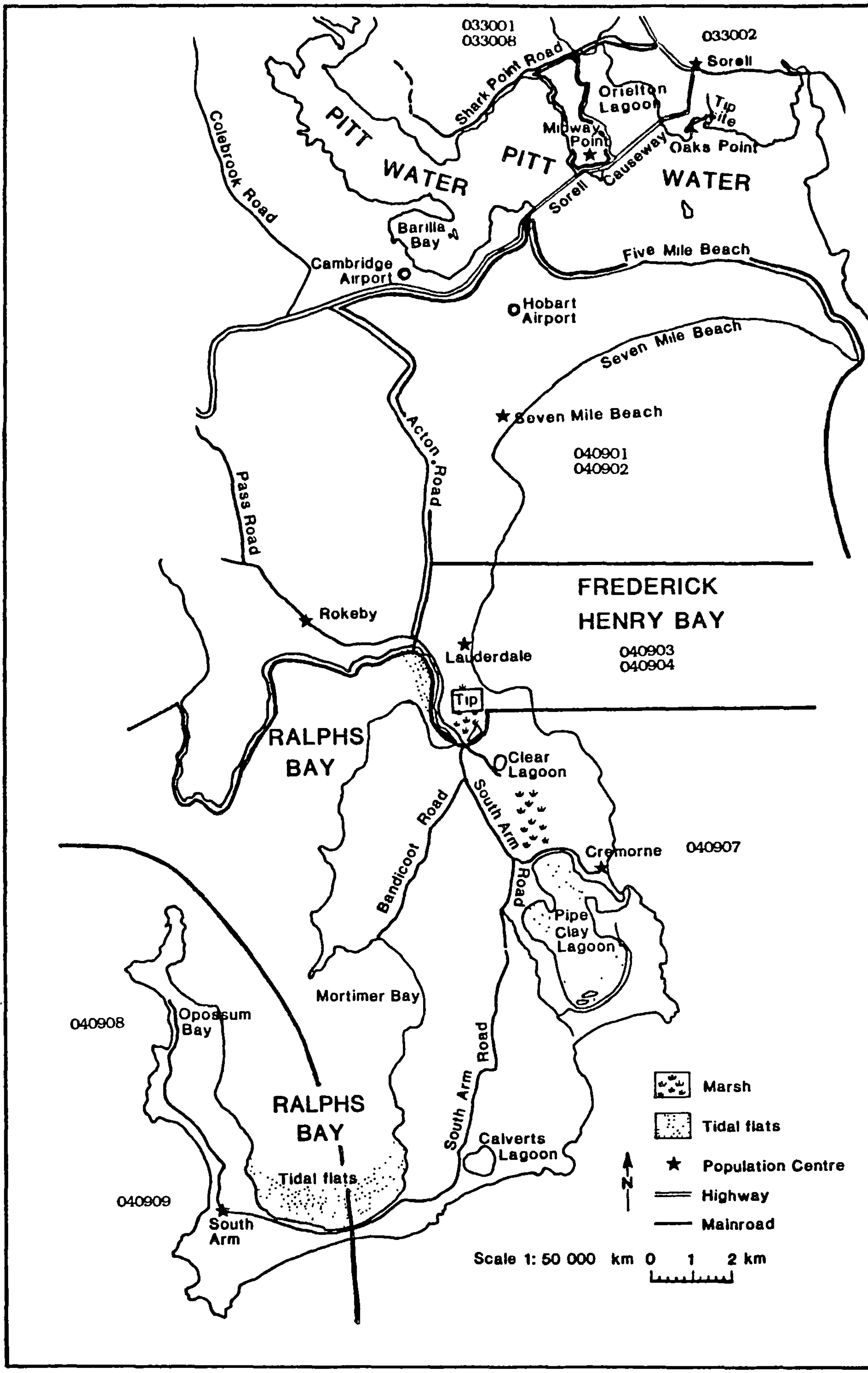

Figure 3.2a: The main census collectors' districts relevant to the study area.

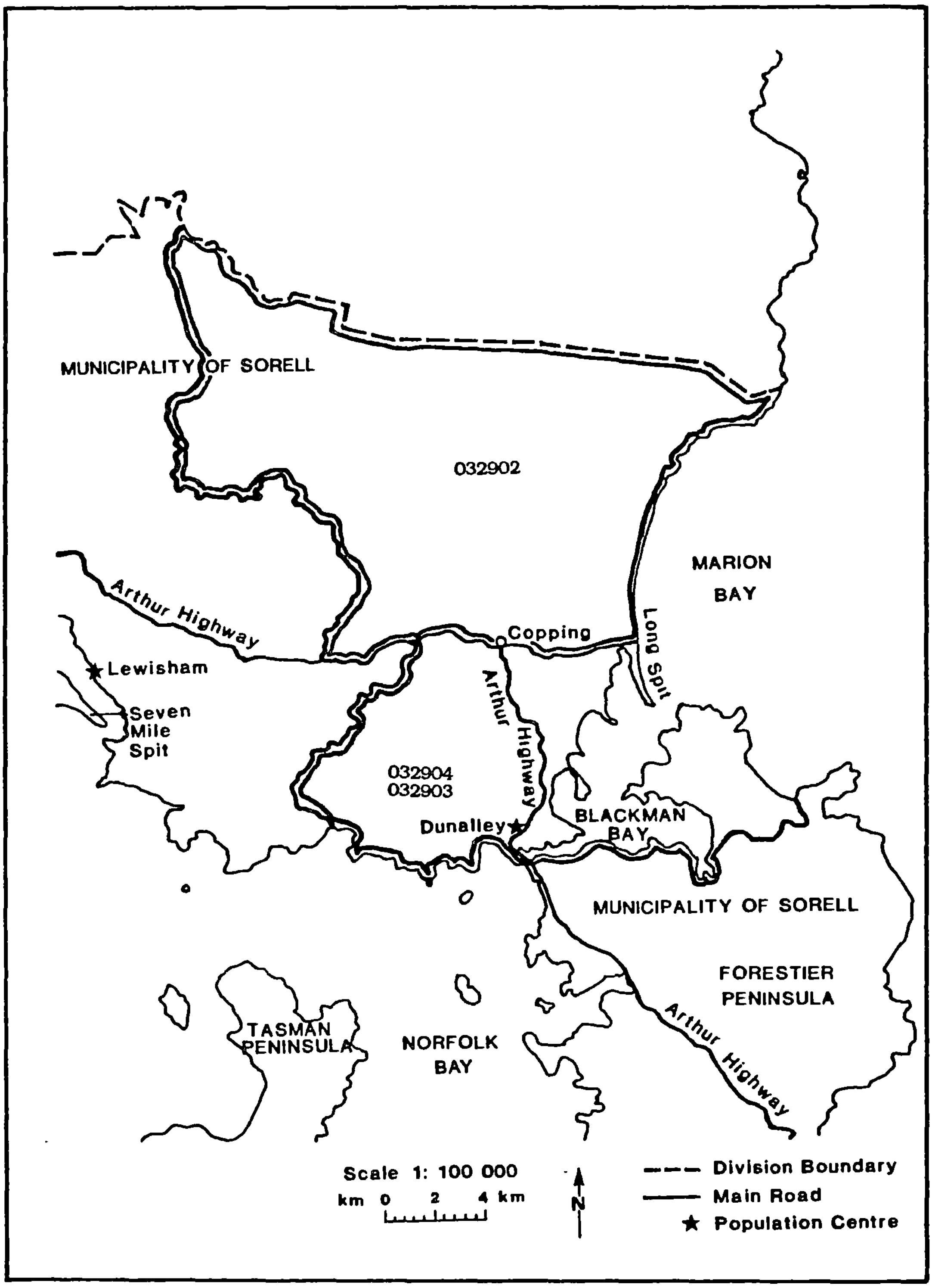

Figure 3.2b: The main census collectors' districts relevant to the study area.

TABLE 3-1: POPULATION STATISTICS FOR SOUTH-EAST TASMANIAN COLLECTORS' DISTRICTS RELEVANT TO THE STUDY AREA, BASED ON 1971 AND 1986 CENSUS DATA. SOURCE: AUSTRALIAN BUREAU OF STATISTICS, HOBART OFFICE.

MARION BAY AREA
COLLECTORS' DISTRICTS: 032902, 032903,032904

	1971	1986	% CHANGE
POPULATION	605	737	+21.8
TOTAL DWELLINGS	274	387	+41.2

SOUTH ARM PENINSULA, EXCLUDING LAUDERDALE
COLLECTORS' DISTRICTS: 040906, 040907, 040908, 040909

	1971	1986	% CHANGE
POPULATION	771	2033	+163.0
TOTAL DWELLINGS	580	1036	+78.0

LAUDERDALE
COLLECTORS' DISTRICTS: 040903, 040904

	1971	1986	% CHANGE
POPULATION	766	1662	+116.0
TOTAL DWELLINGS	273	560	+105.0

SORELL, AREA WITHIN THE HOBART STATISTICAL DIVISION
COLLECTORS' DISTRICTS: 033002 AND SORELL(H), EXCLUDING TOWN

	1971	1986	% CHANGE
POPULATION	1432	3032	+111.7
TOTAL DWELLINGS	1327	2267	+70.8

SEVEN MILE BEACH AND SPIT
COLLECTORS' DISTRICTS: 040901, 040902

	1971	1986	% CHANGE
POPULATION	479	1224	+155.0
TOTAL DWELLINGS	174	410	+136.0

MIDWAY POINT
COLLECTORS' DISTRICTS: 033001, 033008

	1971	1986	% CHANGE
POPULATION	1142	2104	+84.0
TOTAL DWELLINGS	372	713	+91.6

HOBART STATISTICAL DIVISION

	1971	1986	% CHANGE
POPULATION	153216	175082	+14.2
TOTAL DWELLINGS	47029	65991	+40.3

TASMANIA

	1971	1986	% CHANGE
POPULATION	390413	436353	+11.7
TOTAL DWELLINGS	123727	169612	+37.0

compared to values for state population growth, adds support to the statement that the study area is under increasing urban pressure.

3.3.6 Land Tenure

For sites within the study area in the Municipalities of Clarence and Richmond, the councils are responsible for land to High Water Mark within their municipalities, and Sorell Council is responsible for land to Low Water Mark within the Sorell Municipality. Land between High Water Mark and Low Water Mark is under the jurisdiction of the Lands section of the Department of Lands, Parks and Wildlife. Land tenure below Low Water Mark is held by the Marine Board. The Department of Main Roads is the responsible authority for roads and immediately adjacent land in areas where roads border the coast.

3.3.7 Site Descriptions

SOUTH ARM PENINSULA

Six important shorebird sites are located on the South Arm Peninsula, approximately 22 km by road to the southeast of Hobart. The land use is primarily pastoral, with expanses of woodland and coastal heath, and with several small townships. The peninsula's history of agricultural development and current increase in residential development has resulted in a severe modification of the original vegetation (Tasmanian Conservation Trust 1980). The southern coastline of South Arm Peninsula is composed of sandy beaches and dunes, and the sheltered area of Ralphs Bay formed by the "arm" is an expanse of accumulated silt (Tasmanian Conservation Trust 1980). Each of the six shorebird sites on the South Arm Peninsula is described in the following discussion.

LAUDERDALE

Lauderdale is situated at the narrow neck leading to the South Arm Peninsula and separating Frederick Henry Bay and Ralphs Bay. The neck is composed of one of the largest expanses of saltmarsh in South-east Tasmania (Wakefield, SSG, pers. comm.). On the eastern side of the neck is a sandy beach, and on the western side are extensive intertidal mudflats, approximately 2 km^2. The Lauderdale saltmarsh and mudflats comprises important shorebird habitat. The highway to South Arm runs along the edge of the mudflats, which are bordered by a pebble beach. A significant portion of the central marsh area is presently being filled as a tip site. Houses border this marsh on the northern edge. In the south-eastern portion of this remnant marsh lies a saltwater lagoon, known locally as Aerial Lagoon, which is connected to the mudflat area at high tide by a culvert under the highway. A sandy spit extends onto the mudflats at the mouth of the culvert.

Land use in the area is mostly rural and residential (Hepper et al. 1985). The town of Lauderdale stretches northward from the tip site and along the sandy beach on the eastern side of the neck, and shops are located adjacent to the road along the mudflats. Horseback riding trails are located in the saltmarsh area of Racecourse Flats, and there is an "informal boat launching ramp" at Ralphs Bay. Land tenure includes freehold, Council, Council Lease, Crown (Department of Main Roads) and Coastal Reserve (Hepper et al. 1985).

CLEAR LAGOON

Clear Lagoon is a shallow evaporative basin of saline marshland (Blackhall 1986). The water level in the Lagoon is dependant on rainfall (Thomas 1968) and varies both seasonally and over the long-term. At times the Lagoon may be totally dry, and at other times may be as deep as 0.5 metres, within an area of 2 km^2 (Blackhall 1986). When the Lagoon is not totally dry, the muddy perimeter provides feeding habitat for shorebirds. Clear Lagoon was reported to be dry at times during the 1960s (Thomas, SSG, pers. comm.), and was often dry during the early 1980s before partially refilling at the end of 1986 (Blackhall 1986).

The vegetation at Clear Lagoon is composed primarily of Salicornia sp., with some mixed sedges and grasses. The shore supports only sparse vegetation and 50% of the surrounding land is moderately grazed. Frequent burning has also had an impact on the vegetation at the Lagoon (Blackhall 1986).

The area to the north and west of Clear Lagoon has been subdivided within the last few years, and lots are currently on sale. Clear Lagoon was initially reserved by the Lands Department and is now being considered for reservation by the Department of Lands, Parks and Wildlife for its value to waterfowl (Blackhall 1986).

PIPECLAY LAGOON

Pipeclay Lagoon is a shallow, extremely sheltered lagoon approximately 8 km^2 in area. The Lagoon is tidal, opening to Frederick Henry Bay through a narrow channel to the east, and has extensive tidal mudflats and several Salicornia sp. flats around the perimeter (Woodward 1985). Paddocks and areas of scrub abut part of the Lagoon to the north and north-west.

The township of Cremorne stretches along the north-eastern shore of Pipeclay Lagoon. Land has been subdivided and houses built along Bicheno Street at the southern end and in a small area on the western shore. Most of the adjacent land is freehold or under the jurisdiction of the Clarence Council, with sections of Crown foreshore reserve where properties have been subdivided (Tasmanian Conservation Trust 1980).

A study by Woodward (1985) indicated that the richest tidal flat area for faunal abundance and diversity was the northern tidal flat, due to the water circulation and sedimentation patterns within the Lagoon. The heaviest concentration of human population and recreation areas are also at the northern end.

CALVERTS LAGOON

Calverts Lagoon is part of the South Arm State Recreation Area, and thus is under the jurisdiction of the Department of Lands, Parks and Wildlife. The Lagoon is brackish, approximately 0.5 km^2 in area and, as at Clear Lagoon, the water level varies seasonally and over the long term. The Lagoon may be dry or as deep as 2 m (Smith 1981). It has been suggested that the Lagoon has been drying over the past 20 years (Thomas, SSG, pers. comm.). The organisms native to the Lagoon are well adapted to the fluctuations that occur in water level, water chemistry and temperature (Smith 1981).

Two hundred metres of sand dunes separate Calverts Lagoon from the ocean (Smith 1981) and it is possible that the Lagoon was originally a bay or inlet which has been cut off from the sea by sand deposition (Lands Department 1980). Sand dunes lie to the south and east, and to the north and west lie pastures and coastal scrub (Smith 1981). Harwood and Kirkpatrick (1981) have described the vegetation, which is similar to that at Clear Lagoon (Smith, Department of Lands, Parks and Wildlife, pers. comm.). An access road to the ocean beach borders the Lagoon on the south. The road leads to a parking area from which walking tracks provide access to the beach.

SOUTH ARM NECK

The southern end of the South Arm Peninsula curves around to the west in a "J" shape, and the area enclosed by the curve is composed of extensive mud and sand flats and expanses of seagrass that are exposed at low tide (Thomas 1968). South Arm Road borders the southern shore. Along the eastern shore, the road lies adjacent to the mudflats and there is saltmarsh between the road and the mudflats along the western shore. Low shrubs and tussock grassland border the non-beach shores to the west (Tasmanian Conservation Trust 1980). Land to the east of the bay is open woodland with a grassy understory, and to the west is pasture land.

The town of South Arm is composed of permanent homes and holiday shacks, and the population rises sharply in the summer months with seasonal visitors. Land tenure in the region is primarily Council, freehold and Department of Main Roads (Tasmanian Conservation Trust 1980).

The South Arm Neck area has been proposed by NPWS as a Nature Reserve as a means of protecting the shorebird habitat in the area and to halt excessive shooting.

MORTIMER BAY

Mortimer Bay is a sheltered, crescent shaped embayment of northern Ralphs Bay. Gorringes Beach runs most of the length of the bay with bluffs on each end. It is a sandy beach with adjacent tidal sandflats, and a shingle spit used as a roost by shorebirds, particularly the Pied Oystercatcher. The beach is backed by low dunes covered with heath and remnant open woodland (Hepper et al. 1985).

The site is fairly isolated from major population centres, with access along a minor road. However, land behind Gorringes Beach to the north and northeast has been subdivided, and there are foot tracks throughout the area. Land use in the region is rural residential and agricultural (Hepper et al. 1985), and there is evidence of sand mining behind the beach. While there are no public facilities at Mortimer Bay, recreational activities such as horseback riding, boating and dog exercising are popular.

The foreshore is mostly Coastal Reserve, created through subdivision of adjacent property, and thus is under the jurisdiction of the Department of Lands. Other sections of the coastline are freehold property (Tasmanian Conservation Trust 1980).

PITTWATER

Pittwater is an extremely sheltered body of water in the northern reaches of Frederick Henry Bay. The area is located north of the narrow channel between Gwynn's Point and the tip of the Seven-Mile Beach Peninsula, a total of approximately 32 km^2 (Australian National Trust 1981). Pittwater is an estuarine complex into which flows the Coal River and a number of smaller streams. These drain the extensive agricultural land surrounding the water body. The water levels in Pittwater are shallow, ranging in depth from 1.30 to 2.65 m (Harris 1968).

There is extensive saltmarsh in the Pittwater region, particularly at the mouth of the Coal River, at the northern perimeter of Barilla Bay, and at the mouths of the streams flowing into Pittwater. Much of the saltmarsh is made up of species poorly reserved in Tasmania, and Kirkpatrick and Glasby (1981) strongly recommended the reservation of Pittwater on this basis. Little of the original vegetation around Pittwater remains (Tasmanian Conservation Trust 1980). Coastal shrubs and trees remain around the perimeter, but clearing, recreational and residential activities have removed this vegetation from the fringe (Tasmanian Conservation Trust 1980).

Important shorebird sites located within the Pittwater system are Orielton Lagoon, the mudflats at the mouth of the Sorell Rivulet, and Barilla Bay. The Seven Mile Beach Peninsula separates Pittwater from Frederick Henry Bay.

ORIELTON LAGOON

Orielton Lagoon was cut off from the tidal regime of Pittwater when a bridge was built in 1885. The current lagoon was formed when the bridge was converted to a causeway in 1953, incorporating culverts that prevented tidal exchange except at extreme high tide (Mercury, 31 March 1984; Park 1983), essentially damming the Orielton Rivulet at the northern end of the Lagoon. The approximate area of the Lagoon is 2.6 km^2 with a depth of about 1.3 m (Mercury, 31 March 1984). The water level, and hence the availability of feeding and roosting habitat, fluctuates with climatic and tidal conditions. The water level in Orielton Lagoon has been very high for the past several years (Park, SSG, pers. comm.). There are areas of rocky reef, mud and sand around the perimeter of the Lagoon, but the main habitat for shorebirds is at the northern end of the Lagoon where there is a significant area of saltmarsh, mud and a sand spit.

The causeway which separates Orielton Lagoon from the rest of Pittwater supports the Tasman Highway. Around the perimeter of the Lagoon are located an extensive housing development and a sewage treatment plant at Midway Point, a golf course and rural subdivision at the far north end and a subdivision associated with the town of Sorell on the eastern shore.

Land tenure at the site is mostly freehold, with Council-owned land at Midway Point (Tasmanian Conservation Trust 1980). The area of saltmarsh and the sand spit at the north of the Lagoon, which is the most preferred shorebird location for feeding and roosting within Orielton Lagoon, is Crown land.

SORELL

The shorebird site at Sorell is located at the mouth of the Sorell Rivulet between the Sorell Causeway and the mouth of the Iron Creek on the eastern side of Pittwater. The site consists of sand and mudflats with areas of seagrass (Zostera sp.). The mudflats at the mouth of Sorell Rivulet and Oakes Point are a preferred feeding location for shorebirds within the Pittwater estuarine complex. Vegetated islets occur on the mudflats at the mouth of the Sorell Rivulet.

A sewage treatment plant is located at Oakes Point, and there was an abattoir working there until approximately 1973, when it was replaced by a poultry processing plant (Wakefield, SSG, pers. comm.). A tip site which operated on the western side of the Sorell Rivulet until 1975, and which was later used for clean fill (SSG pers. comm.) resulted in a change of topography of the coastline. Land behind the old tip site, under the jurisdiction of the Sorell Council, was recently re-zoned and now supports light industrial operations. The land between Sorell Rivulet and Iron Creek is mostly pastoral. The town of Sorell is located less than one km from the site.

BARILLA BAY

Barilla Bay is a sheltered bay located in the Coal River estuary of Pittwater. The site consists of extensive tidal mud and sand flats, a sandy beach bordering the south-east edge and an expanse of saltmarsh along the north and north-west. Railway Point Spit curves around the northern perimeter to separate Barilla Bay from the Coal River, and saltmarsh is located within the shelter of this arm and on islets off the tip of the spit. A patch of seagrass is located in the north-east corner of the Bay. A smaller mudflat on the northern side of the spit is not heavily used by shorebirds (Patterson 1982; Thomas 1968).

Barilla Bay is bounded mostly by private property. Pastures are located to the west and between the Bay and the Tasman Highway to the south-east. Access to the Bay is by a private road through these pastures, a factor that considerably limits public access. The coastline adjacent to the Cambridge Airport to the south west is owned by the Commonwealth and land adjacent to the causeway is under the jurisdiction of the Clarence Council.

A golf course is located along the southern boundary of the Bay. The pasture to the west of the Bay contains a farm dam and creek, which are also used by some species of shorebirds. An oyster company runs a small operation at the base of Railway Point Spit, with oyster racks adjacent to the mudflats on the northern side of the spit. Another small oyster lease is located near the golf course.

Barilla Bay is located directly in the flight path of the Hobart Airport to the south. The Bay was originally included in a proposed nature reserve for Orielton Lagoon and Pittwater, but was excluded in the mid-1980s, partly because of fears of bird strikes by aircraft as a result of increased numbers of birds at a reserve, but particularly because of a proposal to extend a runway from the Hobart Airport across Barilla Bay.

SEVEN AND FIVE MILE BEACHES

Pittwater and the main section of Frederick Henry Bay are separated by a south-easterly prograding spit, with only a narrow channel connecting the two bodies of water. Five Mile Beach runs the length of the northern side of the spit, and Seven Mile Beach runs along the southern edge. Consolidated dunes are located behind the beaches. The vegetation over most of the spit has been replaced by extensive Pinus radiata plantations, although there is some remnant native vegetation that still exists near the eastern end. The tip of the spit is bare (Tasmanian Conservation Trust 1980). The two beaches, and particularly Five Mile Beach, are shallow, shelving beaches with sandflats which are exposed at low tide.

The township of Seven Mile Beach is located at the base of the spit on the southern side. Hobart Airport extends across the spit to the west of the township. Roads extend eastwards to within 2 km of the tip of the spit, and there is a network of off-road vehicle tracks throughout the area. Recreational day use facilities have been constructed by the Department of Lands, Parks and Wildlife.

Much of the Seven Mile Beach Peninsula is classified as a Protected Area under the Crown Lands Act (Tasmania)1976, and is under the jurisdiction of the Department of Lands. In a protected area, land is managed as a multiple use resource. Tourism, resource utilization and recreational and commercial development are permitted as long as they are at levels compatible with the management of the area for land and nature conservation (Crown Lands Act (Tasmania) 1976, section 8).

Most of the coastal land of the Seven Mile Beach Peninsula is freehold, but the Commonwealth is responsible for land around the Cambridge and Hobart Airports, and the area around the township of Seven Mile Beach is under the jurisdiction of the Municipality of Clarence (Tasmanian Conservation Trust 1980).

MARION BAY

Marion Bay beach is a long sandy ocean beach which has extended southward to form a bayhead spit which shelters Blackman Bay (Tasmanian Conservation Trust 1980). Extensive tidal flats and expanses of saltmarsh have formed behind the spit, and in sheltered areas of Blackman Bay around Boomer Island and Little Boomer.

Areas of the dune system show normal successional stages from tussock grassland through to open woodland. The vegetation has been modified by agricultural clearing, grazing, fire and off road vehicles (Tasmanian Conservation Trust 1980).

Land tenure around Marion Bay and Blackman Bay is primarily freehold and Crown foreshore reserve (Tasmanian Conservation Trust 1980). Houses are located behind Marion Bay Beach adjacent to the mudflats and saltmarsh, and also along Blackman Bay.

CHAPTER 4. IMPACTS UPON SHOREBIRD HABITAT

4.1 Introduction

The global nature of the issue of wetland destruction has already been mentioned in section 1.2 (see also WWF 1987). The importance of maintaining wetlands for their ecological values has been discussed by Bardecki (1984), WWF (1987) and Adam (1984). The threats to estuarine shorebirds and their habitat in Britain has been well documented by Prater (1981). Reffalt (1985) documented the destruction of wetland habitat of the United States and Adam (1984) discussed threats to wetland habitat in Australia.

Due to the increasing awareness that Australian wetlands are under increasing pressure from land use conflicts, there is a now a growing body of literature composed primarily of management plans for Australian wetland areas. The documents describe management issues that need to be addressed, and the issues that involve shorebird habitat are the same in almost every plan.

In South Australia, for example, the extensive wetlands along the Murray River and River Torrens estuaries have been heavily altered by reclamation and changes in water flow from dams, weirs and barrages. Water bodies such as Lake Bonney have been heavily contaminated with discharge from paper and pulp industries (South Australia, Department of Environment and Planning 1983). Saltmarsh has been changed to settlement and salt evaporation ponds near Port Augusta. Saltmarshes and swamps of the Coorong have been damaged by off-road vehicles (Gilbertson and Foale 1977) and freshwater soaks in that extensive wetland region have been subjected to heavy grazing and recreational pressures (South Australia, Department of Environment and Planning 1983).

The Port Phillip Bay Study in Victoria (Lane et al. 1984) considered management issues for each region of significant shorebird habitat within Port Phillip Bay. The study highlighted management issues such as the reclamation of saltmarsh for urban development at Swan Bay, for an aluminium smelter near Geelong, and for industrial and port development and waste disposal at Fisherman's Bend. Shellgrit extraction, grazing pressure on saltmarsh areas, and an aircraft runway proposal were all management issues in the Swan Bay area. Horses, dogs, trail bikes, feral cats, foxes and human access were noted as impacting factors on shorebird habitat at Balcombe Creek (Lane et al. 1984).

At the Jerrabomberra wetlands in the Australian Capital Territory (ACT), a similar list of threats to shorebird habitat was cited as land use pressures which were to be taken into account in future management (National Capital Development Commission (NCDC) 1982). These pressures included extractive industries, catchment uses affecting water quality, control of human access, control of feral animals and recreational activities.

In Western Australia recreational pressure on wetlands has been well documented (see Majer 1979; Bailey 1977). Eutrophication at the Peel-Harvey Estuary in Western Australia was discussed by Hodgkin et al. 1983).

Shorebird habitat is under pressure from a variety of processes that, working individually or in combination, result in habitat alteration . Examples of the same factors impacting upon shorebird habitat in South-east Tasmania can be found across Australia, as well as on most other continents. The purpose of this chapter is to briefly describe each impacting factor and its effects, and to summarize the habitat alteration that has occurred at each study site within the study area.

4.2 Factors Altering the Quality of Shorebird Habitat

For the purpose of this discussion, these factors which alter shorebird habitat have been grouped into three categories: a) physical changes, b) changes due to increased residential development and c) changes due to increased non-residential development. Physical changes may be the result of factors from the other two categories.

4.2.1 Physical Changes

Reclamation

"Reclamation" of a wetland involves the filling or draining of the area and putting it to a land based use rather than maintaining it as a wetland ecosystem. World Wildlife Fund (1987) described agricultural drainage as "one of the greatest single causes of wetland loss", citing vast reductions in wetlands during this century alone. Conversion of wetland areas to tip sites or sports grounds is another frequent reason for reclamation (Plate 4) and fill for projects such as industrial parks, marinas or sports fields is often in the form of industrial or domestic rubbish (Adam 1985). Prater (1981) noted that the use of rubbish as infill for reclamation projects has been a common practice throughout Britain and Ireland, and stressed the danger to habitat when chemicals and nitrogenous compounds leach out of the reclaimed site. Flat, reclaimed coastal land is often financially attractive to developers, as the wetlands replaced are seldom recognized as valuable in their natural state (Prater 1981).

Extensive draining and filling of estuarine areas has been an issue in Australia. A prime example is in South Australia, where the wetlands of the Murray River have been drastically reduced, and the estuarine swamps of the River Torrens have been reclaimed and replaced with the Adelaide Airport and residential development (South Australia, Department of Environment and Planning 1983).

Loss of habitat is one obvious result of wetland reclamation. Other less obvious effects include the increase in nutrients and chemicals from agricultural run-off, the increase in trampling if the area is reclaimed for grazing, and the leaching of materials from tip sites into the water table. The Lauderdale Tip, within the study area, is proposed to become a sports field after filling at the area has been completed. The intensive watering required to maintain lawns could exacerbate any existing leaching situation, and flush chemicals and excessive nutrients into the water table and adjacent estuary.

Cullen (1982) related the concern of the Australian Marine Sciences Association that the destruction of estuarine and wetland habitats, essential as nursery areas and critical food sources for commercially important fish, is threatening productive and profitable fisheries. The Association nominated the filling of wetlands and the pollution of estuaries from septic tanks and other sources as the major problems.

Probably the main reason that reclamation poses such a threat to shorebird habitat is that the cumulative effect of numerous insignificant reclamation projects results in a major decrease in available habitat. In Prater's words:

> **"It may be that only a few hundred square metres are involved.. It is rare that such a development can be opposed successfully on the grounds that it supports X % of the international or even national population (of a species of shorebird). Each removal, however, goes toward reducing the total area available as feeding grounds. The cumulative effect may be considerable"**
> (Prater 1981, p.104).

Odum (1982) summarized the cumulative destruction caused by wetland reclamation as follows:

> **"No one purposely planned to destroy almost 50% of the existing marshland along the coasts of Connecticut and Massachusetts. In fact, if the public had been asked whether coastal wetlands should be preserved or converted to some other use, preservation would probably have been supported. However, through hundreds of little decisions and the conversion of hundreds of small tracts of marshland, a major decision in favour of extensive wetlands conversion was made without ever addressing the issue directly".**

Changes in Water Level

The water level at a shorebird site may increase with the construction of dams, weirs or barrages or from some other process which restricts water flow, or decrease due to drainage or canalization. Flooding or drying may also result from natural fluctuations in water level.

An increase in water level that inundates tidal mudflats restricts available feeding, breeding and roosting habitat, as has occurred along the Murray River in South Australia due to dam and weir construction (South Australia, Department of Environment and Planning 1983). An increase in water level occurred at Orielton Lagoon in South-east Tasmania due to the construction of the causeway (Plate 5). Restriction of water flow provides conditions for eutrophication or modified nutrient and salinity levels (Hodgkin 1983). Continuous flooding or dessication of a habitat alters conditions for invertebrates and plants that are adapted to different levels of exposure or inundation, with the result that the ecology of the area is modified (South Australia, Department of Environment and Planning 1983). Johnson (cited in South Australia, Department of Environment and Planning 1983) reported evidence of a shift to marine fauna in a dammed South Australian estuary as the freshwater inflow was reduced.

Lane (1987) discussed the effect of changes in the balance between the inflow and outflow of water in a wetland, and the impact on aquatic plants and animals, and thus on shorebirds, due to changes in salinity and water level. Adam (1984) described environmental modifications that influence the water regime as the most important affecting wetlands. He stated that "within wetland systems very slight changes in water regime may bring about major biological changes", and gave the example of ruts from off road vehicles acting as drainage channels and changing the hydrology of the adjacent micro-environment in the top centimetres of soil.

There is growing concern over possible implications of the Greenhouse Effect (Barth and Titus 1984; Titus 1986). The anticipated future rise in sea level would seriously alter wetlands that currently provide shorebird habitat.

The basic principle of the Greenhouse Effect is that when sunlight strikes the Earth, it warms the surface, which radiates heat as infra-red radiation. Some of the heat escapes the Earth's atmosphere, but some is trapped inside the atmosphere by water vapour and gases such as carbon dioxide. The result is a warming of the earth's atmosphere similar to the effect inside a greenhouse. The increase in atmospheric carbon dioxide and other gases from human activities is causing more heat to be trapped (Titus 1986).

The most serious ramification is a rise in sea level as a result of melting of permanent ice resources at the Earth's poles. The implications for wetland areas include saltwater intrusion into freshwater wetlands, increased erosion and permanent inundation from a potential sea level rise of 10 to 21 cm by the year 2025 (Titus 1986). Saltmarshes and mudflats could possibly accrete above high water mark at a rate equal to that of the rise in water, providing that there is open land of a soil type appropriate to support saltmarsh communities available landward of the present marshes, and that physical factors such as wave energy and water circulation patterns at the shore are appropriate (Titus 1986; Vanderzee 1988).

Sedimentation

Sedimentation results when a decrease in water flow allows fine particles to settle, or when obstructions within a water body trap particles and a build-up results (Lepp 1973). Resultant restrictions in water flow maybe accompanied by nutrient and chemical changes in

Plate 4

Saltmarsh reclamation for a tip site (Lauderdale).

Plate 5

Sorell Causeway, separating Orielton Lagoon (foreground) from Frederick Henry Bay. Note spillways.

water quality and provide conditions for eutrophication (Hodgkin 1983). Changes in water level and the choking of filter feeding organisms are also potential results of sedimentation (Prater 1981).

Adam (1985) discussed sedimentation as a normal process in wetland communities, but stressed that clearance and disturbance within a catchment artificially accelerates the process, hence increasing the rate of succession towards a terrestrial community. He noted that this situation particularly applies in wetlands on the fringe of urban areas, and that the likelihood that sediment in these areas is contaminated by weed species is high. Severe erosion within the catchment area of rivers also causes a problem with siltation, as in the Onkaparinga River in South Australia (South Australia, Department of Environment and Planning 1983).

Eutrophication

Eutrophication is "the enrichment of aquatic environments with nutrients, commonly phosphorus and nitrogen" (Royle 1987). A nutrient influx to a body of water often causes dramatic vegetative growth. Death and decomposition of the vegetation results in an increased biological oxygen demand. The available oxygen supply is quickly depleted by decomposers and the resultant anoxic condition is only amenable to anaerobic organisms, such as some types of bacteria.

Other effects of eutrophication include decreased water clarity from increased phytoplankton, a change in vegetation types and the choking of the water body with vegetation. Accelerated sedimentation may result as the increase in plants decreases water circulation and the accumulated dead plant base collects sediment (Benforado 1981). This has been one problem, for example, of the eutrophication of Lake Illawarra in New South Wales (Royle 1987).

Eutrophication occurs in confined bodies of water that are not flushed by the tide or that have poor circulation, and which receive large amounts of nutrients from sewage outfall or agricultural run-off. Royle (1987) commented that eutrophication is probably a natural process "vastly accelerated by the development of agriculture, industry, towns and cities within the water-course catchment areas".

To an extent, increased levels of organic materials, for example from sewage, may actually increase the biomass of invertebrates or plants, and thus enrich the bird fauna (Prater 1981). This positive effect is counter-balanced, however, if there is insufficient oxygen to allow the breakdown of the organic matter by decomposers, often due to an insufficient volume of water for dilution (Prater 1981). A study in Britain (Portsmouth Polytechnic 1976) documented the effect of an excessive nutrient increase on mudflats. The high nutrient levels led to a rapid growth of plants which decayed in the winter, causing the mud to become deoxygenated. The result in such a situation is a great reduction in the diversity or abundance of the organisms that provide food for birds.

The effect of eutrophication on shorebird habitat is to decrease the prey resource or alter its make-up, by starving some littoral invertebrates of oxygen by altering oxygen availability on the mudflats.

O'Connor (1976) nominated eutrophication as a common management problem associated with bodies of water in Australia. The Peel-Harvey estuarine system in Western Australia provides a well-known example. Water flow was reduced in Peel Inlet when it was cut off from the sea by natural geological changes. Human activities produced conditions that led to eutrophication within the confined body of water. More than 80 years of drainage of the coastal plain combined with the construction of dams and heavy use of superphosphate fertilizer within the catchment area contributed to an excessive nutrient load entering Peel Inlet. The result was eutrophication and an accumulation of rotting green algae on the shores of the Inlet (Hodgkin et al. 1983).

Royle (1987) stressed that heavy long-term nutrient loading into an aquatic system may provide sufficient nutrient accumulation in the sediment to support eutrophic conditions long after nutrient input has been reduced.

4.2.2 Changes from Increased Residential Development

Based on an inventory of the Australian coastal zone (Galloway 1978), Cullen (1982, p. 186) commented that while one-third of the Australian coastal zone is not used at all and the rest is not heavily used, "there is intense conflict over about 4000 km of the East Coast". Eighty-three percent of Australia's population lives in cities or local government areas adjacent to the coast (Cullen 1982) and every capital city in Australia is centred on an estuary, bay or lake that provides important shorebird habitat. Yapp (1986) discussed the primacy of the coast as a holiday destination. Increases in population have resulted in increases in dwellings, domestic animals, cars and off-road vehicles and recreational demand for beaches. All of these factors have an impact on shorebird habitat.

