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Marine Resources Map of Western Australia

PART 1
The Resources

BY
H. E. JONES

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PERTH
WESTERN AUSTRALIA

MARINE RESOURCES MAP OF WESTERN AUSTRALIA

Part 1 THE RESOURCES

H. E. JONES

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MARINE RESOURCES MAP OF WESTERN AUSTRALIA

PART 1 THE RESOURCES

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INTRODUCTION

The occurrence of large offshore oil spills, such as those from the tankers Torrey Canyon and Amoco Cadiz off England and France in 1967 and 1978 and the Ixtoc 1 production platform in the Gulf of Mexico in 1979, and an increased level of offshore petroleum exploration and production activities in Western Australia have engendered greater local concern on the environmental effects of oil spilled on the sea. This has led to a more detailed consideration of measures to protect the W.A. marine environment from oil spills.

From the history of attempts to deal with oil spills in various parts of the world it has been concluded that in several instances rapid and effective clean-up decisions would have greatly alleviated subsequent damage to the marine environment and resultant costs. Information essential for such decisions should therefore be obtained before authorities are faced with an oil spill.

In addition to factors such as the type, volume, spreading characteristics and evaporation rate of the oil, the wind and wave conditions, currents, tides, coastline structure and the availability of mechanical clean-up equipment and chemical dispersants, the rationale for making a rapid decision on clean-up procedures will require a knowledge of what marine resources are at risk, their economic, ecological, scientific and recreational importance and their susceptibility to oil and to clean-up methods. It can be envisaged that a particular clean-up procedure may protect one resource at the expense of another and a judgement on which resources take priority at any time of year should ideally have been made before an oil spill occurs.

Information on the marine resources in the form of a map as well as a text should facilitate a quicker and more effective formulation of the preferable clean-up approach for an area under threat. Further to its use in oil spill contingency planning, such a map would be of value for assessing the influence of accidental spills of other noxious substances and, at a coarse level, for predicting the likely environmental consequences of any proposed coastal industrial or domestic activity. These activities include development of housing, industries, power stations, marinas and harbours, waste discharge, exploration and exploitation of minerals, pipeline laying and increases in recreational pressures.

The map would thus have a limited introductory role in the initial stages of coastal planning and management exercises. A computerized base would facilitate this use and allow continued up-dating.

The text accompanying the marine resources map of W.A. is in two parts. This main part (Part 1) gives information on the resources and morphological, hydrological and meteorological characteristics of the coastal environment while the subsidiary part (Part 2) deals with the effects of oil on marine resources and associated commercial and recreational activities.

THE RESOURCES

In determining what should be considered a resource a broad approach has been taken. The criteria employed are based predominantly on commercial, ecological, conservation, scientific, educational and recreational concerns and so the term resource covers certain organisms, reserves, particular habitats such as fish nursery areas, areas of scientific research or educational importance, stromatolites, physical features like sandy beaches and reefs, and man-made structures such as marinas and offshore pipelines. In addition, activities associated with the coastal marine environment, for example fishing, swimming and sailing, are considered. Resources of estuarine areas have been largely ignored.

The choice of resources and the extent to which they are described are obviously influenced by the information available. Hence, absence of a resource on the map does not necessarily mean its non-existence, especially in areas remote from metropolitan centres. Organisms such as invertebrates of no commercial importance, and phytoplankton and zooplankton which are variable temporally and spatially and less visually evident than other resources, are not included.

The marine resources and associated activities selected are listed below:

1. PROFESSIONAL FISHING.

- 1.1 Pilchard (*Sardinops neopilchardus*)
- 1.2 Scaly Mackerel (*Sardinella lemuru*)
- 1.3 Southern Bluefin Tuna (*Thunnus maccoyii*)
- 1.4 Sea Mullet (*Mugil cephalus*)
- 1.5 Yellow-eye Mullet (*Aldrichetta forsteri*)
- 1.6 Australian Salmon (*Arripis esper*)
- 1.7 Australian Herring (*Arripis georgianus*)
- 1.8 Pink Snapper (*Chrysophrys unicolor*)
- 1.9 Westralian Jewfish (*Glaucosoma hebraicum*)
- 1.10 Whiskery Shark (*Furgaleus ventralis*)
- 1.11 Western Rock Lobster (*Panulirus cygnus*)
- 1.12 Prawns (four species):
  - Tiger (*Penaeus esculentus*)
  - Banana (*Penaeus merguiensis*)
  - Western King (*Penaeus latisulcatus*)
  - Endeavour (*Metapenaeus endeavouri*)
- 1.13 Southern Saucer Scallop (*Amusium balloti*)
- 1.14 Abalone (two species):
  - Greenlip (*Haliotis laevigata*)
  - Roe's (*Haliotis roei*)

2. RECREATIONAL FISHING.

- 2.1 Shore-based Angling
- 2.2 Boat Angling
- 2.3 Offshore Game Angling
- 2.4 Diving and Spearfishing
- 2.5 Net Fishing and Potting

3. SUBSISTENCE ABORIGINAL FISHING.

4. FISH NURSERY AREAS.

5. OTHER CRUSTACEA.

- 5.1 Southern Rock Lobster (*Jasus novaehollandiae*)
- 5.2 Tropical Rock Lobster (*Panulirus spp.*)
- 5.3 Bay Lobster (*Thenus orientalis*)
- 5.4 Mud (Mangrove) Crab (*Scylla spp.*)
- 5.5 Blue Manna (Sand) Crab (*Portunus pelagicus*)

6. OTHER MOLLUSCS.

6.1 Octopus (Octopus tetricus)
6.2 Squid (Sepioteuthis spp. Nototodarus gouldi)
6.3 Cuttle Fish (Sepia spp.)
6.4 Mussel (Mytilus edulis)
6.5 Trochus (Trochus niloticus)
6.6 Giant Clam (Tridacna maxima)
6.7 Rock Oyster (Saccostrea spp.)
6.8 Mud Oyster (Ostrea angasi)

7. PEARL OYSTERS. (Pinctada maxima)

7.1 Collection
7.2 Culture

8. BREEDING SEA-BIRDS.

8.1 Australian Pelican (Pelecanus conspicillatus)
8.2 Beach Thick-knee (Burhiniss neglectus)
8.3 Black-faced Shag (Leucocarbo fuscescens)
8.4 Bridled Tern (Sterna anaethetus)
8.5 Brown Booby (Sula leucogaster)
8.6 Buff-banded Rail (Rallus philippensis)
8.7 Cape Barren Goose (Careopsis novaehollandiae)
8.8 Caspian Tern (Sterna caspia)
8.9 Common Noddy (Anous stolidus)
8.10 Crested Tern (Sterna bergii)
8.11 Eastern Reef Egret (Egretta sacra)
8.12 Fairy Tern (Sterna nereis)
8.13 Flesh-footed Shearwater (Puffinus carneipes)
8.14 Great-winged Petrel (Pterodroma macroptera)
8.15 Least Frigatebird (Fregata ariel)
8.16 Lesser Crested Tern (Sterna bengalensis)
8.17 Lesser Noddy (Anous tenuirostris)
8.18 Little Penguin (Eudyptula minor)
8.19 Little Pied Cormorant (Phalacrocorax melanoleucos)
8.20 Little Shearwater (Puffinus assimilis)
8.21 Masked Booby (Sula dactylatra)
8.22 Osprey (Pandion haliaetus)
8.23 Pacific Gull (Larus pacificus)
8.24 Pied Cormorant (Phalacrocorax varius)
8.25 Pied Oystercatcher (Haematopus ostralegus)
8.26 Red-tailed Tropicbird (Phaethon rubricauda)
8.27 Roseate Tern (Sterna dougalli)
8.28 Short-tailed Shearwater (Puffinus tenuirostris)
8.29 Silver Gull (Larus novaehollandiae)
8.30 Sooty Oystercatcher (Haematopus fulginosus)
8.31 Sooty Tern (Sterna fuscata)
8.32 Spotless Crake (Porzana tabuensis)
8.33 Wedge-tailed Shearwater (Puffinus pacificus)
8.34 White-bellied Sea-Eagle (Haliaeetus leucogaster)
8.35 White-faced Storm-Petrel (Pelagodroma marina)

9. SALT WATER CROCODILES. (Crocodilus porosus)

10. TURTLES.

- 10.1 Green turtle (Chelonia mydas)
- 10.2 Loggerhead turtle (Caretta caretta)
- 10.3 Hawksbill Turtle (Eretmochelys imbricata)
- 10.4 Flatback Turtle (Chelonia depressa)

11. SEALS.

- 11.1 Australian Sea Lion (Neophoca cinerea)
- 11.2 New Zealand Fur Seal (Arctocephalus forsteri)

12. DUGONGS. (Dugong dugon)

13. MANGROVES.

14. SEAGRASSES.

15. SEAWEEDS.

16. ALGAL MATS.

17. STROMATOLITES.

18. REEFS:

- 18.1 Coral
- 18.2 Limestone
- 18.3 Granite

19. COQUINA BEDS.

20. RECREATION.

- 20.1 Bathing Beaches
- 20.2 Surfing
- 20.3 Skindiving
- 20.4 Water Skiing
- 20.5 Sailing
- 20.6 Boating
- 20.7 Shell Collecting
- 20.8 Tourist Facilities (hotels, boat hire etc.)

21. SCIENTIFIC RESEARCH AND EDUCATIONAL AREAS.

22. SHIPWRECKS.

23. ANCHORAGES, MARINAS, PORTS.

24. INDUSTRIES, OFFSHORE PIPELINES.

25. MARINE RESERVES AND PARKS.

Where appropriate, the condition of the resource throughout the year has been considered, e.g. different stages in the life-cycle of an organism, migratory patterns, time of entry of young seals into the sea, level of utilisation of a bathing beach.

Where available, information is quantitative and although in some instances an indication of the ecological and conservational importance of the resources and habitats has been given in the text the map is essentially an inventory. Much of the information has already been used in a publication from the W.A. Department of Conservation and Environment (Jones et al., 1984) outlining procedures for the protection of the W.A. marine environment from oil spills, particularly those which might emanate from offshore petroleum exploration and production activities.

It must be emphasised that there is a considerable amount of unpublished knowledge on the resources and that new information is continually being produced, especially from detailed studies such as those by the W.A. Department of Conservation and Environment on the Dampier region and by the University of W.A. on Shark Bay. Thus the material provided here forms only a basic introduction to the marine resources of W.A. and does not constitute an exhaustive survey.

No attempt has been made to categorise the marine environment on the basis of ecological or habitat considerations, a pre-requisite for selection of areas for special protection in the form of marine reserve or marine park status. This is outside the scope of the text and the maps and would require much wider consideration and a greater knowledge of the interdependence of organisms and the physical and biological features of habitats than is available here.

SOURCES AND LAYOUT OF INFORMATION

Much of the information in the text and the maps has been obtained from several people and consultants knowledgeable in their particular fields, most of whom are mentioned in the acknowledgements, and from published papers. Because of this mixture of sources and the intended nature of the report, the published papers have not been cited in the text but are included in the bibliography.

The location of each resource or its associated activity, such as fishing and beach recreation, and details available on coastal geomorphology are indicated on four sets of fifty-seven Royal Australian Survey Corps 1:250 000 topographic maps of the W.A. coastline, including Barrow Island and the Abrolhos Islands, and a 1:25 000 map of Rottnest Island. Seagrasses are also mapped at a 1:50 000 scale for the areas Shark Bay, Perth and Albany.

The four sets of maps provide details on (1) coastal geomorphology and seagrasses, (2) professional fishing, (3) recreational fishing and fish nursery areas and (4) the other resources and activities listed earlier. Occasionally the contents of the maps overlap.

Accompanying the maps in the following order in this part are an introductory survey of the W.A. marine environment, information on coastal geomorphology, ocean circulation and wind regimes and notes on the resources and activities.

In some areas, particularly those close to population centres, considerable information on the distribution and the nature of the resources is available. As it is in these areas that perturbation of the marine environment is most likely to occur it is envisaged that further maps of them will be prepared at a scale finer than 1:250 000.

While copies of the text are available in reasonable numbers, it would be impractical and prohibitively expensive to supply matching copies of the maps. These are available for reference at the Marine Research Laboratories, W.A. Fisheries Department.

WESTERN AUSTRALIAN MARINE ENVIRONMENT

The major features of the W.A. marine environment have been well summarised in the chapter "The Sea" contained in the volume entitled "Environment and Science" of the series commemorating the 150th anniversary of W.A. Parts of that chapter are included in the following introductory survey.

THE COASTLINE AND THE CONTINENTAL SHELF

Western Australia has the longest coastline of all Australian states. When estimated on 1:250 000 maps, applying the following provisos - coastline follows mid-tide level and seaward limit of mangroves and has a cut-off point of 1 km width for estuaries, inshore islands are those within 1 km of the mainland - the CSIRO Division of Land Use Research provided figures of 8 230 km for the length of the mainland coastline, 9 280 km when the inshore islands were included and 12 330 km when all islands shown on the maps were included.