In Tasmania there has been a shift from rural areas towards urban centres (Australian Bureau of Statistics 1985). The population within the Hobart Statistical Division, adjacent to an estuarine system, has increased markedly since 1971 (see section 3.3.5).

Recreational Pressures on Wetland Areas

One result of increased population is more people using wetland areas for recreational pursuits. Recreational developments often impact upon wetland areas. Marinas constructed on intertidal flats are one example. Recreational activities also affect shorebird habitat by disturbance (Plate 6). In a study of disturbance of birds at a coastal bay, Burger (1981) found that shorebirds and herons were the birds most affected by disturbance, in that they flew to distant marshes and ponds when disturbed rather than re-settling at the same place or nearby. She also found that activities which featured movements at a short distance, such as jogging, were more likely to cause disturbance than were pursuits that involved slower or more distant motion. Typically, most of the impact associated with recreational disturbance occurs during the summer months, when beaches are most in demand by people. Resident shorebird species are breeding at that time, and overwintering species are replenishing fat supplies for the next migration.

Lane (1987) recounted the poor success of 12 pairs of Hooded Plover, a species which breeds on ocean beaches, in a coastal area of Victoria. From these 12 pairs only a single chick was raised over two years. Disturbance by people walking along the beach and accidental egg and nest destruction was the cause (Dann, cited in Lane 1987).

Shooting

The noise associated with shooting is another disturbance at shorebird sites (Burger 1981), and in Tasmania there have been recorded instances where large shorebirds, such as Eastern Curlew (Newman 1981) and Bar-tailed Godwit (SSG pers. comm.) have been shot.

Tubbs (1977) considered the possibility that low numbers of shorebirds on Hampshire estuaries in Britain in winter may have been attributable to shooting.

In Tasmania, all shorebirds are fully protected under the National Parks and Wildlife Regulations (Tasmania) 1971, Schedule 2. However, shooting directed at shorebirds was the impetus for the proposed reservation of both Pittwater and South Arm Neck.

Off-Road Vehicles

Off-road vehicles (ORVs), including trail bikes, constitute a major threat to shorebird habitat. In addition to the direct disturbance to the shorebirds by the vehicles and the destruction of nests along the foreshore, ORVs degrade the habitat by compacting and rutting the soil, leaving persistent tire tracks (Plate 7). Trampled tracks may act as drains, collecting and channeling water, and affecting the water levels within the wetland (Adam 1984).

Grant et al. (1977) documented hydrological changes in soil in a study of the long term effect of ORVs. Gilbertson (1983) documented the threats to rare and endangered bird species in the Coorong from noise and ORV damage to their habitat.

Wood and Robertson (1976) compiled a checklist of negative impacts of ORV use and Brown (1987) presented an extensive literature review of ORV impacts based on this list. Impacts listed which pertain to wetland areas include i) physical impacts, such as generation of fires, soil compaction, soil erosion, destruction of vegetation, disturbance of wildlife and destruction of animal habitat; ii) hydrological impacts, such as disturbance of drainage patterns, and lowered water quality as a result of increased turbidity; and iii) the spread of weeds and pests.

Plate 6

Beach access to boat launching area (centre background) (Pipeclay Lagoon). **Note proximity of houses to Lagoon.**

Plate 7

Off-road vehicle tracks on saltmarsh vegetation (Clear Lagoon).

Domestic Animals

Domestic animals alter shorebird habitat by disturbance. Horses tend not to disturb shorebirds with their presence (Burger 1981), but their hooves compact and trample saltmarsh, mudflats and nests (Plate 8). Trampling of Pied Oystercatcher eggs and chicks has been recorded in South-east Tasmania (Park, SSG, pers. comm.).

Agistment of hard-hooved stock animals on saltmarsh areas has similar effects (Kirkpatrick and Glasby 1981), but to a greater extent because of the larger numbers that are present at one time. The introduction of alien plant species to wetlands and excessive trampling are two effects of grazing that may adversely affect wetland communities (Adam 1984).

Dogs are a disturbance at shorebird sites because they chase and catch shorebirds and force breeding birds off their nests, leaving the nests open to predators or damage. Their presence as potential predators can in itself be a disturbing factor to the shorebirds. Tip sites provide a food source for feral cats, and cats have been recorded preying on incubating birds and their eggs (Newman unpublished). An increase in both dogs and cats is likely with an increase in the number of dwellings in an area, and dogs and domestic cats have been noted at important roost sites at Lauderdale Spit and at Pipeclay Lagoon in South-east Tasmania (Newman unpublished). Dogs and horses on beaches both adversely affect the quality of shorebird habitat. Clarence Council has set aside specific coastal areas where the exercising of dogs and horses is permitted (Municipality of Clarence 1988), but both are frequently observed on beaches where they are prohibited.

Pollution

Pollution is another factor affecting shorebird habitat, and may originate from a number of sources. Tip sites have already been mentioned as a common cause of coastal reclamation, and the leaching of nitrogenous compounds from tip sites has been recorded in Britain (Portsmouth Polytechnic 1976). Eutrophication is a potential result of nitrogenous enrichment, while water contamination may result from the leaching of chemicals and poisonous substances (Adam 1985). Lane (1987) noted that "pollution, especially in the vicinity of large coastal urban centres, can alter the species composition of intertidal invertebrate communities", presumably by altering characteristics of the habitat making it less favourable to some species and more favourable to others. For example, Prater (1981) noted that on the Teesmouth estuary in Britain, industrial waste eliminated the invertebrate fauna in one area in the latter 1950s, rendering a previously rich feeding area useless for shorebirds.

Nutrient enrichment, as from sewage, is beneficial to wetland ecosystems to an extent, but causes problems when the effluent contains high levels of heavy metals, or when it is released into a small or confined body of water where the potential for eutrophication is great.

Plate 8

Horse hoofprints on beach (Gorringes Beach, Mortimer Bay).

Sewage entering bays and estuaries in South-east Tasmania is supposed to conform to Tasmanian Department of the Environment regulations for maximum Biological Oxygen Demand, non-filterable residue and fecal coliform levels. However, many of the larger municipalities have been granted ministerial exemptions from these regulations (Tasmanian Department of the Environment, Hobart Office). Thus, the effluent entering the receiving waters often does not meet standards set by the Department of the Environment. Most of the sewage entering the Derwent Estuary receives only primary treatment (CSIRO 1986/87), a method that removes only solids from the effluent, does not extract heavy metals and results in a fluid with a high organic content.

Prater (1981) cited European cases of decline in shorebird abundance as a result of heavy metal pollution, anaerobic conditions from paper mill effluent, and agricultural run-off. At the Severn estuary in Britain, analysis of invertebrates collected downstream from an aluminium smelter which released small amounts of cadmium in its effluent showed that they were accumulating that heavy metal (Butterworth et al. 1982). Since biomagnification of heavy metals and some pesticides is well known (Bailey 1973), the likelihood that birds feeding on the contaminated food resource were accumulating the toxins is high. In another example, 3000 shorebirds of several species were found dead on a British estuary with extremely high levels of lead in their tissues. While the cause of death could not be definitely established, lead poisoning was considered a strong possibility (Prater 1981).

Adam (1985) described the role of wetlands as "natural sinks", explaining that they concentrate pollutants, and he stressed that intertidal wetlands receive pollutants not only from their landward catchment but also from the water. Tips placed on wetlands are of particular concern because the "leaching of many of these dumps poses a long term threat of chronic pollution to neighbouring sites" (Adam 1985).

In the late 1960s, oysters raised in the southern Ralphs Bay region of the Derwent River Estuary, within the same area later proposed as the South Arm Wildlife Sanctuary, were making people sick. Studies concluded that heavy metals dumped into the river by industries up-stream were the cause, and levels of heavy metals, particularly zinc, cadmium, copper and mercury were extremely high (Bloom 1975; CSIRO 1974).

Seaweed Collection

Collection of large quantities of seaweed for use as garden mulch may affect species such as Hooded Plover that forage around beach washed vegetation. Seaweed is also used by shorebirds for shelter on ocean beaches. In Tasmania, collection of seaweed is permitted on a small scale even on coastal reserves (Tasmanian Conservation Trust 1980). A serious impact of seaweed collection is that vehicles are often driven onto the beaches in the process (Newman unpublished), with effects already discussed under the section on off-road vehicles.

4.2.3 Changes from Increased Non-residential Development

Industrial

In many places reclaimed coastal wetlands are attractive to industrial developers because they provide flat areas close to waterways, often at a lower price than inland sites (Prater 1981; South Australia, Department of Environment and Planning 1983). Besides loss of habitat, industrial development is a potential hazard to shorebird habitat if waste-water, chemicals or heavy metals escape into the water table or adjacent water, as discussed in the previous section.

Coastal industrial sites that operate with little disturbance to the saltmarshes or mudflats and release no effluent may be preferable to subdivision or other development. For example, at the mouth of the Sorell Rivulet in South-east Tasmania, the land adjacent to the mudflats was recently re-zoned as "light industrial". In terms of the degree of disturbance caused to shorebirds, this was preferable to zoning it for subdivision.

Airports

Flat, low-lying land adjacent to water is particularly desirable for the construction of airports, an explanation for the incidence of optimal shorebird habitat in the vicinity of airports. Adelaide Airport, for example, was built on a drained and filled section of the River Torrens estuary (South Australia, Department of Environment and Planning 1983), and the Hobart Airport is located on the Seven Mile Beach Peninsula, adjacent to the Pittwater estuarine complex.

To an extent, the availability of shorebird habitat around airports protects the area from development, since housing and recreational facilities are unlikely to be sited near airfields. However, the danger of bird strikes is a real threat, and steps to lessen this possibility are necessary. Flocking birds, such as shorebirds, are a particular threat to aircraft since there is the increased danger of ingesting birds into more than one engine . Actions to lessen the potential for birdstrike may involve shooting birds such as gulls, if they become too numerous, modifying habitat to reduce its carrying capacity, and eliminating the food supply (Bokpoel 1976).

Burger (1985) reported on conflict between birds and aircraft at coastal airports and on the effects of aircraft disturbance on birds. She reported that in her study area, birds did not appear to be disturbed by ordinary aircraft, but SSTs (supersonic transport) always disturbed birds when passing overhead.

Shellfish Aquaculture

Aquaculture, and particularly the propagation of shellfish, is a growing industry in South-east Tasmania. Many sheltered bodies of water in the area support oyster leases. The industry requires clean environmental conditions, and aquaculture does not directly affect shorebird habitat. However, activities associated with running shellfish leases, such as gaining access to the sites, may have an impact on the habitat if care is not exercised. In Britain, for example, suction pumps and rakes are sometimes used to harvest shellfish (Prater 1981), and in Tasmania tractors are used to gain access to the oyster racks (pers. obs.).

Sand Mining and Dredging

Dredging for sand or sediment has the potential to affect shorebird habitat if the operation is undertaken on intertidal flats. Mud and sandflats are likely to support a richer invertebrate fauna than rocky or sandy shores (O'Connor 1981). If these organisms were disrupted, those that are relatively sedentary and which only disperse while in the larval form, such as bivalves, might take several years to return to pre-dredging numbers (Richardson, Zoology Department, University of Tasmania, pers. comm.).

Examples of sand mining and dredging as factors impacting upon wetland habitat are present in Australia. Shellgrit extraction has been a management issue in Swan Bay in Victoria (Lane et al. 1984). Cullen (1982) cited this problem with dredging and filling in relation to canal estates in southern Queensland and northern New South Wales and to developments in Botany Bay, New South Wales and Westernport Bay, Victoria.

4.3 Factors Impacting upon Shorebird Habitat at the Study Sites

Appendix 3 summarizes the factors affecting shorebird habitat at the 11 study sites in South-east Tasmania. Three symbols have been used to depict which factors are present at each site. One asterisk (*) indicates the presence of the factor at a site or that the factor has been present at the site in the past. Two asterisks (**) indicate that a factor is or has been present and has resulted in a significant negative impact on shorebird habitat at that site. A question mark (?) indicates that the factor may be present at a site. For example, a question mark has been used for several sites under the heading "pollution or water quality changes" to denote that it is possible that runoff from adjacent agricultural land may be affecting the water quality, but research is needed to determine the extent of the effect, if any. Similarly, cats are probably present at many of the sites, but little information has been recorded.

It must be noted that the information in the table is intended to be a summary, rather than a ranking, of factors present at each site and as such is a subjective rather than quantitative assessment.

4.3.1 Lauderdale

Shorebird habitat at Lauderdale has been severely altered by human activity. A large area of the central saltmarsh was converted to a tip site in 1973 (Mercury undated newspaper clipping), destroying saltmarsh that had been a primary roosting and feeding area for shorebirds (BOAT 1985). The proposed future for the Lauderdale tip site is to fill and grade it and convert it to a sports field (Mercury undated newspaper clipping). As explained previously, the intensive watering needed to maintain a sports field is likely to increase leaching of chemicals and nitrogenous materials into the groundwater and adjacent estuary.

Saltmarsh damage has been caused by trail bikes on the eastern side of the causeway (Newman, SSG, pers. comm.), and beginning drivers have been observed practicing driving in the eastern section of the marsh during dry conditions (Park, SSG, pers. comm.). Part of this saltmarsh area was at one time connected to the mudflats, but has been cut off from all but the highest tides by the construction of South Arm Road, with culverts allowing only minimal water flow. This small lagoon formed with high water levels stagnates in dry conditions. More waterfowl than shorebirds use the lagoon at present but it would probably increase in importance to Pied Oystercatchers if more flushing could occur.

The western side of the Lauderdale neck is heavily disturbed due to its proximity to the highway and people, and roadside garbage is a problem (pers. obs.). The spit which extends onto the mudflats at the mouth of the canal has been eroded and is no longer a good roosting spot for shorebirds, which have to compete for limited roosting space with gulls that have increased with easily available food at the tip site.

The population of the Lauderdale region increased 116% between the 1971 and 1986 censuses (see Table 3.1). Cats and dogs have also become more numerous with the increase in residential development, and cats and rats are in abundance around the tip site (Newman, SSG, pers. comm.).

Horse trails wind through the marsh area around the tip, and both horses and dogs are frequently seen on the mudflats (pers. obs.), even though the exercising of dogs and horses in that area is prohibited (Municipality of Clarence 1988).

4.3.2 Clear Lagoon

The Shorebird Study Group has noted that Clear Lagoon supports fewer shorebirds than it did in the 1960s. Feeding habitat has not been available during much of this decade because the Lagoon has been very dry. The site also has been used less as a high water roost. This may be due to increased disturbance at the site from surrounding subdivision, with a likely associated increase in domestic pets, or possibly to the decrease in shorebirds that has been observed at Lauderdale. It is known that Lauderdale shorebirds often shift to Clear Lagoon at high tide (SSG pers. comm.). Grazing in adjacent paddocks and burning have also contributed to disturbance at the site, and off-road vehicle tracks have been noted adjacent to the Lagoon (pers. obs.).

4.3.3 Pipeclay Lagoon

Shorebird habitat at Pipeclay Lagoon is under pressure primarily due to increased population and recreational activities in the area. Use of the beach at the southern end of the Lagoon has risen, and few shorebirds now use that area (Wakefield, SSG, pers. comm.). The northern beaches, next to the settlement of Cremorne, are heavily used for boat launching and for other recreational pursuits. Tire tracks made by vehicles during boat launching and by off-road vehicles are a persistent feature of the saltmarsh (Wakefield, SSG, pers. comm.). Wheel ruts and excavations in sheltered areas with little sand movement may remain for months, and may accumulate organic material which then decays and changes the make-up of the food resource available in the area (Richardson, Zoology Department, University of Tasmania, pers. comm.). Dogs are often observed loose on the beaches (SSG pers. comm.) although signs explicitly state that they are only permitted under control. Horses are also exercised on the beaches. Oyster leases are present within the Lagoon on the eastern side.

4.3.4 Calverts Lagoon

The South Arm State Recreation area has the stated management aim "to provide for public recreation while still retaining the area's natural environment" (Lands Department 1980). Dogs are allowed under control, vehicles are prohibited on the beach and sand dunes and shooting is prohibited. Horseback riding is allowed, with the posted statement that "intending riders should be aware of the potential damage their horses may cause to sand dunes" (Lands Department 1980). Horses are frequently used on the trails around the Lagoon (Park and Wakefield, SSG, pers. comm.) Although trail bikes are prohibited from the region, they have been observed at the Lagoon (Park, SSG, pers. comm.).

Although Calverts Lagoon is part of a recreation area, the surf beach adjacent to the Lagoon probably draws a disproportionate amount of the recreational visitors to the area. However, it is essential to recognize that while Calverts Lagoon is not heavily disturbed or degraded, the same detrimental factors working at other shorebird sites in South-east Tasmania are present. Enforcement of posted regulations is essential to ensure that dogs, horses and off-road vehicles do not become a problem, and that Calverts Lagoon is buffered from any adjacent development.

4.3.5 South Arm Neck

Most of the threats to South Arm Neck as a shorebird site have been due to rural subdivision in the area, and an associated dramatic increase of horses, loose dogs and vehicles on the mudflats, causing damage to important feeding areas (Newman unpublished). The population of the South Arm peninsula, excluding Lauderdale, has increased 163% between the 1971 and 1986 censuses (see Table 3.1). The South Arm area is popular as a holiday destination. Thus, recreational demand on the area is particularly high in summer, when resident shorebird species are breeding and Palaearctic migrants are dependent on reliable, undisturbed feeding grounds.

Boat launching and seaweed collection are common at the site, and have contributed to the driving of vehicles on the mudflats (SSG pers. comm.).

There are currently no restrictions on shooting at the site. In 1982, two Bar-tailed Godwits were found shot (Wakefield, SSG, pers. comm.), and excessive shooting was one issue which led to the proposal to establish the South Arm Neck Wildlife Sanctuary (Mercury, 14 February 1983)

Pollution in the area has been an issue in the past. Situated in the lower reaches of the Derwent Estuary, Ralphs Bay traps heavy metals and other pollution coming downstream. Oysters harvested in the Derwent Estuary during the early 1970s contained such high levels of heavy metals, particularly mercury, copper, zinc and cadmium, that people were becoming ill after eating them. High levels of lead were also found in the oysters, and high levels of mercury were found in fish (CSIRO 1986/87). The oyster beds in Ralphs Bay were moved to other, less polluted areas, such as Pipeclay Lagoon.

The metals were emanating from industries up-river, particularly from an electrolytic zinc operation and a newsprint mill (CSIRO 1974). Another source of heavy metals in the Derwent River, and one that may still be affecting the river, was the ship which ran into the Tasman Bridge in Hobart and sank. The cargo was heavy metal-containing ore (CSIRO 1986/87).

CSIRO originally reported the results of an early 1970s study on the heavy metal pollution in the Derwent River (CSIRO 1974) and reported a follow-up study conducted in 1983 (CSIRO 1986/87). Between the times of the two studies, restrictions had been placed on the emission of heavy metals to the river, and by 1983 cadmium levels had decreased 93% from 1972 levels, and copper and zinc had decreased 80%. All heavy metal concentrations except that for lead had been brought within the range of Tasmanian requirements for water quality (CSIRO 1986/87). However, CSIRO (1986/87) also reported that the Derwent River is still not suitable for shellfish cultivation, and that excessive, inadequately treated sewage is the reason.

4.3.6 Mortimer Bay

Shorebird habitat at Mortimer Bay has been heavily disturbed. The site's primary importance to shorebirds is as a breeding location for resident species, such as Hooded Plover, Pied Oystercatcher and Red-capped Plover, and it is the beaches used for breeding that are under pressure from human disturbance.

During the early 1980s, Mortimer Bay was the focus of a study on another beach breeding bird, the Fairy Tern (Wakefield 1982), which is a seabird rather than a shorebird. This species bred at the site until 1983, but has abandoned the beach as a breeding location because of heavy disturbance (Wakefield, SSG, pers. comm.). Dogs, horses and trail bikes had a major impact on the tern colony (Wakefield 1982). Newman (SSG, pers. comm.) nominated these same factors as causes of disturbance to Pied Oystercatchers at the site. Lane et al. (1984) classified those species of shorebird that breed on beaches, including those listed above, as the most vulnerable to this type of disturbance.

Land on the forested hillside behind the beach has been extensively subdivided. The beach is heavily used for recreational pursuits, particularly during the summer months, which correspond to the breeding season for resident species. A shingle spit is used as a primary roosting site by shorebirds, but this is subject to almost continual disturbance by dogs, horses and people.

In the early 1980s, a shellgrit extraction operation at Mortimer Bay posed a major threat to shorebird habitat at the site. Sand mining has occurred at a low level at Mortimer Bay since the last century (Wakefield, SSG, pers. comm.). In 1982, however, the Tasmanian Racing Trust began extracting shellgrit to cover a horse trotting track (BOAT files). BOAT, as well as local residents, objected strongly to the operation at the site because vehicles were being run on the beach and dunes, and because of the effect on the area as shorebird habitat. The proposal for rehabilitating the extraction site was to dredge the intertidal zone and use the dredged material to replace the shellgrit removed from the beach. This proposal elicited a strong objection because of the unknown degree of the risk that heavy metals, a known pollutant in the Derwent Estuary, could be dredged up (BOAT files). BOAT was also concerned about the degree of disturbance to the intertidal fauna on which the shorebirds feed. The mining operation was subsequently halted.

4.3.7 Orielton Lagoon

Orielton Lagoon has been brought to public attention a number of times in the past 30 years for various reasons, many of which are factors which alter shorebird habitat.

The main reason for the Lagoon's publicity is its on-going problem with eutrophication. Within five years of the installation of the spillways in 1953, a newspaper article described the bad odor emanating from the Lagoon due to the decomposition of plants (The Mercury, 31 March 1984). Mud at the edges of the saltmarsh is often black and anoxic with a strong smell of decay, and at other times, the mud is covered with a milky white layer (Park, SSG, pers. comm.; pers. obs.).

The eutrophication of Orielton Lagoon has been studied by Buttermore (1977) who attributed the problem to the drainage of adjacent agricultural land and primary treated sewage into the Lagoon, and magnified by the restriction of free water flow from Pittwater because of the Sorell Causeway.

During 1986/87, the Tasmanian Department of the Environment carried out a study to determine the relative importance of the two major nutrient sources entering Orielton Lagoon:

the Midway Point sewage treatment plant and the streams which drain the catchment area for the Lagoon. The impetus for the study was frequent complaints regarding the odor of the Lagoon. The general results of the study were that during periods of heavy rainfall, "very large quantities of both nitrogen and phosphorus were carried into the Lagoon by streams. A significant proportion of this is likely to be flushed through the Lagoon. On the other hand, the Sewage Treatment Plant (STP) effluent contributes a constant flow of phosphorus (about 200 kg/month) and nitrogen to the Lagoon irrespective of the weather." In addition, it was found that "during the study period the STP was the dominant source of nitrogen, and contributed up to one half of the biologically active phosphorus entering the Lagoon. In periods of drought the STP is virtually the sole source of nutrient for many months." (Tasmania, Parliament, Department of the Environment 1987).

Thus, the Sewage Treatment Plant is a major consistent source of nutrients, and agricultural runoff is also,at times, a major contributor. The Department of the Environment acknowledged that plant growth, exacerbated by nutrient influxes to the Lagoon, is the cause of the odor problem.

Increased water levels at the Lagoon since the causeway was built have resulted in a loss of the extensive sand spit and mudflats at the northern end of the Lagoon, traditionally an important feeding and roosting location for shorebirds. Inundation of the northern saltmarsh has caused the death of Barilla bushes, which are native to the area (Park 1983).

Other factors besides eutrophication are also in effect at Orielton Lagoon. In addition to the smell, duck shooting at the Lagoon was also considered a problem in 1970 (Mercury, 15 October 1970). Shooting at the Lagoon was a major contributing factor towards a request by residents that the area be proclaimed a conservation area. Eastern Curlew have also been found shot there (BOAT 1985).

Residential development in the region has increased tremendously between the 1971 and 1986 censuses, particularly at Midway Point, which has increased 84% over that time period. Rural subdivision has also occurred at the northern end of the Lagoon. Problems associated with this increase which impact upon shorebird habitat are an increase in sewage from the Midway Point sewage treatment plant, more people in the vicinity and easy access by dogs and cats to the marsh from houses. Dogs and the tracks of dogs and cats have often been observed in the saltmarsh (Park pers. comm.; pers. obs.). After subdivision of land adjacent to the marsh a section of fence was not replaced and the remaining gap has allowed easy access to the marsh for bicycles and horses, and bicycle tire tracks and hoofprints have often been evident on the marsh (Park, SSG, pers. comm.; pers. obs.). An area of saltmarsh near the road was graded in the early 1980s and used for riding trail-bikes (BOAT files).

The golf course located along the north-eastern edge of the Lagoon will continue to provide a valuable buffer from human disturbance if further subdivision in the area should occur.

4.3.8 Sorell

Reclamation of land for a tip site at the mouth of the Sorell Rivulet decreased the amount of saltmarsh and mudflats at the site. The tip site was established in 1950, closed for garbage in 1975 and accepted clean fill from 1975 to 1983, when it was closed completely (Park 1983). After closure of the site, the Sorell Council was interested in obtaining the area from the Department of Lands, Parks and Wildlife to extend an adjacent industrial site. BOAT also expressed interest in obtaining the site and improving it as a public open space maintained as shorebird habitat. BOAT approached the Department of Lands, Parks and Wildlife with this proposal, which has been accepted (BOAT 1988b). The site will be managed for its value as habitat, a use which will not exacerbate any existing problem of leaching of nitrogenous or other wastes into the adjacent estuary.

To an extent, the site is buffered from heavy human disturbance by the light industries along its perimeter, despite its close proximity to the town of Sorell. Light industrial development has caused less disturbance at the site than would a subdivision, and this should continue to be the case provided that the industries do not flush pollutants into the water or cause disturbance along the shoreline. The location of the site within walking distance of the town of Sorell and a primary school provides an opportunity to develop the site as an environmental education resource while preserving its nature conservation values.

Although the site is fairly buffered from disturbance, there are a few factors working at the site that have an impact on the shorebird habitat. Since 1971, the Sorell sewage plant has been discharging into the mouth of the Sorell Rivulet (Park 1983). The nutrient influx from effluent may not be detrimental to the site provided that the receiving waters are sufficient in volume and there is enough circulation to prevent eutrophication. The abattoir at the site was replaced around 1973 with a poultry processing factory, which is not permitted to flush effluent directly into the water (SSG pers. comm.). Four wheel drive vehicles have been used on the mudflats, often in the process of unloading boats (Park, SSG, pers. comm.; Newman unpublished.).

The Sorell shorebird site is an extremely important feeding location within the Pittwater estuarine complex. It was originally included in the reservation proposal for that area but was later excluded. Management of the site by BOAT as a shorebird area is certainly desirable, but effective long-term management and protection of the site will require reservation of the area under the Department of Lands, Parks and Wildlife. The legal and logistical support available through this department is necessary, but even more important is the official status that such reservation would give the area.

4.3.9 Barilla Bay

Lack of public access to the shoreline of Barilla Bay has limited the degree of human disturbance to that site (Patterson 1982). The land is not under threat of subdivision or under recreational demand. Sheep from adjacent pastures have been observed in large numbers in the saltmarsh next to the oyster lease buildings (pers. obs.). Trampling and compaction of saltmarsh by sheep is thus a factor affecting shorebird habitat at the site. Patterson (1982) reports that the Salicornia sp. in that area is dying but that the cause is unknown.

Since Barilla Bay is surrounded by agricultural land, the site has the potential to be affected by agricultural runoff. The Tasmanian Department of the Environment monitors water quality at the site (Tasmania, Parliament, Department of the Environment Annual Reports), information essential to the aquaculture industry in the area.

Disturbance from the oyster lease at the site is due mostly to associated operations for gaining access to the oyster racks and to loose debris and unleashed dogs in the vicinity of the buildings (pers. obs.). The mudflats on the side of the spit with the oyster racks are not heavily used by shorebirds (Patterson, SSG, pers. comm.), and was only moderately used by shorebirds during the 1960s (Thomas, SSG, pers. comm.), suggesting that restricted use of vehicles in that area may not be detrimental.

Possibly the largest single factor affecting the conservation status of shorebird habitat at Barilla Bay is the site's proximity to the Hobart Airport. The problem of bird strikes at coastal airports has been well documented (Burger 1985; Australian Department of Transport 1977; CSIRO 1978), and flocking birds such as small shorebirds are particularly hazardous in that they may strike more than one engine of a plane (Burger 1985). The only solutions are habitat modification to decrease the carrying capacity of species that pose the greatest threat, and to physically decrease the numbers of birds in the area (Burger 1985). The Jerrabomberra Wetlands Ecological Study group in Canberra (NCDC 1982) suggested that management of shorebird habitat to increase species diversity without increasing abundance may be a satisfactory option.

In Tasmania in the early 1980s, a proposal was advanced to extend a Hobart Airport runway to accommodate larger planes for international flights. This was particularly attractive to the current state government as a means of increasing tourism. The extension would require the infilling of a substantial section of Barilla Bay. The Federal Government refused to extend financial support for the project, saying that the necessity for an international airport in Hobart had not been shown (Mercury, 21 February 1984), but the option for eventual runway extension has been left open should the project be reconsidered.

Patterson (1982) stated that Barilla Bay is "perhaps the least disturbed of the shorebird locations in Pittwater and the Derwent Estuary, but there is no guarantee that the situation will remain unaltered". This statement is particularly relevant now that Barilla Bay has been deleted from the Pittwater Nature Reserve proposal. Barilla Bay is practically a third discrete system within the Derwent and Pittwater estuaries. Some movement of shorebirds between sites does occur, but it is an important area for its own subset of shorebirds (Patterson, SSG, pers. comm.). It has been estimated that if the shorebird habitat at Barilla Bay were destroyed, South-east Tasmania would lose about 20% of its Eastern Curlew population, 20% of its Red-necked Stint population and about 33% of its Lesser Golden Plover population. In addition, it is one of the most important shorebird sites in South-east Tasmania for the Double-banded Plover. It is clear that although the shorebird habitat at Barilla Bay is not under continual human disturbance, it is under threat because of its uncertain future.

4.3.10 Five and Seven Mile Beaches

The two long sandy beaches on the Seven Mile Beach Peninsula, Five and Seven Mile Beaches, are mainly important as breeding and roosting habitat, particularly for Pied Oystercatchers, Red-capped Plovers and Hooded Plovers. The site has increased in importance to shorebirds over the past several years, particularly to Pied Oystercatchers (Fletcher and Newman, SSG, pers. comm.). In 1981, Seven Mile Beach was the only positively known breeding location in the Derwent Estuary region for Hooded Plovers (BOAT files). Tasmania holds a significant percentage of the national population of this native species, and may be the stronghold for the species (Newman and Patterson 1982; Newman 1982; Lane 1987).

The threats to the shorebird habitat on the Seven Mile Beach Peninsula are mostly from heavy recreational use of the area. Although considered a Protected Area, tourism and recreational uses are permitted, and there is currently a proposal to establish a marina and resort on the peninsula. The proposed development will increase the recreational demand already placed on the area. An equestrian centre is already located on the peninsula and horses are ridden on the beaches. Dogs are also exercised on the beaches. Roads and off-road vehicle tracks extend over most of the spit, and people on foot, on trail bikes, on horses and on bicycles have access to the entire coastline of the peninsula, despite signs prohibiting vehicles on the foreshore. The steep dunes towards the end of the spit are attractive as a destination to people in boats as well as on foot and in vehicles. The result is that there is no section of beach in the area that is not subject to disturbance, and therefore no area of guaranteed safety for breeding shorebirds.

4.3.11 Marion Bay

Shorebird habitat near Marion Bay (including that in the adjacent sheltered areas of Blackman Bay) is not under immediate threat from urban pressure, mainly because of its distance from the rapid growth area of the Hobart suburbs. However, several of the factors that impact negatively upon shorebird habitat are in effect at Marion Bay.

Between the 1971 and 1986 censuses, there was a 21.8% increase in population and a 41.2% increase in the number of dwellings in the collectors' districts adjacent to Marion Bay (see Table 3.1).

A small housing development is located at Marion Bay, directly behind the dunes at the base of the spit, next to the saltmarsh and mudflat area. Dogs and off-road vehicles, including trail bikes, are often observed on the grass and saltmarsh areas adjacent to the tidal mudflats (pers. obs.). The mudflats are an important feeding area for many species of shorebirds and the adjacent vegetated areas are a preferred feeding site of the Double-banded Plover. Other species use the vegetated areas as sheltered roosting sites.

Vehicles are often driven along the interface of the saltmarsh and mudflats by people collecting seaweed. Sheep graze in the adjacent dunes and on saltmarsh around Little Boomer in Blackman Bay. Cats have been observed occasionally in the dunes, but there is no documented evidence regarding disturbance to the shorebirds at Marion Bay by cats. Agricultural runoff may be affecting the water quality within Blackman Bay and the hindmarsh area of Marion Bay, but this has not been documented.

There was a proposed development at Boomer Island (actually a tombolo) in 1988 and recreational facilities, including a marina, were proposed for placement on and near saltmarsh used by shorebirds. At the time of writing, this development had not been approved.

CHAPTER 5: SHOREBIRDS IN SOUTH-EAST TASMANIA

Chapter four clearly demonstrated that factors which alter shorebird habitat are presently acting at the main shorebird sites within the South-east Tasmanian study area. This chapter discusses the types of shorebirds found in South-east Tasmania and their patterns of habitat utilization, including a statistical analysis of the utilization of these sites by shorebirds. Data are presented in the form of four standardized indices for one sampling period in the 1960s and another in the 1980s. Statistical methods were employed to investigate whether changes in each index had occurred at each site between the two sampling periods. A significant result indicated a change in utilization of a site by shorebirds. Observed changes in site utilization are then discussed in terms of habitat alteration at the various sites, to determine whether a relationship between the two can be established.

5.1 Three Categories of Shorebirds in South-east Tasmania

Three categories of shorebirds rely on the wetland habitat of South-east Tasmania: Palaearctic breeding species that spend their non-breeding season in the Southern Hemisphere; a New Zealand species which also spends the non-breeding season here; and resident species. The 13 most common shorebird species that can be found in the study area are listed in Appendix 4 with a summary of ecological information about each species. This appendix should be referred to for each of the following three sections, which describe the shorebirds of the study area.

5.1.1 Palaearctic Breeding Species

In addition to the species listed in Appendix 4, several other Palaearctic breeding species, such as the Ruddy Turnstone, Terek Sandpiper, Sharp-tailed Sandpiper, Oriental Plover, Mongolian Plover and Grey-tailed Tattler regularly spend the non-breeding season in south-eastern Tasmania, but in very small numbers. Altogether, individuals from 14 species of Palaearctic breeding shorebirds, primarily those of the families Charadriidae (Plovers) and Scolopacidae (Sandpipers) may spend the non-breeding season within the study area (Lane 1987). Several other species are also less frequent visitors.

Palaearctic breeding shorebirds breed in north-eastern Asia in a wide variety of habitats, including desert, tundra, taiga and grassland. Various populations migrate to wintering areas in the Southern Hemisphere for abundant seasonal food. Those species which visit Australia originate primarily in the Eastern Palaearctic region, while populations in the other zoogeographic regions migrate to places such as South America or South Africa.

The species which migrate to Tasmania for the austral summer range significantly in size, from the Red-necked Stint (length 130-160 mm, wing length 94-112 mm) to the Eastern Curlew (length 600-660 mm, wing length 290-338 mm) (Marchant et al. 1986)

The Red-necked Stint and Curlew Sandpiper differ slightly from the other Palaearctic breeding shorebirds in terms of migration behaviour. Adults arrive in Tasmania in September and depart in March and April. Juveniles (first year birds) arrive in October and November and may spend 18 months on the wintering grounds before returning for their first breeding season (Newman et al. 1986). The proportion of juveniles is greater in the Tasmanian Red-necked Stint and Curlew Sandpiper populations than in the Victorian populations. An hypothesis advanced to explain this situation is that when preferred feeding locations are filled, less experienced (younger) birds are displaced to alternate sites (Barter, Chairman AWSG, pers. comm.). It has been suggested that Tasmania provides alternate shorebird habitat within southern Australia, thus accounting for its disproportionate numbers of juvenile Red-necked Stint and Curlew Sandpiper. The high proportion of juveniles at alternate sites makes these sites particularly important for the future breeding stock of the species.

5.1.2 New Zealand Breeding Species

The Double-banded Plover, a species that breeds in New Zealand, is the only shorebird that crosses the Tasman Sea to spend its non-breeding season in Australia. This small shorebird breeds on beaches or on gravel bars along glacial rivers, and leaves New Zealand in July and August to winter in Australia (Lane 1987).

5.1.3 Tasmanian Resident Species

Five species from two families of shorebirds, Haematopodidae (oystercatchers) and Charadriidae (plovers), are resident species in South-east Tasmania. These five species utilize a wide range of habitats.

The Red-capped Plover can be found on a range of coastal and inland wetlands (Lane 1987). This species can breed at any time of the year, depending on environmental conditions (Favoloro 1949).

The Black-fronted Plover is found primarily on inland wetlands, including farm dams and small pools, and at similar coastal habitats. Both the Red-capped Plover and the Black-fronted Plover move towards the coast in the summer and during dry inland conditions, indicating the importance of coastal refuges in times of drought (Lane 1987).

The Hooded Plover occurs on ocean beaches.

The Pied Oystercatcher uses sandy beaches and mudflats and the Sooty Oystercatcher, while it often occurs in these habitats with the Pied Oystercatcher, is more likely to be found on rocky shores (Lane 1987).

As with all breeding birds, a major factor determining suitable breeding habitat is the availability of food when the chicks have hatched. The absence of disturbance and predators are also essential characteristics. During the winter, the resident species remain in Tasmania rather than migrating, indicating that the food supply is sufficient to support these species throughout the year.

5.2 Patterns in Site Utilization

5.2.1 Methods

Data on the use of the 11 important shorebird habitat sites in South-east Tasmania were analyzed to determine whether the total abundance, species richness or species diversity of shorebirds at each site had changed between a four year sampling period in the 1960s and another in the 1980s.

Three sources of data have been used in this study.

For eight of the 11 sites of shorebird habitat within the study area, data were collected on a monthly basis during the 1960s and 1980s. These data will form the basis of a statistical analysis to determine whether the numbers of shorebirds using the various sites have changed between the two sampling periods.

For the remaining three sites, data were collected on a regular basis only during the 1980s sampling period. Marion Bay and Mortimer Bay were censused monthly and Five and Seven Mile Beaches were censused less regularly. These data have not been analyzed statistically, but still provide valuable information over that short time period. Results for these sites will be presented with Summer and Winter Wader Count results.

All 11 sites have been censused annually since 1972 for Summer Wader Counts (SWCs), and twice annually since 1980, for Winter Wader Counts (WWCs). SWC and WWC data have not been dealt with statistically as the monthly data have been. Rather, these data provide additional information on trends in site utilization since they cover both the 1970s and the 1980s time periods. Summer and Winter Wader Count data will be considered for the complementary information they provide, but the main focus will be the monthly count data. Due to the emphasis placed on the monthly count information, the methods section first briefly explains the data collection for SWCs and WWCs, then the remainder of the section deals exclusively with monthly count data. SWC and WWC information is again addressed at the end of the results section.

DATA COLLECTION

Summer and Winter Wader Counts

These counts were carried out by members of the Shorebird Study Group (SSG) of the Bird Observers' Association of Tasmania (BOAT) in conjunction with national Summer and Winter Wader Counts organized by the Royal Australasian Ornithologists' Union (RAOU) and, since 1985, the Australasian Wader Studies Group (AWSG) of the RAOU. Summer Wader Counts were held during late January or early February, and WWCs were held during late June or early July. An official count day was set, and all sites were counted on that day on the best tide for observing the shorebirds at that site. For example, areas with extensive mudflats were counted as the tide began to ebb so that the birds were concentrated into surveyable areas. Since all sites within Tasmania were not censused concurrently, it is possible that birds had shifted between sites and were counted twice. By counting each area at the best possible time for that area, the counts reflect the likely number of birds to be found at a site under optimal conditions rather than an exact count of shorebirds in the region. This same system of counting has been employed for all monthly counts since 1973.

The above depends largely on the experience of each counter to know the optimal conditions for counting his or her area. Each site was surveyed at least once immediately before the official count day to get an idea of the locations that the birds were using within each site. Since the same people generally counted the same sites, they were well familiar with the areas, and this could be expected to add to the accuracy of the counts. All major shorebird resorts in South-east Tasmania were censused, as well as many areas that hold birds only periodically. Occasionally locations in other parts of the state were surveyed, depending on the availability of people to carry out the counts.

Monthly Counts - 1965-68 and 1981-84

The major shorebird sites in South-east Tasmania are shown in Figure 5-1. From 1964-69, D. G. Thomas conducted regular monthly counts, usually several times per month, at eight of these sites, indicated on Figure 5-1 with a •. Time constraints prevented all counts from being undertaken on the same day, but it was attempted to carry out all counts under optimal tidal conditions for observing shorebirds at each site. From mid-1980 to 1985 these same eight sites were monitored intensively by members of the SSG (Newman and Fletcher 1981), each of whom took responsibility for visiting and counting one or more sites at least once per month. Four consecutive years during each of these decades were chosen to make up two sampling periods for statistical examination of changes in site utilization.

The other three sites shown on Figure 5-1 were included in the 1980s monitoring effort.

A major impetus for the intensive monthly count program of the 1980s was the discovery that the distribution of shorebird species based on SWCs from 1974 to 1980 was quite different from the distribution reported by Thomas for 1964-69. The method of data collection was specifically intended to simulate Thomas', with a primary objective of determining whether the SWCs had been generating realistic figures for comparison with Thomas' data (Newman and Fletcher 1981). Consequently, each site was regularly counted by an individual familiar with the site under optimal tidal conditions for observing shorebirds at that location, and the two sampling periods to be compared here, ie the 1960s and the 1980s, are therefore assumed to be comparable in terms of the methodology used to collect the data.

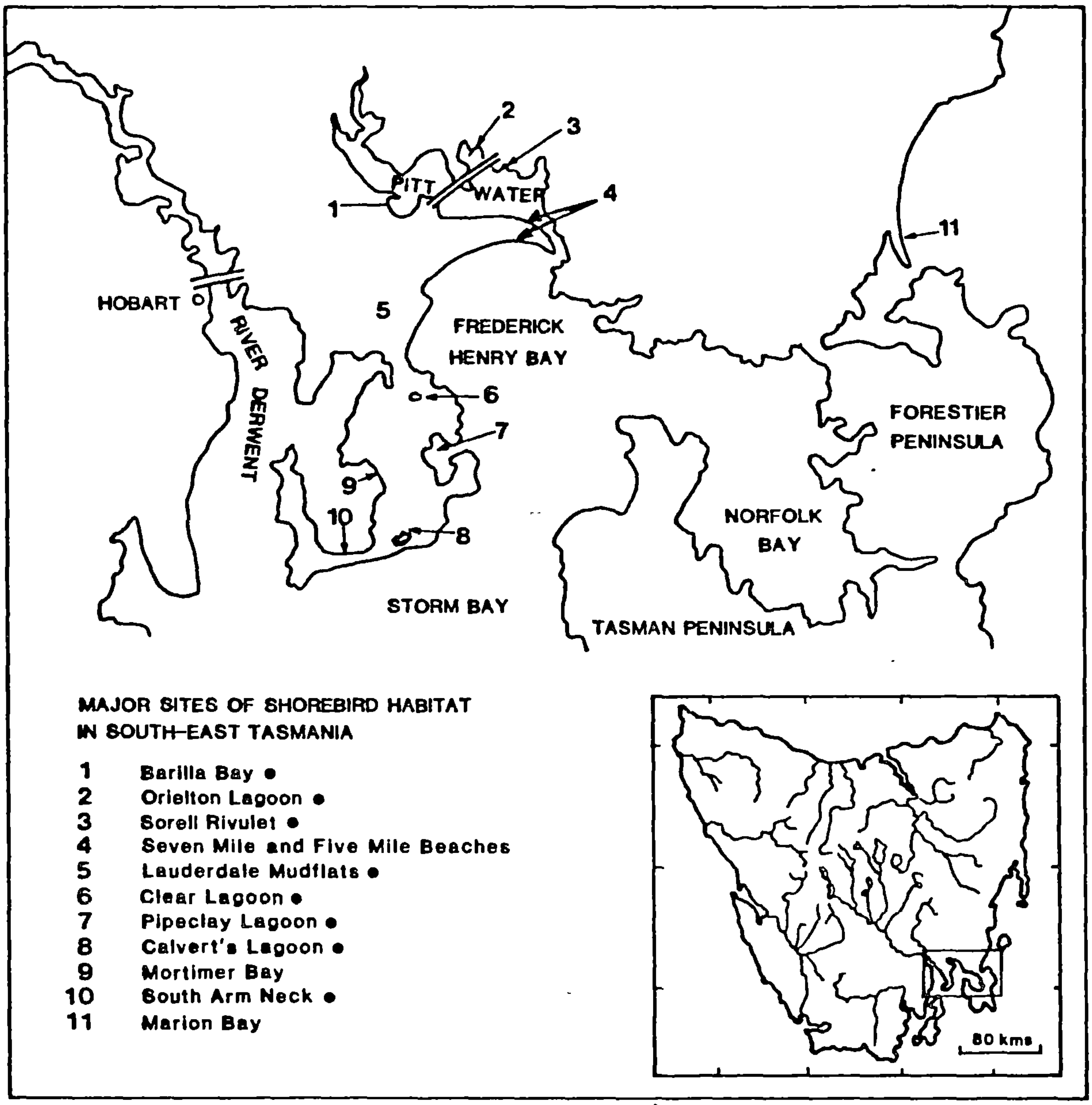

Figure 5.1: The Study Area: the eight sites counted in the 1960s sampling periods by David Thomas are marked with a ●.

DATA PROCESSING

Monthly Medians at Study Sites

The two data sets were analyzed to establish whether there was a change in site utilization by shorebirds between the two sampling periods, and whether any observed pattern in the use of a site over the course of a year - ie, the monthly pattern - had changed between the two sampling periods. To obtain this information, the raw data were processed into median numbers of shorebirds present (total abundance) and maximum numbers of species present (species richness) at each site. This was done for each month of each year of the two sampling periods.

Median numbers, rather than means or maxima, have been used in this study to reflect the most likely number of each species of shorebird that could be expected at a given site in a given month. Medians were considered to be the least artificial of these three population parameters, since many of the shorebird species tend to travel, arrive and depart in flocks. Therefore, out of five counts in which no individuals of species A were seen on four occasions and 500 were seen on the fifth, the median zero is a better reflection of the number of individuals of that species likely to be seen on a given visit than the mean of 100 or the maximum of 500. However, in the example cited above, if the median was calculated to be zero but the species had been sighted at that location during the month, the value was recorded as "0 (500)", indicating that while the median abundance was zero, for the purposes of calculating species richness (see "Standardization of Data") the species was noted as present at the site.

Tick Marks versus Actual Numbers

Occasionally during both sampling periods the individuals of a species would not be counted, but would be marked present by a tick for one of the monthly counts. This was considered to represent "1 plus" of that species present and was treated as a "1" in calculations, thereby recording the presence, but underestimating the abundance of that species. It was considered preferable to interpret a tick as the minimum amount of information available, and thus underestimate rather than bias the information by attempting to guess how many birds the tick may have represented. The use of tick marks versus actual numbers occurred at a similar level during both sampling periods, and thus it is unlikely that the results were skewed by this factor.

Incomplete Counts

The raw data from which medians were compiled included details on the locations which were censused within each site. A "complete count" meant that all shorebird habitat within the site was surveyed. An "incomplete count" meant either that the area was checked only for a few species or that not all the habitat was surveyed. The latter type of incomplete count has been included in the calculation of medians, on the reasonable assumption that the observers relied on extensive experience of their sites to know the locations the birds would seek under various field conditions (SSG pers. comm.). Incomplete counts of the former type were left out of median calculations unless there were no complete counts that month, and were noted accordingly. For example, if an area was only visited to see if Red-necked Stint and Curlew Sandpiper had arrived, and no other species were counted, the data were left out unless there were no other counts for that month. While there were more incomplete counts present in the 1980s data, the number of counts undertaken each month at sites where incomplete counts occurred was large enough that the exclusion of the incomplete counts probably introduced no significant bias into the results.

No Count versus "0"

At times no counts were made at an area during a month. Generally this meant that the site was not visited and therefore there were no data. Wetland sites with highly variable water conditions such as Clear Lagoon and Calverts Lagoon, however, were often dry or too full to provide feeding habitat during a number of months of the year. It should be noted that at times there were no recorded counts for those months, due to the unlikelihood that any shorebirds would have been present. Thus, the majority of these "no counts" (NC) would probably have been "zeros" if visits had been recorded, but were dealt with as "no counts".

An exception to this practice was made if there were no counts made at a site for a given month during each of the four years of that sampling period; for example, if the results for January in each year 1965 through 1968 were "NC", it was assumed that at least one of those "no counts" was a "0". Thus the sample size (number of years counted within the sampling period) was "1", but the value was "0". This assumption is reasonable since visits to the areas were often not recorded if found to be dry. It also gives a more realistic result than a sample size of "0", which indicates that the area was not visited, and therefore that no information was known about the site. The frequency of "no counts" in both the 1960s and 1980s data sets was similar enough that the bias introduced into the results was negligible.

STANDARDIZATION OF DATA

In order to compare shorebird use of the sites between the two sampling periods, the data were standardized into four indices. The indices used were Species Richness, Total Abundance I, Total Abundance II (excluding Red-necked Stint and Curlew Sandpiper), and Species Diversity. Except for Species Richness, which was based on maximum numbers of species observed, the indices were based on the median numbers of birds of each species calculated for each month of each of the eight years 1965-68 and 1981-84 at each site.

It is important to note that the term "index" is used to mean a standardized format which allows comparisons to be made. Of the four indices used here, all but the Species Diversity index were already in a standardized form. Total Abundance I, for example, was simply the median total abundance of birds recorded. Species Diversity was the only index used in which the data were manipulated for standardization.

THE INDICES

Appendix 5 gives an overview of the method used to standardize the data into a format appropriate for statistical analysis, and should be referred to for clarification of the following sections.

Total Abundance I

Total Abundance I is a measure of the likely total number of shorebirds that could be expected on a given visit to a given site. To obtain this index, the median number of each species present during each month, in January 1965 for example, was summed. This resulted in a median total abundance of all species during January 1965. The same process was carried out for each month of 1965. The process was repeated for each month of the years 1966-68, and 1981-84. The result was four values for median total abundance for each month of each year during the 1960s sampling period, and four values for each month of each year during the 1980s sampling period. These data were then analyzed for changes in the number of shorebirds of all species which are likely to be observed at each site during each month between the 1960s and 1980s sampling periods.

Total Abundance II

Total Abundance was recalculated excluding count data for Curlew Sandpiper and Red-necked Stint. This procedure was required due to the large numbers of individuals and the substantial increase in numbers of these two species (Thomas 1987), and therefore the potential for these to mask subtle changes in total abundance of less numerous species. For example, it is not uncommon for these two species to make up >95% of a count at some sites during the summer.

Species Richness

Values of Species Richness were obtained by taking the maximum count of the number of species during one visit to a site during a given month of a given year.

Maximum Species Richness was not based on the median numbers calculated. This index is a measure of the maximum number of shorebird species observed to be using a site during a given month, rather than a measure of the number of species present at a given time. In a case where the median Total Abundance of a species may have been zero, that species may have occurred at the site in question during that month, but too infrequently for it to be expected at the site during that month. The previously given example of five counts in which the number of species A was 0,0,0,0 and 500 individuals should be recalled. The median of zero best describes the likelihood of the number of individuals to be expected there, but the value for Species Richness has been considered "1", to reflect maximum Species Richness.

Species Diversity

Species Diversity was calculated using the Shannon-Wiener index of diversity as shown (Zar 1974):

$$H = \frac{n \log n - \sum_{i=1}^{k} f_i \log f_i}{n}$$

where n = the sample size = the number of counts made at a give site during a given month of a given year
f = the number of observations in each category = the species totals from each of those counts
k = the number of categories = the number of species for which total observations were made during that month

Species Diversity is a measure of even-ness. This index takes the number of species as well as the abundance of each species into consideration. The more even the distribution of numbers between species, the higher the index value. Values range from 0.000 representing no diversity to a maximum diversity at 1.000. A site with five species, and 20 individuals of each, would have a higher diversity index value than a site with five species, and 96 individuals of species A and only one of each of the other four species. A site with 100 individuals of each of four species and 1500 of a fifth species would also have low diversity, even though the total abundance was high. Thus, the Species Diversity index must be put into context by being used in conjunction with indices of total abundance and species richness, as a means of expanding available information or giving an additional context to the results. Its usefulness lies in its ability to bring out patterns in Species Richness and Total Abundance in combination. It should be recognized that huge numbers of one or two species depresses the diversity values obtained.

Median numbers of abundance were used in calculating Species Diversity. A case such as the one described earlier where Total Abundance equals zero, but the presence of the species was noted, ie, 0(500), presents a mathematical difficulty. The formula would not work for input where total abundance equalled zero with a species richness of "1" (presence), since log "0" = error. These values were excluded from the calculations. The alternative would have been to consider Total Abundance as "1" and Species Richness as "1". This would have overestimated Total Abundance and the previous explanation justifying the use of the median again applies. In this situation, with a median Total Abundance of "0", the species occurred in such low numbers or so infrequently that it could not be expected at a given time at a given site.

Monthly counts in which two or more species were recorded only with a tick were disregarded (considered "NC") in calculations as they artificially lowered the values for species diversity quite substantially. They obviously lowered total abundance also, but not as critically as the more sensitive diversity index.

It cannot be stressed too strongly that the Species Diversity index is only useful within a carefully defined context. Species Diversity has been used in other studies as an indicator of conservation significance of a site, for example, for concluding that sites with high diversity have a greater importance for conservation than those with lower diversity (Fuller 1980; Margules and Usher 1981). This use of Species Diversity as an evaluation criterion for ranking areas for their conservation value has been criticized (Gotmark et al. 1986). In this study, however, the Species Diversity index was not used to compare sites. Rather, it was used to compare Species Diversity at the same site between two time periods. Therefore, it provided additional information about what has happened in terms of site utilization at each site between the 1960s and 1980s sampling periods.

Species Richness was also used in this context. Margules and Usher (1981) state that since Species Richness is sample size dependent, "it should not be used uncritically to compare sites unless sample size is equal". The use of Species Richness in this study was not to compare sites, but rather to highlight changes within sites between two sampling periods.

DATA ANALYSIS

The statistical computer software package "BIOΣTAT" was employed to examine the four indices. Specifically, AOV 2-3 was used, a program that performs a Model I 2- or 3- way analysis of variance (ANOVA) for cases with equal or unequal sample sizes (Pimentel and Smith 1986).

Each of the four indices was examined using a 3-way ANOVA, which analyzed the 8 sites, 12 months and 2 time periods of the data sets as well as interactions between these three variables.

The data for each site were then examined using a 2-way ANOVA for each site searching for significant changes in total abundance at each site between the two sampling periods.

For each of the four indices, for each site, the null hypotheses for the ANOVAs were as follows:

(i) There was no difference in Species Richness (or Total Abundance I, or Total Abundance II, or Species Diversity) between the 1960s and 1980s sampling periods (or if there was any difference, then it occurred due to chance).

Rejection of this hypothesis would mean acceptance of the alternative hypothesis, that the index in question did indeed differ between the two sampling periods.

(ii) There was no difference in Species Richness (or Total Abundance I, or Total Abundance II, or Species Diversity) between months (or if there was any difference, then it occurred due to chance).

Rejection of this hypothesis would mean acceptance of the alternative hypothesis, that the index in question did indeed differ between months - ie, that there was a monthly pattern in that index.

(iii) There was no difference in the monthly pattern of Species Richness (or Total Abundance I, or Total Abundance II, or Species Diversity) between the two sampling periods (or if there was any difference, then it occurred due to chance).

Rejection of this hypothesis would mean acceptance of the alternative hypothesis, that the monthly pattern of the index in question did indeed differ between the two sampling periods.

Bartlett's test for homogeneity of variance was used to determine whether a data transformation was necessary to correct departures from homogeneity in the original data. The test was done with the computer software package BIOΣTAT HOV (Pimental and Smith 1986). ANOVA assumptions and data transformations are discussed in Sokal and Rohlf (1981, pp. 400-428) and Zar (1974, pp. 182-185).

The premise of Bartlett's test is to test the null hypothesis that all population variances are equal, and acceptance of the null hypothesis indicates that the variances are equal at the 5% level of significance. When the data were examined for homogeneity of variance (homoschedasticity), the Species Richness data fitted well. Abundance data, however, were found to be non-homoschedastic, and a log transformation [log 10 (X+1)] was applied to the data for Total Abundance I, Total Abundance II and Species Diversity. The transformation brought the Chi-square value within an acceptable level to indicate that the variances were equal.

It should be stressed at this point that in the results section, tables will present the transformed values for data, where transformation has been applied. Figures, however, will be based on actual values since the same trends are present in both data sets.

5.2.2 Results

The use of ANOVA in this study provided a powerful method for determining changes in site utilization. It also generated a huge quantity of information to be summarized into a readable and lucid results section. The following format has been adopted to structure this large volume of data:

ANOVA RESULTS FOR MONTHLY COUNT DATA, 2 SAMPLING PERIODS

RESULTS BY INDEX

(FOR EACH INDEX)

3-WAY ANOVA RESULTS -

FOR SAMPLING PERIOD

FOR SITE / SAMPLING PERIOD INTERACTION

2-WAY ANOVA RESULTS:

CHANGES AT SITES

BETWEEN SAMPLING PERIODS

IN MONTHLY VARIATION

IN MONTHLY VARIATION BETWEEN SAMPLING PERIOD

RESULTS BY SITE

(FOR EACH SITE)

SPECIES RICHNESS RESULTS

TOTAL ABUNDANCE I RESULTS

TOTAL ABUNDANCE II RESULTS

SPECIES DIVERSITY RESULTS

SUMMER AND WINTER WADER COUNT RESULTS

SUMMARY OF RESULTS

Probability levels will follow the pattern set out in Table 5-1. Probability levels, degrees of freedom and F-ratios are presented in the tables of results rather than in the text to facilitate readability.

Table 5-1: Key to probability levels

NS	0.05	$< p$
*	0.01	$< p < 0.05$
**	0.001	$< p < 0.01$
***		$p < 0.001$

ANOVA RESULTS FOR MONTHLY COUNT DATA, 2 SAMPLING PERIODS

RESULTS BY INDEX

3-way ANOVA Results

The 3-way ANOVA analyzed data for site, sampling period and monthly variation as well as all possible interactions between those three variables, for each of the four indices. Two of the seven possible combinations are of interest to this study.

The first was as to whether, within the entire study area (with no breakdown into individual sites), there was a significant change in any index between the two sampling periods (source B data). The results based on this source of data are given in Table 5-2. Complete statistical results for the 3-way ANOVA are presented, for reference, in Appendix 6.

The results in Table 5-2 indicate that Species Richness declined significantly within the study area and that Total Abundance I and Total Abundance II increased significantly within the study area between the two sampling periods. There was no significant change in Species Diversity.

The second was as to whether any of the sites had exhibited a significant change in any of the indices between the two sampling periods, in other words whether the interaction between the sites and the sampling periods (source AB) were significant for each of the indices. The results are given in Table 5-3 (compiled from source AB in the complete 3-way ANOVA results presented in Appendix 6).

The results in Table 5-3 indicate that for each index, there were changes at some of the sites between the two sampling periods. Figure 5-2 illustrates the change in Species Richness at each site between the two sampling periods. Figure 5-3 represents the same information for Total Abundance I, Figure 5-4 for Total Abundance II and Figure 5-5 for Species Diversity. Table 5-4 gives the group mean values upon which the histograms (Figures 5-2 to 5-5) are based. It should be noted that the histograms are based upon non-transformed data.

Each change in each index at each site will be addressed specifically in the next section.

2-way ANOVA Results

Tables 5-5 to 5-16 give the abbreviated statistical results of the 2-way ANOVAs performed on each index, for each site. The complete ANOVA tables are presented in Appendix 7.

Tables 5-5, 5-6 and 5-7 give the abbreviated 2-way ANOVA results for Species Richness at each site.

Table 5-5 depicts changes in Species Richness at each site between the 1960s and 1980s sampling periods. Lauderdale, South Arm Neck, Sorell, Clear Lagoon and Barilla Bay experienced significant decreases in Species Richness. Species Richness increased significantly at Calverts Lagoon, but no significant changes occurred at Pipeclay Lagoon or Orielton Lagoon.

Table 5-2: 3-way ANOVA results summarizing changes within the study area in each of 4 indices between 2 sampling periods (compiled from Source B, Appendix 6).

Index	Data Transformation	Group Means 1960s	Group Means 1980s	F-Ratios	Probability Levels (DF=1)	Relative Change
Species Richness	none	6.024	5.594	9.605	* *	(-)
Total Abundance I	log 10 (X+1)	1.983	2.141	21.254	* * *	(+)
Total Abundance II	log 10 (X+1)	1.579	1.748	28.913	* * *	(+)
Species Diversity	log 10 (X+1)	0.130	0.133	0.578	NS	(=)

Table 5-3: 3-way ANOVA results summarizing results of interactions between 8 sites and 2 sampling periods in each of 4 indices (compiled from Source AB, Appendix 6).

Index	Data Transformation	F-Ratio	Probability Levels (DF=7)
Species Richness	none	10.636	* * *
Total Abundance I	log 10 (X+1)	49.302	* * *
Total Abundance II	log 10 (X+1)	22.812	* * *
Species Diversity	log 10 (X+1)	12.941	* * *

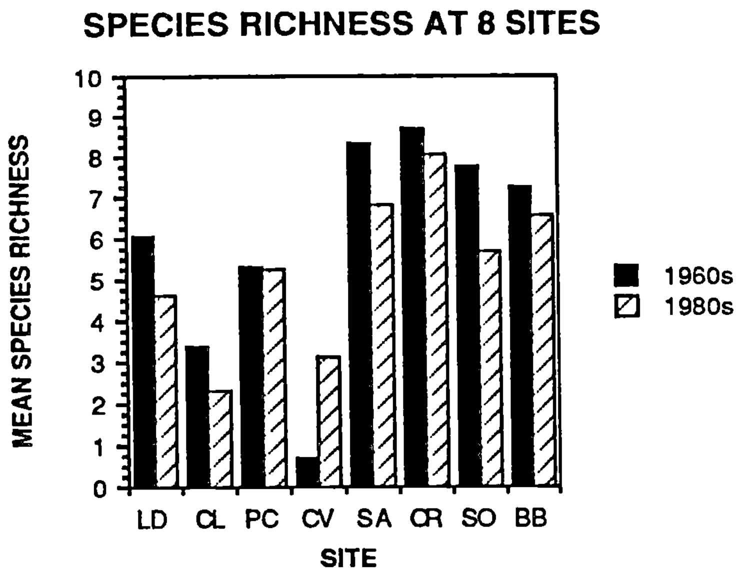

Figure 5.2: Changes in Species Richness between the 1960s and 1980s sampling periods at the eight sites.

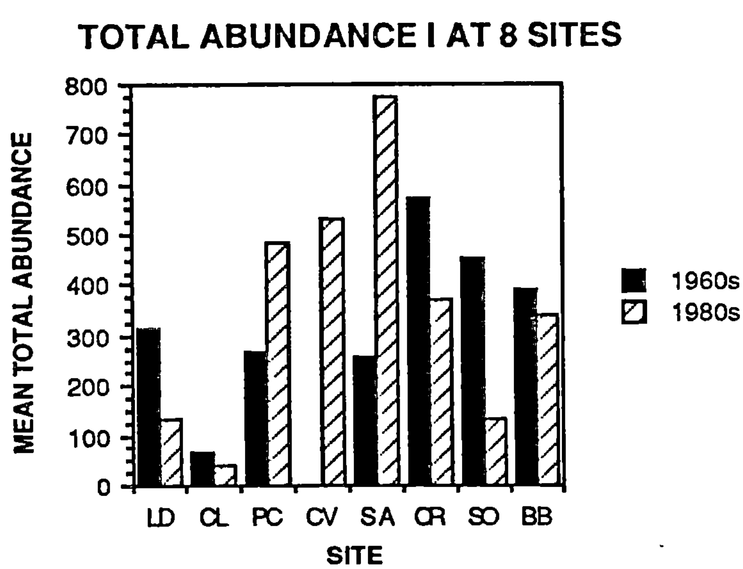

Figure 5.3: Changes in Total Abundance I between the 1960s and 1980s sampling periods at the eight sites.

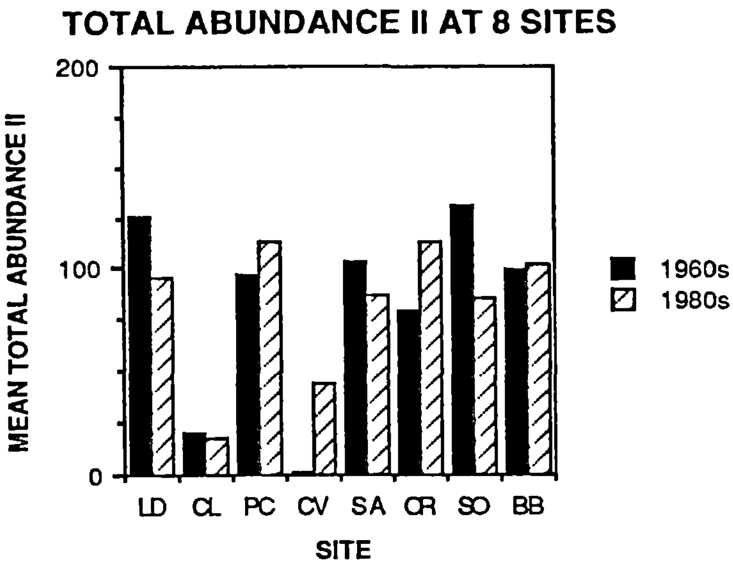

Figure 5.4: Changes in Total Abundance II between the 1960s and 1980s sampling periods at the eight sites.

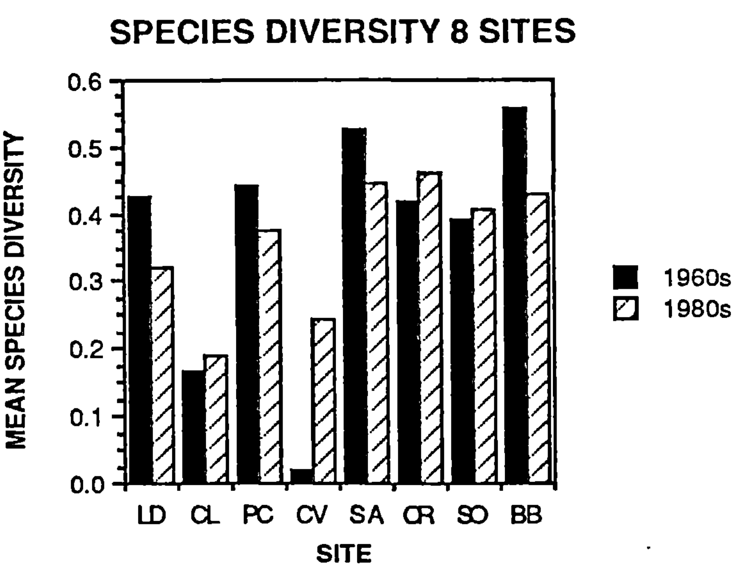

Figure 5.5: Changes in Species Diversity between the 1960s and 1980s sampling periods at the eight sites.

Table 5-4: Group mean values for each of 4 indices, based on non-transformed data for the interaction between site and sampling period (Source AB, 3-way ANOVA).

SITE	SPECIES RICHNESS		TOTAL ABUNDANCE I		TOTAL ABUNDANCE II		SPECIES DIVERSITY	
	GROUP MEAN 1960s	GROUP MEAN 1980s	GROUP MEAN 1960s	GROUP MEAN 1980s	GROUP MEAN 1960s	GROUP MEAN 1980s	GROUP MEAN 1960s	GROUP MEAN 1980s
LAUDERDALE	6.068	4.604	312.341	133.490	125.864	95.562	0.425	0.321
CLEAR LAGOON	3.386	2.310	67.114	40.900	20.216	17.103	0.167	0.188
PIPECLAY LAGOON	5.333	5.256	267.885	484.346	97.451	113.141	0.442	0.377
CALVERTS LAGOON	0.711	3.136	1.961	533.023	1.158	43.795	0.020	0.243
SOUTH ARM	8.289	6.824	259.511	775.176	103.156	86.311	0.525	0.444
ORIELTON LAGOON	8.690	8.085	572.726	371.766	79.500	112.838	0.417	0.460
SORELL	7.773	5.688	455.948	132.833	130.750	86.031	0.391	0.405
BARILLA BAY	7.233	6.563	393.558	340.708	99.826	101.51	0.556	0.428

TABLE 5-5: Significance of change in Species Richness between the 1960s and 1980s sampling periods at each of 8 sites (compiled from Appendix 7, Source A for each site).

SITE	GROUP MEAN 1960s	GROUP MEAN 1980s	F-RATIO	PROBABILITY LEVELS (DF=1)	RELATIVE CHANGE
LAUDERDALE	6.068	4.604	20.717	* * *	(-)
CLEAR LAGOON	3.386	2.310	4.643	*	(-)
PIPECLAY LAGOON	5.333	5.256	0.056	NS	(=)
CALVERTS LAGOON	0.711	3.136	46.853	* * *	(+)
SOUTH ARM	8.289	6.824	13.259	* * *	(-)
ORIELTON LAGOON	8.690	8.085	2.010	NS	(=)
SORELL	7.773	5.688	19.375	* * *	(-)
BARILLA BAY	7.233	6.563	5.882	*	(-)

TABLE 5-6: Significance of monthly variation in Species Richness over 12 months at each of 8 sites (compiled from Appendix 7, Source B for each site).

SITE	F-RATIO	PROBABILITY LEVELS (DF=11)
LAUDERDALE	1.396	NS
CLEAR LAGOON	1.449	NS
PIPECLAY LAGOON	2.545	*
CALVERTS LAGOON	0.480	NS
SOUTH ARM	4.757	* * *
ORIELTON LAGOON	11.082	* * *
SORELL	2.729	* *
BARILLA BAY	3.865	* * *

TABLE 5-7: Significance of changes in Species Richness in the interaction between sampling period and monthly variation, between the 1960s and 1980s sampling periods at each of 8 sites (compiled from Appendix 7, Source AB for each site).

SITE	F-RATIO	PROBABILITY LEVELS (DF=11)
LAUDERDALE	0.721	NS
CLEAR LAGOON	1.201	NS
PIPECLAY LAGOON	0.976	NS
CALVERTS LAGOON	1.792	NS
SOUTH ARM	1.735	NS
ORIELTON LAGOON	1.825	NS
SORELL	2.920	* *
BARILLA BAY	0.965	NS

Table 5-6 depicts whether each study site experienced monthly variation in Species Richness over the 12 months of a year, ie whether there was a monthly pattern in Species Richness at any of the sites. South Arm Neck, Orielton Lagoon, Barilla Bay, Sorell and Pipeclay Lagoon all exhibited significant monthly variation. Lauderdale, Clear Lagoon and Calverts Lagoon did not exhibit significant variation between months, indicating no detectable monthly patterns in Species Richness at these sites.

Table 5-7 gives results of the interaction between sampling period and monthly variation for Species Richness for each of the eight sites. This illustrates whether there has been a change in the monthly pattern of utilization between the two sampling periods. Of the eight sites, only Sorell showed a significant change in the monthly pattern of Species Richness between the 1960s and 1980s.

Total Abundance I

Tables 5-8, 5-9 and 5-10 give the abbreviated 2-way ANOVA results for Total Abundance I at each site.

Table 5-8 depicts changes in Total Abundance I at each site between the 1960s and 1980s sampling periods. Total Abundance I decreased significantly at Lauderdale, Sorell and Orielton Lagoon. South Arm Neck, Calverts Lagoon and Pipeclay Lagoon showed a significant increase in this index. No significant change in Total Abundance I occurred at Clear Lagoon or Barilla Bay between the two sampling periods.

Table 5-9 shows that Pipeclay Lagoon, South Arm Neck, Orielton Lagoon, Sorell and Barilla Bay all exhibited significant monthly variation over the 12 months of a year. Lauderdale, Clear Lagoon and Calverts Lagoon did not exhibit significant variation between months, indicating was no significant monthly pattern in Total Abundance I at these sites.

Table 5-10 gives results of the interaction between sampling period and monthly variation for Total Abundance I for each of the eight sites. This indicates whether there has been a change in the monthly pattern of utilization between the two sampling periods. Of the eight sites, only Calverts Lagoon showed a significant change in the monthly pattern, and this change was highly significant.

Total Abundance II

Tables 5-11, 5-12 and 5-13 give the abbreviated 2-way ANOVA results for Total Abundance II at each site.

Table 5-11 depicts changes in Total Abundance II at each site between the 1960s and 1980s sampling periods. There was a significant increase in Total Abundance II at Calverts Lagoon and a significant decrease at South Arm Neck. At all other sites, there were no significant changes.

TABLE 5-8: Significance of change in Total Abundance I between the 1960s and 1980s sampling periods at each of 8 sites (compiled from Appendix 7, Source A for each site).

SITE	GROUP MEAN 1960s	GROUP MEAN 1980s	F-RATIO	PROBABILITY LEVELS (DF=1)	RELATIVE CHANGE
LAUDERDALE	2.449	2.072	64.082	* * *	(-)
CLEAR LAGOON	1.330	1.077	1.970	NS	(=)
PIPECLAY LAGOON	2.330	2.522	8.175	* *	(+)
CALVERTS LAGOON	0.167	2.151	200.301	* * *	(+)
SOUTH ARM	2.331	2.616	15.091	* * *	(+)
ORIELTON LAGOON	2.388	2.165	5.529	*	(-)
SORELL	2.239	1.914	9.812	* *	(-)
BARILLA BAY	2.445	2.426	0.105	NS	(=)

TABLE 5-9: Significance of monthly variation in Total Abundance I over 12 months at each of 8 sites (compiled from Appendix 7, Source B for each site).

SITE	F-RATIO	PROBABILITY LEVELS (DF=11)
LAUDERDALE	0.962	NS
CLEAR LAGOON	1.260	NS
PIPECLAY LAGOON	5.493	* * *
CALVERTS LAGOON	1.689	NS
SOUTH ARM	5.147	* * *
ORIELTON LAGOON	14.927	* * *
SORELL	3.904	* * *
BARILLA BAY	5.778	* * *

TABLE 5-10: Significance of changes in Total Abundance I in the interaction between sampling period and monthly variation, between the 1960s and 1980s sampling periods at each of 8 sites (compiled from Appendix 7, Source AB for each site).