It is a much-varied coastline in climate and physical characteristics and consequently in biological habitats and species, extending approximately from 14° S to 35° S and from 113° E to 129° E, and is bordered by the Indian Ocean and the Southern Ocean. In the far north the rugged Kimberley coast is deeply indented by drowned river valleys, and there are many coastal islands and fringing and platform coral reefs. Extensive mangrove swamps border much of the north-west shore and there are well-developed coral reefs in many places. The west coast is characterised by long straight sandy beaches, small limestone islands and a moderate swell. The western part of the south coast exhibits massive granite headlands, broad sandy bays pounded by heavy surf from the Southern Ocean, and many sheltered inlets and estuaries which may be barred, while the eastern part is characterised by steep cliffs of limestone.

For the most part, the continental shelf of W.A. is narrow, varying from about 40 km at its narrowest region, off North West Cape, to about 420 km at its widest region, off Eighty Mile Beach. Tectonic deformation in varying degrees has occurred throughout, causing some sections to rise up and others to become down-warped. This has resulted in a series of distinct shelf areas known as the Sahul, North-West, Dirk Hartog, Rottnest, Recherche and Eucla Shelves.

The continental shelf and the present-day coastline adjoining can be viewed as extensions of a series of deep sedimentary basins which border the W.A. continental mass. The shelf sediments are dominantly calcarious fragments of organic origin. Most are derived from fragmental skeletons of corals,

bryozoans, foraminiferans, echinoderms, molluscs and algae which lived on the shelf.

In more recent geological times, during the Late Tertiary and Quaternary periods, the sea-level is known to have fluctuated to a considerable degree, owing to successive periods of glaciation and deglaciation. The effects of these enormous events may still be seen along the coastal plains and on the sea-bed of the inner part of the continental shelf and they are responsible for the existence of many important coastal features, such as Cockburn Sound and the Abrolhos Islands.

Fuller details on the geological and physical characteristics of the coastline are given later in the section on coastal geomorphology.

THE WATERS

Winter and summer coastal sea surface temperatures are from about 25° C to 31° C in the north and about 15° C to 20° C in the south. Tide levels vary considably, the highest astronomical tides ranging from northern values of 11.3 metres at Cockatoo Island, 10.9 m at Derby and 10 m at Broome to southern values of 1.1 m at Fremantle and 1.3 m at Bunbury and Esperance. North of Shark Bay the tides are semi-daily whereas in the south they are predominantly daily.

Water movements off the W.A. coastline are complex and vary considerably between shallow coastal waters and deep water beyond the continental shelf break. In the north, the currents are affected considerably by the changing monsoon wind system. In general, coastal waters of the central and southern west coasts show a weak and erratic northerly movement in summer and a stronger southerly movement in winter. Along the shelf break, there is a southerly movement of warm water from the tropics, called the Leeuwin current, which seems to be strongest in autumn and winter and influences the biogeographic spread of organisms in this area. In addition to the general northerly and southerly movements off the central and southern west coasts, eddies of various sizes often exist. The south coast currents are frequently easterly, and the Leeuwin current is usually found on the continental shelf there.

Further discussion of ocean circulation off W.A. and the wind regimes is given in later sections.

FLORA AND FAUNA

Nutrient levels and productivity in the coastal and offshore waters are low. Values found by CSIRO were in the region of 0.1 to 0.2 mg-atom/1 for phosphate and 0.4 to 0.5 mg-atom/1 for nitrate. However, a wide range of species and biological habitats exist, which is marked by the differentiation between northern and southern organisms. Species north of

North West Cape are almost exclusively tropical, while southern species east of Cape Leeuwin are virtually all temperate. Between these two biogeographical provinces the central and southern west coasts show a mixture of tropical and temperate species.

Some species have a restricted range along the W.A. coast but others are widespread, even beyond Australia. A few, such as the Australian salmon and the Spanish mackerel are migratory, travelling long distances to complete their life cycles or following water currents rich in food.

The North Coast

The marine area north of North West Cape belongs to the Indo-West Pacific Biogeographical Province which includes the entire tropical Indian Ocean and the tropical western part of the Pacific. Most of the species found along the north coast of W.A. are widespread in the Indo-West Pacific Province. Coral reefs and mangrove swamps (mangals) are important habitats in this coastal region.

Coral-fringing and platform reefs supporting complex communities of associated organisms are well developed on banks and around islands of the Sahul and North-West Shelves. From the outer edge of both these shelves arise a number of large coral atolls, the Seringapatam and Scott Reefs on the Sahul Shelf and the three atolls of the Rowley Shoals on the North-West Shelf.

The richest mangals in W.A. occur in the broad land-locked drowned river valleys along the Kimberley coast in the far north. They comprise many mangrove species of several families and support a rich associated fauna of invertebrates and fishes. Further south, on the Pilbara coast, mangrove habitats provide nursery areas for commercial fish species and supply considerable nutrients to the coastal waters.

The Central and Southern West Coast

This section of the W.A. coast is known as the Western Overlap Zone. Southward from North West Cape there is a gradual diminution in the number of tropical species, and northward from Cape Leeuwin there is a comparable diminution in temperate species.

Along the western edge of North West Cape a long reef exists, the Ningaloo Reef, which is rich in corals and easily accessible from the shore. This reef is scheduled to be part of a marine park. Mangroves markedly decrease in numbers in the overlap zone and sea grasses appear, especially in sheltered areas such as Shark Bay and Geographe Bay.

Shark Bay contains waters of high salinity and is globally important due to the considerable number of living and dead stromatolites (see later) which occur in its southern regions.

Limestone reefs are prevalent off the west coast, but about 75 km west of Geraldton are found the Houtman Abrolhos Islands where coral reefs containing a large diversity of coral species are abundant. These reefs are the most southerly coral reefs in W.A.

In the vicinity of Fremantle, marine animal and plant communities consist of a mixture of tropical and temperate species in roughly equal proportions.

One of the endemic species in the overlap zone is the western rock lobster which is the most important species fished commercially in Australian waters.

The South Coast

This region east of Cape Leeuwin, known as the Flindersian Province, is warmly temperate and contains many endemic species. The coastal habitats are very different from those to the west and north. Numerous inlets, sandy bays, estuaries, granite headlands and steep limestone cliffs occur and the shores are generally swept by heavy surf.

Beds of seagrass are extensive, especially in sheltered bays and inlets. They support a fauna peculiar to southern Australia, particularly small gastropod molluscs and certain fish species which appear to be adapted to life in seagrass beds.

Table 1. W.A.Beach Types

Temperate, Low-tidal Region

Mapping Unit	Description
1.	Broad, smooth gently sloping coarse grained sandy beach with low primary dune showing extensive vegetation; includes barrier beaches and may include marshes, swamps or enechelon lake systems in swales.
2.	Broad smooth gently sloping coarse grained sandy beach with some active dunes and unstable blowout areas.
3.	Broad smooth sloping sandy beach with well vegetated primary dune, often backed by parallel beach ridges or stabilised parabolic dunes.
4.	Broad smooth curving sandy beach, which may be cuspate or crenulate, formed between or in association with resistant headlands.
5.	Variable width sandy beach formed in areas protected by offshore reefs; may include some beachrock as low cliffs or headlands.
6.	Narrow sandy beach without extensive beachrock backed by continuous stable well-vegetated high dunes which may include calcarenite.
7.	Narrow sandy beach with extensive beachrock.
8.	Beachrock dominates beach with occasional sandy sections; may have a low undercut beachrock cliff face.
9.	Exposed high energy shorelines with eroded igneous or metamorphic rocks associated with overlying beachrock or aeolean limestone.
10.	Undercut steep cliff face eroding cainozoic sedimentary material.

Table 1 (continued)

Tropical, High-tidal Region

Mapping unit	Description
11.	Broad smooth gently sloping beach with an extensive intertidal zone, which may be backed by an extensive supra-tidal zone.
12.	Broad complex system of tidal channels and flats.
13	Limited tidal flat development with some channels, may back onto low cliffs and sand ridges.
14.	Major tidal creek channels with complex relict sandy beaches, some tidal flat development between headlands.
15.	Tidal flat development is variable, with some sandy and/or fine grained beach material, and is controlled by protection from offshore and onshore reefline systems.
16.	Narrow sandy or silty beach with a high tide range may be marked by chenniers, beach ridges or low cliffs.
17.	Complex exposed resistant low cliffs; beaches may be formed between headlands due to high tidal range.
18.	Beachrock and adjacent barrier reefline - formed coast with some beach formation between headlands.
19.	Major creeks or rivers incised into sediments; some tidal flats development in areas afforded protection or where extensive deposition has occurred.
20.	Highly-resistant structurally-controlled headlands, islands or drowned river valleys; all may show minor embayments with tidal flat or small beach development.

COASTAL GEOMORPHOLOGY

The coastline has been considered initially as two regions, Temperate, Low-tidal and Tropical, High-tidal, which merge in the Shark Bay region. The tropical region is frequently characterised by the presence of mangroves.

Each region has been differentiated into ten beach types, giving a total of 20 mapping units (Table 1), using existing data sources, principally Landsat colour enhancements at 1:250 000 from the W.A. Department of Lands and Surveys, to complement the already extensive information on the 1:250 000 topographic maps. This differentiation simplifies and generalises the coastline into manageable and descriptive forms. However, it is somewhat arbitrary since there are areas in which comparable sediment source and energy diffraction occur where the coast is represented by a temperate region unit even though it is in the tropical region. These occur just north of Shark Bay.

In addition, the coast has been divided into eight sections based mainly on the broad geological provinces of its hinterland (Figure 1). This classification was chosen as the geology primarily affects the shape of the coastline, and acting upon this the effects of eustacy, tectonism, erosion and accretion have produced the present situation. These sections broadly follow those described in Bulletin 49 from the W.A. Department of Conservation and Environment, and are, from north to south:

KIMBERLEY
CANNING
PILBARA
NINGALOO
ZUYTDORP
SWAN
ALBANY
NULLARBOR

They differ from the six marine geographic zones proposed for W.A. following the Council of Nature Conservation Ministers (CONCOM) workshop in 1985.

Beach types (mapping units) are indicated on the 1:250 000 topographic maps by colour coding, and the presence of mangroves in an extensive or interrupted form is shown by stippling. Where the background colour of a map interferes with the colour representation of the mapping unit, the unit is differentiated by marking with the appropriate number. Thus a "3" indicates mapping unit 3 irrespective of the colour produced.

A brief description and subsequent notes specific to the interpretation of each section follow, which expand the information on beach types given in Table 1. The mapping units should not be considered in isolation from these additional notes.

KIMBERLEY

Maps:-
Medusa Banks
Cambridge Gulf
Londonderry
Drysdale
Montague Sound
Prince Regent
Camden Sound
Charnley
Yampi (Part)

This section extends from the Northern Territory border westward to King Sound. Geologically it consists of Proterozoic sedimentary rocks which have been modified to form a ria (drowned river valley) and a drowned structurally-oriented coastline, apart from a small area of Quaternary fluvial deposits east of Cambridge Gulf. Parts of the coast afforded protection or sedimentary input have developed mangrove-covered tidal flats. Much of the coastline and islands lie in deep water with sheer cliff faces.

In places where the Proterozoic sedimentary surface still retains a mantle of unstripped lateritic material, as around Cape Bougainville and the Mitchell Plateau, the units are marked with a "b".

The Yampi sheet has for a large part been mapped as a "20" mapping unit, or an "18" mapping unit when offshore reef occurs; the complexity of this structurally controlled coastline cannot be adequately mapped at a scale of 1:250 000.

CANNING

Maps:-
Yampi (Part)
Derby
Pender
Broome
La Grange/Munro
Mandora

The Canning section comprises the coastal edge of the Canning Basin but excludes the De Grey Delta, which has been included in the Pilbara section.

The Canning Basin is formed from marine sediments of late Mesozoic age which have undergone Quaternary and Holocene modification. The coast takes two general forms, the smooth curving Eighty Mile Beach example and the less regular Broome to Derby portion.

Mapping unit 11 - This unit in the Canning Section covers the wide tidal flats exposed by the huge tidal range. The absence of a frontal fringe of mangroves is typical. Drowned Holocene shorelines may be present and provide protection to these gently sloping beachlines. Parallel beach ridges and chenniers are common on the landward side, and in the example of Eighty Mile Beach, on the seaward side. The landward fringe of the tidal flat has been mapped.

Mapping unit 13r - Example of a transgressed shoreline providing reef protection to coastal mangrove complexes (Cape Bossut-La Grange).