SITE	F-RATIO	PROBABILITY LEVELS (DF=11)
LAUDERDALE	0.721	NS
CLEAR LAGOON	1.401	NS
PIPECLAY LAGOON	1.388	NS
CALVERTS LAGOON	3.896	* * *
SOUTH ARM	1.459	NS
ORIELTON LAGOON	0.539	NS
SORELL	1.567	NS
BARILLA BAY	0.477	NS

TABLE 5-11: Significance of change in Total Abundance II between the 1960s and 1980s sampling periods at each of 8 sites (compiled from Appendix 7, Source A for each site).

SITE	GROUP MEANS 1960s	GROUP MEANS 1980s	F-RATIO	PROBABILITY LEVELS (DF=1)	RELATIVE CHANGE
LAUDERDALE	1.977	1.955	0.160	NS	(=)
CLEAR LAGOON	1.023	0.883	0.894	NS	(=)
PIPECLAY LAGOON	1.745	1.915	2.737	NS	(=)
CALVERTS LAGOON	0.148	1.439	122.729	* * *	(+)
SOUTH ARM	1.983	1.746	5.458	*	(-)
ORIELTON LAGOON	1.707	1.815	1.427	NS	(=)
SORELL	1.925	1.822	1.961	NS	(=)
BARILLA BAY	1.949	1.932	0.208	NS	(=)

TABLE 5-12: Significance of monthly variation in Total Abundance II over 12 months at each of 8 sites (compiled from Appendix 7, Source B for each site).

SITE	F-RATIO	PROBABILITY LEVELS (DF=11)
LAUDERDALE	4.806	* * *
CLEAR LAGOON	0.846	NS
PIPECLAY LAGOON	4.500	* * *
CALVERTS LAGOON	1.355	NS
SOUTH ARM	0.794	NS
ORIELTON LAGOON	4.077	* * *
SORELL	3.870	* * *
BARILLA BAY	8.398	* * *

TABLE 5-13: Significance of changes in Total Abundance II in the interaction between sampling period and monthly variation, between the 1960s and 1980s sampling periods at each of 8 sites (compiled from Appendix 7, Source AB for each site).

SITE	F-RATIO	PROBABILITY LEVELS (DF=11)
LAUDERDALE	1.529	NS
CLEAR LAGOON	1.543	NS
PIPECLAY LAGOON	1.338	NS
CALVERTS LAGOON	1.901	NS
SOUTH ARM	0.385	NS
ORIELTON LAGOON	1.413	NS
SORELL	2.540	* *
BARILLA BAY	1.415	NS

Table 5-12 shows that Lauderdale, Pipeclay Lagoon, Orielton Lagoon, Sorell and Barilla Bay all exhibited significant monthly variation over the 12 months of a year. Results for Clear Lagoon, Calverts Lagoon and South Arm Neck were not significant.

Table 5-13 gives results of the interaction between sampling period and monthly variation for Total Abundance II for each of the eight sites. This illustrates whether there has been a change in the monthly pattern of utilization between the two sampling periods. Of the eight sites, only Sorell exhibited a significant change in the monthly pattern of Total Abundance II between the 1960s and 1980s.

Species Diversity

Tables 5-14, 5-15 and 5-16 give the abbreviated 2-way ANOVA results for Species Diversity at each site.

Table 5-14 depicts changes in Species Diversity at each site between the 1960s and 1980s sampling periods. Lauderdale, Barilla Bay, South Arm Neck and Pipeclay Lagoon experienced significant decreases in Species Diversity. Calverts Lagoon experienced a significant increase in Species Diversity. No significant changes occurred at Clear Lagoon, Orielton Lagoon or Sorell

Table 5-15 shows that Lauderdale, Pipeclay Lagoon, Sorell and Barilla Bay all exhibited significant variation over the 12 months of a year. Clear Lagoon, Calverts Lagoon, South Arm Neck and Orielton Lagoon did not exhibit significant variation between months, indicating no detectable monthly patterns in Species Diversity at the sites.

Table 5-16 gives the results of the sampling period and monthly variation for Species Diversity for each of the eight sites. This indicates whether there has been a change in the monthly pattern of utilization between the two sampling periods. Orielton Lagoon, Lauderdale, Barilla Bay and Calverts Lagoon exhibited a significant change in monthly variation. Clear Lagoon, Pipeclay Lagoon, South Arm Neck and Sorell exhibited no significant change.

RESULTS BY SITE

Tables 5-5 to 5-16 are the relevant tables for this section, also, as they present the statistical information for each site for the various indices. Appendix 7 presents this same data in its original format by site and index. Figures 5-6 to 5-13 illustrate, in graph form, changes in each index between the 1960s and 1980s sampling periods, monthly patterns of utilization for each index for each site and changes in those patterns of utilization between the two sampling periods. For example, Figure 5-6 as a whole presents the information for Lauderdale, within which Figure 5-6a shows Species Richness, 5-6b shows Total Abundance I, Figure 5-6c shows Total Abundance II and Figure 5-6 shows Species Diversity. For each figure

TABLE 5-14: Significance of change in Species Diversity between the 1960s and 1980s sampling periods at each of 8 sites (compiled from Appendix 7, Source A for each site).

SITE	GROUP MEANS 1960s	GROUP MEANS 1980s	F-RATIO	PROBABILITY LEVELS (DF=1)	RELATIVE CHANGE
LAUDERDALE	0.151	0.118	16.799	* * *	(-)
CLEAR LAGOON	0.064	0.069	0.123	NS	(=)
PIPECLAY LAGOON	0.155	0.136	6.957	*	(-)
CALVERTS LAGOON	0.008	0.091	2.377	* * *	(+)
SOUTH ARM	0.182	0.158	9.630	* *	(-)
ORIELTON LAGOON	0.149	0.159	0.958	NS	(=)
SORELL	0.139	0.145	0.236	NS	(=)
BARILLA BAY	0.191	0.152	31.884	* * *	(-)

TABLE 5-15: Significance of monthly variation in Species Diversity over 12 months at each of 8 sites (compiled from Appendix 7, Source B for each site).

SITE	F-RATIO	PROBABILITY LEVELS (DF=11)
LAUDERDALE	16.799	* * *
CLEAR LAGOON	1.256	NS
PIPECLAY LAGOON	14.979	* * *
CALVERTS LAGOON	1.313	NS
SOUTH ARM	0.886	NS
ORIELTON LAGOON	1.895	NS
SORELL	2.097	*
BARILLA BAY	5.335	* * *

TABLE 5-16: Significance of changes in Species Diversity in the interaction between sampling period and monthly variation, between the 1960s and 1980s sampling periods at each of 8 sites (compiled from Appendix 7, Source AB for each site).

SITE	F-RATIO	PROBABILITY LEVELS (DF=11)
LAUDERDALE	2.544	* *
CLEAR LAGOON	0.811	NS
PIPECLAY LAGOON	1.304	NS
CALVERTS LAGOON	2.377	*
SOUTH ARM	1.076	NS
ORIELTON LAGOON	4.364	* * *
SORELL	0.644	NS
BARILLA BAY	3.108	* *

in this series, a,b,c and d always relate to the indices in this same order. The figures are based on the data values before log transformation was applied.

LAUDERDALE

There was a significant decrease in Species Richness at Lauderdale (Figure 5-6a) between the 1960s and 1980s sampling periods. The site did not exhibit a significant monthly pattern of Species Richness nor did the monthly pattern of Species Richness change significantly between the two sampling periods.

Total Abundance I at Lauderdale (Figure 5-6b) also decreased significantly. There was no significant monthly pattern of Total Abundance I, nor was there a significant change in monthly pattern between the 1960s and 1980s sampling periods.

Total Abundance II at Lauderdale (Figure 5-6c) did not change significantly between the two sampling periods. The site did exhibit significant monthly variation in Total Abundance II, which peaked during the winter months, and the change in the pattern of that variation between the 1960s and 1980s was not statistically significant.

There was a significant decrease in Species Diversity (Figure 5-6d) between the two sampling periods. Lauderdale exhibited significant monthly variation in Species Diversity, with maximum Species Diversity during the winter months, and a lower peak in that index in early summer, and a significant change in that monthly pattern between the two sampling periods.

CLEAR LAGOON

Clear Lagoon exhibited a significant decrease in Species Richness (Figure 5-7a) between the two sampling periods. This was the only significant change in any of the indices for Clear Lagoon (see Figures 5-7a to 5-7d).

PIPECLAY LAGOON

There was no significant change in Species Richness at Pipeclay Lagoon (Figure 5-8a) between the 1960s and 1980s sampling periods. The site did exhibit a significant monthly pattern in Species Richness, with slightly higher Species Richness during the late summer. There was no significant change in the monthly pattern of Species Richness between the two sampling periods.

Pipeclay Lagoon experienced a significant increase in Total Abundance I between the 1960 and 1980s sampling periods, and the graph for this index (Figure 5-8b) indicates that the increase was primarily during the summer months. Pipeclay Lagoon exhibited significant monthly variation in Total Abundance I but the change in the monthly pattern of utilization between the 1960s and 1980s sampling periods was not significant.

Fig. 5-7c: Total Abundance II

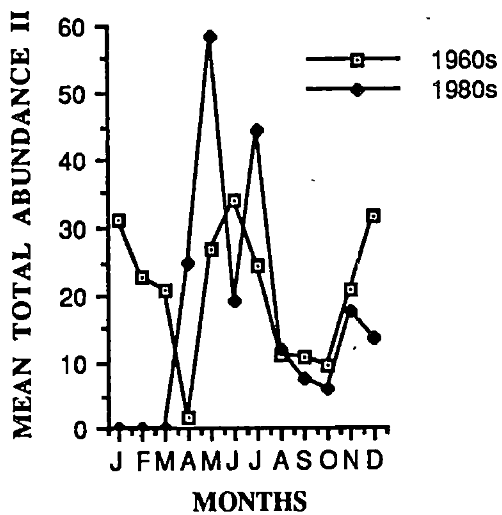

Fig. 5-7d: Species Diversity

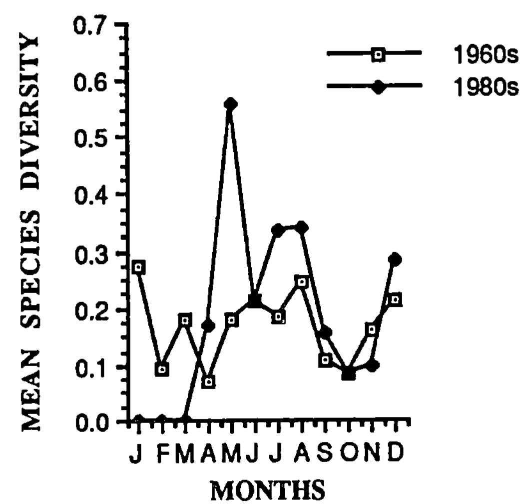

Figure 5.7c: Total Abundance II at Clear Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Figure 5.7d: Species Diversity at Clear Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-7a: Species Richness

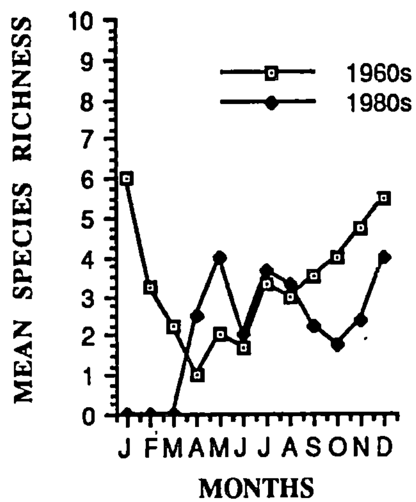

Fig. 5-7b: Total Abundance I

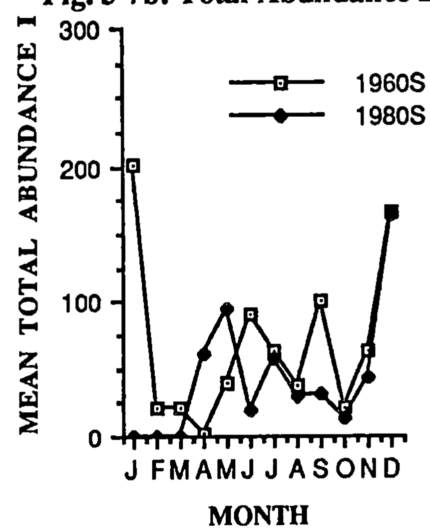

Figure 5.7a: Species Richness at Clear Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Figure 5.7b: Total Abundance I at Clear Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-6c: Total Abundance II

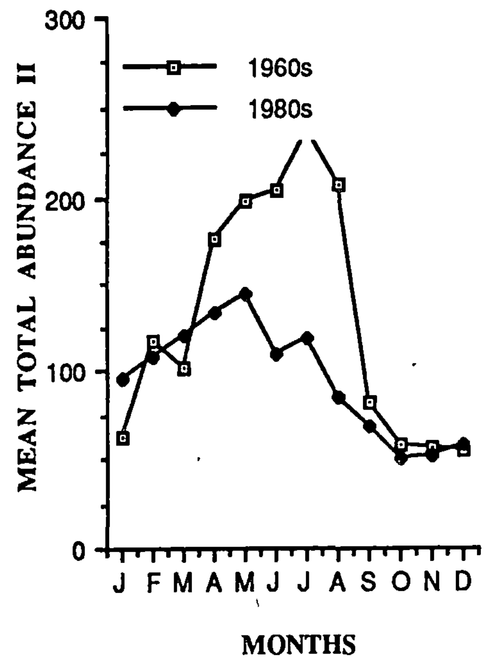

Figure 5.6c: Total Abundance II at Lauderdale based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-6d: Species Diversity

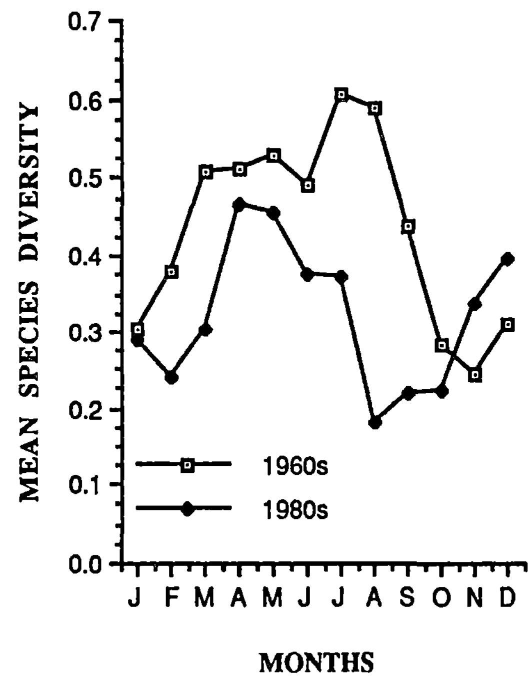

Figure 5.6d: Species Diversity at Lauderdale based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-6a: Species Richness

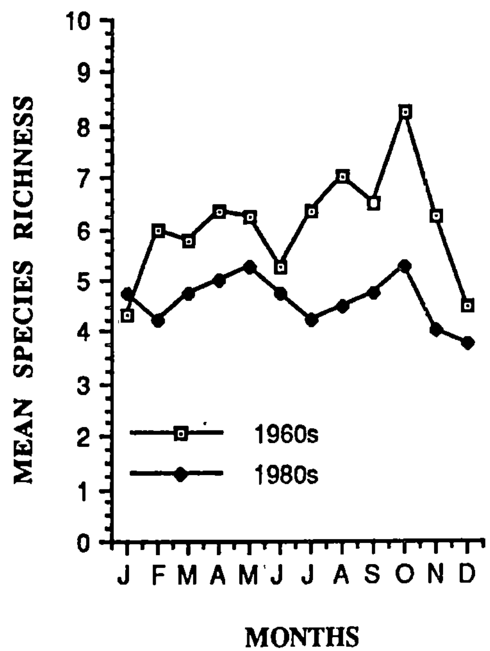

Figure 5.6a: Species Richness at Lauderdale based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-6b: Total Abundance I

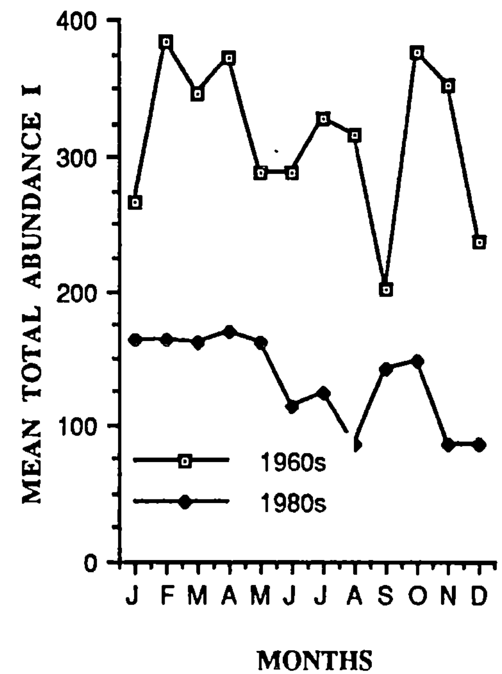

Figure 5.6b: Total Abundance I at Lauderdale based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

There was no significant change in Total Abundance II at Pipeclay Lagoon (Figure 5-8c). The site did exhibit significant monthly variation, with maximum Total Abundance II during the winter months, and there was no change in the monthly pattern of variation between the two time periods.

Pipeclay Lagoon experienced a significant decrease in Species Diversity between the two sampling periods (Figure 5-8d), reflecting the large increase in Total Abundance I. The site exhibited significant monthly variation in Species Diversity, which was significantly greater during the autumn and winter months than during the spring and summer months. This monthly pattern did not change significantly between the 1960s and 1980s sampling periods.

CALVERTS LAGOON

Species Richness at Calverts Lagoon (Figure 5-9a) increased significantly between the 1960s and 1980s sampling periods. The site did not exhibit significant monthly variation for Species Richness, nor did the monthly pattern change significantly between the two time periods.

The change in Total Abundance I (Figure 5-9b) between the two sampling periods was significant. There was no significant monthly variation; however, it is clear from the graph that there was a definite monthly pattern in the 1980s data. The reason for the discrepancy is probably that by averaging the two sets of data to obtain the monthly group means, the pattern was obscured. The data clearly show a significant change in the monthly pattern over the two time periods. The graph illustrates that many more birds were using Calverts Lagoon during the 1980s sampling period, and that there was a very pronounced monthly pattern in Total Abundance I.

For Total Abundance II there was a significant increase (Figure 5-9c) at Calverts Lagoon between the two sampling periods, but no significant monthly variation. There was no statistical change in the monthly pattern of variation between the two sampling periods; however, the graph illustrates that while the patterns, or absence of patterns, might be similar, the values for the 1980s data are of a much greater magnitude.

Species Diversity (Figure 5-9d) also increased significantly at Calverts Lagoon between the two sampling periods. There was no significant monthly variation in this parameter, probably for the reasons given above, but there was a significant change in the patterns of use of the site between the two sampling periods.

SOUTH ARM

Species Richness at South Arm (Figure 5-10a) decreased significantly between the 1960s and 1980s sampling periods. The site showed significant monthly variation in Species Richness, with the peak number of species over the summer months, and there was no significant change in this monthly pattern between the two sampling periods.

Fig. 5-10c: Total Abundance II

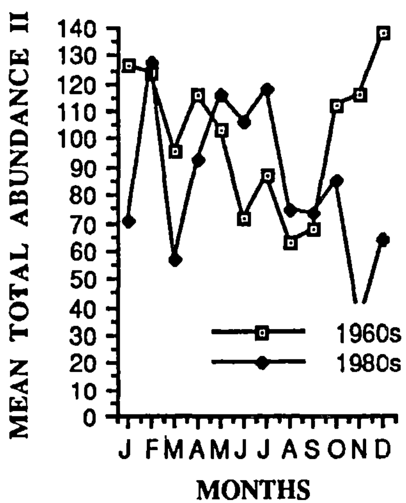

Figure 5.10c: Total Abundance II at South Arm based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-10d: Species Diversity

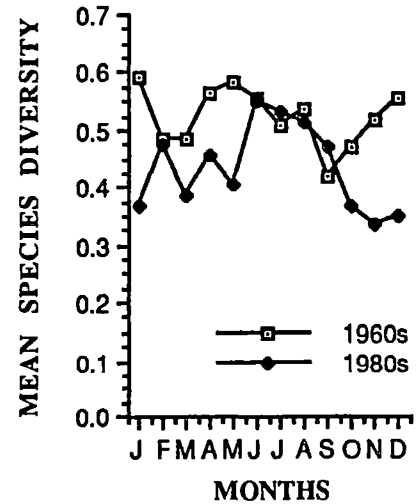

Figure 5.10d: Species Diversity at South Arm based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-10a: Species Richness

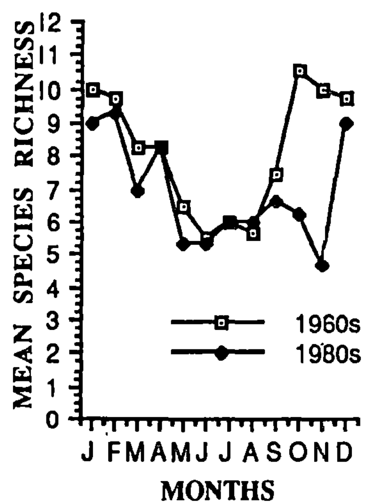

Figure 5.10a: Species Richness at South Arm based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-10b: Total Abundance I

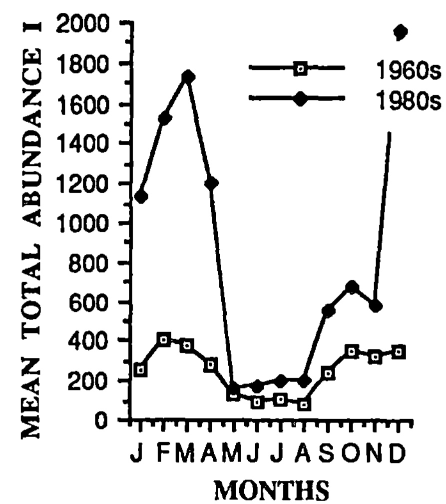

Figure 5.10b: Total Abundance I at South Arm based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-9c: Total Abundance II

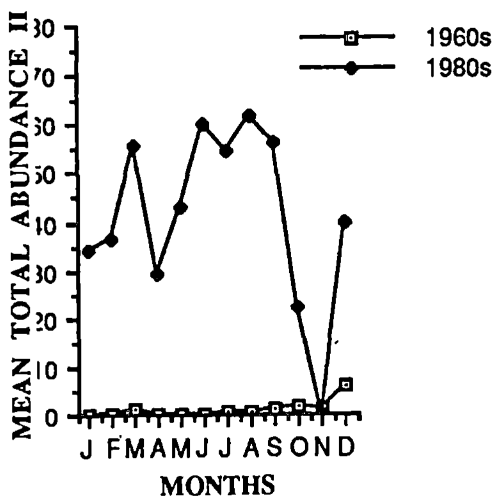

Fig. 5-9d: Species Diversity

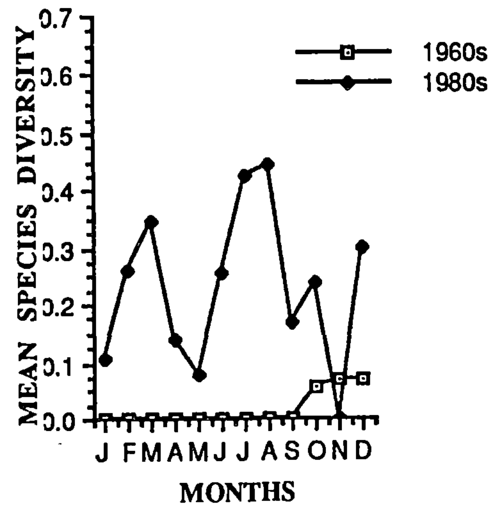

Figure 5.9c: Total Abundance II at Calverts Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Figure 5.9d: Species Diversity at Calverts Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

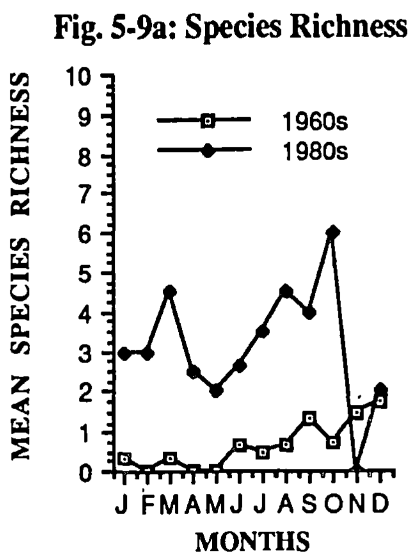

Figure 5.9a: Species Richness at Calverts Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

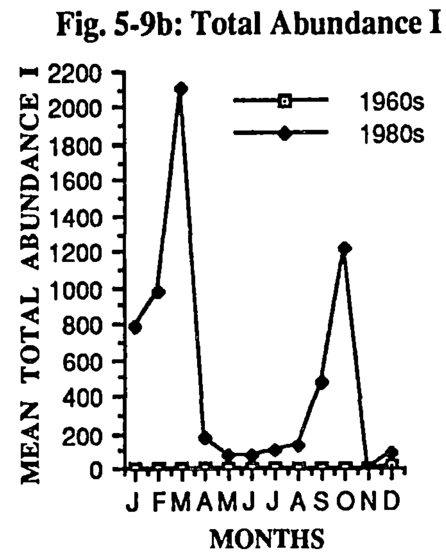

Figure 5.9b: Total Abundance I at Calverts Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-8c: Total Abundance II

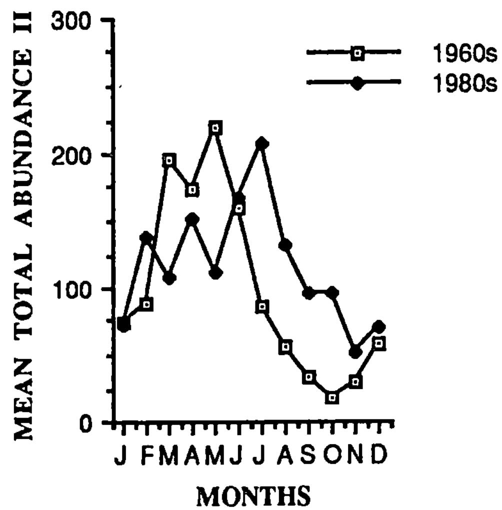

Fig. 5-8d: Species Diversity

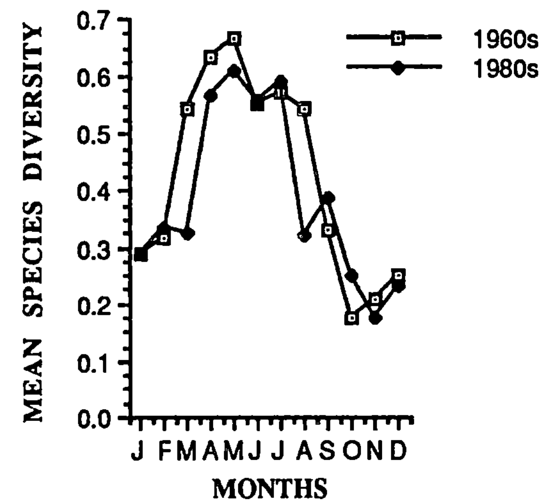

Figure 5.8c: Total Abundance II at Pipeclay Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Figure 5.8d: Species Diversity at Pipeclay Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-8a: Species Richness

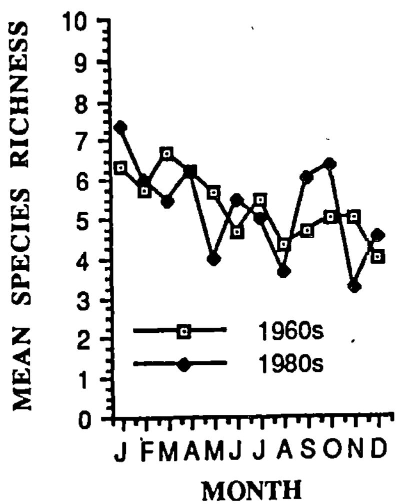

Fig. 5-8b: Total Abundance I

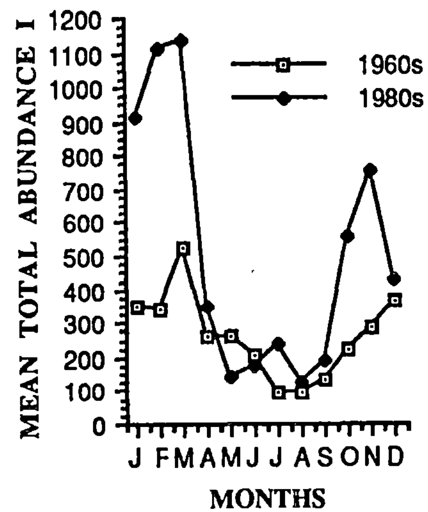

Figure 5.8a: Species Richness at Pipeclay Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Figure 5.8b: Total Abundance I at Pipeclay Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

There was a significant increase in Total Abundance I (Figure 5-10b) at the site, with significant monthly variation in Total Abundance I and a peak in abundance during the summer months; however, this monthly pattern did not change significantly between the two sampling periods.

Total Abundance II decreased significantly at South Arm Neck, and Figure 5-10c indicates that the main decrease has been during the summer months. There appears to have been a slight increase during the winter months, however, for both Total Abundance I and Total Abundance II. There was no significant monthly variation in Total Abundance II exhibited and the monthly pattern did not change significantly between the two sampling periods.

There was a significant decrease in Species Diversity (Figure 5-10d) at South Arm Neck between the 1960s and 1980s sampling periods. The results show no significant monthly variation in Species Diversity at the site, but the graph for this parameter indicates that Species Diversity for the 1980s sampling period peaked in mid-winter and declined to low values in the summer.

The change in the monthly pattern of species Diversity was not statistically significant. Figure 5-10d, however, indicates that changes in the monthly pattern did occur, and the reason may again be that by averaging the two sets of data to obtain the monthly group means examined, the pattern was obscured.

ORIELTON LAGOON

There was no significant variation in Species Richness (Figure 5-11a) at Orielton Lagoon between the 1960s and 1980s sampling periods. There was significant monthly variation in Species Richness at the site, with a peak number of species during the summer months and a minimum number during the winter, but there has been no significant change in this monthly pattern between the two sampling periods.

Total Abundance I (Figure 5-11b) decreased slightly at Orielton Lagoon between the 1960s and 1980s sampling periods, with the most noticeable decrease during the summer months. There was significant monthly variation in Total Abundance I at the site, with peak abundance during the summer months and lowest abundance during the winter, reflecting migratory patterns. This monthly pattern did not change significantly between the two sampling periods.

There was no significant change in Total Abundance II between the 1960s and 1980s at Orielton Lagoon. There was significant monthly variation similar to that for Total Abundance I, and this pattern has not changed between the two sampling periods.

The results show that Species Diversity at Orielton Lagoon (Figure 5-11d) did not change significantly between the 1960s and 1980s sampling periods, and that there was no significant monthly variation at this site, but that the existing pattern of monthly variation has changed

Fig. 5-11a: Species Richness

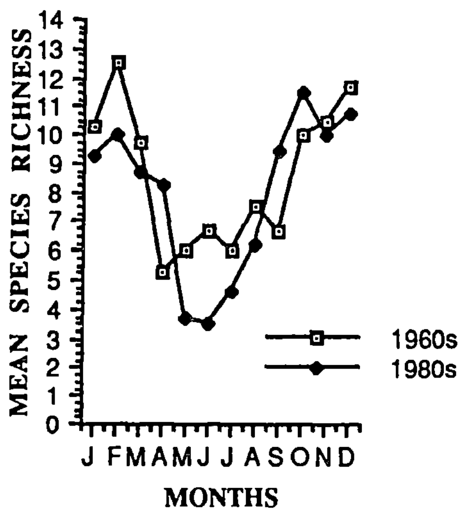

Figure 5.11a: Species Richness at Orielton Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-11b: Total Abundance I

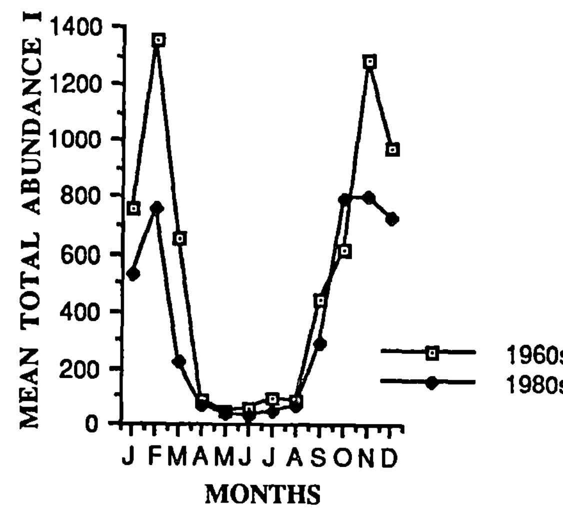

Figure 5.11b: Total Abundance I at Orielton Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-11c: Total Abundance II

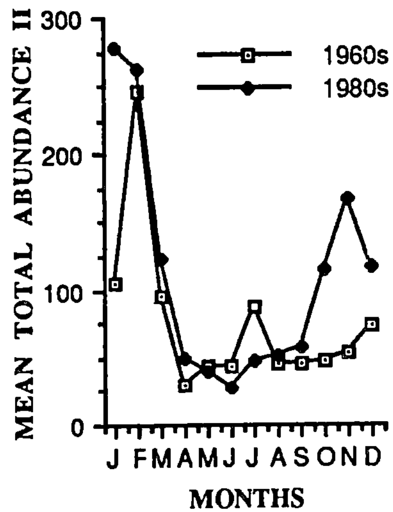

Figure 5.11c: Total Abundance II at Orielton Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-11d: Species Diversity

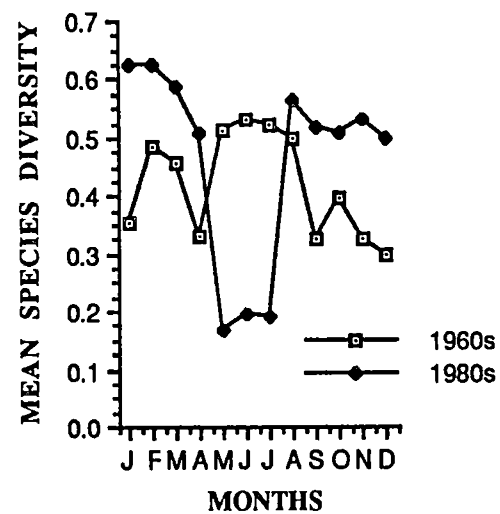

Figure 5.11d: Species Diversity at Orielton Lagoon based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

significantly between the two time periods. The graph for this index clearly illustrates that there was significant monthly variation in Species Diversity at Orielton Lagoon, and how the monthly pattern has changed between the two sampling periods. The discrepancy is again probably due to a "canceling" effect as a result of averaging the data to obtain the group means for the ANOVA. During the 1960s, Species Diversity peaked during the winter months and declined in the summer, and during the 1980s, the pattern was the opposite.

SORELL

There was a significant decrease in Species Richness (Figure 5-12a) at Sorell between the 1960s and 1980s sampling periods. The site exhibited significant monthly variation in Species Richness, as shown on Figure 5-12a, and there has been a significant change in the monthly pattern between the two sampling periods.

Total Abundance I (Figure 5-12b) decreased significantly at Sorell, with the main decrease occurring during the summer months. The site exhibited significant monthly variation, with peak numbers of birds present during the summer months. While there has not been a statistically significant change in the monthly pattern between the two sampling periods, Figure 5-12b illustrates a trend towards fewer numbers shorebirds present during the summer months in the 1980s sampling period.

There was no statistically significant decrease in Total Abundance II at Sorell between the two sampling periods. The site did exhibit a significant monthly pattern of variation, as well as a significant change in that pattern between the two sampling periods. The graph for Total Abundance II at Sorell indicates that during the 1960s, peak Total Abundance II was during the summer months, dropping to a low point in winter. The 1980s data is similar, except that there are fewer birds during the summer in the 1980s than in the 1960s and slightly more birds present in the winter during the 1980s sampling period.

The change in Species Diversity at Sorell was not significant, although Figure 5-12d indicates that there was a greater Species Diversity during the first nine months of the 1980s sampling period than during the same time period in the 1960s, and lesser Species Diversity October-November in the 1980s than in the 1960s.

There was significant monthly variation in Species Diversity, as shown on Figure 5-12d, but no significant change in this pattern between the two sampling periods.

BARILLA BAY

There was a significant decrease in Species Richness at Barilla Bay (Figure 5-13a) between the 1960s and 1980s sampling periods. Monthly variation at the site was significant with lowest numbers of species present in the winter months, and there was no significant change in the monthly pattern of variation between the two sampling periods.

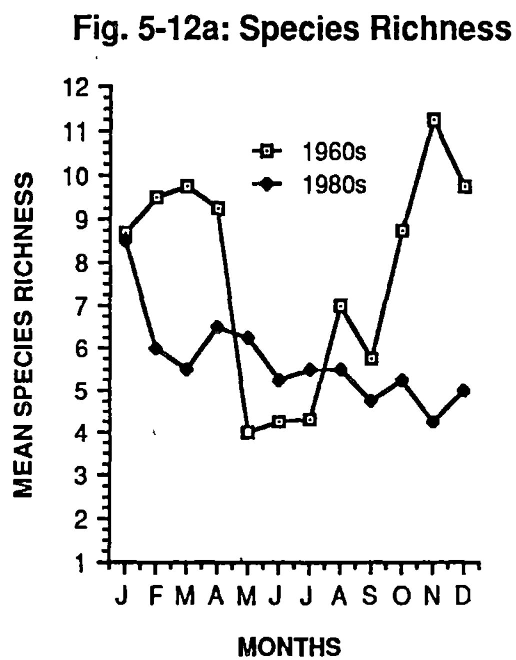

Figure 5.12a: Species Richness at Sorell based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample, sizes for each point are given in Appendix 8.

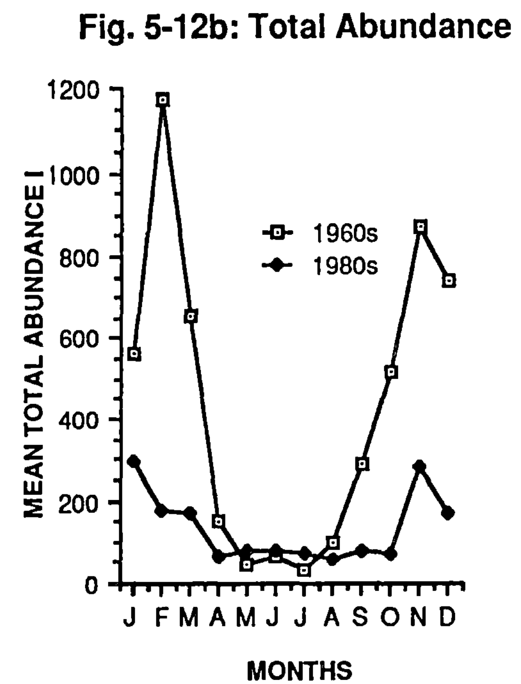

Figure 5.12b: Total Abundance I at Sorell based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-12c: Total Abundance II

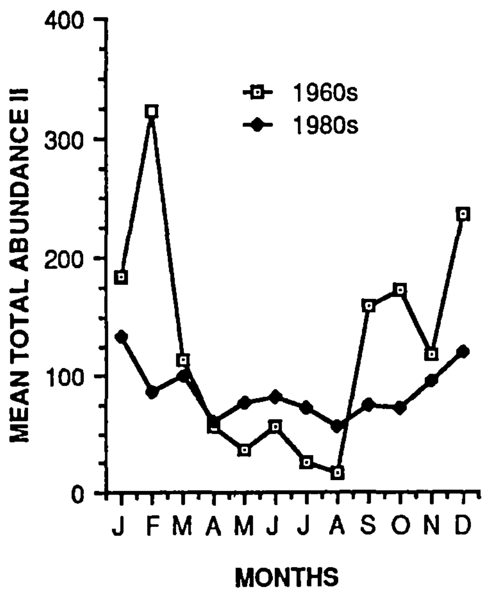

Figure 5.12c: Total Abundance II at Sorell based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-12d: Species Diversity

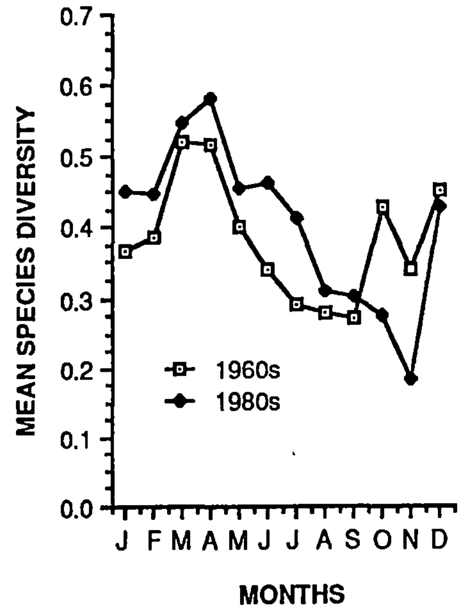

Figure 5.12d: Species Diversity at Sorell based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-13a: Species Richness

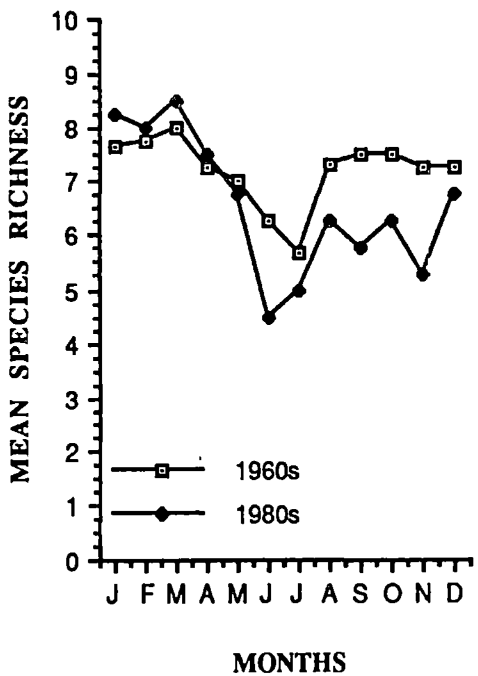

Figure 5.13a: Species Richness at Barilla Bay based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-13b: Total Abundance I

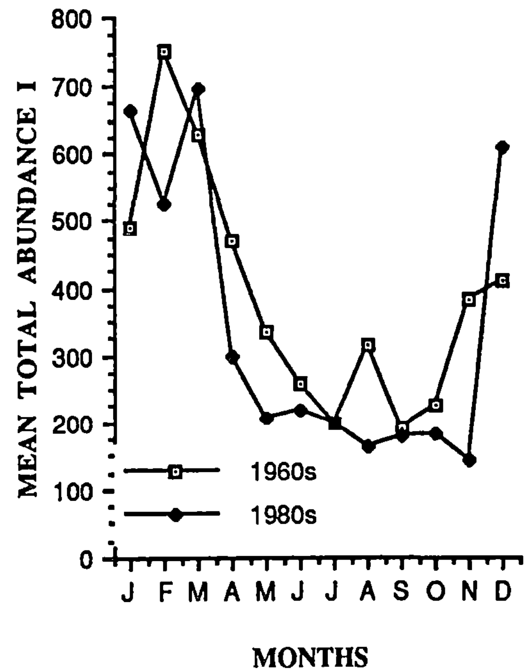

Figure 5.13b: Total Abundance I at Barilla Bay based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Fig. 5-13c: Total Abundance II

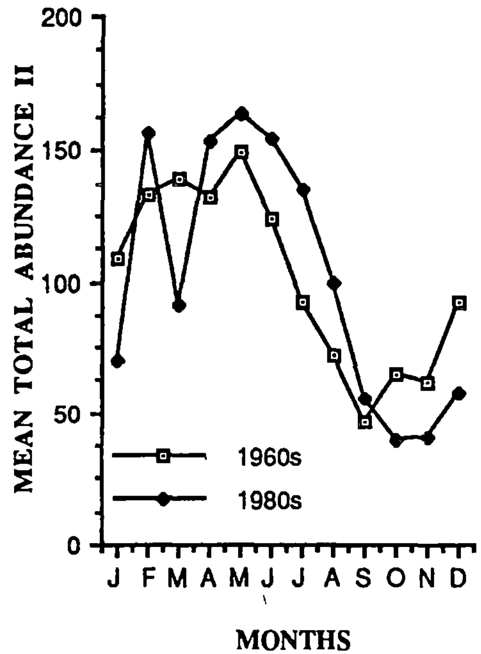

Fig. 5-13d: Species Diversity

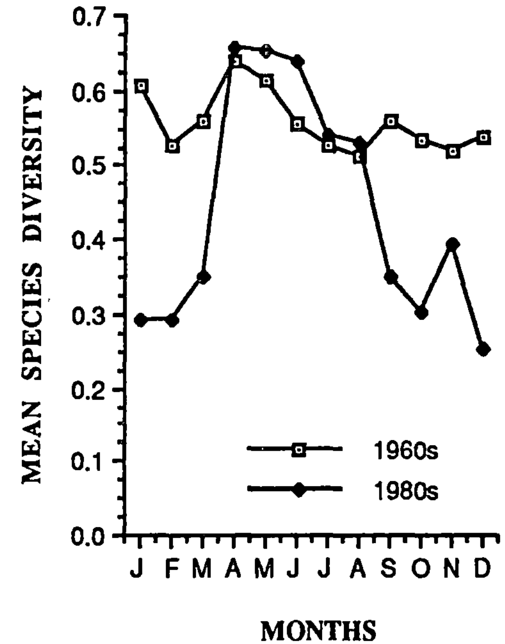

Figure 5.13c: Total Abundance II at Barilla Bay based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Figure 5.13d: Species Diversity at Barilla Bay based on non-transformed group mean values for the 1960s and 1980s sampling periods. The means, standard deviations and sample sizes for each point are given in Appendix 8.

Total Abundance I (Figure 5-13b) did not change significantly between the two sampling periods. Monthly variation at the site was significant, peaking in summer and reaching a low point in winter. There was no significant change in this pattern between the 1960s and 1980s sampling periods.

Total Abundance II (Figure 5-13c) also did not change significantly between the two sampling periods. Again monthly variation at the site was significant but, without Red-necked Stint and Curlew Sandpiper numbers, there was a peak in numbers of birds in the autumn months of April, May and June. There was no significant change in the pattern of monthly variation between the two sampling periods.

There was a significant decrease in Species Diversity (Figure 5-13d) between the 1960s and 1980s sampling periods. Monthly variation in Species Diversity at the site was also significant, with lowest Species Diversity during the summer months. There was also a significant change in the pattern of monthly Species Diversity at Barilla Bay. Diversity in the 1980s dropped dramatically in the summer months as compared with the 1960s results.

SUMMER AND WINTER WADER COUNT RESULTS

Tables 5-17 and 5-18 give the total abundance and number of species at each of 11 sites for Summer Wader Counts 1973-1988 and Winter Wader Counts 1980-1988. The 1972 Summer Wader Count data has not been included because it is believed by members of the SSG to be incomplete (Newman and Fletcher 1981). For each site for each year is given is the total number of shorebirds present, the total number of species present, and the percentage of the total count for the entire census area that was held for that site.

"NC" under total abundance indicates that no count was made at that site, as does a blank in the "number of species" column. "0 or NC" in a column indicates that no data were available for a count at that site. At times Calverts Lagoon and Clear Lagoon were too full or too dry to provide feeding or roosting habitat for shorebirds, and were therefore not counted, or more accurately, were found to hold no shorebirds, and no count was recorded. For these locations, a "NC" was probably often a "0". The reason that no data were not available for sites like Seven-mile Beach, however, is most likely that not enough time or people were available to count a large, spread out area, and so birds were probably present, but were not counted.

Summer Wader Counts

Some trends in site utilization over the period 1973-present can be derived from Table 5-17, based on summer shorebird count data. The percentage of each count held at Lauderdale appears to have declined in recent years as compared to the early 1970s, with values of less than five percent occurring consistently since the early 1980s. No clear trend stands out for Clear Lagoon, probably due to its irregular water levels and unpredictable suitability for shorebirds, or for Mortimer Bay, for which Summer Wader Counts were not held until 1981.

TABLE 5-17: Summer wader count data, 1975 - 1988: Summary of Total Abundance, number of species at each site and percentage of the South-east Tasmanian count recorded at each site.

SITE DATE	LAUDERDALE ABUNDANCE	LAUDERDALE NO. SPECIES	LAUDERDALE % OF TOTAL	CLEAR LAGOON ABUNDANCE	CLEAR LAGOON NO. SPECIES	CLEAR LAGOON % OF TOTAL	MORTIMER BAY ABUNDANCE	MORTIMER BAY NO. SPECIES	MORTIMER BAY % OF TOTAL
1973	528	5	19.5%	0	0	0.0%	NO	DATA	AVAILABLE
1974	372	4	7.7%	0	0	0.0%	NO	DATA	AVAILABLE
1975	63	3	1.5%	0	0	0.0%	NO	DATA	AVAILABLE
1976	566	5	10.2%	0	0	0.0%	NO	DATA	AVAILABLE
1977	25	5	0.5%	0 OR NC	0 OR NC	0 OR NC	NO	DATA	AVAILABLE
1978	488	6	9.5%	10	3	0.2%	NO	DATA	AVAILABLE
1979	323	2	6.5%	33	4	0.6%	NO	DATA	AVAILABLE
1980	372	5	6.7%	0	0	0.0%	0	0	0.0%
1981	347	5	4.9%	0	0	0.0%	30	1	0.4%
1982	130	4	2.5%	34	2	0.6%	24	2	0.5%
1983	108	2	1.6%	0	0	0.0%	8	1	0.1%
1984	123	4	1.9%	0	0	0.0%	12	1	0.2%
1985	109	4	2.2%	11	2	0.2%	61	3	1.2%
1986	187	5	3.0%	0	0	0.0%	9	1	0.1%
1987	123	4	2.4%	20	1	0.4%	53	2	1.0%
1988	146	5	3.1%	0	0	0.0%	9	1	0.2%

Table 5 - 17: Continued.

SITE DATE	PIPECLAY LAG. ABUNDANCE	PIPECLAY LAG. NO. SPECIES	PIPECLAY LAG. % OF TOTAL	CALVERTS LAG ABUNDANCE	CALVERTS LAG NO. SPECIES	CALVERTS LAG % OF TOTAL	BARILLA BAY ABUNDANCE	BARILLA BAY NO. SPECIES	BARILLA BAY % OF TOTAL
1973	71	5	2.6%	3	1	0.1%	652	7	24.1%
1974	1858	8	38.3%	35	1	0.7%	298	6	6.1%
1975	1477	6	34.0%	0	0	0.0%	412	6	9.5%
1976	1794	7	26.5%	0	0	0.0%	375	6	6.7%
1977	1728	6	35.4%	0 OR NC	0 OR NC	0 OR NC	270	6	5.5%
1978	1548	6	30.1%	0 OR NC	0 OR NC	0 OR NC	547	7	10.6%
1979	1789	6	36.1%	0	0	0.0%	198	3	3.9%
1980	1151	5	20.8%	0	0	0.0%	254	4	4.6%
1981	1287	7	18.1%	1826	5	25.7%	895	6	12.6%
1982	966	5	18.3%	396	3	7.5%	653	6	12.4%
1983	1031	6	14.8%	0	0	0.0%	536	9	7.7%
1984	918	5	14.1%	33	2	0.5%	870	7	13.4%
1985	673	3	13.8%	15	3	0.3%	437	5	8.9%
1986	492	3	7.9%	0	0	0.0%	311	5	5.0%
1987	451	3	8.8%	0	0	0.0%	754	11	14.7%
1988	679	5	14.3%	1621	8	34.2%	931	11	19.7%

Table 5 - 17: Continued.

SITE DATE	ORIELTON/SORELL ABUNDANCE	ORIELTON/SORELL NO. SPECIES	ORIELTON/SORELL % OF TOTAL	MARION BAY ABUNDANCE	MARION BAY NO. SPECIES	MARION BAY % OF TOTAL	SOUTH ARM ABUNDANCE	SOUTH ARM NO. SPECIES	SOUTH ARM % OF TOTAL
1973	1324	12	49.0%	NO	DATA	AVAILABLE	126	4	4.7%
1974	2067	14	42.6%	NO	DATA	AVAILABLE	227	9	4.7%
1975	1341	10	30.9%	NO	DATA	AVAILABLE	1049	10	24.2%
1976	1813	12	32.6%	NO	DATA	AVAILABLE	1019	9	18.3%
1977	1759	12	36.0%	NO	DATA	AVAILABLE	1102	10	22.6%
1978	1495	12	29.0%	NO	DATA	AVAILABLE	1060	9	20.6%
1979	466	8	9.3%	NO	DATA	AVAILABLE	2158	12	43.3%
1980	907	9	16.4%	NO	DATA	AVAILABLE	2841	11	51.4%
1981	1182	11	16.6%	733	8	10.3%	809	13	11.4%
1982	957	11	18.2%	549	7	10.4%	1561	9	29.6%
1983	1628	12	23.4%	638	8	9.2%	3015	7	43.3%
1984	1037	8	15.9%	698	8	10.7%	2781	8	42.7%
1985	1153	13	23.6%	218	9	4.5%	2136	6	43.7%
1986	1312	16	21.0%	516	7	8.3%	3416	6	54.7%
1987	825	12	16.1%	NO	DATA	AVAILABLE	2888	5	56.5%
1988	892	12	18.8%	271	8	5.7%	187	6	3.9%

Note: Data for Orieton/Sorell 1982-1985
include Five Mile Beach.

Table 5 - 17: Continued.

SITE DATE	7 MILE BEACH ABUNDANCE	7 MILE BEACH NO. SPECIES	7 MILE BEACH % OF TOTAL	TOTAL ABUNDANCE	TOTAL NO. SPECIES
1973	NO	DATA	AVAILABLE	2704	13
1974	NO	DATA	AVAILABLE	4857	15
1975	NO	DATA	AVAILABLE	4342	13
1976	NO	DATA	AVAILABLE	5567	13
1977	NO	DATA	AVAILABLE	4884	15
1978	NO	DATA	AVAILABLE	5148	15
1979	NO	DATA	AVAILABLE	4976	12
1980	NO	DATA	AVAILABLE	5525	14
1981	NO	DATA	AVAILABLE	7109	16
1982	NO	DATA	AVAILABLE	5270	14
1983	NO	DATA	AVAILABLE	6964	17
1984	38	2	0.6%	6510	12
1985	72	5	1.5%	4885	15
1986	NO	DATA	AVAILABLE	6243	16
1987	NO	DATA	AVAILABLE	5114	15
1988	NO	DATA	AVAILABLE	4736	18

The percentage of the total count held at Pipeclay Lagoon during the summer from the early 1970s to the present has apparently declined, from values in the mid-30s to values in the teens. The number of species present also appears to have declined slightly at that site. Calverts Lagoon is another irregularly suitable wetland site, so while it appears that the site is supporting more species in the summer at present than in the 1970s, more data is needed to bring out this trend. Barilla Bay Summer Wader Count data seem to fluctuate fairly widely from year to year, and the more detailed information from monthly count data is needed to bring out trends. Orielton Lagoon and Sorell, treated together here because they were generally combined for Summer and Winter Wader Counts, but were separated in monthly counts, decreased markedly in the percentage of the Summer Wader Count total the area supported each year, declining from values in the 30s and 40s in the 1970s to those in the teens and low 20s at present. Summer Wader Counts were not carried out at Marion Bay during the 1970s, and the data for the 1980s reflect no obvious trend. South Arm seems to have increased greatly in the numbers of shorebirds it supports at the time of the Summer Wader Counts, climbing from values ranging from zero to the low 20s, to values well into the 40s and 50s. An exception was in the summer of 1988, when only 3.9% of the count was held at the site as opposed to 56.0% the year before. However, it seems that the number of species has declined. Calverts Lagoon held 34.2% of the count as opposed to 0% the year before. It is locally well known that Calverts Lagoon is used as an alternative feeding and roosting location to South Arm (SSG pers. comm.). There is little data for Seven Mile Beach, which was infrequently counted. It is a large area of sandy beach, with relatively few species, and it has only been during the last few years that it has been recognized as a more important location for the Pied Oystercatcher, and perhaps the Hooded Plover, than was previously thought.

Winter Wader Counts

Table 5-18 gives the results of Winter Wader Counts, 1980-1988. No clear changes in the percentage of the total count held can be seen for Lauderdale. The percentage held at Clear Lagoon each year varied with the availability of feeding habitat, a result of water levels. Mortimer Bay held a much larger percentage of the total count in 1987 than it had previously, 7.90% as opposed to earlier values ranging from 0.20 to 3.20%. No definite trends could be determined for Pipeclay Lagoon, Calverts Lagoon, Barilla Bay, or South Arm. Orielton/Sorell may have increased very slightly in the percentage of the total count held, Marion Bay may have decreased slightly, and there is not enough data for Seven Mile Beach to determine a trend.

SUMMARY OF RESULTS

Table 5-19 presents a summary of the changes in shorebird numbers that have occurred at each of the 11 sites of shorebird habitat within the study area. These are derived from the

TABLE 5-18: Winter wader count data, 1980 - 1988: Summary of Total Abundance,number of species at each site and percentage of the South-east Tasmania count recorded at each site.

SITE	LAUDERDALE	LAUDERDALE	LAUDERDALE	CLEAR LAGOON	CLEAR LAGOON	CLEAR LAGOON	MORTIMER BAY	MORTIMER BAY	MORTIMER BAY
DATE	ABUNDANCE	NO. SPECIES	% OF TOTAL	ABUNDANCE	NO. SPECIES	% OF TOTAL	ABUNDANCE	NO. SPECIES	% OF TOTAL
1980	81	4	6.8	0 OR NC	0 OR NC	0 OR NC	7	2	0.6
1981	147	4	1.3	105	2	9.5	2	1	0.2
1982	114	3	8.4	17	2	1.2	44	1	3.2
1983	135	4	8.5	8	1	0.5	43	1	2.7
1984	143	4	10.6	0	0	0.0	10	1	0.7
1985	97	4	7.3	7	2	0.5	16	1	1.2
1986	150	4	11.3	2	1	0.2	50	1	3.8
1987	68	3	6.7	17	1	0.0	80	1	7.9
1988	89	3	6.6	20	2	1.5	1	1	0.1

Table 5 - 18: Continued.

SITE DATE	PIPECLAY LAGOON ABUNDANCE	PIPECLAY LAGOON NO. SPECIES	PIPECLAY LAGOON % OF TOTAL	CALVERTS LAGOON ABUNDANCE	CALVERTS LAGOON NO. SPECIES	CALVERTS LAGOON % OF TOTAL	BARILLA BAY ABUNDANCE	BARILLA BAY NO. SPECIES	BARILLA BAY % OF TOTAL
1980	84	4	7.0	64	2	5.4	196	3	16.5
1981	172	2	15.5	39	3	3.5	77	2	7.0
1982	215	5	15.8	22	2	1.6	308	5	22.6
1983	243	5	15.4	10	2	0.6	300	6	19.1
1984	242	4	17.9	109	3	8.1	260	6	19.3
1985	280	5	21.2	2	1	0.2	228	7	17.3
1986	229	6	17.2	0 OR NC	0 OR NC	0 OR NC	270	5	20.3
1987	127	4	12.6	0 OR NC	0 OR NC	0 OR NC	190	6	18.8
1988	96	1	7.1	53	4	3.9	310	5	23.0

Table 5 - 18: Continued.

SITE DATE	ORIELTON/ SORELL ABUNDANCE	ORIELTON/ SORELL NO. SPECIES	ORIELTON/ SORELL % OF TOTAL	MARION BAY ABUNDANCE	MARION BAY NO. SPECIES	MARION BAY % OF TOTAL	SOUTH ARM ABUNDANCE	SOUTH ARM NO. SPECIES	SOUTH ARM % OF TOTAL
1980	214	7	18.0	247	6	25.0	298	9	25.0
1981	125	6	11.3	224	6	20.2	216	5	19.5
1982	219	6	16.1	99	5	7.3	324	7	23.8
1983	159	6	10.1	164	6	10.4	466	6	29.5
1984	132	7	9.8	241	5	17.9	101	3	7.5
1985	244	10	18.5	194	5	14.7	217	6	16.4
1986	365	10	27.5	NC	NC	NC	262	7	19.7
1987	221	7	21.9	136	4	13.5	171	4	16.9
1988	390	12	28.9	290	7	21.5	99	4	7.3

Note: Data for Orielton/Sorell 1982-1987 include Five Mile Beach.

Table 5 - 18: Continued.

SITE DATE	7 MILE BEACH ABUNDANCE	7 MILE BEACH NO. SPECIES	7 MILE BEACH % OF TOTAL	TOTAL ABUNDANCE	TOTAL NO. SPECIES
1980	NO	DATA	AVAILABLE	1191	11
1981	NO	DATA	AVAILABLE	1107	9
1982	NO	DATA	AVAILABLE	1362	11
1983	53	5	3.4	1581	11
1984	112	5	8.3	1350	11
1985	35	5	2.7	1320	12
1986	NO	DATA	AVAILABLE	1328	12
1987	NO	DATA	AVAILABLE	1010	10
1988	NO	DATA	AVAILABLE	1058	14

TABLE 5-19: SUMMARY OF CHANGES IN SHOREBIRD NUMBERS AT EACH OF 11 SITES BETWEEN THE 1960s AND 1980s SAMPLING PERIODS (BASED ON 2-WAY ANOVA RESULTS, SOURCE A).

	SPECIES RICHNESS	TOTAL ABUNDANCE I	TOTAL ABUNDANCE II	SPECIES DIVERSITY	TREND BASED ON SWC DATA	TREND BASED ON WWC DATA	QUALITATIVE ASSESSMENT BY SSG MEMBERS
LAUDERDALE	(-)	(-)	(=)	(-)	(-)	NOT CLEAR	(-)
CLEAR LAGOON	(-)	(=)	(=)	(=)	NOT CLEAR	NOT CLEAR	NOT CLEAR
PIPECLAY LAGOON	(=)	(+)	(=)	(-)	(-)	NOT CLEAR	(+) 1970s/1980s (-) AT PRESENT
CALVERTS LAGOON	(+)	(+)	(+)	(+)	(+)	NOT CLEAR	(+)
SOUTH ARM	(-)	(+)	(-)	(-)	(+)	NOT CLEAR	(+) SMALL SPECIES (-) LARGE SPECIES
ORIELTON LAGOON	(=)	(-)	(=)	(=)	(-)	NOT CLEAR	(-)
SORELL	(-)	(-)	(=)	(=)	(-)	NOT CLEAR	(-)
BARILLA BAY	(-)	(=)	(=)	(-)	NOT CLEAR	NOT CLEAR	(-) SOME SPECIES
MORTIMER BAY	NO DATA COLLECTED FROM 1960s SAMPLING PERIOD				NOT CLEAR	NOT CLEAR	(-)
5 AND 7 MILE BEACHES	NO DATA COLLECTED FROM 1960s SAMPLING PERIOD				NOT CLEAR	NOT CLEAR	NOT CLEAR
MARION BAY	NO DATA COLLECTED FROM 1960s SAMPLING PERIOD				NOT CLEAR	NOT CLEAR	(=)

results for each index from the monthly counts during the 1960s and 1980s sampling periods, the results of the Summer and Winter Wader Counts, and the qualitative assessment of the members of the Shorebird Study Group. This table provides an overview of results for reference during the discussion in the following section.

5.2.3 Discussion

Scope and Limitations of the Data and the Method of Analysis

The main limitation of the data was that although the data were collected for the purpose of monitoring the numbers of shorebirds at the sites, they were not collected to fit a specific method of analysis. The experimental design would have been improved had more emphasis been placed on ensuring that data were obtained every month during the period of the study, and on carrying out an equal number of counts each month. Also, the importance of consistently recording real values rather than tick marks, and being consistent in the completeness of the censuses and in the type of information collected, was not realized at the time of collection. These factors resulted in discrepancies that would have been minimized if the method of analysis had been established in advance.

A second limitation of the data concerns the data from Summer and Winter Wader Counts. These data have been referred to in order to interpret the results, but it is felt that this data should be interpreted with some caution. Such counts are basically "snapshot pictures", and as such are subject to error associated with small sample size. The SWCs were considered by Newman and Fletcher (1981) to reflect the peak summer shorebird population. However, although the counts are held at approximately the same time each year, climatic variation in Tasmania, as well as on the mainland and overseas, and variation in departure and arrival times of migratory birds introduce the potential for considerable error when comparing counts on a monthly basis.

A third limitation of the data is common to most scientific studies that attempt to determine causal factors for an event. While the evidence strongly suggests that changes to the shorebird habitats in South-east Tasmania have influenced the numbers of shorebirds using each of the sites, unknown factors, such as long term cycles in shorebird numbers and use of sites, and cycles in ecological components of the sites, may also have had influence on the trends observed. Further research would be necessary to determine to what extent, if any, these are causal factors.

It should be noted that in come cases, there was no statistical variation between months or between sampling periods, but the graph of the data illustrates clear changes (see, for example, Figure 5-11d, Species Diversity at Orielton Lagoon). The likely reason is that the averaging of the group means from the 1960s and 1980s, to determine whether the site exhibited monthly variation, probably obscured the pattern.

It should also be noted that during the following discussion, reference is occasionally made to information, shown on the graphs, that may not have been statistically significant. These are mentioned based on the speculation that some of the seasonal trends evident on the graphs, although not significant in the examination of one group mean for the 1960s as compared with one group mean for the 1980s, may be significant if the data were sets were broken up and analyzed by seasons. The references to these trends do not question the significance of the results of the ANOVAs, but rather point out that other trends may be present, and that further analysis of the data, grouped differently, is necessary to bring out this information.

By using the method of analysis as described, the limitations inherent in the data have been minimized where possible, and the interpretation of the data has been carried out with full recognition of these limitations. It is believed that the trends uncovered in this study are realistic, and have not been unduly biased by the data limitations described. Furthermore, reasonable assessments of the causal factors will produce hypotheses which will remain to be tested by future counts and analyses.

Species Richness

The results of the 3-way ANOVA indicated that Species Richness declined within the entire study area between the 1960s and 1980s sampling periods. There are two explanations that may account for this decline. The count data in the SSG files for the two sampling periods in the SSG files indicates that smaller numbers of rarities and vagrants were observed during the 1980s sampling period. In addition, large decreases in some species, such as Eastern Curlew and Bar-tailed Godwit (Thomas 1987), decrease the likelihood of observing these species during a census. Decreases at individual sites between the two sampling periods, as disclosed by the 2-way ANOVA, may also be a result of these two factors.

The shorebird sites of South Arm Neck, Orielton Lagoon and Barilla Bay and to a lesser extent Pipeclay Lagoon and Sorell, showed peak species numbers during the summer months. This corresponds to the use of the sites by migratory species. There is an influx of Palaearctic migrants to these sites during the austral summer.

Total Abundance I

Total Abundance I increased significantly within the entire study area between the 1960s and 1980s sampling periods. This has primarily been the result of the marked increase in numbers of Red-necked Stint and Curlew Sandpiper coming to the region (Thomas 1986), and it should be noted that numbers of several other species, notably Sharp-tailed Sandpiper, Bar-tailed Godwit, Eastern Curlew and Lesser Golden Plover were less numerous within the study area during the 1980s than they were during the 1960s (Thomas 1986).

Decreases in Total Abundance I at the individual study sites may reflect a shift in preference of sites by the shorebirds, possibly due to degradation of breeding, feeding or roosting habitat of those sites. Such changes could also be due to ecological changes, of unknown cause, at the sites. The decline in numbers of some species, as noted above, within the study area, may also be a reason for some observed decreases in this index at individual sites.

Increases in total Abundance I at the study sites may be a result of the increased numbers of Red-necked Stint and Curlew Sandpiper, or other species shorebirds present in South-east Tasmania, or it may reflect an improvement in the shorebird habitat at those sites. The observed pattern of increased Total Abundance I at some sites and decreased Total Abundance I at others most probably reflects a shift in shorebird numbers to previously less preferred sites.

As with Species Richness, sites which showed strong monthly variation in Total Abundance I had peak numbers of individuals present during the summer, again indicating an influx of migratory species, and particularly Red-necked Stint and Curlew Sandpiper, at that time.

Total Abundance II

Total Abundance II was calculated to distinguish trends in the number of species of shorebirds other than Red-necked Stint and Curlew Sandpiper. Of all the species of shorebirds which occur in South-east Tasmania, these two species occur in the largest flocks, and their numbers obscure changes in the abundance of less numerous shorebirds.

As with Total Abundance I, Total Abundance II increased significantly within the study area, with a slight increase in the mean number of shorebirds present between the 1960s and 1980s sampling periods. The possible reasons for observed increases in Total Abundance II at the individual sites are similar to those for Total Abundance I: they may reflect an improvement in habitat at the site, or they may reflect a shift in site preference and thus in site utilization. The possible reasons for observed decreases in Total Abundance II are the same as those for decreases in Total Abundance I.

Five of the eight sites exhibited a significant pattern of monthly variation in Total Abundance II. At Orielton Lagoon and Sorell, the peak in Total Abundance II was during the summer, reflecting the influx of summer migrants to those sites. At Barilla Bay, Pipeclay Lagoon and Lauderdale, the peak in Total Abundance II was during the winter, reflecting the winter influx of Double-banded Plover, and probably an increase in the winter flocking of oystercatchers as well. This helps to illustrate that all of the shorebird sites in South-east Tasmania are utilized year-round, by various species at different times.

Differences that have emerged in Total Abundance I and Total Abundance II at particular sites will be addressed more fully in the discussion of the individual sites.

Species Diversity

It is relevant to recall at this point that Species Diversity is essentially a measure of even-ness. It is altered by any change which shifts the proportion of individuals of each species away from an "even" state. For example, the index is depressed by large increases and elevated by large decreases in a small number of species, such as Red-necked Stint and Curlew Sandpiper. It is also affected by changes in Total Abundance I, Total Abundance II and Species Richness that alter the even-ness of the proportion of each species at a site.

There was no significant change in the study area as a whole. Reasons for observed changes in species Diversity at individual sites will be discussed in the following sections.

Once again it is important to point out that Species Diversity has not been used in this study to compare sites. Its main importance in this study has been to highlight changes occurring at one site over time; for example, changes in the pattern of Species Diversity between the two sampling periods highlights the months when Species Richness or Total Abundance I or Total Abundance II have changed the even-ness of the proportions of species at that site.

Lauderdale

Lauderdale experienced a significant decrease in Species Richness, Total Abundance I and Species Diversity between the 1960s and 1980s sampling periods, and Figure 5-6c illustrates an apparent decrease in Total Abundance II over the winter months, although there was no statistically significant change in the monthly pattern as a whole between the two sampling periods. Based on the SWC data, the percentage of the entire SWC held at Lauderdale each year also has decreased since the early 1970s.

The significant decrease in each of these four indices is most probably a result of heavy disturbance and habitat alterations at the site. The SSG (pers. comm.) reported that smaller shorebirds, such as Red-necked Stint and Curlew Sandpiper, which have clearly decreased at the site (Figure 5-6b), now have to compete for roosting space with birds such as gulls, which are attracted to the area by the tip site. Fewer of the small species of shorebirds, and particularly Red-necked Stint, are utilizing the shorebird habitat at Lauderdale. .

The decrease in Total Abundance II during the winter months of the 1980s sampling period reflects the lower numbers of Double-banded Plover, Pied Oystercatcher, Red-capped Plover, Bar-tailed Godwit recorded at the site during that time period.

The decrease in Species Richness indicates that fewer species were using the site during the 1980s sampling period. The incidence of Bar-tailed Godwit and Eastern Curlew at Lauderdale decreased markedly between the two sampling periods. Thomas (1987) reports the steady decline in abundance of these species in Tasmania since the early 1970s. The decreased

Species Diversity at Lauderdale is a result of the loss of some species, the reduced abundance of others, and the relative dominance of the remainder.

Clear Lagoon

No significant results were obtained for Clear Lagoon except for a slightly significant decrease in Species Richness between the two sampling periods (Figure 5-7a).

The results of the ANOVAs performed on Clear Lagoon data, whether they indicated a change between the two sampling periods or not, must be viewed with caution. Clear Lagoon only provides suitable habitat for shorebirds when it is wet enough to provide mud, yet not so full that there is no exposed feeding habitat. Therefore, when the site is suitable for shorebirds, it is used, but its suitability is irregular and unpredictable. No conclusive comments can be made as to whether the site has changed in its ability to support shorebirds, based on the four indices, because water level introduces such an unpredictable variable into data collected each year.

Pipeclay Lagoon

Species Richness at Pipeclay Lagoon did not change significantly between the 1960s and 1980s sampling periods (Figure 5-8a). Total Abundance I at the site increased significantly, particularly during the summer (Figure 5-8b). Although Total Abundance II at Pipeclay Lagoon did not change significantly between the two sampling periods, Figure 5-8c indicates that slightly more shorebirds were using the site in the spring and early summer months during the 1980s sampling period. This again may reflect a shift from previously preferred sites.

Total Abundance II appeared to decrease somewhat during the early winter months. SSG count data indicates that fewer Pied Oystercatcher and Lesser Golden Plover and slightly fewer Double-banded Plover were using the site during these months in the 1980s as compared to the 1960s. The results for the entire site was not significant, but seasonal changes in some species could be.

Thomas (pers. comm.) commented that based on his regular visits to Pipeclay Lagoon since the early 1960s, the site did not hold particularly large numbers of shorebirds during that decade, and held many more in the 1970s and early 1980s. He attributed this partly to the increase in Red-necked Stint and Curlew Sandpiper in south-eastern Tasmania during that same time period, as reported in Thomas (1987).

Other members of the SSG (pers. comm.) have noted a recent decline in shorebird numbers at Pipeclay Lagoon, particularly since 1984. Since that time, Red-necked Stint have declined slightly and Curlew Sandpiper have continued to increase. The increase and then the recent decline in shorebird numbers at Pipeclay Lagoon since the 1980s sampling period has two possible explanations. It may reflect natural fluctuations in shorebird numbers at the site. However, it may also be that the original increase was due partly to increased numbers of

Red-necked Stint and Curlew Sandpiper, and partly to birds shifting from more disturbed areas to the less disturbed habitat at Pipeclay Lagoon. The recent decrease in shorebird numbers may reflect the documented increase of disturbance at the site.

Species Diversity was slightly reduced during the 1980s sampling period, although the pattern did not change significantly. This is probably due to increases in some species and decreases in others as discussed above. Species diversity increased significantly between the two sampling periods, and the main cause was probably the large increase in Red-necked and Curlew Sandpiper.

Calverts Lagoon

Calverts Lagoon experienced a significant increase in all four indices between the two sampling periods (see Figures 5-9a to 5-9d). Thomas counted the Lagoon regularly during the 1960s sampling period, but monthly median numbers of birds using the site were consistently low - usually close to zero and seldom more than one or two individuals at a time. This was primarily because Calverts Lagoon was generally full, with little exposed feeding or roosting area (Thomas, SSG, pers. comm.).