PILBARA

Maps:-
Port Hedland/Bedout Island
Roebourne
Dampier
Barrow Island
Yarraloola
Onslow
Yanrey

This section extends from Cape Keraudren to Exmouth Gulf near Learmonth and covers a complex range of coastal types, which have been grouped together since they all drain from the Pilbara geological province. Fluvial sediments contribute significantly to the nature of the coastline in many parts of this section. The De Grey delta area is formed from the erosion of Archean and Proterozoic rocks of the northern Pilbara Block. Finer-grained sedimentary material is deposited in coastal regions from the erosion of basaltic (igneous) and Proterozoic (sedimentary) rocks by the major rivers draining the Hamersley, Ashburton and Bangemall provinces. The felsic intrusions associated with the Burrup Peninsula and the Archean sedimentary rocks in the Point Samson and Cape Preston areas are anomalous to the remainder of this section.

The Quaternary alluvial deposits of the Onslow plain, which have extended due to the protection afforded by offshore islands and the Cape Range Peninsula, comprise the western portion of the Pilbara section.

The units describing the De Grey Delta are marked with a "d". The coastal parts of the delta comprise fluvial sediments subject to periodic modification and have therefore been separated from the tropical series because they have characteristics similar to the temperate series. Barrow

Island and the Monte Bello Islands have been included in the Pilbara Section although their units of mapping may more closely follow the Ningaloo units.

Mapping unit 12 - The Pilbara Section often has a seaward berm or chennier which is frequently broached by tidal channels; where they are extensive they are mapped as a "15" unit with a "12" unit inshore, but in other cases it is more appropriate to represent them as a "12" unit and note their presence.

Mapping unit 15 - Has also been used to describe coral reefs offshore from unit 12 on the Yarraloola and Onslow Sheets.

Mapping units 16 to 18 - Used to describe the type of protective reefline and old shoreline which lie offshore or are incorporated as the present beachline. They are often associated with the extensive mangrove complexes.

Mapping unit 20 - Includes outcropping igneous rock islands and peninsulas which on rare occasions have small beaches in some protected embayments.

NINGALOO

Maps:- Yanrey/Onslow
Ningaloo
Minilya (Part)

This section of the coastal part of the Cape Range Peninsula and Carnarvon Basin has been described separately, due to the presence of the Ningaloo reef system and the effect which this has had on the coast.

Cape Range was formed by the uplift and folding of marine sediments. These soft limestone rocks have eroded rapidly, supplying sediment for extensive coastal plain development.

The major portion of the west facing-coastline has been mapped as "14" or "15" units. These categories best fit this system although the the absence of beachrock is normal. Coral reefs join the present coastline in places, and in some protected areas mangroves may have established.

The transition from Ningaloo to Zuytdorp units is marked by a change from tropical to temperate descriptions. For simplicity the point of transition was placed on the map at Gnaraloo Station, 23° 50'S.

ZUYTDORP

Maps:-
Quobba/Minilya (Part)
Shark Bay/Wooramel
Edel/Yarringa
Ajana
Geraldton

This section comprises the coast from Gnaraloo to Geraldton, including Shark Bay and the Houtman-Abrolhos Islands. It is the coastal edge of the Carnarvon Basin which, as a result of tectonic and eustatic changes, has high cliffs exposed to the erosive forces of the sea.

The Zuytdorp cliffs are one of the most striking features of the Western Australian coast. These cliffs may be tectonically controlled as they form a straight, almost unbroken line from Steep Point to just north of the Murchison River, a distance of 225 km. They attain a maximum height of nearly 300 m above sea level. Marine erosion has produced coastal platforms and "paddy-field" terraces at the foot of the cliffs, and blowholes have been formed at several localities due to undercutting.

Shark Bay's east-facing coastlines consist mainly of a low Tamala limestone cliff face, with younger benches often with remnant parallel dunes intermittently occurring. These do not necessarily occur between headlands and they can in some cases form minor headlands themselves. The beaches are mostly too small to be mapped at this scale. The limestone cliff usually has a very narrow sandy beach at its foot and has been mapped as a "7" or "8" unit depending upon the detectable presence of an intertidal beach.

SWAN

Maps:-
Dongara
Hill River
Perth
Pinjarra
Collie/Busselton/Augusta

This section extends from Dongara southward down the Swan Coastal Plain and along the Leeuwin Horst to the Yeagarup sand dune area. The Swan Coastal Plain consists of Cainozoic aeolean deposits on the west side and fluvial deposits from the crystalline Archean rocks of the Darling Plateau on the east. It is bounded by older Mesozoic sedimentary deposits of the Dandaragan Plateau to the north and the Donnybrook Sunkland to the south. The Perth Basin is a graben whose only remnant on the western side is the Leeuwin Horst. The resistant nature of the rocks of the exposed Horst and the extent of littoral sediment available has created a coast with steep cliffs and narrow beaches between headlands. This area has been included in this section to simplify the

map interpretation but has been separated from the Swan mapping units by marking with an "h". Much of the mapping has been taken from CSIRO publications and generalised to conform with this scale.

Mapping unit 1 - The "1" unit in Geographe Bay differs from the "1" unit along the Leschenault/Lake Preston area due to the protection afforded by the Leeuwin Horst; as in Cockburn Sound these areas are marked with a "g".

Mapping unit 2 - Mapping of this unit is taken from CSIRO publications and it occurs where greater than one-third of the coast has been mapped as unstable; less than one-third is mapped as a "3" unit.

Mapping unit 3 - May include infrequent occurrences of beach rock after winter erosion.

Mapping unit 3d - Separates the area known as the Greenough Flats. The coast has eroded fluvial deposits which contribute to offshore reef material and has extensive dune systems overlying these sediments.

Mapping unit 5 - Mapped where Pleistocene limestone and wave cut benches are exposed at the coast.

ALBANY

Maps:-
Pemberton/Irwin Inlet
Albany/Mount Barker
Bremer Bay/Newdegate
Ravensthorpe
Esperance/Mondrain Island
Malcolm/Balladonia/Cape Arid

This section extends from Cape Beaufort (Black Point) to Israelite Bay and includes numerous offshore islands.

The coastline is controlled by headlands and islands of Archean (western part) and Proterozoic (eastern part) granitic rocks which are resistant to exposure from the erosive forces of the Southern Ocean. Between these headlands are numerous crenulate embayments which have steep foredunes of cemented calcarenite, often with a planed beachrock platform. Occasionally these dunes are broached by unstable blowout areas.

Mapping unit 2y - Yeagarup sand dune area which consists of extensive unstable dunes behind broad smooth gently curving exposed coast with a planed beach (may include beachrock).

Mapping unit 4x - Has a crenulate shape characteristic of a "4" unit in this section, but the beach has a planed shoreline platform backed by steep calcarenite vegetated dunes (best example the Nullaki Peninsula).

Mapping unit 9i - Included to cover islands along the south coast, is usually steep sided and exposed but vegetated; may have aeolianite capping over igneous rocks.

NULLARBOR

Maps:- Malcolm/Balladonia/Cape Arid
Culver
Burnabbie
Eucla/Nooneara

This section extends from Israelite Bay to the W.A. border at Eucla.

The coast comprises Tertiary marine limestone, sandstone and some ironstone. A younger Quaternary formation comprising aeolian sand and limestone forms a broad coastal plain from Eyre to Eucla.

Mapping units 1 and 2 - Extensive aeolean sand drifts and sand ridges.

Mapping unit 2s - Notes the presence of swampy swales within extensive dune systems near the coast.

Mapping unit 5 - Beachrock control of sediment access to coast.

Mapping unit 8 - Extensive beachrock in association with adequate sediment supply has created a broad band of unstable dunes on the landward edge of this unit.

Mapping unit 10 - Sheer cliffs in excess of 60 metres.

OCEAN CIRCULATION

Present views on the ocean circulation off W.A., obtained mainly from hydrological studies and satellite imagery conducted by the CSIRO, have been summarised in a recent CSIRO publication by Pearce and Cresswell. In southern areas, the seasonal interchange of cool, high-salinity subtropical water in summer and warmer less saline tropical water in winter was confirmed. The tropical water movement, known as the Leeuwin Current, was described as a band of warm low-salinity water of tropical origin, 50 km wide and some tens of metres deep, which flows southward and is mainly above the continental slope from Exmouth to Cape Leeuwin where it pivots eastward onto the continental shelf towards the Great Australian Bight.

It was emphasised that although the larger-scale aspects of the ocean circulation off W.A. are gradually being resolved, details of finer resolution are still uncertain due to the great spatial and temporal variability of the current systems.

The brief review on seasonal water circulation off W.A. which follows and Figures 2,3, and 4 are taken from the CSIRO publication.

OVERALL MEAN CIRCULATION

The gross circulation in the south-east Indian Ocean is depicted diagrammatically in Figure 2. Recent studies have suggested that the driving force for the Leeuwin Current may result from the flow of warm low-salinity water from the Western Pacific ocean through the Indonesian Archipelago into tropical regions of the Indian Ocean. This would explain some of the anomalous features of the circulation off the W.A. coast compared with other western coasts, such as the lack of upwelling and consequent paucity of nutrients in the coastal waters.

The low-salinity water contributes to a strengthening of the South Equatorial Current and floods the Northwest Shelf area. Of more dynamic importance however, it causes the sea level in the tropics to be some 55 cm higher than that along the southern coast of Australia. This north-south pressure gradient produces a weak (about 0.02 m/s or 0.04 knot) eastward flow from the central Indian Ocean towards W. A. between latitudes of about 15° S and 35° S, and the flow is then deflected southward along the edge of the continental shelf. The northerly portion of this inflow (augmented by the tropical water from the North West Shelf) forms the warm low-salinity "core" of the Leeuwin Current, while the eastward flow south of about 28° S consists of more saline subtropical water which forms an offshore boundary to the Current. As a result of the continuous inflow from the Indian Ocean, the Current strengthens in its passage southward and its salinity

gradually rises by mixing.

In particular, the Current seems to accelerate as it approaches Cape Leeuwin, where it pivots eastward, rides up onto the shelf, and flows towards the Great Australian Bight as a shelf current. It can be traced at least as far as 124°E (i.e. east of Esperance), and then it may separate from the coastline as it continues eastward. By late winter, it may even approach the South Australian Gulfs, but there is some evidence that it loses its identity before that by mixing with Bight waters. As a result, the suggestion has been made, that a new current, the "East Bight Current", can then be identified flowing from the central Bight region towards Tasmania.

Following the above description, it appears that there is a potential "Leeuwin Current" throughout the year, but its behaviour and strength are modified seasonally by changes in the meridional sea level gradient and wind stress.

SEASONAL VARIABILITY - SUMMER PATTERN

In the Southern Hemisphere summer (December to March), the north-south sea level gradient along the shelf-break between Exmouth and Cape Leeuwin is weaker than in winter, and the mean wind stress along much of the coast is strongly northward. These factors contribute towards a weakening of the Leeuwin Current and perhaps to a northwards penetration of cooler subtropical waters. Regionally, the circulation may be summarised as follows:

Northwest Shelf: The winds in summer are largely from the west. The currents are generally weak and variable, with a net southwestward tendency which can easily be reversed during periods of strong winds from the southwest. Mild upwelling may occur under such conditions.

Exmouth to Cape Leeuwin: There is generally a weak southward flow along the continental slope over most of this region. South of about 30°S there is an intensification of the current due to a strong inflow of subtropical water from the southwest; this water flows around a dynamic trough of cool water as shown in Figure 3. The eddy field associated with this circulation is strong, with two distinctive length scales of about 150 km and 300 km. The former occurs in regions of strong currents, while the latter tends to be found where the large-scale circulation is weaker.

On the inner continental shelf there tends to be a mean northwards flow, about 0.1-0.2 m/s (0.2 to 0.4 knot), of high-salinity water from as far south as Cape Naturaliste which is driven by the dominantly northwards wind stress. However, the currents fluctuate (and reverse) due to variations in the wind stress, with periods of about a week.

Cape Leeuwin to the Great Australian Bight: Little is known about the circulation on or off the shelf east of Cape Leeuwin in summer.

SEASONAL VARIABILITY - WINTER PATTERN

During the southern winter (May to August), the alongshore sealevel gradient almost doubles as the tropical water builds up in equatorial regions. The windstress off most of Western Australia is much weaker and more variable than in summer, with perhaps a small northwards tendency. The southward slope current is accordingly much stronger (at least between Exmouth and Cape Leeuwin) than in summer, and can usually be identified by its water properties as the Leeuwin Current.

Northwest Shelf: The south-east trade winds contribute towards a net southwestward shelf flow, with speeds of 0.2 to 0.3 m/s (0.4 to 0.6 knot). This consistent alongshore flow of low salinity water is now an important source of the Leeuwin Current, although its strength varies from year to year presumably in response to variations in the Pacific throughflow and the wind stress.

Exmouth to Cape Leeuwin: In this region the Leeuwin Current is generally strong and well-defined, running southward along the slope and flooding the continental shelf with tropical water. Jet-like streams along the shelf-break alternate with dramatic offshore meanders of the Current. Both warm-core (anticlockwise) and cool (clockwise) eddies are evident, particularly south of Shark Bay.

Along the mid-continental shelf the currents tend to be southward at 0.2 to 0.3 m/s (0.4 to 0.6 knot). In water shallower than 20 m or so, the currents are more influenced by local winds and are therefore more variable than farther offshore.