As in the 1960s, during periods in the 1980s when the Lagoon was totally full, no shorebirds were present. In months when the Lagoon was not totally full, however, the numbers of birds and species at the site decreased dramatically. Up to five species were often present, with Total Abundance I at the site ranging from from 15 to 3000 individuals.

Calverts Lagoon is known to be a secondarily preferred feeding and roosting site for shorebirds pushed from South Arm Neck by disturbance or high tide (SSG pers. comm.). During very poor weather conditions and high tidal conditions, Calverts Lagoon may provide sheltered roosting habitat for shorebirds at other sites on the South Arm Peninsula. This illustrates the value of alternate sites to shorebirds, and the value of Calverts Lagoon as such an alternate site. It must be stressed, however, that the birds need both primary preferred sites and alternate sites because each serves a different function, and one generally could not be substituted for the other.

The pattern of monthly variation for the graph of Total Abundance I at Calverts Lagoon (Figure 5-9b) reflects the seasonal utilization of the site by large numbers of Red-necked Stint and Curlew Sandpiper.

During the 1980s sampling period, only one count was held during each of the months September, October and December out of the four years, and no counts were held in November during that sampling period. this is probably an example of the situation discussed previously where the Lagoon was full and held no shorebirds and "no count" was recorded when in reality the count would have been zero.

South Arm Neck

South Arm Neck has experienced significant decreases both in Species Richness and in Total Abundance II, but a significant increase in Total Abundance I. The site is a "staging area" - a location where shorebirds accumulate before setting off on a stage of migration - and the percentage of the total SWC held at South Arm Neck has increased from 20% or less during the 1970s to more than 50% in 1986 and 1987 (see Table 5-17). However, while the site has been holding increasingly large numbers of smaller shorebirds, particularly Red-necked Stint and Curlew Sandpiper, there have been fewer large shorebirds utilizing the area. For example, fewer Eastern Curlew, Bar-tailed Godwit and Lesser Golden Plover were recorded using the site during the 1980s sampling period than during the 1960s sampling period. These species have declined within the study area generally, and South Arm is holding fewer numbers of the individuals that remain.

The extremely low count for the 1988 SWC at South Arm, and the very high count at Calverts Lagoon for the same year, were probably associated, reflecting the systemic nature of habitat utilization.

Low Species Diversity at South Arm Neck during the summer months (Figure 5-10d) is a function of the disproportion resulting from lower Species Richness and huge numbers of Red-necked Stint and Curlew Sandpiper.

Orielton Lagoon

Total Abundance I decreased significantly at Orielton Lagoon between the 1960s and 1980s sampling periods, and Total Abundance II, Species Richness and Species Diversity did not change significantly between those time periods.

Species Richness, Total Abundance I and Total Abundance II at Orielton Lagoon all exhibited a significant monthly variation, and values for each of these indices was highest in summer and lowest in winter, reflecting the use of Orielton Lagoon by Palaearctic migrants.

Total Abundance I decreased noticeably during the summer months (Figure 5-11b). One reason for the decrease was a decline in Red-necked Stint and Curlew Sandpiper at the site between the two sampling periods. The likely reason for this decrease, considering that these two species were increasing in the region and had increased at other sites, is almost certainly the inundation of the primary roosting and feeding area at the northern end of the Lagoon. Other species which have decreased at Orielton Lagoon include Lesser Golden Plover, Red Knot, Eastern Curlew and Bar-tailed Godwit.

Species Diversity at Orielton Lagoon decreased markedly during the winter months, probably reflecting a decrease in numbers of species present at that time. Species Diversity increased markedly during the summer months, a function of the large decrease in Red-necked Stint and Curlew Sandpiper.

Sorell

Species Richness and Total Abundance I decreased significantly at Sorell between the 1960s and 1980s sampling periods. Figures 5-12a and 5-12b illustrate that the decrease occurred particularly during the summer months, indicating that the numbers of Palaearctic migrants were well during the 1980s sampling period. There was not a significant change in Total Abundance II overall at the site, but a qualitative assessment of Figure 5-12c indicates that Total Abundance II also declined during the summer months between the two sampling periods.

Species Diversity at Sorell did not change significantly between the 1960s and 1980s sampling periods.

Total Abundance I at both Orielton Lagoon and Sorell declined between the two sampling periods, reflecting a decline in the numbers of Red-necked Stint and Curlew Sandpiper using the sites.

The results indicate that Sorell has experienced a decline in Species Richness and Total Abundance between the two sampling periods and that Orielton Lagoon has experienced in Total Abundance I. Qualitative assessment of the graphs for these two sites suggests that an additional examination of the indices for changes in season use between the two sampling periods might highlight additional changes.

It must be stressed that the treatment of the two sites as separate entities is an arbitrary, and perhaps misleading, practice. The two sites are really just the two ends of one body of water, and, as two components of the Pittwater system of shorebird habitat, it is reasonable to expect that changes to habitat at one of the two locations would have an impact on shorebirds at both locations, since they move back and forth between the two. Thus, one very possible reason for a decrease in numbers at Sorell, which is a site which is fairly sheltered from disturbance, is the loss of roosting habitat through inundation at the northern end of Orielton Lagoon.

Barilla Bay

Barilla Bay, like Sorell, is one of the least disturbed of the shorebird study sites. It is a third component of the Pittwater system. Patterson (pers. comm.) believes that Barilla Bay may hold a separate subset of shorebirds, but reports that there is still a considerable exchange of birds with the rest of the Pittwater system later in the summer. Thus, Barilla Bay probably is also affected by factors which impact upon shorebird habitat at the other two sites.

Species Richness at Barilla Bay decreased significantly between the 1960s and 1980s sampling periods, and Figure 5-13a indicates that this decrease occurred over most of the year except for the late summer months.

Once again, qualitative assessment of the graphs suggests that a statistical analysis examining data on a seasonal basis between the two sampling periods might highlight seasonal trends that are not evident from an analysis that compares group means for entire years.

5.2.4 CONCLUSIONS

The following conclusions can be drawn regarding the status of the null hypotheses concerning changes in site utilisation at the eight sites monitored intensively during both the 1960s and 1980s sampling periods, (Table 5-19).

1. The null hypothesis that, at each site, there was no significant difference in the number of species present (Species Richness) between the two sampling periods must be rejected for five of the sites at which a significant decrease in Species Richness occurred (Lauderdale, Clear Lagoon, South Arm, Sorell and Barilla Bay) and for one site at which a significant increase occurred (Calverts Lagoon). At two sites (Pipeclay Lagoon and Orielton Lagoon), no significant change in Species Richness occurred between the two sampling periods, and thus the null hypothesis cannot be rejected for these two sites.

2. The null hypothesis that, at each site, there was no significant difference in the total number of shorebirds present (Total Abundance I) between the two sampling periods must be rejected for three sites at which a significant decrease in Total Abundance I occurred (Lauderdale, Orielton Lagoon and Sorell) and for three sites at which a significant increase in Total Abundance I occurred (Pipeclay Lagoon, Calverts Lagoon and South Arm). At two sites (Clear Lagoon and Barilla Bay), no significant change in Total Abundance I occurred, and thus the null hypothesis cannot be rejected for these sites.

3. The null hypothesis that, at each site, there was no significant difference in the total number of shorebirds present, excluding Red-necked Stints and Curlew Sandpipers, (Total Abundance II) between the two sampling periods must be rejected for one site at which a significant decrease in Total Abundance II occurred (Calverts Lagoon). At six sites (Lauderdale, Clear Lagoon, Pipeclay Lagoon, Orielton Lagoon, Sorell and Barilla Bay) no change in Total Abundance II occurred, and thus the null hypothesis cannot be rejected.

4. The null hypothesis that, at each site, there was no significant difference in the index Species Diversity (relative proportions of the numbers of species present) between the two sampling periods must be rejected for four sites (Lauderdale, Pipeclay Lagoon, South Arm and Barilla Bay) at which a significant decrease in Species Diversity occurred, and for one site at which there was a significant increase in Species Diversity (Calverts Lagoon). At three sites (Clear Lagoon, Orielton Lagoon and Sorell) there was no significant difference in Species Diversity between the two sampling periods and thus the null hypothesis cannot be rejected.

It must be stressed once again that increases and decreases in Species Diversity indicate a change in the relative proportions of abundance and numbers of species present, and that, for example, an increase in Species Diversity could be a function of the decrease of some species.

5. The null hypothesis that, at each site, there was no significant difference in Species Richness between months, (Table 5-6); ie, no evident monthly pattern, must be rejected for five sites (Pipeclay Lagoon, South Arm, Orielton Lagoon, Sorell and Barilla Bay), indicating a monthly pattern in Species Richness at these sites. This hypothesis cannot be rejected for three sites (Lauderdale, Clear Lagoon and Calverts Lagoon).

6. The null hypothesis that, at each site, there was no significant difference in Total Abundance I between months, (Table 5-9), must be rejected for five sites (Pipeclay Lagoon, South Arm, Orielton Lagoon, Sorell and Barilla Bay), indicating a significant monthly pattern at these sites, but cannot be rejected for three sites (Lauderdale, Clear Lagoon and Calverts Lagoon).

7. The null hypothesis that, at each site, there was no significant difference in Total Abundance II between months, (Table 5-12), must be rejected for five sites (Lauderdale, Pipeclay Lagoon, Orielton Lagoon, Sorell and Barilla Bay), indicating a significant monthly pattern, but cannot be rejected for three sites (Clear Lagoon, Calverts Lagoon and South Arm).

8. The null hypothesis that, at each site, there was no significant difference in Species Diversity between months, (Table 5-15), must be rejected for four sites (Lauderdale, Pipeclay Lagoon, Sorell and Barilla Bay), indicating a significant monthly pattern, but cannot be rejected for the other four sites (Clear Lagoon, Calverts Lagoon, South Arm and Orielton Lagoon).

9. The null hypothesis that, at each site, there was no significant difference in the monthly pattern of Species Richness between the two sampling periods, (Table 5-7), must be rejected for one site (Sorell). This hypothesis cannot be rejected for the other seven sites.

10. The null hypothesis that, at each site, there was no significant difference in the monthly pattern of Total Abundance I between the two sampling periods, (Table 5-10), must be rejected for one site (Calverts Lagoon). This hypothesis cannot be rejected for the other seven sites.

11. The null hypothesis that, at each site, there was no significant difference in the monthly pattern of Total Abundance II between the two sampling periods, (Table 5-13), must be rejected for one site (Sorell). This hypothesis cannot be rejected for the other seven sites.

12. The null hypothesis that, at each site, there was no significant difference in the monthly pattern of Species Diversity, (Table 5-16), must be rejected for four sites (Lauderdale, Calverts Lagoon, Orielton Lagoon and Barilla Bay). This hypothesis cannot be rejected for four sites (Clear Lagoon, Pipeclay Lagoon, South Arm and Sorell).

13. A statistical re-examination of the data by seasons between the two sampling periods is needed to highlight seasonal trends that are not evident from an analysis that compares group means for entire years.

The following conclusion can be drawn regarding changes in site utilisation at the three shorebird sites not monitored during the 1960s sampling period, (Table 5-19).

The numbers of shorebirds which regularly utilise Mortimer Bay, Marion Bay, Five Mile Beach and Seven Mile Beach have not been monitored long enough for clear trends in utilisation of these sites to be quantitatively determined. However, the qualitative assessment by members of the Shorebird Study Group is that there appears to be a decrease in the numbers of shorebirds using Marion Bay and Mortimer Bay.

Based on changes in habitat and changes in site utilisation, the reasons for observed changes in shorebird numbers at some of the shorebird sites in South-east Tasmania are quite clear. Loss of habitat by reclamation, such as at Lauderdale, or by inundation, as at Orielton Lagoon, is a tangible event and can easily be related to decreases in shorebird numbers, as the drying trend and increased habitat availability at Calverts Lagoon can be directly related to an increase in shorebird numbers. Other reasons for changes, such as habitat alteration and disturbance to habitat, are less obvious, and it is difficult to definitively state the effect they have on site utilisation by shorebirds. The levels of habitat alteration and disturbance that shorebirds can, or will, tolerate before they will seek out alternative sites, have not been well-studied.

Despite the difficulty of determining causes for changes in shorebird numbers at sites of shorebird habitat, the evidence presented in this thesis provides the basis for a fairly realistic working hypothesis; specifically, that the disturbances and alterations to South-east Tasmanian shorebird habitat, documented in Chapter 4, are contributing causes, and perhaps the primary causes, for the changes in site utilisation documented in Chapter 5.

If it is assumed that the pattern of site utilisation during the 1960s reflects habitat preference, then the current pattern reflects a secondary preference. If this is the case, then a critical point has already been reached, and the protection and conservation of currently important shorebird habitat in South-east Tasmania is urgently required to ensure the maintenance of suitable feeding, breeding and roosting habitat.

Management objectives must be established upon which actions for conserving the habitat can be based. Chapter 6 provides an overview of management actions that have been taken in other states of Australia for the management of wetland areas, and specifically with those that provide shorebird habitat. Chapter 6 also presents management priorities for the conservation of shorebird habitat in South-east Tasmania.

CHAPTER 6: AUSTRALIAN EXAMPLES OF WETLAND CONSERVATION AND MANAGEMENT

6.1 Introduction

The preceding chapters have presented evidence that strongly supports the need for management action to conserve the major sites of shorebird habitat in South-east Tasmania. It has also been made clear in Chapter 2, however, that the State Government of Tasmania and the various agencies and organizations with responsibilities for these sites have not taken sufficient action to ensure the continued protection and conservation of these sites.

Section 6.2 briefly summarized wetland conservation actions taken in other States and Territories of Australia that may serve as precedents and examples for such actions that can be undertaken in South-east Tasmania. Section 6.3 lists and discusses the management priorities for the conservation of shorebird habitat in South-east Tasmania.

Precedents for conserving and managing wetland areas can be found throughout Australia. Some states, recognizing the threat of wetland attrition due to ad hoc planning, have devised conservation strategies, policies, or legislation that address wetland management. Management plans have been developed for numerous wetland areas in many states, particularly for wetlands in the vicinity of major urban centres. Every capital city in Australia is located on an estuary or other important wetland area, and the result of increased urban pressure on those wetlands is now being addressed by management documents. Many of these documents formally state that the maintenance of wetland ecosystems for their importance to shorebirds as a primary objective. A comprehensive review of all the literature and legislation for each state is beyond the scope of this thesis, and therefore only material relevant to, or comparable with, the South-east Tasmanian situation has been included.

6.2 Wetland Conservation Actions in Australia

The following discussion provides a brief overview of wetland conservation actions that have been taken in each state in Australia, and draws on specific management actions that have been used to address wetland management issues similar to those affecting wetlands that provide shorebird habitat in South-cast Tasmania. This discussion is based on Wetland Conservation in South Australia (South Australia, Department of Planning and Environment 1983) with additional information obtained from various state agencies.

In South Australia, the incumbent Government at the State election in 1982 made a commitment to: "Introduce a programme aimed at safeguarding remaining wetlands and extending them where possible in conservation parks and Crown Lands. A research proposal will be initiated to delineate, describe and assess the future viability of the State's wetlands." (South Australia, Department of Planning and Environment 1983).

This commitment led to a report by the Department of Environment and Planning (1983) which assessed the past, and current situation of wetland conservation in that state and recommended necessary future action for protection of wetland areas.

The report also briefly summarized wetland conservation in each state of Australia, and noted that wetland conservation appeared to be an important priority in each State and Territory except for Tasmania, although non-government conservation groups in Tasmania have been active in surveying and classifying the State's wetlands.

New South Wales has developed a state environmental planning policy on coastal wetlands as a legal planning instrument to ensure "that the likely effects of development proposals on wetlands are properly considered, while allowing existing landholders to continue to manage their wetlands" (New South Wales State Environmental Planning Policy 14 1985).

The New South Wales National Parks and Wildlife Service has a permanent research team working on wetlands and waterbirds, in conjunction with CSIRO (South Australia, Department of Environment and Planning 1983). A survey of the wetlands of coastal New South Wales was completed in 1970 (Goodrick 1970).

Adam (1984) strongly argued the case for a wetlands conservation strategy for the state of New South Wales, on the basis that: "at the present, the case against developments has to be developed de novo in each instance. Ideally we should work towards a situation where a developer has to prove that it is in the public interest for a development in a wetland to proceed, against a background where wetland preservation is paramount". At present, no such strategy has been published.

In Queensland, ecological research on coastal wetlands and the preparation of guidelines for preservation of significant wetland areas has been undertaken by the Fisheries Department. The Queensland National Parks and Wildlife Service has also undertaken wetland and waterbird research (South Australia, Department of Environment and Planning 1983), as well as reporting on wetland conservation activities that have been commissioned by the Premier's Department. However, these are not yet in the public domain (Queensland National Parks and Wildlife Service 1988).

In the Northern Territory, considerable research has been carried out on the wetlands of Kakadu National Park (South Australia, Department of Environment and Planning 1983). With respect to coastal management, the Northern Territory government has a policy which only addresses wetlands generally with the objectives: "protection of areas of high conservation value by establishing marine and coastal national parks and reserves" and "ensuring major development proposals affecting the coastal zone are subject to environmental assessment" (Northern Territory Coastal Management Policy Pamphlet undated).However, a management study is currently underway in Darwin Harbour to classify mangrove areas and associated mudflats into five zones, three of which are for conservation, preservation, and education and research (Dames and Moore 1987).

In the Australian Capital Territory a management plan has been devised for Lake Burley Griffin, near Canberra, to balance recreational utilization of the lake and conservation values (National Capital Development Commission (NCDC) 1987). The Jerrabomberra Wetlands within the Lake Burley Griffin study area have received particular attention for their importance to waterbirds, and in 1982, a set of guidelines were published which specifically considered an "ecological basis for planning and development" of Jerrabomberra Wetlands (NCDC 1982). These guidelines formed a basis for the Jerrabomberra Wetlands section of the Lake Burley Griffin Policy Plan.

The management issues and recommendations for the Jerrabomberra Wetlands are particularly relevant to the management of shorebird habitat in South-east Tasmania, which has similar management issues. The planning proposal for the site was to conserve the area as protected habitat for wildlife and waterbirds, and to provide public viewing and interpretation facilities (NCDC 1987). A major constraint, however, was the proximity of Canberra Airport to this wetland. This is a management issue similar to that at Barilla Bay in South-east Tasmania. The guidelines proposed that habitat could be managed for increased species diversity rather than for increased abundance. The guidelines stress that "from the information available to date, the creation of a range of diverse wetland habitats, restricted in extent but of high quality, with appropriate public access, would achieve a greater variety of wetland birds while not significantly increasing the number of birds likely to pose a hazard to aircraft operations" (NCDC 1982).

The Jerrabomberra Wetlands are essentially a backwater of Lake Burley Griffin, and their location close to the city exposes them to considerable urban pressures. Management issues include recreational pressure, drainage from agricultural land within the catchment, grazing and feral animal control (NCDC 1987), all issues which also occur at South-east Tasmanian shorebird sites. The plan made recommendations for the management of these issues in accordance with the status of the site as a protected wetland area of significance to wildlife and waterbirds and to the public for its nature interpretation values (NCDC 1982, 1984).

The Western Australian Department of Conservation and Environment published Guidelines for the Protection and Management of Wetlands in 1977 and again in 1980 (Western Australia, Department of Conservation and Environment 1986). The Western Australian Environmental Protection Authority recently published draft guidelines dealing specifically with wetland conservation in the Perth Metropolitan Region (Western Australia, Environmental Protection Authority 1986). In addition, numerous localized wetland surveys and management plans have been carried out in Western Australia (see Majer 1979; Swan River Management Strategy Task Force 1987; Western Australia, Environmental Protection Authority 1987; Western Australia, Department of Fisheries and Wildlife 1978; Bartle et al. 1987).

A management plan for Forrestdale Lake in Western Australia was published in 1987. This lake is a significant waterbird habitat, and the major objectives of the management plan were: "to protect and enhance the area as a waterbird habitat for the range of species presently utilizing the lake, retaining the area as a representative sample of Swan Coastal Plain wetlands; ensure recognition of the Reserve as a valuable research and educational resource; and ensure the continued presence of a diversity of native flora and fauna..." (Bartle et al. 1987).

The main management issues at Forrestdale Lake were water quality, water quantity, and appropriate public use. There was an indication that the lake contained excessively high nutrient levels, with a serious potential for eutrophication, a management issue also present at Orielton Lagoon in South-east Tasmania. Monitoring of nutrient levels were recommended and strategies to reduce nutrient levels will be considered in the future if necessary (Bartle et al. 1987). Water levels have fluctuated at Forrestdale Lake, and water in the lake is not regular or reliable. The plan stated that the objective was "to maintain an annual pattern of water levels which will meet the needs of the full range of waterbirds currently using the lake" (Bartle et al. 1987), while maintaining the current filling and draining cycle. This objective is also relevant to Calverts Lagoon in South-east Tasmania, and maintenance of water levels at the Lagoon may be a consideration in the future.

Another important objective described in the Forrestdale Lake Management Plan was "to ensure that the classification of the Lake and its surrounds reflects its importance as a conservation area for flora and fauna" (Bartle et al. 1987). The objectives for public use of Forrestdale Lake are: "to ensure that public use of the Reserve does not detract from its conservation values", and "to minimize conflict between uses" (Bartle et al. 1987). Fencing, erection of signs and a public information brochure are planned to fulfil these objectives.

Victoria has taken extensive action for wetland conservation. The Fisheries and Wildlife Department carried out a systematic survey and classification of the State's wetlands on which to base conservation action (South Australia, Department of Environment and Planning 1983).

The report Birds of Port Phillip Bay was commissioned in 1982 by the Port Phillip Authority. The purpose was to investigate birds and their habitats in thc Port Phillip Bay region, which includes the city of Melbourne, with a view to providing a basis for preparing a co-ordinated conservation strategy (Lane et al. 1984). The report was designed specifically "to contribute to government policy on bird conservation, and to provide direct input to management plans prepared by the Port Phillip Authority" (Lane et al. 1984). The objective of the study was "to describe in detail the avifauna of Port Phillip Bay's coastline, their habitat requirements, and management procedures necessary for their conservation" (Lane et al. 1984).

Consideration of the Port Phillip Bay study is relevant to the South-east Tasmanian shorebird habitat study because of the urban influence Melbourne and its suburbs exerts on the bay. In the Port Phillip Bay study, management issues, objectives and management recommendations were discussed for significant bird habitats at a number of sites. Many of the sites had management issues comparable to those at shorebird sites in South-east Tasmania. For example, management issues at Swan Bay within Port Phillip Bay included human impacts such as saltmarsh reclamation, saltmarsh destruction from ORVs, impact of stock on unfenced saltmarsh and human disturbance of breeding Pied Oystercatchers. Recommended management actions for the site included fencing to exclude stock, people and dogs from sensitive areas, limiting foreshore access to existing access points to protect undisturbed areas for breeding shorebirds, restricting further development in sensitive areas and reservation of some locations for wildlife protection (Lane et al. 1984).

Beach breeding shorebirds are considered to be particularly vulnerable to habitat changes and disturbance within the Port Phillip Bay region. Lane et al. (1984) stated that Red-capped Plover and Pied Oystercatcher breeding areas may have been reduced to a few, relatively undisturbed beaches as a result of intense human disturbance within the Bay. Disturbance during breeding season leaves birds and their eggs and young susceptible to attack. Management objectives which addressed the problem recommended limiting human activities on shorebird breeding beaches, and reducing the numbers of introduced predators. Management actions recommended to fulfil these objectives included limiting access and recreational facilities in sensitive areas, erecting explanatory signs and developing a control program to decrease populations of introduced predators (Lane et al. 1984).

A study of another shorebird habitat site in Victoria was also carried out, on Seaford Swamp (Donnelley et al. 1985). The primary aim of that study was "to develop a management plan which integrates the conservation and enhancement of ecology and values with cultural and economic values of the Seaford Swamp wetlands" (Donnelley et al. 1985). The Swamp was considered to be of major conservation significance, due to its status as one of the last 'natural' wetland habitats in the Metropolitan area.

Management issues at Seaford Swamp included water quality and the potential for eutrophication, management of water levels, stock grazing and the desire to develop the site for environmental study. Management strategies addressing multiple-use management, surrounding land use, water quality and levels, vegetation and management of exotic predators were all discussed, and a development plan proposed which allocated management zones to correspond with "recommended land use activities and intensities" (Donnelley et al. 1985). Nature conservation and wetland zones were identified with appropriate measures recommended to meet objectives of protection, conservation and habitat enhancement for these zones. Recommended actions included exclusion of grazing stock, discouragement of pedestrian access within these zones, planting of native wetland vegetation, and consideration of the future need to manage water levels (Donnelley et al. 1985).

In 1986, the Victorian Department of Conservation, Forests and Lands; the Department of Water Resources; and the Ministry for Planning and Environment jointly published a draft wetlands conservation statement on the wetlands in Victoria, with a series of wetland conservation recommendations (Victoria, Department of Conservation, Forests and Lands et al. 1986). In 1987, the Conservation Strategy for Victoria was published (Victoria, 1987). It specifically addressed wetlands, with a State Government commitment to:

> **"...prepare a State-wide wetlands policy which will initiate a strategy for the survey and evaluation of Victoria's wetland, a program for the effective management and protection of wetlands on private land (such as planning controls, guidelines, heritage agreements and covenants, and a publicity and education campaign on the importance of wetlands on private land; implement, by 1990, actions to protect wetland bird habitats on Port Phillip Bay, based on measures identified in the Birds of Port Phillip Bay report; and undertake an on-going annual purchase program for freehold wetlands and develop priorities for land acquisition..."**
> (Victoria 1987, p. 55).

It is clear from this brief discussion that steps have been taken in a number of cases around Australia to address management issues similar to those at wetland areas in South-east Tasmania. Several of these are specifically concerned with managing the areas as shorebird habitat (Lane et al. 1984; Western Australia, Environmental Protection Authority; NCDC 1982), and nearly all of them take the value of wetlands as shorebird habitat into account.

6.3 Management Priorities for Shorebird Habitat in South-east Tasmania

The following management objectives are statements of what needs to be done for effective management and conservation of the South-east Tasmania shorebird sites to occur. They are based on the evidence, presented in Chapters 4 and 5, that the limited areas of shorebird habitat within the study area are being altered and lost, with a resultant change in site utilization by shorebirds. These are management priorities, and recommendations are listed in Chapter 8 that specify the actions required for the following objectives to be met.

The overriding, primary objective is: **to maintain the major shorebird sites in South-east Tasmania as feeding, breeding and roosting habitat for shorebirds.**

Secondary objectives are:

1. **to ensure that each site receives the appropriate level of management to meet the primary objective**

Different levels of management action are required to address different intensities of management issues. For example, at some sites, such as Mortimer Bay, management actions such as fencing sensitive areas of breeding habitat to exclude disturbance to nesting birds and posting interpretive signs may suffice to achieve the primary objective. Other sites, such as South Arm and those that comprise Pittwater, urgently require protective reservation under the Tasmanian National Parks and Wildlife Act 1970 to ensure total protection of the shorebird habitat.

2. **to develop management plans for each site**

A management plan should be developed for each of the 11 shorebird sites as a joint effort by the municipalities involved, the Department of Lands, Parks and Wildlife, BOAT, and any other agencies with a concern at each site. Such a management plan need not be extensive, but simply a precis of the management objectives for that site, agreed upon by all relevant parties, and forming a framework within which each party carries out its normal activities with respect to that site.

3. **to continue to permit multiple-use of the shorebird sites, within the primary constraint of protecting and maintaining the shorebird sites**

Habitat retention should be recognized as one of the "multiple-uses" that wetland areas provide for. At shorebird sites in South-east Tasmania, other uses must not conflict with the primary objective.

4. **to ensure that the shorebird sites are managed and protected as components of systems of shorebird habitat**

The breakdown of the shorebird habitat systems into individual sites is artificial. Shorebirds utilize systems of wetland habitat by moving between the sites of a system for refuge from disturbance, for feeding or roosting habitat during high tide or after disturbance to these activities at another site, for breeding locations, and for sheltered roosting locations during bad weather. The importance of individual sites to shorebirds is thus influenced by the availability of other sites, to provide alternative habitat for other activities or as a refuge. Management actions must manage shorebird habitat at a systemic level, addressing management issues at each site with the recognition that each site is a component of a larger system.

5. **to obtain, at the local government level, a commitment to develop land use planning and zoning regulations to fulfil the primary objective**

Land use planning and zoning regulations that take the importance of wetland areas as shorebird habitat into account have been incorporated into the Eastern Shore Planning Scheme 1986 (unpublished) by the Municipality of Clarence (Douglas, Municipality of Clarence, Planning Section, pers. comm.). There is a critical need for other municipalities which have jurisdiction over important shorebird habitat to include similar strategies in their planning documents.

6. **to establish a state-wide management policy for wetlands that incorporates the ecological and educational values inherent to wetlands**

At present, the State Government has no stated commitment to protect Tasmania's wetland areas from destruction, alteration or attrition. There is an urgent need for the State Government to develop guidelines for the protection of wetland areas, and to recognize the ecological importance of these areas, including that as shorebird habitat. Such guidelines should define actions that will be taken to conserve wetlands.

7. **to encourage educational use of the sites for i) scientific and ecological research, at various levels, ii) for community education, providing an opportunity for nature interpretation, and iii) to educate the public about the processes and values of wetland ecosystems**

The sites of shorebird habitat in South-east Tasmania provide an excellent opportunity for education and research. Several of the sites, such as Orielton Lagoon, Calverts Lagoon, Pipeclay Lagoon and Mortimer Bay have already been the foci for ecological studies by University of Tasmania students and others (Guiler 1953; Buttermore 1977; Smith 1981; Woodward 1985; Richardson, Zoology Department, University of Tasmania, pers. comm.). The development of educational material at the sites, including pamphlets and interpretational signs, and the increased use of the sites for educating members of the public about wetlands, would raise the public profile of wetland areas and help to prevent unwitting destruction through recreational pressure and attrition.

8. **for decision-makers dealing with areas of shorebird habitat to draw on the resources of the Bird Observers' Association of Tasmania in an advisory capacity when developing management plans for the areas and in planning considerations for these areas**

BOAT, and particularly the Shorebird Study Group, has been active in research and monitoring at the major sites of shorebird habitat since the mid-1960s, and members have considerable knowledge concerning those sites and the shorebirds they support. In the past, much of BOAT's input on planned developments on wetland sites has been reactive rather than pro-active. The Association should be included in the planning process concerning developments or activities which affect shorebird habitat.

9. **to encourage community involvement with the sites**

Conservation of the wetland areas to maintain their importance as shorebird habitat would not "tie-up" the sites and make them inaccessible to the public. Rather, the public would be encouraged to use the majority of the sites within the context of the primary objective. Management of the sites for this purpose would require that activities that conflict with this aim be excluded, but non-conflicting uses would be encouraged, as would the use of the sites for education and research.

The shorebird sites in South-east Tasmania should be managed and protected as a community asset, within the framework of management priorities described.

CHAPTER 7: DISCUSSION

7.1 Introduction

Wetland loss and alteration is a global problem, and an increased recognition of wetland values and threats to wetland areas, and the development of actions to conserve wetlands, have come about only recently. The current situation is that of government and non-government agencies and organisations at all levels, from local to international, attempting to conserve wetlands against a background of wetland attrition, low values attributed to wetlands, and a lack of public understanding of the ecological importance of these areas.

In Tasmania, as across Australia, the wetland areas that provide shorebird habitat are under increasing urban pressure. The problem has reached a critical stage in South-east Tasmania, where the majority of the region's extremely limited shorebird habitat is adjacent to Hobart. The analysis of census data from 25 years at the major shorebird sites has established that there has been a shift in the pattern of utilisation of the sites of shorebird habitat since the mid-1960s. Changes in the total numbers of species and total numbers of shorebirds occurred at several of the most important shorebird sites. Changes in Species Diversity also occurred, indicating that the composition of the proportions of various species using the various sites had changed.

The evidence strongly suggests that habitat alteration, including disturbance, resulting from urban pressure, was a primary cause of decreases that occurred in the numbers of shorebirds and the numbers of species at the sites, and for the change in the pattern of site utilisation. The trends observed suggest that the shorebirds have shifted to previously less-preferred sites, which are less altered and less disturbed.

7.2 Management Options

Having established a relationship between habitat degradation and changes in shorebird numbers at the sites between the 1960s and 1980s sampling periods, and the importance of the affected habitat to resident and migratory shorebirds in South-east Tasmania, two management options exist:

1. manage the habitat for its ecological value to shorebirds
2 not manage the habitat

If the option not to manage is chosen, the likely outcome would be a continuation of the factors affecting the habitat, as discussed in Chapter 4. There is no reason to assume that population growth in the region will not continue, or that additional increases in recreational use of beaches will not occur, or that the occurrence of off-road vehicles, domestic and feral animals in wetland areas will abate. Without management at the sites, there is no basis to assume that the current low public profile of the sites will change, or that further attrition and degradation will not occur at the sites.

Therefore, since the conclusion of this study was that shorebird use of the study sites was negatively affected by habitat degradation, and if the objective is to maintain habitat for its importance to shorebirds, then the only conclusion that can be reached is that the situation warrants immediate management action.

7.3 Management Constraints

Management constraints are factors which influence whether a course of action is implemented and successful, and whether management objectives are met.

In Tasmania, there is a lack of commitment to wetland conservation by government authorities. The State Government has no stated commitment or policy dealing with the protection or management of wetland areas in Tasmania. While a policy alone does not accomplish anything tangible, it is the first step in acknowledging an issue and stating a commitment to its resolution. Policies run the risk of being ineffectual if they simply re-state management issues. The need is for policies which spawn management plans which state objectives and define a course of action.

Of the three Municipalities which have jurisdiction over major sites of shorebird habitat in South-east Tasmania, only the Municipality of Clarence has taken the protection of wetland habitat into account in its planning document.

The responsibility for wetland areas in South-east Tasmania is split between various authorities, and increased co-ordination between these authorities would be necessary for management of the sites to be successful.

Although the majority of study sites are located within the Municipality of Clarence, jurisdiction over land adjacent to Pittwater is split between three local government authorities. Thus, although a site may be under the jurisdiction of one Municipality, its ecology may be influenced by land or water use in adjacent local government areas. Thus, effective management of wetland needs to take land use within the catchment area into consideration.

Responsibility is also split between state and local authorities. The Crown is not bound by local government planning documents which stipulate land use, and thus Crown Land may be put to a use not consistent with the plan. Also, while a local government authority can designate the land use of an area for its nature conservation value, actual protective reservation can only be proclaimed through the Department of Lands, Parks and Wildlife.

Land tenure at each of the sites is in many cases divided between several owners or managers, and the problem of split responsibility is exacerbated by the number of parties involved. At present, there is no management plan for any of the sites, and thus there is nothing to co-ordinate and unify the actions of these various parties, and there is no agreed-upon framework within which each involved party can operate at the sites.

Wetlands and shorebirds have a low public profile and are not widely perceived as valuable by the public. In South-east Tasmania, this has prevented constructive conservation measures from being taken. There is limited public awareness of the importance of wetland areas as shorebird habitat, and limited resources are spent on higher profile, but not necessarily more important, issues. Few people in the region are aware of the international importance of the wetland areas to migratory shorebirds, and most are probably not aware that shorebirds resident in Tasmania breed on saltmarshes and beaches, since the birds are secretive and the nests cryptic. Education and interpretation at the sites are essential to raise the public awareness of shorebirds and wetlands, and to increase the profile of conservation issues relevant to them.

Timing and the availability of resources also play a role in the effectiveness of management actions. Government organisations expend their limited resources on management issues which have a high public profile. The political, social and economic climate at any time also influences the effectiveness of management actions, particularly in the reservation of areas for their conservation value. The elevation of a management issue to a high profile at a time when resources are available, public interest is high, and the political, economic and social climates favour management actions such as conservation is essential if the actions are to be implemented and effective. Finally, the over-riding factor as to whether management recommendations are implemented and successful is the commitment and willingness to act by governments and managing authorities and organisations.

7.4 Management Priorities

The management priorities for the conservation of shorebird habitat in South-east Tasmania fall into five major categories:

1. establishment of reserves
2. specific management actions
3. education
4. establishment of wetland conservation plans, and
5. further ecological research

These five categories address all of the management issues at the sites. The management priorities were presented in Chapter 6 as management objectives, and as objectives can be met through a course of action.

7.5 Discussion of the categories of management objectives and site-specific recommendations

7.5.1 Reserves

The establishment of reserves needs to be based on ecological criteria. Shorebirds tend to be faithful to sites (Thomas, personal communication), so it cannot be assumed that the reservation of only one site within a region will be sufficient and that the shorebirds displaced from other sites will shift there. Shorebirds tend to use systems of habitat; for example, the Pittwater system, or the South Arm Peninsula system, and use various sites within each system for different activities. Some sites, for example, may function as roosting sites at high tide, while others are used as alternative feeding sites during bad weather. Also, because of the irregular nature of the tides in South-east Tasmania and the irregularity of suitable water levels in the near shore lagoons, it is essential that several feeding and roosting sites are available to shorebirds.

Management plans need to be drafted for reserved areas. A management plan functions as a framework to co-ordinate all parties involved with a site in working towards agreed upon management objectives for the area.

Some of the study sites urgently require protective reservation, in order to ensure that major areas of habitat are preserved, and to ensure that a cross-section of ecologically required habitats is maintained. The Pittwater system, including Barilla Bay, Orielton Lagoon and Sorell, requires reservation for its importance to large numbers of migratory and resident shorebirds.

The failure to reserve Pittwater and South Arm as Conservation Areas exemplifies the role of management constraints in the implementation of management actions already recognised as necessary steps to ensure conservation of shorebird habitat. As one of the most significant wetland areas for waterbirds in South-east Tasmania, its inclusion of the List of Wetlands of International Importance, and on the Register of the National Estate, Pittwater should have protected status. Yet there has been no commitment on the part of the State Government to ensure the protection of the area. On ecological grounds, Orielton Lagoon, Sorell and Barilla Bay are integral parts of a system of shorebird habitat and yet the compromises necessary to gain acceptance of the reserve from all agencies and organisations involved in the area resulted in a proposal that would provide only one-third of the system with critically needed protection, and alone would not fulfill the objective to safeguard sufficient habitat to protect the shorebirds.

All three sites should be included in a resubmission of the proposal to State Cabinet. If the political reality is that there is no possible compromise which will allow Barilla Bay and Sorell to be included in the reserve, then these sites must be given some alternative form of protection, ie. as Conservation Areas under the National Parks and Wildlife Act 1970, or as Protected Areas under the Department of Lands, Parks and Wildlife, until such time that an agreement to incorporate them into the reserve can be reached.

Issues that need to be addressed in a management plan for the area include: eutrophication; the establishment of buffer zones; ensured protection of Barilla Bay and Sorell irrespective of whether or not they are included in a nature reserve for Pittwater; water levels in Orielton Lagoon; water quality monitoring for Pittwater; options for Barilla Bay with respect to its proximity to the airport and the proposed runway extension, ie, how to best protect the maximum amount of shorebird habitat possible in the event that (a) the runway extension does someday occur, or (b) that it does not occur, or may not occur for quite some time. Pittwater should be promoted as community asset due to its standing as a Wetland of International Importance. At Orielton Lagoon, the best action to take concerning water levels would be to maintain present water levels, and to allow no further inundation of the limited amount of habitat which remains at the northern end of the Lagoon to occur. Water quality monitoring and strict control of the standards of wastewater discharged into the Lagoon should occur to prevent, or minimise, eutrophication problems. Public access to the northern end of the Lagoon, including trail bikes and bicycles, should be discouraged, and the area protected as roosting and feeding habitat for shorebirds.

BOAT has been granted permission from the Department of Lands, Parks and Wildlife to maintain the Sorell shorebird site, and the Association intends to re-vegetate the area and to promote the site as a location for viewing shorebirds, and as an educational resource for local schools.

There is great potential for developing this site as an educational resource while maintaining and protecting it as shorebird habitat. The site should be established as a viewing location and interpretation site as a component of a Wetland of International Importance. The area should be re-vegetated with native plants to provide a buffer zone for the mudflats. The use of native species is important not only from an ecological point of view, but also because they would not require intensive watering and could rely on rainfall once established, thus not instigating a potential problem with leaching from the former tip site.

The existing gate should remain closed, and a boulder barrier should be placed along the access road to the site and parking area to prevent vehicles and boats from gaining access to the mudflats.

Although the shorebird habitat at Barilla Bay has been relatively sheltered from alteration and disturbance, its future is uncertain because of the possibility of an airport extension that would involve infilling of the Bay. The Bay provides important feeding habitat within the Pittwater system and should be reserved as part of that system, as previously discussed. Specific management actions required at Barilla Bay include excluding dogs and sheep from the saltmarsh and mudflat areas, and the management plan for the site needs to be in conjunction with oyster farmers and local residents so that measures to maintain the ecology of the site are agreed upon by all involved parties at the sites.

South Arm Neck is a staging area for migratory species and is a relatively undisturbed and unaltered site when compared to sites such as Lauderdale or Orielton Lagoon, and it has become a preferred site, holding greater than 50% of the total count for South-east Tasmania at the 1987 Summer Wader Count. The larger shorebirds have decreased at the site; smaller shorebirds have increased tremendously, apparently using the site as a refuge from more disturbed sites. It is essential that this site is established as a reserve. Management issues such as shooting and the use of vehicles on the saltmarsh and mudflats threaten the site's conservation status, and is a matter of urgency that South Arm neck be proclaimed a Wildlife Sanctuary under the Tasmanian National Parks and Wildlife Act 1970. The boundaries should remain as previously proposed, and a management plan for the area is of the highest priority. Interpretative signs or displays should be erected at a suitable viewing area adjacent to the mudflats.

The management plan for the site should consider the following points: the exclusion of vehicles from the saltmarshes and mudflats, which may require barriers such as large rocks or ditches at access points to those areas, as well as educational signs, and the removal of litter from the area between South Arm Road and the mudflats. The sand mining operation nearby is already used as habitat by Black-fronted Plover and some species of ducks, and the feasibility of the rehabilitation of the mining sites as shorebird habitat should be investigated.

7.5.2 Specific Management Actions

While reservation is the optimum form of management for some sites, at most the sites actions are needed to deal with specific management issues. A management plan for each site should be established as a précis of the management objectives for that site, and the course of action to be undertaken to meet those objectives, agreed upon by all relevant parties, and forming a framework within which each party carries out its normal activities with respect to that site.

While the "multiple use" of an area is the goal, shorebird habitat is one of the "multiple uses" that wetland areas provide for. However, unlike the majority of recreational uses of wetland areas, it is not substitutable; many of these uses can take place elsewhere, whereas the shorebirds are dependent on specific sites. The amount of suitable shorebird habitat in South-east Tasmania is so limited that it must be considered the priority use of these wetland areas.

One specific management action that is applicable to all the shorebird sites is the establishment of buffer zones. Angel and Hayes (1983) defined these as "areas of terrestrial vegetation extending from the tidal, flood, or permanent lake level", and their use is as a form of protection for vulnerable wetland areas. Management plans for each site should incorporate buffer zones whenever possible as a means of sheltering the site from disturbance.

The management requirements of Orielton Lagoon, Barilla Bay, Sorell and South Arm have been discussed in section 7.5.1, since these sites urgently require protective reservation. The other seven sites are in need of more specific management actions to deal with specific problems at the sites.

The shorebird habitat at Lauderdale has been severely altered over the past 25 years, with loss of saltmarsh due to the construction of the tip site; increased competition for roosting space by gulls attracted to the tip site; horses, dogs and off-road vehicles present on areas of shorebird habitat; and widespread human disturbance. The significant decreases in each of the four indices of shorebird numbers analysed is most probably a result of the heavy disturbance and habitat alteration at the site.

To maintain the site as shorebird habitat, a number of management actions are required. The tip site should be relocated to a non-wetland area and the present tip site converted to a use that would not deleteriously affect the adjacent wetland area. A development such as the sports field currently proposed for the site would be inappropriate, due to the leaching problems associated with intensive watering of the grass. Aerial Lagoon, located in the Lauderdale saltmarsh, was cut off from regular flushing by the construction of the road and the small culverts under the road for water flow to the Lagoon. The size of the culverts should be increased. The resultant increased flushing of the Lagoon would make stagnation less likely, and the habitat would be more attractive to Pied Oystercatchers for feeding, as the area already provides an important roosting site for shorebirds, especially in bad weather. Barriers and educational notes need to be erected to exclude horses, dogs and off-road vehicles from the saltmarsh and mudflats.

As an irregularly filled wetland, Clear Lagoon does not provide reliable shorebird habitat. Blackhall (1986) stressed the importance of Clear Lagoon as waterfowl habitat, and the site is probably relatively more important for waterfowl than for shorebirds. The site is currently under consideration for the establishment of a conservation area managed for its value for waterfowl. Management as a waterfowl site would be beneficial to shorebirds as well, providing that some of the shoreline was maintained bare of vegetation, or with very low vegetation, to provide good roosting habitat for shorebirds.

The shorebird habitat at Pipeclay Lagoon became a preferred site for Red-necked Stint and Curlew Sandpiper during the 1970s and early 1980s, when these two species were increasing in number in South-east Tasmania (Thomas 1986). It appears from Summer Wader Count data and from a qualitative assessment by members of the Shorebird Study Group (pers. comm.), that shorebird utilisation of the site is declining again. Considering that the increase in numbers of Red-necked Stint in the region is beginning to level off, and the numbers of Curlew Sandpiper are still increasing (Thomas pers. comm.), and in view of the high degree of disturbance to the saltmarshes and mudflats at the site from horses, dogs, off-road vehicles, recreational activities and the adjacent subdivision of land, it is highly likely that the recent decrease in shorebird numbers at the site is a result of habitat degradation.

Management actions needed at the site include protective status for the remaining areas of saltmarsh, exclusion of horses, dogs and off-road vehicles from the saltmarshes and tidal flats, and a limit to the number of dwellings that can be built adjacent to the site.

The reason for the increase in all four indices at Calverts Lagoon between the 1960s and 1980s sampling periods is that the Lagoon has been drying over the past few decades and provides feeding habitat for shorebirds only when the muddy perimeter is exposed. Calverts Lagoon is relatively unaltered and undisturbed when compared to shorebird sites closer to population centres, and provides alternative feeding and roosting habitat to other shorebird sites on the South Arm Peninsula. The trend towards an increased number of birds using the site suggests that Calverts Lagoon has increased in importance as an alternative to the more heavily disturbed sites.

The feasibility of proclaiming the Lagoon a Nature Reserve under the Tasmanian National Parks and Wildlife Act 1970, even though it is already within the South Arm State Recreation Area, should be investigated as a means of providing increased protection to the site specifically for its value as shorebird habitat.

The management plan devised for Calverts Lagoon should provide for the monitoring of water quality and potential for eutrophication, as well as the water level. If the drying trend of the Lagoon observed over the past 20 years continues, it will be necessary to decide whether the water levels in the Lagoon should be artificially maintained. In addition, horses and dogs need to be excluded from the marshy perimeter of the Lagoon.

Mortimer Bay's primary importance to shorebirds has been to resident rather than migratory shorebirds. Past management measures have been taken at the site in an attempt to reduce disturbance to the Fairy Tern population at the location. These actions included cordoning off the nesting area during the breeding season, the erection of "breeding birds" signs, and the erection of a fence across the beach and extending into the water as a means of excluding horses and off-road vehicles.

Beach breeding shorebirds are particularly vulnerable to disturbance, and the same management actions that were undertaken for the Fairy Terns are relevant to shorebirds. Notices prohibiting dogs, horses and off-road vehicles are needed, and need to be enforced, and notices explaining the importance of the beach as breeding shorebird habitat are also called for. The existing fence across the beach, which restricts access to pedestrians, is in disrepair and needs to be fixed.

Seven and Five Mile Beaches have only been censused occasionally for Summer and Winter Wader Counts, and have not been monitored intensively over a period of years as have many of the other sites. Thus, no trends in the numbers of birds using the beaches can be assessed. It is known, however, that the beaches are used for breeding Pied Oystercatcher and

Hooded Plover, and that the level of disturbance on the beaches, from off-road vehicles, bicycles, horses and recreational users, is extremely high.

The recreational use of the beach is too heavy to be able to permanently set aside areas for shorebirds. A more realistic approach would be to exclude dogs, bicycles, and off-road vehicles from the beaches and to restrict horses to marked trails away from the beach and dunes. As at so many of the sites, signs that prohibit dogs and off-road vehicles are generally ignored, and educational signs would probably receive more attention.

If breeding sites are to be protected from disturbance, it will probably have to be as individual nest sites. BOAT could monitor the beaches annually for nest sites, and these sites could be cordoned off, with buffer zones, and signposted as temporarily restricted locations. Access to the spit could also be restricted in order to prevent disturbance of roosting shorebirds, with a signposted buffer area on both the terrestrial and seaward approaches.

Marion Bay was monitored intensively only during the 1980s sampling period. Although long term assessment of shorebird numbers is not possible, it appears from the 1980s data that shorebird numbers at the site have not been deleteriously affected by habitat change at the sites. However, many of the same pressures that are in effect at other shorebird sites in South-east Tasmania are beginning to occur at Marion Bay, such as rapid population growth, and increased recreational pressure, including the use of the beach for exercising dogs and driving off-road vehicles. The saltmarsh areas behind the spit and at Big and Little Boomer are not well protected, and these areas are subject to increasing use and disturbance. These areas should be protected for their ecological value under the planning document for the Municipality of Sorell. The prohibition of off-road vehicles and dogs needs to be enforced. The prohibitive notices should be accompanied by educational notices about the use of, and importance of, the beach, saltmarsh and mudflats by breeding and migratory shorebirds. Sheep should be excluded from the saltmarsh and mudflats to prevent trampling of vegetation and of shorebird breeding sites. The grazed fields at the base of the spit, however, provide good habitat for Double-banded Plover, and continued grazing in that area would be beneficial.

7.5.3 Education

The most important single action that can be taken to protect shorebirds and their habitat is to educate the community, including the decision-makers, about the ecological importance of wetlands and the flora and fauna they support. Just as attrition is one of the main causes of the loss of wetland habitat, a major reason that attrition occurs is simply a lack of awareness and understanding on the part of the public that wetlands perform important functions, and that shorebirds are an important component of that ecosystem. The public profile of wetlands and shorebirds must be raised, as it is only with public support that management can be effective.

The Bird Observers' Association of Tasmania, and particularly the Shorebird Study Group, as the experts on South-east Tasmania's shorebirds and their habitat needs, have a major role to play in this respect. A series of visits to the sites, with the public invited, would succeed in making people aware of the shorebirds reliant on the region's wetland sites, and the need for protection of those sites. BOAT could also produce interpretive pamphlets that briefly describe the sites, and that encourage their use for bird-watching and nature observation, explain the importance of the habitat to breeding, feeding and roosting, and explain the necessity of excluding dogs, horses, off-road vehicles and disturbance from sensitive areas. The organisation should investigate the feasibility of distributing these pamphlets, perhaps to ratepayers in co-operation with the local councils. At several of the sites, the presence of dogs, horses and off-road vehicles are management issues. These need to be restricted or prohibited at most of the sites. Enforcing these restrictions using educational notices would be more effective than with just prohibitive statements on signs. For example, a sign stating "no dogs allowed" is less likely to provoke empathy, and therefore compliance, than a sign that briefly explains the importance of excluding dogs from sites used by breeding shorebirds.

Calverts Lagoon provides an excellent educational opportunity for raising public awareness of shorebirds and wetland ecosystems. The site is well suited for public education, and the development of educational displays and the sensitive placement of a limited number of sheltered viewing sites could increase community interest in the shorebirds and lead to an increased value being placed on wetland sites in the region. Viewing locations at Calverts Lagoon should be placed to provide a view of the habitat and shorebirds, but should be located near the road, and access to the actual Lagoon should be restricted to these sites. The site should be developed and managed as a site for observing shorebird.

A pamphlet describing the South Arm State Recreation Area, which includes Calverts Lagoon, was developed by the Lands Department (Lands Department 1980), and could easily be revised with an expanded interpretive section on shorebirds, viewing opportunities at the site and the importance of conservation of shorebird habitat in South-east Tasmania.

Similarly, interpretive displays established at Sorell could function as the interpretive focus of a Nature Reserve at Pittwater, with educational displays, and with the potential for educational use by local schools.

7.5.4 Plans, not policies alone

The establishment of wetland conservation management plans, not just policies, by state and local government authorities are urgently needed. It is essential that policies are formulated as commitments to constructive action and not just "on the books".

7.5.5 Further Ecological Research

The role of this study has primarily been to compile existing information about the pressures affecting shorebird habitat in South-east Tasmania and its effect on shorebird utilisation of the sites. In spite of the large volume of data that has already been collected by the Shorebird Study Group, much information that will contribute to a further understanding of shorebird ecology and use of habitat in the region is still missing.

Information is lacking, particularly in Australia, on the effect of disturbance and habitat alteration on shorebirds, and on the way which events that have occurred in other parts of their ranges influence the numbers of various species of shorebirds using shorebird habitat in South-east Tasmania. There is insufficient information regarding why shorebirds prefer particular sites over others, whether ecological changes at the sites have been a cause of observed changes in site utilisation, and whether such changes, if they occurred, were due to habitat alteration or to natural cycling, and whether the numbers of shorebirds at the sites and the patterns of site utilisation is a cyclic event.

Feeding studies at the sites are needed to determine what the birds are feeding on, why they prefer particular sites and their patterns of movement between sites. The carrying capacities of the various sites are unknown, and studies on the availability of the food resource at each site are required.

CHAPTER 8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The following conclusions can be drawn from the evidence presented in this thesis.

The primary conclusion is that the research hypothesis has been supported by the evidence presented. The presence of a relationship between habitat alteration and disturbance and observed changes in the pattern of site utilisation of shorebird sites has been established, with the conclusion that habitat alteration, primarily due to urban pressure, was a strongly contributing factor, and some cases the causal factor, for the changes in utilisation between the 1960s and 1980s sampling periods.

The null hypotheses concerning whether changes in utilisation of the 11 study sites occurred were addressed in detail in the Chapter 5 conclusion section, 5.2.4. In summary, there were significant changes in shorebird numbers at the majority of the sites, and the pattern of site utilisation changed between the two sampling periods, with some sites exhibiting an increase, and others a decrease, in various indices.

While some of the changes in the numbers of shorebirds at some of the sites may be attributable to unknown ecological factors, to natural cycles in shorebird numbers or use of sites, or to changes in the abundance of individual species visiting the area, the significant point is that the pattern of site utilisation changed. The observed trend was away from areas where the habitat had been heavily disturbed or altered (ie, Lauderdale, Pipeclay Lagoon, Mortimer Bay and South Arm). At other sites, the relationship between habitat alteration and changes in shorebird numbers at the sites was not as apparent, but still evident, with the change in site utilisation reflecting habitat changes elsewhere in the systems of habitat, (ie, Sorell, Barilla Bay, South Arm and Calverts Lagoon).

Two additional points must be considered in drawing a final conclusion. Shorebird habitat in Tasmania is limited, and particularly so in the south-east of the state. It is assumed that the pattern of site utilisation in the 1960s was the preferred pattern, and that changes from that pattern represent a less preferred situation. Failure to take action to protect and conserve existing habitat would most likely result in the continued degradation and loss of that habitat, conceivably to the point that the ecology of the sites was irreparably affected, and rehabilitation no longer possible. Therefore, the most reasonable and prudent course of action would be to act immediately to manage, protect and conserve the 11 sites of shorebird habitat in South-east Tasmania for their utility to shorebirds.

In conclusion, the over-riding management priority for the 11 major sites of shorebird habitat in South-east Tasmania is the conservation and management of these sites as feeding, breeding and roosting habitat for shorebirds. Secondary priorities, expressed as management objectives in Chapter 6, fall into five major categories:

1. Immediate protective reservation of Pittwater (including Sorell, Orielton Lagoon and Barilla Bay) and South Arm is essential. The extent of the reserves and the details of their management plans must be based on ecological, rather than political, criteria, and must deal with the reserved areas as components of systems of shorebird habitat.

2. Specific management actions are necessary for all 11 sites, irrespective of reservation status, and must include the development of management plans and appropriate levels of management to adequately address the management issues at each site.

3. Education of the community, including decision makers, about wetland processes and values is imperative in order to raise the public profile of shorebirds and wetlands.

4. The establishment of wetland conservation management plans, not just policies, by state and local government authorities are urgently needed. It is essential that policies are formulated as commitments to constructive action and not just empty statements that are never implemented.

5. Further ecological research is necessary to more fully understand, and to monitor, the ecology of the shorebirds using shorebird habitat in South-east Tasmania.

8.2 Recommendations

The following recommendations define actions that are necessary to accomplish the management priorities as identified:

8.2.1 General

It is recommended that:

1. The State Government develop and implement a statewide wetlands conservation policy, and that the mechanism for action within this policy be the formulation of management plans;

2. an overall management plan be developed for South-east Tasmanian shorebird habitat, with consideration of each of the 11 sites as a component of a larger system of shorebird habitat;

3. a management plan be produced for each of the 11 shorebird sites within the study area, as a means of providing a set of guidelines for the management of each site to serve as a framework

within which all agencies and groups involved with the site can work toward common, pre-defined goals;

4. buffer zones should be included for each site where-ever possible, and allowance for these zones should be addressed in the management plans;

5. land and water use and management within the catchment areas for the 11 sites should be consistent with the primary objective of the protection, conservation and management of the habitat;

6. BOAT produce interpretive pamphlets that briefly describe the sites of shorebird habitat in South-east Tasmania, encourage the use of these sites for bird-watching and nature observation, explain the importance of the habitat for breeding, roosting and feeding shorebirds, and explain the importance of excluding dogs, horses, off-road vehicles and disturbance from these sites;

7. BOAT distribute these pamphlets with the notices sent out to ratepayers in co-operation with local councils;

8. BOAT (Shorebird Study Group) members organise a series of public visits to view the shorebird sites, stressing shorebird observation, conservation requirements at the sits and nature interpretation to raise public awareness; and that:

9. ecological research at the sites should continue.

Lauderdale

It is recommended that:

1. the Lauderdale tip site be relocated to a non-wetland location;

2. the existing tip site be converted to a use compatible with the surrounding wetland vegetation, and that any future use which may exacerbate any leachate problem, such as a sports field or other development that requires intensive watering of vegetation, not be placed on the site;

3. the culverts under the road which connect the mudflats and Aerial Lagoon be enlarged to increase the rate of flushing of Aerial Lagoon;

4. steps be taken to prevent the use of vehicles on the saltmarsh and mudflats, including the placement of barriers at access points to the areas and the posting of educational notices; and that:

5. educational notices be posted prohibiting dogs and horses on the saltmarsh and mudflats, and that horses be restricted to marked horse trails around the perimeter of the saltmarsh.

Clear Lagoon

It is recommended that:

1. the site be managed as a waterfowl site, as described in Blackhall (1986), with protective status under the Department of Lands, Parks and Wildlife; with the exceptions that:

2. some sections of the shoreline be maintained free from brush, to provide feeding and roosting habitat for shorebirds; and that:

3. some areas of short vegetation be maintained around the Lagoon to provide roosting, and possibly breding habitat for shorebirds.

Pipeclay Lagoon

It is recommended that:

1. The remaining areas of saltmarsh at Pipeclay Lagoon be afforded protective status under the jurisdiction of the Municipality of Clarence;

2. vehicles, horses and dogs be excluded from the saltmarshes and the tidal flats, and that educational notices be posted to accomplish this; and that:

3. the number of dwellings in existing settlements around the Lagoon be limited to their present numbers.

Calverts Lagoon

It is recommended that:

1. Calverts Lagoon be developed and managed as a site for observing shorebirds;

2. interpretive signs and displays be erected at the site;

3. a limited number of observation hides be erected at the site, in locations that provide viewing opportunities but cause minimal disturbance to the site, and that access to all other areas around the marsh be restricted;

4. the pamphlet put out by the Department of Lands, Parks and Wildlife be expanded to include an interpretive section on shorebirds, the shorebird viewing opportunities at Calverts Lagoon, and the importance of conservation of shorebird habitat;

5. the feasibility of proclaiming the Lagoon a Conservation Area under the Tasmanian National Parks and Wildlife Act 1970 in addition to its status as part of the South Arm State Recreation Area be investigated;

6. the management plan for Calverts Lagoon take into consideration that water levels may have to be artificially maintained at some point in the future if the drying trend at the Lagoon continues, and that the plan provide for monitoring of water levels at the Lagoon;

7. the management plan provide for monitoring of nutrient levels and eutrophication at the site; and that:

8. horses be excluded from the shoreline of the Lagoon and restricted to trails which are behind the natural buffer zone of vegetation.

South Arm

It is recommended that:

1. The shorebird site at South Arm be reserved immediately as a Conservation Area under the Tasmanian National Parks and Wildlife Act 1970, with the same boundaries proposed at the time of submission to State Cabinet in 1986;

2. a management plan be developed immediately;

3. shooting be strictly limited to a specific season, times and location, to minimise interference to shorebirds;

4. vehicles be excluded from the saltmarsh and mudflats, including vehicles used for collection of seaweed. This may require barriers at access points, sections of low fencing or ditches, and the posting of educational notices;

5. interpretive signs or displays be erected adjacent to the saltmarsh and mudflats;

6. litter from the margin of the mudflats and adjacent to South Arm Road be removed; and that:

7. the feasibility of rehabilitating nearby sand mining sites, when closed down, as shorebird habitat.

Pittwater

It is recommended that

1. Pittwater, including the shorebird sites of Orielton Lagoon, Barilla Bay and Sorell, be reserved immediately as a Nature Reserve under the Tasmanian National Parks and Wildlife Act 1970;

2. a management plan for the entire Pittwater system be drafted immediately;

3. if absolutely no compromise can be reached to include Barilla Bay or Orielton Lagoon within the Nature Reserve, Orielton Lagoon should be protected as Nature Reserve and Barilla Bay and Sorell should receive the maximum protection possible; all three sites should be included in an overall management plan for Pittwater, with defined management actions to be adhered to by all involved parties.

4. Pittwater be heavily promoted as a community asset due to its standing as a Wetland of International Importance, with an interpretative display at the Sorell shorebird site.

Orielton Lagoon

It is recommended that:

1. Orielton Lagoon be reserved immediately as part of the Pittwater Nature Reserve:

2. the northern end of Orielton Lagoon be fenced off from the road which allows only pedestrian access to the area;

3. water quality monitoring within Orielton Lagoon continue, and a water quality standard set that will reduce the probability of eutrophication in the Lagoon, and that the limit is applied to all parties discharging into the Lagoon;

4. the northern end of Orielton Lagoon be managed for its value as a fairly isolated roosting location, and the general public encouraged to use other locations for observation of shorebirds (except for monitoring activities); and that:

5. particular consideration be given to the establishment of a buffer zone at Orielton Lagoon.

Sorell

It is recommended that:

1. Sorell be reserved immediately as part of the Pittwater Nature Reserve, with the boundaries from the causeway to and including the mouth of Iron Creek;

2. the Department of Lands, Parks and Wildlife make a long term commitment to permit BOAT to manage the site as shorebird habitat;

3. BOAT develop the site as a viewing location and interpretation site to educate members of the public of shorebirds and wetland ecosystems, and to promote the importance of Pittwater as a Wetland of International Importance, particularly for migratory shorebirds in Tasmania;

4. interpretive displays be constructed at the site;

5. the existing gate at the site remain closed, and a rock barrier placed along the road to the mudflats to keep vehicles and boats from gaining access to the mudflats; and that:

6. BOAT re-vegetate the area with native vegetation to provide a buffer zone between the site and the mudflats.

Barilla Bay

It is recommended that:

1. Barilla Bay be reserved immediately as part of the Pittwater Nature Reserve;

2. the oyster lease managers be included in drafting the management plan for the site;

3. the oyster lease managers and local residents restrain their dogs from the saltmarsh and mudflats;

4. Barilla Bay be managed to conserve existing shorebird habitat, but that no actions be taken that would increase the numbers of shorebirds such that the risk of birdstrikes to aircraft would be increased (actions that increase diversity of shorebirds without increasing abundance would, however, be acceptable); and that:

5. sheep be excluded from the saltmarsh areas.

Mortimer Bay
It is recommended that:

1. the existing fence at the site erected to exclude off-road vehicles and horses from the breeding beach for shorebirds be repaired and maintained; and that:

2. an educational sign be erected in addition to the "breeding birds" sign, and educational notices be posted which prohibit horses, dogs and off-road vehicles on the beaches.

Seven Mile Beach Peninsula: Five and Seven Mile Beaches
It is recommended that:

1. horses, dogs, off-road vehicles and bicycles be excluded from the beaches and dunes, and that horses be restricted to marked trails and to exercise areas allowed by the Municipality of Clarence;

2. that educational notices explaining the use of the area by shorebirds be posted along the beaches and at the end of the spit where boats gain access to the area; and that:

3. that the area be surveyed annually by BOAT members for nesting areas, and these areas signposted and cordoned off as sensitive breeding locations.

Marion Bay
It is recommended that:

1. that the saltmarsh areas be designated protected areas for their ecological values under the planning document for the Municipality of Sorell;

2. the management plan for this site should exclude sheep from the saltmarsh areas around Big and Little Boomer, and from the saltmarsh and mudflat areas behind the spit. Continued

grazing of the fields at the base of the spit would not negatively affect shorebird habitat, and would maintain the area as suitable Double-banded Plover habitat;

3. educational notices be erected regarding the use of the beach, saltmarshes and mudflats by breeding and migratory shorebirds;

4. off-road vehicles be prohibited from the beach and saltmarsh areas; and that

5. as stated by the Tasmanian Conservation Trust (1979), "the marshes in the hinterland and at the causeway should remain. No roadworks, filling firing, grazing, etc. which would alter the ecological system should take place".

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Appendix 1:

Criteria for Identifying Wetlands of International Importance for Designation for the List under Article 2 of the Ramsar Convention: as revised at the Third Meeting of the Conference of the Contracting Parties in Regina (ANPWS 1987a)

<u>A wetland is suitable for inclusion in the List if it meets any one of the criteria set out below:</u>

1. Criteria for assessing the value of representative or unique wetlands.

   A wetland should be considered internationally important if it is a particularly good example of a specific type of wetland characteristic of its region.

2. General criteria for using plants or animals to identify wetlands of importance.

   A wetland should be considered internationally important if

   (a) it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal or an appreciable number of individuals of any one or more of these species; or

   (b) it is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna; or

   (c) it is of special value as the habitat of plants or animals at a critical stage of their biological cycles; or

   (d) it is of special value for its endemic plant or animal species or communities.

3. Specific criteria for using waterfowl to identify wetlands of importance.

   A wetland should be considered internationally important if

   (a) it regularly supports 20,000 waterfowl; or

   (b) it regularly supports substantial numbers of individuals from particular groups of waterfowl indicative of wetland values, productivity or diversity; or

   (c) where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.

Guidelines

A wetland could be considered for selection under Criterion 1 if:

(a) it is an example of a type rare or unusual in the appropriate biogeographical region; or

(b) it is a particularly good representative example of a wetland characteristic of the appropriate region; or

(c) it is a particularly good representative of a common type where the site also qualifies for consideration under criteria 2a, 2b or 2c; or

(d) it is representative of a type by virtue of being part of a complex of high quality wetland habitats. A wetland of national value could be considered of international importance, if it has a substantial hydrological, biological or ecological role in the functioning of an international river basin or coastal system; or

(e) in developing countries, it is a wetland which, because of its outstanding hydrological, biological or ecological role, is of substantial socio-economic and cultural value within the framework of sustainable use and habitat conservation.

Waterfowl indicative of wetland values, productivity or diversity under Criterion 3(b) include: divers (loons), grebes, pelicans, storks, ibises, spoonbills, herons, flamingos, swans, geese, ducks, cranes, rails and coots, waders (shorebirds), gulls and terns.

Appendix 2:

Shorebirds Listed in the Annexes to the Migratory Bird Agreements.

Shorebirds Listed in the JAMBA Annex:

Ringed Plover	Charadrius hiaticula
Mongolian Plover	Charadrius mongolus
Large Sand Plover	Charadrius leschenaultii
Oriental Plover	Charadrius veredus
Lesser Golden Plover	Pluvialis dominica
Grey Plover	Pluvialis squatarola
Ruddy Turnstone	Arenaria interpres
Western Sandpiper	Calidris mauri
Red-necked Stint	Calidris ruficollis
Long-toed Stint	Calidris subminuta
Baird's Sandpiper	Calidris bairdii
Pectoral Sandpiper	Calidris melanotos
Sharp-tailed Sandpiper	Calidris acuminata
Curlew Sandpiper	Calidris ferruginea
Red Knot	Calidris canutus
Great Knot	Calidris tenuirostris
Sanderling	Calidris alba
Ruff	Philomachus pugnax
Buff-breasted Sandpiper	Tryngites subruficollis
Broad-billed Sandpiper	Limicola falcinellus
Asian Dowitcher	Limnodromus semipalmatus
Marsh Sandpiper	Tringa stagnatilis
Greenshank	Tringa nebularia
Wood Sandpiper	Tringa glareola
Grey-tailed Tattler	Tringa brevipes
Wandering Tattler	Tringa incana
Common Sandpiper	Tringa hypoleucos
Terek Sandpiper	Tringa terek
Black-tailed Godwit	Limosa limosa
Bar-tailed Godwit	Limosa lapponica
Eastern Curlew	Numenius madagascariensis
Whimbrel	Numenius phaeopus
Little Curlew	Numenius minutus

Shorebirds Listed in the CAMBA Annex:

Grey Plover	Pluvialis squatarola
Lesser Golden Plover	Pluvialis dominica
Ringed Plover	Charadrius hiaticula
Little Ringed Plover	Charadrius dubius
Mongolian Plover	Charadrius mongolus
Large Sand Plover	Charadrius leschenaultii
Caspian Plover	Charadrius asiaticus
Little Curlew	Numenius minutus
Whimbrel	Numenius phaeopus
Eurasian Curlew	Numenius arquata
Eastern Curlew	Numenius madagascariensis
Black-tailed Godwit	Limosa limosa
Bar-tailed Godwit	Limosa lapponica
Redshank	Tringa totanus
Marsh Sandpiper	Tringa stagnatilis
Greenshank	Tringa nebularia
Wood Sandpiper	Tringa glareola
Common Sandpiper	Tringa hypoleucos
Grey-tailed Tattler	Tringa incana
Terek Sandpiper	Tringa terek
Ruddy Turnstone	Arenaria interpres
Asian Dowitcher	Limnodromus semipalmatus
Red Knot	Calidris canutus
Great Knot	Calidris tenuirostris
Red-necked Stint	Calidris ruficollis
Long-toed Stint	Calidris subminuta
Sharp-tailed Sandpiper	Calidris acuminata
Dunlin	Calidris alpina
Curlew Sandpiper	Calidris ferruginea
Sanderling	Calidris alba
Broad-billed Sandpiper	Limicola falcinellus
Ruff	Philomachus pugnax

Appendix 3: Summary of factors affecting habitat at 11 South-east Tasmanian shorebird sites

Three symbols have been used to depict which factors are present at each site. They are:

- * indicates the presence of the factor at a site or that the factor has been present at the site in the past.

- ** indicates that the factor is, or has been, present and has resulted in a significant negative impact on shorebird habitat at that site.

- ? indicates that the factor may be present at a site. For example, if the presence of the factor is likely or suspected, but has not been documented

It must be noted that the information in the table is intended to be a summary, rather than a ranking, of factors present at each site and as such is a subjective rather than quantitative assessment.

APPENDIX 3:

Summary of factors affecting habitat at 11 South-east Tasmanian shorebird sites.

SITE / FACTOR	LAUDERDALE	CLEAR LAGOON	PIPECLAY LAGOON	CALVERTS LAGOON	SOUTH ARM	ORIELTON LAGOON	SORELL	BARILLA BAY	MORTIMER BAY	MARION BAY	SEVEN AND FIVE MILE BEACHES
RECLAMATION	* *						* *				
CHANGE IN WATER LEVELS	* *	* *		* *		* *					
LOSS OF SALT MARSH	* *		*		?	* *				*	
SILTATION						*		*			
EUTROPHICATION						* *					
POLLUTION OR WATER QUALITY CHANGES	?	?	?	*	* *	* *	*	?		?	
RUBBISH - LITTER OR TIP SITES	* *				* *	*	* *	* *			
EROSION	*								* *		
SEAWEED COLLECTION					* *					* *	
RECREATION - PEOPLE	* *		* *	*	*	* *			* *	* *	* *
RECREATION - ORVs	* *	*	* *	*	* *	* *	*		* *	* *	* *

APPENDIX 3: Continued.

SITE / FACTOR	LAUDERDALE	CLEAR LAGOON	PIPECLAY LAGOON	CALVERTS LAGOON	SOUTH ARM	ORIELTON LAGOON	SORELL	BARILLA BAY	MORTIMER BAY	MARION BAY	SEVEN AND FIVE MILE BEACHES
RECREATION-SHOOTING				?	* *	* *	*			*	
SEWAGE						* *	*				
GRAZING		*						* *		* *	
HORSES	* *		* *	* *	* *	*			* *		* *
DOGS	* *	*	* *	*	* *	* *		* *	* *	* *	* *
CATS	* *	?	?			?			?	?	?
SUBDIVISION	* *	* *	* *		*	* *			* *	*	*
RECREATION-DEVELOPMENT										* *	* *
INDUSTRIAL							*				
AIRPORT								* *			
AQUACULTURE			*		*			* *			
SAND AND SHELLGRIT MINING									* *		

APPENDIX 4:

Summary of ecological information about 13 of the most common species of shorebirds in South-east Tasmania.