Cape Leeuwin to the Great Australian Bight: The extension of the Leeuwin Current eastwards into the Bight is well defined, largely as a shelf flow with its outer (southern) boundary generally closely associated with the shelf break (Figure 4). A surface temperature gradient of up to 5°C in a few kilometres may be encountered in the Leeuwin to Esperance region. Associated with this strong temperature front (and presumably shear zone) is a succession of warm eddy-like features spinning off the Leeuwin Current and interacting with the cool Southern Ocean Waters.

WIND REGIMES

Wind conditions are represented by two types of rose, one prepared for eight large areas off the W.A. coast (Figure 5) from ship observations supplied by the Bureau of Meteorology, Melbourne and the other produced by the Bureau from records of 10 coastal stations from Troughton Island to Esperance. Together they indicate the likely wind influences on an oil spill both offshore and inshore.

The ship observations were mainly from 1952-1976 and were taken at 0,6,12 and 18 hour Greenwich Mean Time. The position of the ships within each area when the observations were made is not known and observations may thus be concentrated in particular regions of each area.

The observations are recorded seasonally with all 6-hourly records combined so that no distinction is made between a.m. and p.m. and any day-time effects of localised sea breezes are consequently not differentiated. The wind roses (Figure 6) are divided into 12 directions of 30° intervals, and wind speeds from 1 to 34 knots and above are represented in five categories.

The scale is such that for each rose 10 cm represents the total number of observations in that season in that area; that is all wind speeds, including calms, in all directions. Where frequencies of a wind speed category in a particular direction are less than 1% of the total number of observations in that season in that area (equals less than 1 mm in length), they are not recorded.

The wind roses from the coastal stations (Figure 7) are also seasonal, but are for 9 a.m. and 3 p.m., and give percentage frequency of wind direction for 8 compass points, and speeds from 1 to 30 km per hour and above divided into three categories. The scale is 1 cm represents 25% frequency.

They are produced from records up to 1976 of usually more than 15 years duration but those for North West Cape have been added separately and come from Navy Alpha records of six years duration.

NOTES ON RESOURCES AND ACTIVITIES

1. PROFESSIONAL FISHING

The extent of current professional fishing in W.A. may be gauged by the catch and value figures and by the number of licensed fishermen and boats for the 1982-83 season. In that year 16 486 tonnes of fish, 12 482 tonnes of rock lobsters, 3 115 tonnes of prawns, 124 tonnes of crabs, 4 208 tonnes of scallops, 264 tonnes of abalone, 222 tonnes of mussels, 44 tonnes of squid and 21 tonnes of other molluscs were caught, giving a gross value to the fishermen of $12.2 million for the fish, $110.4 million for the crustaceans and $3.6 million for the molluscs. The most important species, both in weight and value, was the western rock lobster which yielded 12 456 tonnes worth $93.1 million, while 1 833 tonnes of the western king prawn gave $9.7 million. Three finfish species were caught in amounts greater than 2 000 tonnes. These were southern bluefin tuna, Australian salmon and pilchard. By far the largest catch was the tuna, 5 809 tonnes worth $3 million. However, this was an exceptional year and quotas introduced since 1983 will cause the annual tuna catch to approach the 2 000 tonnes weight of earlier years.

The total number of licensed fishermen was 4 124 and the total number of licensed fishing boats was 1 971. Of these, 780 were western rock lobster boats, 72 were prawn boats, 35 were for scallops, 26 for abalone and almost all the remaining 1 058 boats were approximately equally divided between estuarine and marine finfish fisheries.

Principal fishing localities where more than 1 000 tonnes were landed were, in order of importance by weight, Albany (fish), Denham (scallops, prawns, fish), Carnarvon (scallops, prawns, fish), Esperance (fish), Fremantle (rock lobsters, fish), Abrolhos Islands (rock lobsters, scallops), Mandurah (fish, rock lobsters), Geraldton (rock lobsters), Exmouth Gulf (prawns), Bunbury (fish) and Lancelin (rock lobsters).

Figures given on the 1:250 000 topographic fishing area maps represent catch results during the year 1982-83 for the W.A. block numbers used by the Australian Bureau of Statistics (ABS). Thus block 2015 means the area in which fish are caught between 20° S to 21° S latitude and 115° E to 116° E longitude. Block numbers 9600, 9504, 9505 (Cockburn Sound, Princess Royal Harbour and King George Sound, and Oyster Harbour respectively) do not follow this pattern. Only species caught in amounts greater than 5 tonnes per block are included, so the figures for total catches of fish, molluscs or crustacea in a block are frequently greater than the sum of the figures for individual species listed in the block.

The 18 commercial species included in the list of resources were chosen because they were caught in W.A. in amounts greater than 500 tonnes or were worth more than $500 000 gross value to the fishermen in any of the 8 years between 1975 and 1983, according to the Bureau. Certain fish, although not satisfying the above criteria, are nevertheless valuable and of local importance, e.g. Barramundi in the northern towns. Although the Whiskery Shark is included in the list its wide distribution prevents representation of catch areas on the map.

The 18 species constitute about a third of the number of species caught professionally in the year 1982-83 in amounts greater than 5 tonnes per block. Brief information on them, incorporating their habits, major catch areas, method of catch, yield and gross value to the fishermen for the year 1982-83, is given below, accompanied by pictorial representation of the quantity of each caught per ABS block, based on % of total W.A. catch per fish species (Figure 8).

The pearl oyster fishery is treated separately in a later section.

Fish

1.1 Pilchard (Sardinops neopilchardus).

In W.A. pilchard are found between Shark Bay and Eucla from near the shore to at least the edge of the continental shelf. They are pelagic, feed mainly on plankton and are abundant in open waters, especially the Bight, and in marine embayments such as Geographe Bay.

Breeding year classes are aged 2+, and spawning takes place offshore mainly in autumn with a high fecundity. Larvae develop into juveniles within a month.

The main fishing areas for pilchard are Princess Royal Harbour, King George Sound, Geographe Bay and Cockburn Sound and the principal method of catch is by purse seines but ring nets and drop nets are also used. The fish caught range in size from about 15 to 23 cm, weigh 100 to 200 g and are in demand as bait for angling. The total W.A. catch for 1982-83 was 2 008 tonnes, worth $764 000 gross value to the fishermen.

1.2 Scaly Mackerel (Sardinella lemuru).

These fish occur between Port Hedland and Albany from near the shore to at least the edge of the continental shelf. They are pelagic, feed mainly on plankton and are found in open waters and in marine embayments.

The main fishing area in W.A. is Cockburn Sound where they are caught by purse seining. The fish caught are about 20-25 cm long and weigh 150-250 g and are mainly used as bait in rock lobster pots. The W.A. catch for 1982-83 was 242 tonnes, worth $126 000.

1.3 Southern Bluefin Tuna (Thunnus maccoyii).

Southern bluefin tuna are distributed widely in marine waters of the southern hemisphere, and off W.A. They are found from near the shore to at least the edge of the continental shelf, from about latitude 20° S to the south-west corner and then along the south coast. They are pelagic, feed on fish, cephalopods, crustacea and salps, with pilchard as the main fish and food source.

Southern bluefin tuna are migratory. They reach maturity between 6 and 7 years (about 130 cm long, 35 kg in weight) and spawn in the warm waters of the Java Sea from October to March, each producing about 14 million eggs during two periods. The young fish gradually move southwards, some of them passing along the shores of W.A. and reaching the mid and lower west coasts in late spring and summer. They winter close to the south coast as 2 year-old fish but some return to the lower west coast in spring. Most of the population remains along the south coast for about a year and then, at about 4 years old, moves further offshore in all directions for long distances. At about 6 to 7 years old they move northwards in the southern winter to reach the Java Sea spawning ground situated between 10° S to 20° S and 110° E to 120° E.

Close to the W.A. coast, greatest concentrations of southern bluefin tuna are found near Albany between March and July and east of Esperance between November and April, where they occur as 2 to 3 year-old fish. They are caught mainly in these areas by dead bait and pole, the schools generally located by trolling, but incidental catches are taken around Busselton. The fish taken average about 70 cm in length and 7 kg in weight but larger fish are caught offshore between New Zealand and South Africa by Japanese longliners. The W.A. catch for 1982-83 was 5 809 tonnes, worth $3 million, but quotas introduced since 1983 will reduce the tonnage caught.

1.4 Sea Mullet (Mugil cephalus)

Sea mullet are distributed in the coastal and estuarine waters of all States in Australia. They occur throughout the water column, preferring the upper reaches in estuaries, but feed on detrital material and thus have preference for areas with silty or muddy bottoms such as Peel Inlet and Exmouth Gulf.

In tropical W.A. little is known about sea mullet but, from knowledge of other tropical locations in Australia, it is likely that tidal estuaries, creeks and bays with muddy bottoms are important nursery areas.

In temperate W.A. sea mullet generally spend up to the first three years of life in estuarine nursery areas. After this stage most enter the sea in late summer and migrate northwards to spawn between March and September. Breeding year classes are between 3 to 7 years and they have a high fecundity. Since fish aged 0+ have only been found in estuaries it is evident that the estuaries are entered during the late larval and early juvenile stages. This recruitment occurs between May and November in permanently open estuaries, but in seasonally closed estuaries the timing is dependent upon when the sand bars are breached. Early juvenile sea mullet initially feed on plankton before becoming detritivorous.

Sea mullet are caught commercially by hauling or setting gill nets. The major catch area is at Peel Inlet/Harvey Estuary but Shark Bay and Exmouth Gulf are also important catch areas. The fish taken range from 24 cm (minimum legal size) to about 60 cm and weigh between 300 g and 4 kg. The W.A. catch for 1982-83 was 715 tonnes, worth $568 000.

1.5 Yellow-eye Mullet (Aldrichetta forsteri)

In W.A. this fish is found in the near-shore coastal waters and estuaries from Kalbarri to Eucla. It is omnivorous, consuming principally small crustaceans, molluscs and algae. Like sea mullet this species is principally a benthic feeder, but prefers protected coastal marine environments and the middle to lower reaches of estuaries.

The adults migrate from the estuaries to the coastal seas around April in order to spawn. Breeding year classes are 3 to 7 years old and fecundity is high. Spawning occurs from May to September and the juveniles (0+) then remain in the near-shore waters or enter the estuaries from about June to October.

The majority of yellow-eye mullet taken in commercially important estuaries are mostly immature 1+ fish. All fish are caught by either hauling or setting gill nets. The Peel Inlet/Harvey Estuary is the principal catch area, followed by Leschenault Inlet and the protected waters south of Fremantle. The fish taken range from 23 cm (minimum legal size) to 40 cm and weigh between 100 and 800 gm. The catch for 1982-83 was 650 tonnes, worth $410 000.

1.6 Australian Salmon (Arripis esper)

Australian salmon occur in W.A. waters from Geraldton to Eucla, mainly near the shore and in estuaries. They are pelagic and feed on fish such as pilchards and yellow-eye mullet, but the juveniles may also eat plankton.

The fish are migratory and move westwards from southern and eastern States waters in February and March in order to breed. Breeding year classes are about 3 to 5 years old. There is a high fecundity, spawning taking place over a period of about 3 weeks from March to May, principally between Cape Leeuwin and Cape Naturaliste. Larvae and juveniles move eastwards from the southwest from April to June and the juveniles enter estuaries and sheltered waters where they remain for about 2 years before moving into open marine waters.

The professional fishery for Australian salmon operates mainly during February and March in the southern area and during March and April in the south western area. When migrating to spawn, the fish rest on sandy surf beaches where they are caught with beach seines. Principal catch areas are just east and west of Albany and in Bremer Bay. The fish caught range from 30 cm (minimum legal size) to 70 cm and weigh between 1 to 6 kg, but very few below 50 cm in length are taken in W.A. The catch for 1982-83 was 2 289 tonnes, worth $1.1 million.

1.7 Australian Herring (Arripis georgianus).

This fish is distributed in W.A. from Shark Bay to Eucla, mainly near the shore and in estuaries such as Wilson Inlet and Broke Inlet. It is pelagic and feeds on small fish, such as white bait, blue sardines and juveniles of other fish, and also on small crustacea.

As with Australian salmon, adults migrate westwards from southern and eastern States waters in February and March to breed. This takes place between Rottnest Island and Cape Leeuwin over a period of about 5 weeks during May and June. Breeding year classes are 3 to 5 and fecundity is moderate, about 100 000 eggs per season. After spawning, the adults remain in W.A. waters. The juveniles move eastwards to the south coast from May to July and are found close to the shore.

The professional fishing season is mainly in March and April. Beach seines and set nets are used and the principal catch areas, as with Australian salmon, are beaches just east and west of Albany and in Bremer Bay. Australian herring are also an important amateur angling species throughout the year. The fish taken are from 18 cm (minimum legal size) to 25 cm and weigh 150 to 300 gm. In 1982-83 the commercial catch was 935 tonnes, worth $474 000.