PALAEARCTIC BREEDING SPECIES	BREEDING RANGE	NON-BREEDING HABITAT IN AUSTRALIA	PRESENT IN TASMANIA
LESSER GOLDEN PLOVER (Pluvialis fulva)	Breed in north-eastern Asia in a variety of habitats, ranging from the Gobi Desert in Mongolia, to the steppes and taiga of Siberia, to the tundra above the Arctic Circle (a)	Coastal mudflats, near coastal saltmarsh and pasture. Occasionally found on rocky shores, sandy beaches. (a)	Late Aug to Mar/Apr (d)
EASTERN CURLEW (Numenius madagascariensis)		Intertidal mudflats, especially with seagrass. Roosts in saltmarsh, mangroves, sandy beaches and spits, occasionally in non-tidal areas near coastal wetlands. (a)	Aug/Sep to Mar/Apr (d)
GREENSHANK (Tringa nebularia)		Intertidal mudflats, near coastal saline wetlands, saltmarshes. (a)	Aug to May (d)
BAR-TAILED GODWIT (Limosa lapponica)		Intertidal mudflats, roosts on sandy beaches and spits at high tide. (a)	Sep/Nov to Mar/Apr (d)
RED KNOT (Calidris canutus)		Intertidal mudflats, roosts on sandy beaches and spits at high. tide. (a)	Sep/Oct to Apr (d)

RED-NECKED STINT (Calidrus ruficollis)		Coastal and inland wetlands of wide variety, including intertidal mudflats, sandy beaches, freshwater swamps.(a)	Adults Aug/Sept to Mar/Apr Juveniles arrive Oct/Nov and some overwinter. Many winter in Tasmania as well as on the mainland. (e)
CURLEW SANDPIPER (Calidrus ferruginea)		Intertidal mudflats, roosts on sand spits and beaches, saline near-coastal wetlands, sewerage and salt works. (a)	Adults Aug/Sept to Mar/Apr Juveniles as for Stint, above. Many winter in Tasmania as well as on the mainland. (e)
NEW ZEALAND BREEDING SPECIES			
DOUBLE-BANDED PLOVER (Charadrius bicinctus)	New Zealand on gravel bars along glacial rivers, on sandy beaches and occasionally on pastures. (a)	Intertidal mudflats, esp. near saltmarsh or grazed pasture, for roosting at high tide. Few on inland salt lakes. (a)	Feb to Jul/Aug (a)
RESIDENT SPECIES			
PIED OYSTERCATCHER (Haematopus ostralegus)	Australia, incl. Tasmania Sandy beaches above high tide mark, dunes, occasionally saltmarsh, earth, or pasture. (b)	Sandy beaches, intertidal mudflats. May shelter in saltmarsh, seen feeding in pastures around Hobart. (a)	year-round (a)
SOOTY OYSTERCATCHER (Haematopus fuliginosis fulginosis)	Australia, incl. Tasmania. Sandy or shingle beaches, occ. grassy tussock, usually on offshore islands. (c)	Feeds on rocky shores, on mudflats and sandy ocean beaches. (a)	year-round (a)

HOODED PLOVER (Charadrius rubricollis)	Australia, incl. Tasmania. Gravel or sand above high tide mark on open beaches or dunes. (a)	Ocean beaches (a)	year-round (a)
RED-CAPPED PLOVER (Charadrius ruficapillis)	Australia, incl. Tasmania. On sand, shingle or gravel beaches or occ. on short grass; can breed year-round. (c)	Wide range of wetland habitats, coastal and inland. Inland salt lakes, to intertidal mudflats, sandy beaches and spits (a)	year-round (a)
BLACK-FRONTED PLOVER (Charadrius melanotus)	Australia, incl. Tasmania. Gravel or open ground near water. (c)	Farm dams, small pools, inland wetlands. (a)	year-round (a)

KEY TO REFERENCES: (a) Lane 1987; (b) Newman, cited in Lane 1987; (c) RAOU Nest Record Scheme, cited in Lane 1987. (d) Thomas 1970; (e) Newman et al. 1985

APPENDIX 5:
Overview of Data Processing

Four data sheets, one for each index, were compiled from the raw count data. The data on these sheets were used by the ANOVAs. An example of one of these data sheets is presented here, with a flow-chart style overview of how the values on the chart were derived.

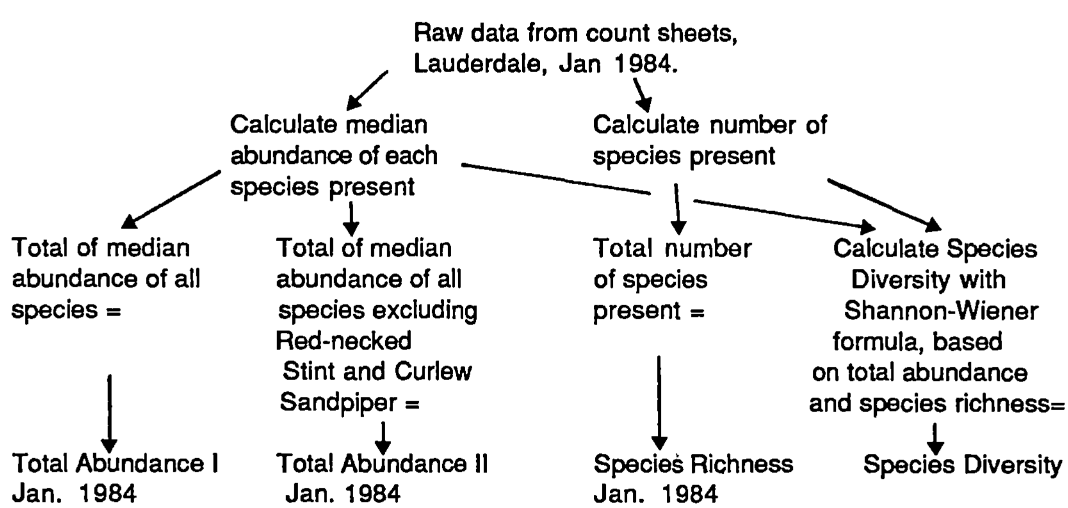
INDEX: TOTAL ABUNDANCE I	LAUDERDALE		CLEAR LAGOON		ETC...
	1960s	1980s	1960s	1980s	
JANUARY					
FEBRUARY					
MARCH ETC...					

Within each cell were four values, one for each year of the sampling period, in the following format.

1965 ->
1966 ->
1967 ->
1968 ->

1981 ->
1982 ->
1983 ->
1984 ->

An example of the derivation for each index at Lauderdale, January 1984 follows:



APPENDIX 6: Complete 3-way ANOVA results from examination of 8 sites, 2 sampling periods and 12 months for each of 4 indices.

INDEX	DATA TRANSFORMATION	SOURCE	DEGREES OF FREEDOM	F-RATIO	PROBABILITY LEVELS
SPECIES RICHNESS	NONE	A	7	124.057	* * *
		B	1	9.605	* *
		C	11	12.048	* * *
		AB	7	10.636	* * *
		AC	77	2.783	* * *
		BC	11	2.521	* *
		ABC	77	7.483	* * *
TOTAL ABUNDANCE I	LOG 10 (X+1)	A	7	131.783	* * *
		B	1	21.254	* * *
		C	11	12.571	* * *
		AB	7	49.302	* * *
		AC	77	3.337	* * *
		BC	11	1.059	NS
		ABC	77	7.492	* * *
TOTAL ABUNDANCE II	LOG 10 (X+1)	A	7	110.986	* * *
		B	1	28.913	* * *
		C	11	4.562	* * *
		AB	7	22.812	* * *
		AC	77	2.458	* * *
		BC	11	0.487	NS
		ABC	77	7.754	* * *
SPECIES DIVERSITY	LOG 10 (X+1)	A	7	84.447	* * *
		B	1	0.578	NS
		C	11	7.592	* * *
		AB	7	12.941	* * *
		AC	77	2.213	* * *
		BC	11	0.451	NS
		ABC	77	7.794	* * *

SOURCE A: SITE
SOURCE B: SAMPLING PERIOD
SOURCE C: MONTHLY VARIATION
SOURCE AB: INTERACTION BETWEEN SITE AND SAMPLING PERIOD
SOURCE AC: INTERACTION BETWEEN SITE AND MONTHLY VARIATION
SOURCE BC: INTERACTION BETWEEN SAMPLING PERIOD AND MONTHLY VARIATION
SOURCE ABC: INTERACTION BETWEEN SITE, SAMPLING PERIOD AND MONTHLY VARIATION

APPENDIX 7: Complete 2-way ANOVA results for each of 8 sites from examination of 2 sampling periods and 12 months for each of 4 indices.

SPECIES RICHNESS

	SOURCE	DEGREES OF FREEDOM	F-RATIO	PROBABILITY LEVELS
LAUDERDALE	A	1	20.717	* * *
	B	11	1.396	NS
	AB	11	0.721	NS
	ERROR	68		
CLEAR LAGOON	A	1	4.463	*
	B	11	1.449	NS
	AB	11	1.201	NS
	ERROR	49		
PIPECLAY LAGOON	A	1	0.056	NS
	B	11	2.545	*
	AB	11	0.976	NS
	ERROR	54		
CALVERTS LAGOON	A	1	46.853	* * *
	B	11	0.480	NS
	AB	11	1.792	NS
	ERROR	36		
SOUTH ARM	A	1	13.259	* * *
	B	11	4.757	* * *
	AB	11	1.735	NS
	ERROR	55		
ORIELTON LAGOON	A	1	2.010	NS
	B	11	11.082	* * *
	AB	11	1.825	NS
	ERROR	65		
SORELL	A	1	19.375	* * *
	B	11	2.729	* *
	AB	11	2.920	* *
	ERROR	68		
BARILLA BAY	A	1	5.882	*
	B	11	3.865	* * *
	AB	11	0.965	NS
	ERROR	67		

SOURCE A = SAMPLING PERIOD
SOURCE B = MONTHLY VARIATION
SOURCE AB = INTERACTION BETWEEN SAMPLING PERIOD AND MONTHLY VARIATION

Appendix 7: Continued.

TOTAL ABUNDANCE I

	SOURCE	DEGREES OF FREEDOM	F-RATIOS	PROBABILITY LEVELS
LAUDERDALE	A	1	64.082	* * *
	B	11	0.962	NS
	AB	11	0.721	NS
	ERROR	68		
CLEAR LAGOON	A	1	1.970	NS
	B	11	1.260	NS
	AB	11	1.401	NS
	ERROR	49		
PIPECLAY LAGOON	A	1	8.175	* *
	B	11	5.493	* * *
	AB	11	1.388	NS
	ERROR	54		
CALVERTS LAGOON	A	1	200.301	* * *
	B	11	1.689	NS
	AB	11	3.896	* * *
	ERROR	36		
SOUTH ARM	A	1	15.091	* * *
	B	11	5.147	* * *
	AB	11	1.459	NS
	ERROR	55		
ORIELTON LAGOON	A	1	5.529	*
	B	11	14.927	* * *
	AB	11	0.539	NS
	ERROR	65		
SORELL	A	1	9.812	* *
	B	11	3.904	* * *
	AB	11	1.567	NS
	ERROR	68		
BARILLA BAY	A	1	0.105	NS
	B	11	5.778	* * *
	AB	11	0.477	NS
	ERROR	67		

SOURCE A = SAMPLING PERIOD
SOURCE B = MONTHLY VARIATION
SOURCE AB = INTERACTION BETWEEN SAMPLING PERIOD AND MONTHLY VARIATION

Appendix 7: Continued.

TOTAL ABUNDANCE II

	SOURCE	DEGREES OF FREEDOM	F-RATIOS	PROBABILITY LEVELS
LAUDERDALE	A	1	0.169	NS
	B	11	4.806	* * *
	AB	11	1.529	NS
	ERROR	68		
CLEAR LAGOON	A	1	0.894	NS
	B	11	0.846	NS
	AB	11	1.543	NS
	ERROR	49		
PIPECLAY LAGOON	A	1	2.737	NS
	B	11	4.500	* * *
	AB	11	1.338	NS
	ERROR	54		
CALVERTS LAGOON	A	1	122.729	* * *
	B	11	1.355	NS
	AB	11	1.901	NS
	ERROR	36		
SOUTH ARM	A	1	5.458	*
	B	11	0.794	NS
	AB	11	0.385	NS
	ERROR	55		
ORIELTON LAGOON	A	1	1.427	NS
	B	11	4.077	* * *
	AB	11	1.413	NS
	ERROR	65		
SORELL	A	1	1.961	NS
	B	11	3.870	* * *
	AB	11	2.540	* *
	ERROR	68		
BARILLA BAY	A	1	0.208	NS
	B	11	8.398	* * *
	AB	11	1.415	NS
	ERROR	67		

SOURCE A = SAMPLING PERIOD
SOURCE B = MONTHLY VARIATION
SOURCE AB = INTERACTION BETWEEN SAMPLING PERIOD AND MONTHLY VARIATION

Appendix 7: Continued.

SPECIES DIVERSITY

	SOURCE	DEGREES OF FREEDOM	F-RATIOS	PROBABILITY LEVELS
LAUDERDALE	A	1	16.799	***
	B	11	3.575	***
	AB	11	2.544	**
	ERROR	68		
CLEAR LAGOON	A	1	0.123	NS
	B	11	1.256	NS
	AB	11	0.811	NS
	ERROR	49		
PIPECLAY LAGOON	A	1	6.957	*
	B	11	14.979	***
	AB	11	1.304	NS
	ERROR	54		
CALVERTS LAGOON	A	1	70.488	***
	B	11	1.313	NS
	AB	11	2.377	NS
	ERROR	36		
SOUTH ARM	A	1	9.630	**
	B	11	0.886	NS
	AB	11	1.076	NS
	ERROR	55		
ORIELTON LAGOON	A	1	0.958	NS
	B	11	1.895	NS
	AB	11	4.364	***
	ERROR	65		
SORELL	A	1	0.236	NS
	B	11	2.097	*
	AB	11	0.644	NS
	ERROR	68		
BARILLA BAY	A	1	31.884	***
	B	11	5.335	***
	AB	11	3.108	**
	ERROR	67		

SOURCE A = SAMPLING PERIOD
SOURCE B = MONTHLY VARIATION
SOURCE AB = INTERACTION BETWEEN SAMPLING PERIOD AND MONTHLY VARIATION

Appendix 8: Group mean, standard deviation and sample size for months of 2 sampling periods, for each index at each of 8 study sites.

LAUDERDALE - SPECIES RICHNESS

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	4.33	0.58	3	4.75	0.50	4
Feb.	6.00	1.83	4	4.25	1.89	4
Mar.	5.75	1.29	4	4.75	0.96	4
Apr.	6.33	1.16	3	5.00	0.82	4
May	6.25	0.50	4	5.25	0.50	4
Jun.	5.25	0.50	4	4.75	0.50	4
Jul.	6.33	0.58	3	4.25	0.96	4
Aug.	7.00	2.00	3	4.50	1.29	4
Sep.	6.50	1.00	3	4.75	0.50	4
Oct.	8.25	5.44	4	5.25	1.26	4
Nov.	6.25	0.96	4	4.00	0.82	4
Dec.	4.50	0.58	4	3.75	1.26	4

LAUDERDALE - TOTAL ABUNDANCE I

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	266.3	119.3	3	162.9	101.7	4
Feb.	383.1	167.2	4	164.0	111.1	4
Mar.	345.8	223.6	4	160.4	79.3	4
Apr.	371.5	123.7	3	168.6	21.3	4
May	288.8	125.6	4	162.0	16.4	4
Jun.	289.2	89.3	4	114.2	18.5	4
Jul.	328.0	85.9	3	123.6	19.3	4
Aug.	316.3	64.9	3	86.0	20.0	4
Sep.	201.9	92.6	4	141.1	115.4	4
Oct.	376.1	220.0	4	146.8	171.2	4
Nov.	351.5	55.4	4	86.5	52.1	4
Dec.	237.4	130.5	4	85.8	31.4	4

LAUDERDALE - TOTAL ABUNDANCE II

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	62.7	21.2	3	95.2	16.8	4
Feb.	117.2	33.1	4	108.0	5.3	4
Mar.	102.1	78.5	4	120.4	6.1	4
Apr.	177.2	9.5	3	134.6	15.0	4
May	198.1	13.0	4	144.4	17.1	4
Jun.	204.1	26.5	4	110.3	19.0	4
Jul.	237.0	3.6	3	119.1	17.4	4
Aug.	206.7	37.1	3	85.8	20.5	4
Sep.	82.8	39.8	4	68.6	12.8	4
Oct.	57.1	34.0	4	50.5	16.9	4
Nov.	55.7	30.5	4	51.5	6.7	4
Dec.	54.8	24.3	4	58.2	4.8	4

LAUDERDALE - SPECIES DIVERSITY

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.304	0.055	3	0.298	0.051	4
Feb.	0.378	0.114	4	0.241	0.100	4
Mar.	0.510	0.254	4	0.303	0.102	4
Apr.	0.512	0.057	3	0.467	0.089	4
May	0.530	0.051	4	0.455	0.021	4
Jun.	0.491	0.116	4	0.376	0.106	4
Jul.	0.607	0.022	3	0.371	0.190	4
Aug.	0.589	0.030	3	0.180	0.128	4
Sep.	0.440	0.143	4	0.219	0.081	4
Oct.	0.283	0.085	4	0.223	0.173	4
Nov.	0.245	0.132	4	0.338	0.200	4
Dec.	0.309	0.145	4	0.396	0.207	4

Appendix 8: Continued.

CLEAR LAGOON - SPECIES RICHNESS

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	6.0	2.6	3	-	-	-
Feb.	3.2	2.6	4	0.0	0.0	2
Mar.	2.2	1.3	4	-	-	-
Apr.	1.0	1.7	3	2.5	2.1	2
May	2.0	1.4	4	4.0	0.0	1
Jun.	1.7	1.5	3	2.0	1.0	3
Jul.	3.3	1.2	3	3.7	1.9	4
Aug.	3.0	1.4	4	3.3	0.6	3
Sep.	3.5	2.4	4	2.2	1.0	4
Oct.	4.0	3.6	4	1.8	1.7	4
Nov.	4.8	2.8	4	2.3	2.1	3
Dec.	5.5	3.7	4	4.0	1.4	2

CLEAR LAGOON - TOTAL ABUNDANCE I

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	201.0	228.6	3	-	-	-
Feb.	22.7	9.3	4	0.0	0.0	2
Mar.	20.9	23.6	4	-	-	-
Apr.	1.7	2.9	3	60.5	47.3	2
May	39.5	33.8	4	95	0.0	1
Jun.	91.0	82.8	3	19.8	32.6	3
Jul.	62.3	32.2	3	57.5	49.1	4
Aug.	37.2	34.2	4	29.7	21.9	3
Sep.	100.4	124.5	4	30.6	27.5	4
Oct.	21.8	28.8	4	13.5	24.0	4
Nov.	63.6	95.8	4	43.3	52.7	3
Dec.	165.2	187.9	4	163.5	224.2	2

CLEAR LAGOON - TOTAL ABUNDANCE II

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	31.0	17.1	3	-	-	-
Feb.	22.6	16.9	4	0.0	0.0	2
Mar.	20.9	23.7	4	-	-	-
Apr.	1.7	2.9	3	25.0	2.8	2
May	26.9	31.5	4	58.5	0.0	1
Jun.	34.0	39.3	3	19.3	31.8	3
Jul.	24.3	8.3	3	44.5	34.7	4
Aug.	11.2	15.4	4	11.8	8.0	3
Sep.	10.8	10.6	4	7.5	3.7	4
Oct.	9.5	7.1	4	6.0	9.1	4
Nov.	20.8	25.6	4	17.5	14.8	3
Dec.	31.5	26.4	4	13.5	12.0	2

CLEAR LAGOON - SPECIES DIVERSITY

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.275	0.024	3	-	-	-
Feb.	0.096	0.123	4	0.000	0.000	2
Mar.	0.181	0.136	4	-	-	-
Apr.	0.072	0.125	3	0.169	0.240	2
May	0.182	0.136	4	0.556	0.000	1
Jun.	0.214	0.228	3	0.212	0.185	3
Jul.	0.185	0.180	3	0.337	0.259	4
Aug.	0.248	0.133	4	0.339	0.211	3
Sep.	0.110	0.131	4	0.155	0.182	4
Oct.	0.087	0.175	4	0.086	0.173	4
Nov.	0.161	0.132	4	0.097	0.200	3
Dec.	0.211	0.145	4	0.284	0.207	2

Appendix 8: Continued.

PIPECLAY LAGOON - SPECIES RICHNESS

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	6.3	1.5	3	7.3	2.3	3
Feb.	5.8	1.0	4	6.0	1.0	3
Mar.	6.7	0.6	3	5.5	0.7	2
Apr.	6.2	1.5	4	6.2	0.5	4
May	5.7	1.2	3	4.0	2.6	3
Jun.	4.7	0.6	3	5.5	1.0	4
Jul.	5.5	0.7	2	5.0	0.0	2
Aug.	4.3	1.5	3	3.7	2.1	3
Sep.	4.7	1.5	3	6.0	0.8	4
Oct.	5.0	2.0	4	6.3	1.5	3
Nov.	5.0	1.1	4	3.2	1.5	4
Dec.	4.0	1.0	3	4.5	2.1	4

PIPECLAY LAGOON - TOTAL ABUNDANCE I

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	347.7	155.5	3	910.3	186.8	3
Feb.	344.5	123.7	4	1112.0	244.8	3
Mar.	525.0	242.5	3	1139.0	325.3	2
Apr.	261.9	40.0	4	349.6	138.5	4
May	260.0	61.0	3	145.0	-	3
Jun.	208.2	104.4	3	175.0	35.9	4
Jul.	95.8	46.3	2	237.5	4.2	2
Aug.	93.2	43.4	3	131.0	102.3	3
Sep.	134.5	116.0	3	190.4	141.9	4
Oct.	224.9	139.1	4	554.8	-	3
Nov.	282.8	162.7	4	751.5	343.5	4
Dec.	364.8	99.7	3	427.8	-	4

PIPECLAY LAGOON - TOTAL ABUNDANCE II

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	74.2	45.6	3	71.7	60.1	3
Feb.	87.8	54.4	4	137.3	6.5	3
Mar.	196.7	25.3	3	107.5	51.5	2
Apr.	173.1	37.2	4	151.4	34.1	4
May	219.8	34.9	3	111.5	44.4	3
Jun.	159.5	55.3	3	167.2	44.6	4
Jul.	85.2	53.4	2	208.0	15.6	2
Aug.	56.2	47.3	3	131.0	102.3	3
Sep.	34.8	31.6	3	95.9	22.5	4
Oct.	17.6	18.9	4	95.5	1.5	3
Nov.	30.1	36.1	4	51.2	69.6	4
Dec.	57.3	14.6	3	69.4	51.8	3

PIPECLAY LAGOON - SPECIES DIVERSITY

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.288	0.85	3	0.288	0.13	3
Feb.	0.316	0.12	4	0.334	0.08	3
Mar.	0.544	0.09	3	0.328	0.18	2
Apr.	0.636	0.03	4	0.568	0.10	4
May	0.667	0.03	3	0.611	0.36	3
Jun.	0.554	0.14	3	0.560	0.11	4
Jul.	0.574	0.02	2	0.590	0.08	2
Aug.	0.542	0.28	3	0.320	0.14	3
Sep.	0.330	0.12	3	0.389	0.12	4
Oct.	0.177	0.06	4	0.251	0.06	3
Nov.	0.208	0.07	4	0.174	0.13	4
Dec.	0.252	0.04	3	0.232	0.05	3

Appendix 8: Continued.

CALVERTS LAGOON - SPECIES RICHNESS

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.33	0.58	3	3.00	2.58	2
Feb.	0.00	0.00	4	3.00	1.73	3
Mar.	0.33	0.58	3	4.50	0.71	2
Apr.	0.00	0.00	3	2.50	1.54	2
May	0.00	0.00	2	2.00	0.00	2
Jun.	0.67	1.16	3	2.67	1.53	3
Jul.	0.50	0.71	2	3.50	0.71	2
Aug.	0.67	1.16	3	4.50	0.71	2
Sep.	1.33	1.53	3	4.00	0.00	1
Oct.	0.75	0.96	4	6.00	0.00	1
Nov.	1.50	2.38	4	-	-	-
Dec.	1.75	1.50	4	2.00	0.00	1

CALVERTS LAGOON - TOTAL ABUNDANCE I

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.00	0.3	3	794.00	619.4	2
Feb.	0.00	0.0	4	986.33	1267.8	3
Mar.	1.00	1.7	3	2105.50	1351.3	2
Apr.	0.00	0.0	3	183.00	258.8	2
May	0.00	0.0	2	71.50	43.1	2
Jun.	0.00	0.0	3	68.33	48.3	3
Jul.	0.50	0.7	2	97.50	37.5	2
Aug.	0.33	0.6	3	132.75	1.1	2
Sep.	1.67	0.8	3	482.00	0.0	1
Oct.	1.75	2.4	4	1222.00	0.0	1
Nov.	4.75	9.5	4	-	-	-
Dec.	10.00	20.0	4	90.00	0.0	1

CALVERTS LAGOON -TOTAL ABUNDANCE II

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.17	0.3	3	34.00	2.8	2
Feb.	0.00	0.0	4	36.33	38.1	3
Mar.	1.00	1.7	3	55.50	7.8	2
Apr.	0.00	0.0	3	29.00	41.0	2
May	0.00	0.0	2	43.00	4.2	2
Jun.	0.00	0.0	3	60.17	47.1	3
Jul.	0.50	0.7	2	54.50	27.6	2
Aug.	0.33	0.7	3	62.00	50.9	2
Sep.	1.17	0.8	3	56.00	0.0	1
Oct.	1.50	1.9	4	22.00	0.0	1
Nov.	1.00	2.0	4	-	-	-
Dec.	6.25	12.5	4	40.00	0.0	1

CALVERTS LAGOON - SPECIES DIVERSITY

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.000	0.0	3	0.106	0.073	2
Feb.	0.000	0.0	4	0.260	0.065	3
Mar.	0.000	0.0	3	0.347	0.043	2
Apr.	0.000	0.0	3	0.138	0.195	2
May	0.000	0.0	2	0.079	0.042	2
Jun.	0.000	0.0	3	0.258	0.224	3
Jul.	0.000	0.0	2	0.426	0.033	2
Aug.	0.000	0.0	3	0.444	0.224	2
Sep.	0.000	0.0	3	0.170	0.000	1
Oct.	0.054	0.109	4	0.234	0.000	1
Nov.	0.069	0.138	4	-	-	-
Dec.	0.072	0.144	4	0.298	0.000	1

Appendix 8: Continued.

SOUTH ARM - SPECIES RICHNESS

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	10.0	2.58	4	9.0	1.0	3
Feb.	9.8	0.5	4	9.3	2.3	3
Mar.	8.2	1.0	4	7.0	0.0	2
Apr.	8.2	2.1	4	8.2	1.2	4
May	6.5	1.0	4	5.3	3.2	3
Jun.	5.5	1.3	4	5.3	0.6	3
Jul.	6.0	0.0	2	6.0	1.4	2
Aug.	5.7	2.6	3	6.0	2.0	3
Sep.	5.7	1.3	4	6.7	0.6	3
Oct.	10.5	1.3	4	6.2	1.7	4
Nov.	10.0	1.4	4	4.7	4.7	3
Dec.	9.8	1.0	4	9.0	0.0	1

SOUTH ARM - TOTAL ABUNDANCE I

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	258.6	77.4	4	1139.7	729.3	3
Feb.	405.5	136.2	4	1521.3	1094.2	3
Mar.	372.5	122.9	4	1732.0	1729.6	2
Apr.	286.2	180.4	4	1204.0	1069.0	4
May	131.0	90.7	4	162.3	75.2	3
Jun.	90.1	55.7	4	173.7	20.6	3
Jul.	104.5	58.7	2	197.0	127.3	2
Aug.	78.8	25.4	3	199.0	66.7	3
Sep.	242.6	83.6	4	558.0	290.8	3
Oct.	356.2	27.8	4	675.6	426.8	4
Nov.	320.0	91.5	4	584.7	968.8	3
Dec.	345.2	87.9	4	1963.5	0.0	1

SOUTH ARM - TOTAL ABUNDANCE II

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	126.8	47.4	4	70.3	42.9	3
Feb.	123.2	29.6	4	127.7	85.2	3
Mar.	95.5	54.8	4	57.0	2.8	2
Apr.	116.2	46.5	4	92.3	69.4	4
May	103.0	51.8	4	115.5	82.9	3
Jun.	71.8	37.0	4	106.0	20.2	3
Jul.	86.8	33.6	2	118.0	124.7	2
Aug.	62.8	3.7	3	74.2	56.7	3
Sep.	68.0	20.3	4	73.5	54.3	3
Oct.	111.6	10.1	4	84.8	18.7	4
Nov.	115.5	19.4	4	34.8	16.4	3
Dec.	138.4	29.3	4	63.5	0.0	1

SOUTH ARM - SPECIES DIVERSITY

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.594	0.116	4	0.371	0.065	3
Feb.	0.487	0.131	4	0.476	0.137	3
Mar.	0.486	0.175	4	0.388	0.059	2
Apr.	0.567	0.083	4	0.458	0.225	4
May	0.585	0.192	4	0.405	0.125	3
Jun.	0.555	0.135	4	0.549	0.055	3
Jul.	0.507	0.269	2	0.530	0.141	2
Aug.	0.535	0.75	3	0.512	0.067	3
Sep.	0.419	0.084	4	0.471	0.086	3
Oct.	0.473	0.014	4	0.369	0.140	4
Nov.	0.518	0.045	4	0.337	-	3
Dec.	0.556	0.063	4	0.351	0.0	1

Appendix 8: Continued.

ORIELTON LAGOON - SPECIES RICHNESS

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	10.25	1.50	4	9.25	3.03	4
Feb.	12.5	1.00	4	10.00	1.41	4
Mar.	9.75	1.71	4	8.75	2.50	4
Apr.	5.25	2.99	4	8.25	0.96	4
May	6.00	2.16	4	3.75	2.50	4
Jun.	6.67	1.53	3	3.50	2.65	4
Jul.	6.00	1.73	3	4.67	3.21	3
Aug.	7.50	2.12	2	6.25	2.63	4
Sep.	6.67	2.08	3	9.50	2.08	4
Oct.	10.00	0.82	4	11.50	1.91	4
Nov.	10.50	0.58	4	10.00	2.16	4
Dec.	11.67	1.15	3	10.75	2.87	4

ORIELTON LAGOON - TOTAL ABUNDANCE I

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	755.6	575.4	4	531.0	262.2	4
Feb.	1353.0	881.2	4	759.1	398.0	4
Mar.	648.6	504.7	4	229.8	178.8	4
Apr.	85.5	111.8	4	63.1	14.0	4
May	48.0	32.0	4	39.3	35.8	4
Jun.	64.7	16.7	3	27.2	39.1	4
Jul.	90.3	93.1	3	47.3	50.6	4
Aug.	88.8	41.4	2	63.0	64.3	4
Sep.	441.8	202.8	3	291.2	90.5	4
Oct.	617.2	426.8	4	794.2	628.1	4
Nov.	1288.4	600.5	4	804.4	330.2	4
Dec.	977.0	400.3	3	730.4	175.5	4

ORIELTON LAGOON - TOTAL ABUNDANCE II

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	105.1	118.8	4	277.5	118.8	4
Feb.	246.8	216.0	4	263.1	77.2	4
Mar.	95.1	67.0	4	123.2	81.1	4
Apr.	30.8	20.7	4	49.8	30.0	4
May	44.5	31.1	4	39.2	35.8	4
Jun.	43.8	2.6	3	27.0	38.6	4
Jul.	88.0	94.2	3	47.3	50.6	4
Aug.	44.8	15.2	2	52.0	46.4	4
Sep.	46.2	53.6	3	58.3	30.5	4
Oct.	46.8	38.4	4	115.9	80.3	4
Nov.	54.4	37.7	4	166.6	30.3	4
Dec.	74.3	54.4	3	117.8	32.9	4

ORIELTON LAGOON - SPECIES DIVERSITY

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.356	0.103	4	0.624	0.114	4
Feb.	0.485	0.177	4	0.623	0.063	4
Mar.	0.456	0.220	4	0.588	0.062	4
Apr.	0.333	0.258	4	0.508	0.153	4
May	0.514	0.110	4	0.167	0.153	4
Jun.	0.534	0.153	3	0.195	0.251	4
Jul.	0.525	0.048	3	0.192	0.222	4
Aug.	0.500	0.050	2	0.564	0.139	4
Sep.	0.326	0.161	3	0.520	0.159	4
Oct.	0.397	0.148	4	0.507	0.070	4
Nov.	0.325	0.029	4	0.531	0.089	4
Dec.	0.299	0.105	3	0.500	0.014	4

Appendix 8: Continued.

SORELL - SPECIES RICHNESS

	1960s Mean	S.D.	n	1980s Mean	S.D.	n
Jan.	8.7	1.5	3	8.5	1.3	4
Feb.	9.5	3.4	4	6.0	0.8	4
Mar.	9.8	1.5	4	5.5	0.6	4
Apr.	9.2	3.1	4	6.5	2.4	4
May	4.0	2.7	4	6.2	2.2	4
Jun.	4.2	2.6	4	5.2	1.0	4
Jul.	4.3	3.2	3	5.5	0.6	4
Aug.	7.0	4.2	2	5.5	3.1	4
Sep.	5.8	3.1	4	4.8	1.3	4
Oct.	8.8	2.4	4	5.2	1.7	4
Nov.	11.2	1.5	4	4.2	3.4	4
Dec.	9.8	1.0	4	5.0	2.4	4

SORELL - TOTAL ABUNDANCE I

	1960s Mean	S.D.	n	1980s Mean	S.D.	n
Jan.	565.5	339.1	3	295.4	213.9	4
Feb.	1176.9	1149.4	4	175.0	153.3	4
Mar.	658.9	894.4	4	172.0	130.1	4
Apr.	150.9	121.4	4	65.4	33.8	4
May	45.0	28.9	4	76.9	30.1	4
Jun.	62.9	48.4	4	81.4	41.0	4
Jul.	31.7	21.4	3	72.0	54.6	4
Aug.	99.0	140.0	2	56.6	51.3	4
Sep.	290.0	197.4	4	77.4	60.9	4
Oct.	519.1	335.4	4	72.0	64.2	4
Nov.	870.4	906.0	4	282.1	406.5	4
Dec.	744.1	481.8	4	167.9	105.5	4

SORELL - TOTAL ABUNDANCE II

	1960s Mean	S.D.	n	1980s Mean	S.D.	n
Jan.	185.0	97.4	3	134.5	88.9	4
Feb.	323.0	41.1	4	86.5	81.8	4
Mar.	114.6	51.0	4	100.6	50.7	4
Apr.	56.6	22.7	4	60.6	26.7	4
May	35.2	17.1	4	76.9	30.1	4
Jun.	56.2	43.5	4	81.4	41.0	4
Jul.	25.2	11.4	3	72.0	54.6	4
Aug.	17.0	24.0	2	56.6	51.3	4
Sep.	159.4	67.0	4	75.6	63.0	4
Oct.	173.1	77.6	4	72.0	64.2	4
Nov.	117.6	93.1	4	94.2	70.2	4
Dec.	236.2	39.9	4	121.0	56.4	4

SORELL - SPECIES DIVERSITY

	1960s Mean	S.D.	n	1980s Mean	S.D.	n
Jan.	0.368	0.136	3	0.450	0.167	4
Feb.	0.386	0.077	4	0.447	0.168	4
Mar.	0.522	0.156	4	0.546	0.079	4
Apr.	0.517	0.130	4	0.581	0.167	4
May	0.402	0.268	4	0.455	0.104	4
Jun.	0.342	0.295	4	0.463	0.088	4
Jul.	0.290	0.341	3	0.414	0.106	4
Aug.	0.281	0.398	2	0.308	0.208	4
Sep.	0.273	0.197	4	0.301	0.086	4
Oct.	0.428	0.169	4	0.277	0.112	4
Nov.	0.341	0.108	4	0.850	0.154	4
Dec.	0.450	0.081	4	0.430	0.148	4

Appendix 8: Continued.

BARILLA BAY - SPECIES RICHNESS

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	7.7	1.2	3	8.2	1.5	4
Feb.	7.8	0.5	4	8.0	1.8	4
Mar.	8.0	0.8	4	8.5	1.3	4
Apr.	7.3	0.5	4	7.5	1.9	4
May	7.0	0.0	2	6.8	0.5	4
Jun.	6.2	1.0	4	4.5	1.7	4
Jul.	5.7	1.2	3	5.0	0.8	4
Aug.	7.3	1.2	3	6.2	0.5	4
Sep.	7.5	1.7	4	5.8	1.0	4
Oct.	7.5	1.7	4	6.2	2.6	4
Nov.	7.2	0.5	4	5.2	1.7	4
Dec.	7.2	0.5	4	6.8	1.3	4

BARILLA BAY - TOTAL ABUNDANCE I

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	488.0	162.7	3	664.5	232.0	4
Feb.	751.5	241.5	4	525.9	206.1	4
Mar.	627.8	162.2	4	697.4	81.4	4
Apr.	467.8	241.5	4	298.0	147.7	4
May	332.5	231.2	2	208.6	34.3	4
Jun.	257.8	278.5	3	217.8	94.3	4
Jul.	199.8	46.9	3	197.8	61.3	4
Aug.	314.2	226.6	4	163.6	68.5	4
Sep.	189.1	204.5	4	180.4	113.0	4
Oct.	227.2	189.9	4	182.9	74.5	4
Nov.	383.5	588.1	4	143.1	72.9	4
Dec.	408.4	327.0	4	608.6	340.9	4

BARILLA BAY - TOTAL ABUNDANCE II

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	108.8	61.3	3	69.6	35.7	4
Feb.	132.9	32.3	4	156.5	125.0	4
Mar.	138.6	32.7	4	91.2	18.5	4
Apr.	132.3	37.0	4	153.6	70.7	4
May	148.8	15.9	2	163.6	17.8	4
Jun.	123.6	65.9	3	154.6	60.8	4
Jul.	92.5	59.5	3	135.5	36.4	4
Aug.	72.0	6.1	4	99.6	33.9	4
Sep.	47.1	32.1	4	55.5	16.8	4
Oct.	65.2	29.9	4	39.6	12.6	4
Nov.	61.9	23.2	4	40.2	18.8	4
Dec.	92.1	26.0	4	58.4	19.9	4

BARILLA BAY - SPECIES DIVERSITY

	1960s			1980s		
	Mean	**S.D.**	**n**	**Mean**	**S.D.**	**n**
Jan.	0.607	0.101	3	0.291	0.134	4
Feb.	0.528	0.064	4	0.291	0.080	4
Mar.	0.561	0.089	4	0.349	0.066	4
Apr.	0.637	0.094	4	0.655	0.041	4
May	0.612	0.008	2	0.652	0.054	4
Jun.	0.556	0.073	3	0.637	0.041	4
Jul.	0.528	0.155	3	0.543	0.071	4
Aug.	0.511	0.216	4	0.529	0.117	4
Sep.	0.559	0.049	4	0.350	0.041	4
Oct.	0.534	0.095	4	0.302	0.079	4
Nov.	0.519	0.128	4	0.393	0.192	4
Dec.	0.539	0.144	4	0.251	0.101	4