1.8 Pink Snapper (Chrysophrys unicolor).

Pink snapper are distributed in non-tropical shelf waters off the Australian mainland, and in W.A. are found from Exmouth Gulf southward where they normally concentrate off nursery areas such as Shark Bay and Cockburn Sound. This species is a generalised carnivore, feeding mainly on molluscs, crustacea and small fish. Although usually demersal, snapper are known to swim at times in mid-water for spawning and perhaps also for feeding.

The spawning season varies with latitude. At the northern end of its range the species spawns from June to August while at the southern end it spawns in November and December. Snapper aggregate inshore for spawning and this must involve migration from their normal feeding areas. Breeding year classes are from 4 upwards and fecundity is high. Juveniles are found on soft bottoms in estuaries and marine embayments, moving after their first year to hard-bottom reef habitats, a proportion of the population moving offshore. Snapper appear to have a restricted home range for at least part of their life; some tagged animals have stayed on the same small reef for more than a year and thus stocks in different areas may be separate from one another.

The bulk of the W.A. snapper catch is taken from spawning aggregations around the mouth of Shark Bay in June and July by hand-line and trap fishing. Apart from this highly localised fishery, and a smaller one on summer spawning aggregations in Cockburn Sound, snapper are taken throughout the year as part of a multi-species wetline fishery and are a popular target for amateur fishermen.

The fish taken range from 28 cm (southern minimum legal size) and 38 cm (Shark Bay minimum legal size) to 90 cm and weigh about 800 gm to 8 kg. The commercial W.A. catch for 1982-83 was 745 tonnes, worth $1.1 million.

1.9 Westralian Jewfish (Glaucosoma hebraicum)

The westralian jewfish is distributed from Kalbarri to Cape Leeuwin from about 30 to 200 m water depth and usually on rocky or coralline algal-covered bottoms. It is demersal and feeds on octopus, small fish and crustacea.

For breeding purposes the adults of several year-classes move into waters of about 30 to 60 m depth, spawning occurring from December to February. The eggs are demersal but the larvae are pelagic and may be carried considerable distances by surface currents. Juveniles tend to remain in shallower waters than adults and are usually found in waters less than 100 m deep.

Westralian jewfish are caught offshore, mainly by hand lines, along the length of the south west coast and the principal fishing areas are around the Abrolhos Islands and off Jurien Bay and Cape Naturaliste. The fish taken range from 50 cm (minimum legal size) to 90 cm, weigh 3 to 20 kg and attain the highest price per kilogram for fish in W.A. The catch for 1982-83 was 188 tonnes, worth $753 000.

1.10 Whiskery Shark (Furgaleus ventralis).

Although shark species are caught in considerable numbers, only the whiskery shark catch has been worth more than $500 000 in any one year. Bronze whaler and gummy sharks are also caught in valuable quantities and a significant number of sharks are caught which are given no identification in ABS data. The whiskery shark is distributed inshore and offshore, throughout the water column, mainly from the Abrolhos Islands south to the South Australian border. It usually feeds on fish, squid and octopus.

Little is known about the spawning areas or breeding behaviour of the whiskery shark. It is a live-bearer and about 10 to 20 young are born to each female per breeding season.

The main method of capture is by gill net, but longline and handline are also used. It is caught throughout its distribution but most fishing effort is concentrated in water depths of 40 to 80 m. The fish caught range from about 60 to 120 cm with a dressed weight of 3 to 8 kg. The catch for 1982-83 was 379 tonnes, worth $400 000.

Crustacea

1.11 Western Rock Lobster (Panulirus cygnus)

The western rock lobster is found in reef areas from Shark Bay to Cape Leeuwin in water depths up to about 200 m. It is gregarious and nocturnal, only leaving rocky crevices or weed beds at night to search for food which consists of molluscs, echinoderms, crustacea, worms, small fish, coralline algae and the algal genus Ecklonia. As with all crustacea, growth is accompanied by a number of moults of the hard exoskeleton.

At maturity, about 5 to 6 years old, the rock lobsters move from the shallow inshore reefs to the deeper offshore reefs between late November and late December. This is referred to as the migration of "the whites". Mating occurs in the deeper waters in winter or early spring, sperm packets being deposited on the underside of the female, but fertilisation does not take place until late spring and summer when the females spawn, each producing up to about 700 000 eggs.

Fertilised eggs are carried on the female's abdomen for 1 to

2 months until the larvae are hatched. The larvae are carried up to 2000 km westward on the surface of the Indian Ocean. They undergo a series of stages and moults before returning after about 10 months, as puerulus larvae, to settle in the shallow inshore reefs in water depths less than 20 m. The developing juvenile lobsters remain in the shallows until they migrate to breed.

The rock lobster fishery is the most lucrative in Australia. The main catch areas are off the Abrolhos Islands, Dongara, Jurien Bay, Fremantle and Rottnest Island, and baited pots are used. The legal size limit is a carapace length of not less than 76 mm. Most of the rock lobsters taken weigh about 0.5 kg but they can approach 5 kg. The catch for 1982-83 was 12 456 tonnes, worth $93.1 million.

1.12 Prawns (four species)

All four prawn species described below have an annual life cycle which comprises spawning offshore with a high fecundity, fertilisation of the eggs in the water column, a three stage larval phase, post-larval settlement, and growth of the juveniles in shallow areas followed by migration of the adults into deeper waters.

The brown tiger prawn (Penaeus esculentus) occurs in coastal areas from Shark Bay northwards, usually in muddy areas which may contain seagrass. Major stocks are found in Shark Bay and Exmouth Gulf where the adults and juveniles feed mainly on worms, small molluscs and detrital material.

Spawning in this species occurs towards the end of the first year of life in spring and summer. Eggs are released into the water column several times during the spawning season and pass through the three larval stages before reaching the post-larval stage when they move into shallow nursery habitats, typically protected seagrass beds, to settle. The entire larval stage is encompassed in about 10 days. After a period of approximately three months, the juveniles, about 10 cm in length, begin to migrate offshore, entering the shallow trawling grounds during autumn. In winter, the prawns, now adult, continue to move slowly offshore until they reach oceanic waters where spawning occurs. At this stage the tiger prawn has reached lengths of about 15 cm for males and 18 cm for females.

As with all prawns, the tiger prawn is caught commercially by trawling, usually in depths of 6 to 60 m. This takes place at night in muddy or silty habitats in nearshore oceanic areas during the autumn migration. The major fishing localities are Shark Bay and Exmouth Gulf and the catch in W.A. for 1982-83 was 509 tonnes, worth $3.5 million.

The banana prawn (Penaeus merguiensis) is distributed from Exmouth Gulf northwards to the Kimberleys but significant populations are currently only found along the Nickol Bay to De Grey River coastline and the Kimberley area. Its life cycle is like that of the tiger prawn but spawning takes place early in spring. However, in contrast to other penaeid species the juveniles use river or tidal creek estuaries as nursery areas. Migration towards the ocean usually occurs in autumn when the prawns are about 10 cm long. This movement is often associated with cyclonic freshwaters flooding the nursery areas. Adults are normally found close to river mouths on muddy bottoms in depths less than 20 m.

An unusual feature of banana prawns is that they form dense schools during daylight hours, which is when commercial trawling occurs. They are a little larger than tiger prawns and may reach about 22 cm. The main fishing areas are from Nickol Bay to the De Grey River and the quantity caught in 1982-83 was 276 tonnes, worth $1.8 million.

The western king prawn (Penaeus latisulcatus) is the most important prawn species commercially in W.A., where it occurs in coastal waters along most of the coastline. Significant stocks of this species are found sporadically in hypersaline/marine south coast estuaries and consistently in west coast estuaries and in the major marine embayments of the central and northern coasts.

According to the geographical distribution of the animal the timing of events in the life-cycle may differ, spawning occurring during summer in the south and all year round in the north. Post-larvae and juveniles are found in coastal marine estuaries and embayments but are most abundant in areas where hypersaline conditions prevail. The preferred habitat for juveniles is a shallow silty or sandy bottom just below low water mark. After about three months in the shallows the sub-adults move offshore to oceanic waters, predominantly in March and April, where they later spawn in areas with silty sand or hard coral sand bottoms.

Adults reach a similar size to the tiger prawn and are trawled in areas which usually extend further offshore than the tiger prawn grounds. The main areas are off Shark Bay and Exmouth Gulf but trawling also occurs in Nickol Bay and off Onslow, Fremantle and Mandurah. The catch for 1982-83 was 1 833 tonnes, worth $9.7 million.

The endeavour prawn (Metapenaeus endeavouri) is distributed along the north west coast from Shark Bay to Port Hedland. It is similar in size to the tiger and western king prawns.

Spawning occurs mainly in late summer and autumn and recruitment of post-larvae into the shallows is predominantly in late autumn. Due to overwintering, the juveniles may spend up to 9 months in the nursery areas but

at a different time of year from the juveniles of the western king prawn. The offshore migration occurs in spring and early summer. Adults are not normally found in water depths greater than 25 m in W.A. and their distribution falls between that of the more offshore western king prawn and the more inshore tiger prawn.

Endeavour prawns are mainly trawled in Exmouth Gulf and to a lesser extent in Shark Bay. The 1982-83 catch was 273 tonnes, worth $1.2 million.

Molluscs

1.13 Southern Saucer Scallop (Amusium balloti)

Southern saucer scallops are distributed from Dampier south to Albany on sandy bottoms in inshore waters, about 10 to 40 m depth, in the lee of an island or headland. Major concentrations occur at Shark Bay. They are normally sedentary, feeding on plankton by a filter mechanism, but swim when disturbed by clapping their shells and expelling water.

Spawning takes place in late spring and summer with a high fecundity and the eggs are released into the water column, where fertilisation occurs. Larvae are pelagic and develop shells in late summer and autumn, at which stage they settle on the sea bottom in areas determined by the presence of eddies or strong mixing currents. This settling is referred to as spatfall. After overwintering as juveniles, maturity is reached the following summer when the shells are about 8 cm in height. They eventually reach about 11 cm in height.

Scallops are caught by trawling, with sometimes a tickler chain added. The bulk of the catch is from Shark Bay and minor catches are taken near the Abrolhos Islands and Rottnest Island. Those caught are usually above 9 cm in shell height. The catch for 1982-83 was 4 208 tonnes, worth $1.9 million.

1.14 Abalone (two species)

Abalone are herbivorous marine gastropods which inhabit coastal reefs in temperate and tropical seas. Two species form the basis of the commercial fishery in W.A.

Greenlip abalone (Haliotis laevigata) occur in W.A. from Busselton on the south west coast along the south coast to Eucla, with major populations around Cape Leeuwin and the islands of the Recherche Archipelago off Esperance. The typical habitat is a sublittoral reef at depths from 2 to 50 m, particularly along the edges of the reef/sand interface where drifting algae, the main food source, tend to accumulate. The larger abalone are relatively sedentary, movements generally being restricted to those required for

feeding.

The life history comprises spawning during spring and summer with a high fecundity, and fertilisation of the eggs in the water column followed by a planktonic larval stage of one to two weeks prior to settlement on the reef. Growth to maturity takes about five years, depending on the availability of food, at which stage they are around 10 to 11 cm in shell length.

The principal commercial catch areas are on reefs off Augusta and Esperance where fishing is conducted by compressed air diving, usually in depths of 10 to 20 m. The catch for 1982-83 was 143 tonnes.

Roe's abalone (Haliotis roei) reach further north than Greenlip abalone and are distributed from Shark Bay south to Eucla on coastal limestone reef platforms attached to the mainland or a major island. These are prevalent in the south west. The abalone are usually restricted to the surf zone, extending to a depth of 2 to 3 m depending on the degree of wave action. The food source is locally-attached algae and drifting algae, which the animal actively catches from its semi-permanent position in crevices in the reef.

Spawning occurs sporadically all year with a high fecundity and, as with greenlip abalone, fertilisation is in the water column followed by a short larval stage and settlement at the post-larval stage. The nursery area for post-larvae is considered to be where intertidal coralline encrusting algae occur along the outer margin of the reef. As the juveniles grow they move onto the reef face adjacent to the coralline zone. Maturity is reached in this zone between about 3 to 5 years of age, at which time the shell length is approximately 6 cm. Maximum shell lengths approach 13 cm.

The most productive reef areas are at Kalbarri, Greenough River, metropolitan beaches and from Cape Naturaliste to Cape Leeuwin, and the minimum legal size for professional fishing is 6 cm diameter (7 cm at metropolitan areas). The commercial catch for 1982-83 was 84 tonnes.

The combined gross value to the fishermen of both abalone species was $1.5 million.

2. RECREATIONAL FISHING

Recreational fishing consists mainly of angling, but diving, spearfishing, net fishing and potting are also practised. With certain species and in certain localities Fisheries Department regulations govern the numbers caught and the method used, e.g. a daily bag limit of eight rock lobsters of carapace length not less than 76 mm can be caught during the specified fishing season by potting or by hand but not by spear fishing.

Amateur angling may be divided into three categories: shore-based fishing from beach, reef, rock and mangrove areas, boat fishing in which dinghys and runabouts are principally used up to about 30 km from the shore, and offshore game fishing which requires more specialised boats and equipment and operates mainly on a seasonal basis and in specific areas. Species caught by boat fishing overlap those caught by shore-based and, to some extent, by offshore game fishing.

The composition of the amateur angling catch was estimated by examining the records of recreational fishing clubs belonging to three associations, the Australian Anglers Association (AAA), the Australian National Sportfishing Association (ANSA), and the W.A. Gamefishing Association (WAGA). Although only a small percentage of anglers belong to clubs, the fish caught by club members in a particular area were considered to be representative of those taken by amateur anglers in general.

Where information of a more qualitative nature obtained from local knowledge or fishing journalists has been used, the source is indicated on the map.

2.1 Shore-based Angling

Clubs from the AAA and ANSA mainly fish from the shore. A list of selected clubs along the coast from Esperance to Geraldton was provided by the AAA. These clubs conduct regular competitions at given locations and, by use of their field day records, the number of fish of each species taken competitively at each location was obtained and expressed as a percentage of the total number of fish of all species caught at that location. Such percentages were assigned a category number, as shown below, which is placed on the map alongside the appropriate fish species.

Category	Percentage of total fish caught
1	>80
2	60-80
3	40-60
4	20-40
5	5-20

Only those species of fish which represented more than 5% of the total catch for a locality are included on the map.

Additionally, where the catch rate of a particular species

$$\left(\frac{\text{No. of that species}}{\text{No. of fishermen}} \text{ per field day} \right)$$

was considerably better in one locality than in others in the area it is denoted on the map by a (*).

It should be noted that some bias may be introduced by the nature of AAA competitions. Points are awarded for the number of fish taken and total weight of fish caught but, since most anglers do not seek exclusively particular species of a certain size, only the numbers taken have been considered here. Furthermore, all the clubs strictly followed Fisheries Department fishing regulations and imposed additional club restrictions; except for 2 clubs, the maximum number of any one species of fish permitted was 50, apart from selected reef fish with a limit of 10 and salmon with a limit of 5. However, since only a minority of competition anglers ever caught their bag limit of any species, the percentage catch figures are a reasonable indication of the relative importance of each species in most localities. Where the bag limit was reached it was usually with herring and salmon and only in a few localities.

It is also realised that some fish are easier to catch than others by virtue of their habits rather than their numbers, and that the equipment used may favour the catching of particular fish. Catch data are thus not an ideal estimation of fish numbers in a locality, but should be viewed in terms of angling practices rather than as a measure of abundance.

Anglers belonging to ANSA clubs fish competitively throughout W.A., attempting to catch a wide variety of fish species according to tackle divisions and line classes. Only the largest fish in each section are recorded and it is not possible to determine the relative abundance of a given species from these records. However, where AAA club records were absent, descriptive information from ANSA was used. Supplementary information was taken from "Coast Watch", a weekly article in the "West Australian" newspaper which provides notes on the fish species taken most frequently by anglers at a variety of recreational localities.

AAA field day records for the southern part of the State showed that fewer than four species often comprised the bulk of the total catch. Along the south coast the dominant species by number was the Australian herring, which frequently represented up to 90% of competition catches. Southern trevally and whiting were also regularly taken, but in lower numbers. Australian salmon were recorded in large numbers from beaches in the Esperance region, where they were most common between April and August.

On the lower west coast, the main species was again Australian herring. Southern trevally were commonly taken around the rocky areas at Cape Leeuwin. Australian salmon were caught during field day meetings on beaches in the Yallingup area but, unlike Australian herring and southern trevally, they are not prevalent all year round and catches show marked seasonality.

Further up the west coast, tailor were taken in increasing numbers, and replaced Australian herring as the dominant species (by number) north of Perth. Southern trevally and whiting were again frequently represented in catches. To the north of Perth, particularly in the Geraldton area, mulloway was an important recreational fish.

In the Carnarvon region important beach (rock) fishing sites were Steep Point, where tailor and pink snapper were dominant, and the Point Quobba to Cape Cuvier coast, where spangled emperor and various mackerel were major species.

Further to the north the diversity of the catch increased, but no estimate of the proportions of species in the catch could be made.

2.2 Boat Angling

Records from clubs associated with the AAA were also used to determine the composition of the catch for boat fishermen. In some country centres where clubs were new and had few records, or no club could be contacted, little information was available, and records for boat fishing were not available south of Bunbury.

Jewfish and shark were the most commonly taken large fish in the Bunbury area, while assorted small fish including Australian herring, sweep, whiting and flathead were also caught. In the Perth area, herring, whiting and southern trevally, and occasionally garfish, were the dominant species caught nearshore. When trolling, the boat anglers also caught pike. Jewfish, pink snapper and breaksea cod were the main species caught in deeper waters off Rottnest and Direction Bank. From Lancelin to Jurien Bay, pink snapper and jewfish were the most common species.

Field day records were not available for boat fishing in the north of the State, where information supplied by ANSA members was used to determine the important species. Most boat fishing in the north occurs during the "dry" period of the year, April to September, since conditions are less safe and somewhat unpleasant during the "wet" months. A very wide range of species is taken by northern anglers. The most frequently caught pelagic species include Spanish mackerel, queenfish and trevally. Fish commonly referred to as "snapper" (Lethrinidae, Lutjanidae), in particular spangled emperor and red emperor, constitute a large part of the demersal catch. Coral trout and cod are also regularly taken. From Port Hedland to Broome another two species, threadfin salmon and mangrove jack, are caught in large numbers close to shore and in the tidal creeks by boat fishermen who can enter areas which are difficult to reach by road.

2.3 Offshore Game Angling

The West Australian Gamefishing Association has four affiliated clubs, the most active being at Perth, Exmouth and Dampier. The Perth club regularly fishes the Rottnest area, taking salmon and yellow-tail kingfish at the west end of the island, while dolphin fish, sharks and Spanish mackerel are the main species taken at "The Trench", west of Rottnest Island. At Exmouth, Spanish mackerel, sailfish and dolphin fish are the dominant species. Spanish mackerel and sailfish, along with queenfish, are the most frequently caught gamefish at Dampier.

Gamefishing is considered to involve large boats and specialised equipment. However, the principal gamefishing targets - Spanish mackerel, sailfish and marlin - are increasingly being sought by anglers using small runabouts.

Charter boats offering game and general fishing largely operate to the north of Perth, the season decreasing to virtually winter in the localities furthest north. Main areas for chartering are the Abrolhos Islands, Exmouth, Mackerel Islands (Onslow) and Broome.

2.4 Diving and Spearfishing

Since divers supposedly select the species of fish they take, their preference, rather than the resource available, is presumably shown by their catches. Along the south coast, at places such as Madfish Bay, Windy Harbour and Bald Island (Albany), spearfishermen take blue groper, blue morwong, jewfish and samson fish. To the east, at Hopetoun and Esperance, divers collect southern rock lobsters and the large greenlip abalone.

On the lower west coast western rock lobsters, and several fish species - blue groper, blue morwong, jewfish and samson fish - are the main targets for divers. Spanish mackerel are speared in increasing numbers north of Perth, where Moore River, Beagle Island and African Reef are important diving sites. The range of blue groper appears to end at Beagle Island.

The Abrolhos Islands represent a major diving area, and are visited by diving parties using charter boats and private boats. Coral trout, baldchin groper, jewfish, samson fish, Spanish mackerel and western rock lobsters are the main species taken. Coral trout and baldchin groper are also the main species taken at Shark Bay.

Exceptional diving conditions occur in the Coral Bay/Ningaloo area amongst the extensive reefs. Spanish mackerel, baldchin groper, blue tusk fish, and very large cod are caught along with the northern rock lobster. Coral trout are reported to be in low numbers, possibly due to fishing pressure.

Farther north in the Dampier area, there is a large diving community. The main species sought are coral trout, cod, and northern rock lobsters, the latter species not occurring in large numbers near the shore.

2.5 Net Fishing and Potting

Recreational fishermen may use nets to catch fish, provided they comply with Fisheries Department regulations. The extent of net fishing was not established and no estimate of net catches was possible because records were unavailable.

In the southern part of the State, nets are more frequently used in estuaries than in the ocean. The main target species are sea mullet, which are not readily taken by line, and yellow-eye mullet. Nets are also used widely in the tidal and mangrove creeks of the north where threadfin salmon and barramundi are the principal targets.

Blue manna crabs and prawns are caught by amateurs using various types of nets in the southern part of the State, but this is largely an activity confined to estuaries. Large numbers of blue mannas are caught in Cockburn Sound by amateurs using drop nets. The northern mud crab is caught by netting (dropnet, set net) in mangrove creeks from Carnarvon to Broome.

Western rock lobsters are caught by recreational fishermen using pots. The main areas fished are around Perth (Safety Bay-Rottnest-Two Rocks) and Geraldton. In these areas the Fisheries Department has estimated that more lobsters are caught by pot fishermen than by divers. However, in the north of the State lobsters are usually taken by diving, since northern species do not readily enter pots.

3. SUBSISTENCE ABORIGINAL FISHING

Aboriginal fishing is classified as subsistence when it is considered important as a food source, as an economic necessity and as a way of life to a substantial part of an aboriginal community. Such fishing occurs in several areas north of Onslow including rivers inundated by tidal flows. Information on these areas was obtained from the Commonwealth Department of Aboriginal Affairs.

4. FISH NURSERY AREAS

In tropical W.A., little work has been done on the extent of fish nursery areas. Protected areas, such as tidal creeks, embayments, many marine coastal inlets and tidal regions of rivers, are usually fringed with mangrove communities and are likely to provide important nursery habitats for a great many coastal fish species.

It is also likely that sandy and rocky foreshores provide nursery areas for other species. However the relative importance of mangroves and other foreshores to the various coastal fish species is at present difficult to assess.

It should be noted that nursery habitats in regions which experience a substantial tidal exchange, e.g. Cambridge Gulf, may be less important than nursery areas available in small protected tidal creeks which are not subject to such extreme tidal activity.

In temperate W.A., results of research conducted by the Fisheries Department and CSIRO have shown that the inshore marine environment offers nursery areas for a large number of commercially important species. For many species, these are alternative habitats to those found in estuaries.

The greater the protection from the influence of the open ocean, the better the nursery area. For example, protected marine embayments such as Cockburn Sound and Shark Bay offer nursery habitats for a wide variety of species, whose requirements varying from sandy shoreline habitats (whiting) to deeper silty habitats (snapper).

Areas inside offshore reefs also offer protected habitats. Drift algae detached from the reefs during periods of heavy swell, together with drift seagrass from beds growing in areas protected by these reefs, accumulate in the surf-zone and over the bottom in depressions outside the surf-zone. In both regions, this drift seaweed supports a rich assemblage of invertebrate prey fauna and provides a protective habitat for many juvenile commercial fish. To date it appears that although beds of live seagrass (Amphibolis spp.,Posidonia spp.) also provide important nursery habitats for many fish species, these are mainly non-commercial species.

Ongoing research in this nearshore region has shown that clear sandy shorelines are not as important to many of the fish that are associated with the drift weed. However, indications are that they may be essential for a different community of fish, some of which are commercially important.

5. OTHER CRUSTACEA

5.1 Southern Rock Lobster (Jasus novaehollandiae)

In W.A. this lobster is mainly found in the reefs east of Esperance, with lesser numbers between Esperance and Albany. Mating occurs in winter and early spring and the eggs hatch in spring and summer. The larvae drift offshore and spend about 1 year there before returning to settle inshore the following spring. It takes about 5 to 6 years for an animal to reach maturity.

There is a small commercial fishery for this species, using baited traps, at Esperance and eastwards at Duke of Orleans Bay, Cape Arid and Point Malcolm. In 1982-83, the professional catch was 23 tonnes, worth $171 000.

5.2 Tropical Rock Lobster (Panulirus spp.)

These are not abundant and are found north of Exmouth Gulf, particularly in the Rowley Shelf. The major species are the painted cray (P. ornatus) and the green cray (P. versicolor) while less common species are the scalloped rock lobster (P. homarus) and the double-spined rock lobster (P. penicillatus). Their life histories are similar to those of the other rock lobsters which have been described.

There is no commercial fishery for any of the tropical species and most are caught by diving.

5.3 Bay Lobster (Thenus orientalis)

The Bay lobster is also known as the Moreton Bay bug or the shovel-nosed lobster. This species occurs in small numbers at various areas along the north west coast where silt, sand or mud occur, e.g. Exmouth Gulf and Nickol Bay.

There is no specific commercial fishery for bay lobsters but they are caught during prawn trawling.

5.4 Mud (Mangrove) Crab (Scylla spp.)

Mud crabs occur on the W.A. coastline from Shark Bay northwards, with significant stocks only existing north of Exmouth Gulf, particularly in the Kimberley coast. Their usual habitat is in tidal mangrove creeks and estuaries where they occupy burrows in the warmer months and feed on slow-moving or immobile animals such as molluscs and hermit crabs.

Females move away from the shore into marine waters to spawn. From 1 to 8 million eggs are produced which remain attached to the abdomen for a short period before hatching to release planktonic larvae. After 2 to 3 weeks the post-larval stage is reached and settling takes place onto the bottom. Growth to maturity takes 1 to 2 years.

Fishing for mud crabs on the north west coast is usually carried out with drop nets or crab pots and is predominantly by amateurs. Commercial fishing is of limited importance but is increasing, especially in areas north of Broome. The size of crabs taken varies from a carapace width of 12 or 15 cm (minimum legal size limit depending on which of the two species caught) to about 20 cm.

5.5 Blue Manna (Sand) Crab (Portunus pelagicus)

The blue manna crab is a wide-ranging species in the Indo-Pacific region and occurs all along the W.A. coastline. Significant stocks are found in estuaries and marine embayments such as Geographe Bay, Leschenault Inlet, Peel Inlet/Harvey estuary, Swan River estuary, Cockburn Sound, Murchison River estuary, Shark Bay, Exmouth Gulf and Nickol Bay. The habitat ranges from intertidal to water depths of about 40 m, although most occur close inshore in less than 10 m depth, and the food source is mainly slow-moving benthic invertebrates.

Spawning occurs in marine waters in summer in the south west and all year round in the north west of W.A. and may be repeated 2 or 3 times a year. Up to 2 million eggs are produced at a single spawning and released into the water column. The planktonic larval stage lasts for about 4 to 6 weeks before the small post-larval crabs take up a benthic life and return to the estuaries and rivers. They take about a year to reach maturity and live up to 3 years.

Crab fishing is a popular amateur sport in south-western coastal areas where they are caught by drop nets. Professional fishing also occurs in these areas to supply the local market. The stocks in more remote areas of the State are fished as a by-catch when prawn trawling; but little of the catch is retained. The blue manna crab reaches a similar size to the mud crab, 12.7 cm carapace width (minimum legal size) to about 20 cm.

The combined professional catch of mud crabs and blue manna crabs in 1982-83 was 124 tonnes, worth $315 000.

6. OTHER MOLLUSCS

6.1 Octopus (Octopus tetricus)

The octopus occurs in the south western coastal areas of the State from about Quobba down to Albany, in water depths from the intertidal to over 30 m, although the highest density is in the 0 to 20 m range.

It has a short lifespan of approximately 12 months; females lay eggs only once in their lifetime and die shortly after the eggs have hatched. The newly-hatched young are planktonic and feed on small crustaceans in the plankton. Larval life is probably around 25 to 40 days, and the juveniles settle out at a size of about 9 mm mantle length, weighing in the region of 0.4 kg. The maximum size of adults is usually around 2 to 2.5 kg. Sexual maturity in males occurs at about 500 g, while females lay eggs when they are between 1 and 2 kg.

Adults and large juveniles are predators on slow-moving crustaceans and molluscs in benthic communities. A small fishery for octopus occurs in the Cockburn Sound/Fremantle area where they are caught by the use of unbaited pipes, pots and traps and they are also found extensively in baited rock lobster pots.

6.2 Squid (Sepioteuthis spp; Nototodarus gouldi)

Sepioteuthis australis, the broad-finned squid, is the most common species, occurring in coastal waters, bays and inlets of southern Australia from southern W.A. to New South Wales. It is usually caught in depths of less than 70 m and is primarily a demersal species, although in shallow areas (10-15 m) it is found throughout the water column. Eggs are laid on the sea floor, with spawning occurring over a large part of the year. A few squid are caught just south of Fremantle by jigging.

Nototodarus gouldi occurs in continental shelf waters of southern Australia from Queensland to southern W.A., with the greatest abundance in waters 50 to 200 m deep. This is the species sought by off-shore fishing operations using mechanised jigging and it is an important prey for many offshore fish. Reproductive data indicate a prolonged breeding season.

Squid feed mainly on crustaceans, fish and cephalopods. The professional catch in 1982-83 was 44 tonnes, worth $73 000.

6.3 Cuttlefish (Sepia spp.)

Probably only two species are important, Sepia apama in the south and S. pharaonis in the north of Australia. Both species are found in inshore areas and bays as well as further offshore. In general they are demersal and feed on fish and crustaceans in seagrass and seaweed beds.

6.4 Mussel (Mytilus edulis)

Mussels are attached to hard substrates from the intertidal down to water depths of about 18 m, with the greatest abundance in the intertidal zone and down to a few metres below the surface. The species has a world-wide distribution in temperate areas of both hemispheres. In Australia it is found along the shores of all southern States. In southern W.A. mussels spawn in late winter to spring, often with very large spatfalls in favourable areas. A filter feeder on marine phytoplankton, it has the ability to cease filtering and remain tightly closed for periods up to a week if presented with adverse conditions. The lifespan is probably 2 or 3 years and it is collected by hand. In 1982-83, the professional catch was 222 tonnes, worth $185 000.

6.5 Trochus (Trochus niloticus)

This is a browsing gastropod found in shallow tropical waters around the northern coastline, particularly the northern reaches of King Sound, and on the intertidal reef platforms at Rowley Shoals, Browse Island, Scott Reef, Seringapatam Reef, Ashmore Reef and Cartier Island. It feeds on algae and, in common with other trochids, probably has a planktonic phytotrophic larval stage.

Trochids are taken from exposed reef tops in King Sound during low tide periods by the Bardi aboriginal community and the shell is used for buttons.

6.6 Giant Clam (Tridacna maxima)

This large filter-feeding bivalve occurs in the tropical waters of northern Australia, but in W.A. its distribution is mostly limited to the cleaner waters of the offshore islands. Generally associated with reef areas, it is found from the intertidal down to water depths of around 15 m. The giant clam is a very slow-growing species which may reach over 1 m in length. It is protected from exploitation as a rare species.

6.7 Rock Oyster (Saccostrea spp.)

Members of this genus usually develop first as males, but some change later to females. Spawning is simultaneous with fertilisation, and the larvae are pelagic, feeding on phytoplankton for about three weeks before settling out on areas inhabited by the adults. These areas are intertidal rocky substrates either along the coast or in bays and estuaries.

The genus is distributed around Australia but only one species, Saccostrea commercialis in New South Wales, is found in sufficiently large quantities to be commercially exploited. To collect and grow this species, oyster farmers usually place horizontally-spaced wooden stakes in estuaries or inlets known to have consistently large spatfalls.

6.8 Mud Oyster (Ostrea angasi)

This oyster also develops first as a male, but unlike Saccostrea spp. it changes sex on a regular basis for each breeding season. Released larvae are pelagic for about two to three weeks before settling out subtidally on any hard substrate where the seafloor is muddy.

Small populations in Oyster Harbour, Albany were once dredged commercially. Renewed interest in commercial exploitation of the mud oyster is occurring in the eastern States of Australia.

7. PEARL OYSTERS (Pinctada maxima)

With the decline in world demand for pearl oyster shell the majority of pearl oysters collected in W.A. are for pearl culture. There are now ten companies licensed to culture pearls in W.A. with lease sites in Kuri Bay, King Sound, Beagle Bay, Willie Creek, Roebuck Bay, the Monte Bello Islands and Exmouth Gulf and for a smaller species of Pinctada in Shark Bay.

Most of the pearl oysters are collected from the sea floor off Eighty Mile Beach, south of Broome, between March and November and then transported to the lease site for a period of acclimatisation. Pearl culture is started by inserting a nucleus into the oyster, which is then placed on the sea bottom or held in baskets suspended about 5 m below rafts or longlines for 1 to 2 years. The oysters filter-feed on phytoplankton and the average size of those used for cultivation is around 15 x 18 cm.

In 1982 the industry produced about $18 million worth of cultured pearls and shells which makes it the second most valuable fishing industry in W.A.

8. SEA, SHORE AND WADING BIRDS IN WESTERN AUSTRALIA

In the first part of this section, the distribution of resident or migrant sea, shore and wading birds along the W.A. coastline has been divided into 16 areas from the Northern Territory border to the South Australian border (Figure 9). Within each area the breeding sea-birds are listed and the presence of other coastal birds is noted by the use of category numbers which are explained in the second part. The nomenclature used is that recommended by the Royal Australasian Ornithologists Union, 1978.

In the final part, nesting, breeding and feeding habits of the resident sea-birds are briefly described. Localities where they are known to breed or which serve as important feeding areas are marked on the maps.

AREA 1. Northern Territory border to Cape Londonderry

A very rough and rugged coastline extending around part of the north Kimberley. Very few beach areas but many exposed tidal flats at low tide. Mangrove areas are abundant, with most river systems having several species along them. Islands are generally rugged, being predominantly of sandstone and basalt. Few islands are of sand and coral.

Breeding Sea-birds

Australian Pelican

Other Sea-birds and Shore-birds

Categories: 2,4,5,7.

Special Notes

Although there are many islands in this area they are not particularly suited to sea-birds for breeding purposes.

Due to the remoteness of this strip of coastline much of the area has not been suitably surveyed to ascertain the full details of nesting sea birds. Undoubtedly more work would record more species nesting i.e. terns, gulls, Osprey, White-bellied Sea-Eagle and cormorants etc..

AREA 2 Cape Londonderry to Cape Leveque

The coastline and islands are like those of Area 1.

Breeding Sea-birds

Australian Pelican	Sooty Tern
Masked Booby	Bridled Tern
Brown Booby	Crested Tern
Pied Cormorant	Lesser Crested Tern
Least Frigatebird	Common Noddy

Other Sea-birds and Shore-birds

Categories: 2,4,5,7.

Special Notes

Adele Island and the Ashmore Reef islands are the major breeding islands in this area, carrying some five and six species respectively. It is very probable that other species, e.g. Silver Gull, Crested Tern, Osprey, White-bellied Sea-Eagle etc., would also nest on the islands in this region.

It is also worthy of note that Swan Island, a few kilometres to the east of Cape Leveque, no longer supports a breeding colony of the Least Frigatebird as mentioned in some publications.

AREA 3. Cape Leveque to Cape Keraudren

Extensive areas of sandy beaches and exposed tidal flats with large patches of dense mangroves. The few islands which do exist, the Lacepedes, are of sand, coral and limestone formation.

Breeding Sea-birds

Australian Pelican	Silver Gull
Brown Booby	Caspian Tern
Pied Cormorant	Fairy Tern
Least Frigatebird	Common Noddy

Other Sea-birds and Shore-birds

Categories: 2,4,5,6.

Special Notes

Of great importance in this area are the very extensive tidal flats along Eighty Mile Beach and Roebuck Bay to the south of Broome. These flats are frequented by visiting migratory waders and many hundreds of thousands are present at certain times of the year.

The Lacepede Islands, the only islands in this region, are also of considerable importance to breeding sea-birds. A count of the Brown Booby in July, 1982 revealed some 7 400 occupied-nests on West Island and 10 300 on Middle Island, indicating that about 35 400 birds were present on these two islands.

AREA 4. Cape Keraudren to North West Cape

Sandy beaches, areas of mangrove, tidal flats with rocky headlands. The islands in this area range from limestone and sand to the rugged islands of the Dampier Archipelago.

Breeding Sea-birds

Wedge-tailed Shearwater
Australian Pelican
Masked Booby
Brown Booby
Pied Cormorant
Least Frigatebird
Osprey
White-bellied Sea-Eagle
Beach Thick-knee
Silver Gull
Caspian Tern
Roseate Tern
Sooty Tern
Crested Tern
Lesser Crested Tern
Common Noddy

Other Sea-birds and Shore-birds

Categories: 2,4,5,6.

Special Notes

The most significant island in this area for breeding sea-birds is Bedout Island which supports eight species.

North Turtle Island is a regular breeding locality of the Australian Pelican.

AREA 5. North West Cape to Cape Cuvier

Sandy beaches, areas of mangroves, rocky shorelines with only one small island in the area.

Breeding Sea-birds

Pied Cormorant
Caspian Tern
Roseate Tern
Crested Tern

Other Sea-birds and Shore-birds

Categories: 2,4,5.

AREA 6. Cape Cuvier to Cape Inscription (Shark Bay)

A mixture of sandy beaches and limestone headlands. All islands in this area are of limestone formation.

Breeding Sea-birds

Wedge-tailed Shearwater
Australian Pelican
Pied Cormorant
Osprey
White-bellied Sea-Eagle
Silver Gull
Pacific Gull
Caspian Tern
Roseate Tern
Bridled Tern
Fairy Tern
Crested Tern

Other Sea-birds and Shore-birds

Categories 2,4,5.

Special Notes

Of considerable importance in this area is Pelican Island, a regular nesting site of the Australian Pelican. Dirk Hartog Island carries the greatest number of breeding sea-birds, supporting six species.

AREA 7. Cape Inscription to Shoal Point

A very rugged strip of coastline with some sandy beach but mainly high vertical cliffs. There are no islands in this area. Dirk Hartog Island has been included in the previous region, the Shark Bay area.

Breeding Sea-birds

Although no actual breeding records are available it is almost certain that the White-bellied Sea-Eagle and Osprey would nest along the cliff areas north and south of the Murchison River.

Other Sea-birds and Shore-birds

Categories: 1,3,5.

AREA 8. Houtman Abrolhos

An extensive system of limestone and coral shingle islands divided into four separate groups and situated between 50 km and 80 km from the mainland. Many of the islands carry extensive areas of mangroves (Avicennia marina).

Breeding Sea-birds

Wedge-tailed Shearwater
Little Shearwater
White-faced Storm-Petrel
Pied Cormorant
Eastern Reef Egret
Pacific Gull
Caspian Tern
Roseate Tern
Sooty Tern
Bridled Tern

Osprey
White-bellied Sea-Eagle
Spotless Crake
Silver Gull
Fairy Tern
Crested Tern
Common Noddy
Lesser Noddy

Other Sea-birds and Shore-birds

Categories: 1,3,5.

Special Notes

The Houtman Abrolhos could be considered the most important sea bird breeding islands off W.A. or perhaps the Australian coastline. Several species, including the Common Noddy, Lesser Noddy, Sooty Tern and Wedge-tailed Shearwater, nest in countless thousands on many of the islands in the group. Of special note is the Lesser Noddy which throughout the world only nests in one other locality, the Seychelles Islands. It is therefore very important to protect the mangroves in which this species breeds. The most important island in the group is Pelsart Island, which accommodates 16 of the 18 species listed, followed by Wooded Island which supports 12 breeding species.

AREA 9. Shoal Point to Cape Leschenault (Coastal)

Mainly sandy beaches with occasional rocky limestone headlands. All islands in this area are of limestone formation.

Breeding Sea-birds

Wedge-tailed Shearwater
Little Shearwater
White-faced Storm-Petrel
Pied Cormorant
Little Pied Cormorant
Eastern Reef Egret
Osprey
Buff-banded Rail
Pied Oystercatcher
Silver Gull
Pacific Gull
Caspian Tern
Roseate Tern
Bridled Tern
Crested Tern

Other Sea-birds

Categories: 1,3,5.

Special Notes

The islands of this region are of considerable significance to breeding sea-birds. Three islands, Sandland, Buller and the Cervantes group each support ten species of breeding sea-birds and the Beagle Island group carries nine species.

AREA 10. Cape Leschenault to Cape Naturaliste

The coastline and islands are similar to those of Area 9.

Breeding Sea-birds

Little Penguin	Silver Gull
Wedge-tailed Shearwater	Pacific Gull
Little Shearwater	Caspian Tern
White-faced Storm-Petrel	Bridled Tern
Pied Cormorant	Fairy Tern
Osprey	Crested Tern

Other Sea-birds and Shore-birds

Categories: 1,3,5.

Special Notes

Seal Island (Safety Bay), Carnac island and Green Island (off Rottnest) each support six species of breeding sea-birds.

AREA 11. Cape Naturaliste to Cape Leeuwin

Sandy beaches and rocky headlands with a few islands close inshore. Some of these islands are of limestone whilst others are predominantly granite-gneiss.

Breeding Sea-birds

Flesh-footed Shearwater	Silver Gull
White-faced Storm-Petrel	Crested Tern
Red-tailed Tropicbird	

Other Sea-birds and Shore-birds

Categories: 1,3,5.

Special Notes

Of great importance in this area is the present breeding colony of the Red-tailed Tropicbird on Sugarloaf Rock, a few kilometres to the south of Cape Naturaliste. This breeding locality along with the Rowley Shoals are the only ones at present known for this species in W.A.

AREA 12. Cape Leeuwin to West Cape Howe

Sandy beaches and rocky headlands with a few granite-gneiss islands.

Breeding Sea-birds

Little Penguin	Silver Gull
Great-winged Petrel	Caspian Tern
Flesh-footed Shearwater	Bridled Tern
Little Shearwater	Fairy Tern
White-faced Storm-Petrel	Crested Tern
Sooty Oystercatcher	

Other Sea-birds and Shore-birds

Categories: 1,3,5.

Special Notes

In this area, St Alouarn Island carries the greatest number of breeding sea-birds, a total of six species.

AREA 13. West Cape Howe to Bremer Bay

Similar coastline to Area 12.

Breeding Sea-birds

Australian Pelican
Little Penguin
Great-winged Petrel
Flesh-footed Shearwater
Little Shearwater
White-faced Storm-Petrel
Sooty Oystercatcher
Silver Gull
Pacific Gull
Caspian Tern

Other Sea-birds and Shore-birds

Categories: 1,3,5.

Special Notes

Of special importance in this area are Coffin Island, on which seven of the area's ten breeding sea-birds have been found nesting, and Green Island in Oyster Harbour which supports the only breeding colony of the Australian Pelican south of Shark Bay.

AREA 14. Bremer Bay (Cape Knob) to Butty Head

Similar coastline to Areas 12 and 13.

Breeding Sea-birds

Little Penguin
Flesh-footed Shearwater
Crested Tern

Other Sea-birds and Shore-birds

Categories: 1,3,5.

AREA 15. Butty Head (Recherche) to Israelite Bay

Sandy beaches and rocky headlands. This area includes the islands of the Recherche Archipelago. These islands, with the odd exception, are of granite-gneiss formation.

Breeding Sea-birds

Little Penguin
Great-winged Petrel
Flesh-footed Shearwater
Short-tailed Shearwater
Little Shearwater
White-faced Storm-Petrel
Black-faced Shag
Cape Barren Goose
Silver Gull
Pacific Gull
Caspian Tern

Other Sea-birds and Shore-birds

Categories: 1,3,5.

Special Notes

Three of the breeding species, Short-tailed Shearwater, Cape Barren Goose and Black-faced Shag, only breed in the Recherche Archipelago in W.A. although there are several breeding localities in eastern Australia.

The Western Australian race of the Cape Barren Goose is a different sub-species from the population in eastern Australia.

AREA 16. Israelite Bay to South Australian Border

Extensive stretches of limestone cliffs and sandy beaches.

Breeding Sea-birds

Little Penguin (nests in cliffs near Eyre).

Other Sea-birds and Shore-birds

Categories 1,3,5.

Sea-bird Categories

Birds which are included in the category numbers 1 to 7, used in the above area descriptions, are given below.

Category 1. Resident sea, shore and wading birds south of Shark Bay

Little Penguin
Flesh-footed Shearwater
*Wedge-tailed Shearwater
+Short-tailed Shearwater
Little Shearwater
White-faced Storm-Petrel
Australian Pelican
+Black-faced Shag
Pied Cormorant
Little Black Cormorant
Little Pied Cormorant
*Red-tailed Tropicbird
Eastern Reef Egret
Rufous Night Heron
Osprey
White-bellied Sea-Eagle
Buff-banded Rail
Spotless Crake
Pied Oystercatcher
Sooty Oystercatcher
Hooded Plover
Red-capped Plover
Black-winged Stilt
Red-necked Avocet
Silver Gull
Pacific Gull
Caspian Tern
*Roseate Tern
*Sooty Tern
*Bridled Tern
Fairy Tern
Crested Tern
*Common Noddy
*Lesser Noddy

* Uncommon or absent on south coast.
+ Uncommon or absent on west coast

Category 2. Resident sea, shore and wading birds in Shark Bay and northwards

Wedge-tailed Shearwater
Australian Pelican
Masked Booby
Brown Booby
Pied Cormorant
Little Pied Cormorant
Least Frigatebird
Red-tailed Tropicbird
Eastern Reef Egret
Rufous Night Heron
Osprey
Brahminy Kite
White-bellied Sea-Eagle
Buff-banded Rail
Bush Thick-knee
Beach Thick-knee
Pied Oystercatcher
Sooty Oystercatcher
Red-capped Plover
Black-winged Stilt
Red-necked Avocet
Silver Gull
Pacific Gull (south of NW Cape)
Gull-billed Tern
Caspian Tern
Roseate Tern
Sooty Tern
Bridled Tern
Little Tern
Fairy Tern
Crested Tern
Lesser Crested Tern
Common Noddy

Category 3. Visiting non-breeding sea birds south of Shark Bay

Rockhopper Penguin
Fiordland Penguin
Erect-crested Penguin
Wandering Albatross
Royal Albatross
Black-browed Albatross
Grey-headed Albatross
Yellow-nosed Albatross
Shy Albatross
Sooty Albatross
Light-mantled Sooty Albatross
Southern Giant-Petrel
Northern Giant-Petrel
Southern Fulmar
Cape Petrel
White-headed Petrel
Kerguelen Petrel
Soft-plumaged Petrel
Blue Petrel
Broad-billed Prion
Lesser Broad-billed Prion
Antarctic Prion
Slender-billed Prion
Fairy Prion
Grey Petrel
White-chinned Petrel
Hutton's Shearwater
Wilson's Storm-Petrel
Kerguelen Petrel
Australian Gannet
Great Skua
Arctic Jaeger
Pomarine Jaeger
Kelp Gull
White-winged Tern
Common Tern
Arctic Tern

Category 4. Vising non-breeding sea birds in Shark Bay and northwards

Yellow-nosed Albatross
Cape Petrel
White-headed Petrel
Hutton's Shearwater
Wilson's Storm-Petrel
Leach's Storm-Petrel
Sooty Storm-Petrel
Great Frigatebird
White-tailed Tropicbird
White-winged Tern
Common Tern

Category 5. Migrant waders

Grey Plover
Lesser Golden Plover
Mongolian Plover
Double-banded Plover
Large Sand Plover
*Oriental Plover
Ruddy Turnstone
Eastern Curlew
Whimbrel
Grey-tailed Tattler
Common Sandpiper
Greenshank
*Redshank
*Terek Sandpiper
*Pin-tailed Snipe
*Swinhoe's Snipe
*Asian Dowitcher
*Black-tailed Godwit
Bar-tailed Godwit
Red Knot
Great Knot
Sharp-tailed Sandpiper
*Pectoral Sandpiper
Red-necked Stint
Curlew Sandpiper
Sanderling
*Broad-billed Sandpiper
*Ruff
*Red-necked Phalarope

* These species are scarcer south of the tropics.

Category 6. Mangrove Birds in the Pilbara and southwards

Striated Heron
Osprey
Brahminy Kite
White-bellied Sea-Eagle
Lesser Noddy
Sacred Kingfisher
Collared Kingfisher
Dusky Flyeater
Mangrove Robin
Mangrove golden Whistler
White-breasted Whistler
Shining Flycatcher
Brown Honeyeater
Yellow White-eye
White-breasted Woodswallow

Category 7. Mangrove Birds in the Kimberley

Great-billed Heron
Striated Heron
Black-necked Stork
Plumed Whistling-Duck
Radjah Shelduck
Osprey
Brahminy Kite
White-bellied Sea-Eagle
Chestnut Rail
Torresian Imperial-Pigeon
Azure Kingfisher
Sacred Kingfisher
Collared Kingfisher
Green-backed Gerygone
Large-billed Gerygone
Dusky Gerygone
Mangrove Gerygone
Mangrove Robin
Lemon-bellied Flycatcher
Mangrove Golden Whistler
White-breasted Whistler
Little Shrike Thrush
Broad-billed Flycatcher
Leaden Flycatcher
Shining Flycatcher
Rufous Fantail
Northern Fantail
White-gaped Honeyeater
Brown Honeyeater
Red-headed Honeyeater
Yellow White eye
Yellow Oriole
Spangled Drongo
White-breasted Woodswallow
Black Butcherbird

Notes on the Sea-birds Breeding in Western Australia

8.1 Australian Pelican (Pelicanus conspicillatus)

Widespread in W.A. and throughout Australia. Rests on the sea surface. Sedentary feeder, alone or in flocks, by catching fish, prawns and freshwater crayfish below the water surface. Few marine nesting areas. Colonial breeder on islands on sand in autumn and winter. Following completion of nesting, birds disperse up and down the coastline.

8.2 Beach Thick-knee (Burhinus neglectus)

Distributed from the Tropic of Capricorn northwards in W.A. and occurs in northern parts of Australia. Feeds by foraging for crabs and other marine invertebrates in beach areas. Breeds in pairs or small groups in hollows scratched in the sand just above the high-water mark in late spring and summer. Often roosts on the fringe of mangroves.

8.3 Black-faced Shag (Leucocarbo fuscescens)

Not widespread in W.A., where breeding areas are restricted to Middle Island and Lion Island in the Recherche Archipelago, but it is also found in southern Australia. Sedentary feeder on fish, crustaceans and molluscs by diving below water and swimming for 20 to 30 seconds. Colonial breeder in seaweed nests on bare rocks just above high tide levels, mainly in late spring and early summer.

8.4 Bridled Tern (Sterna anaethetus)

Occurs from Cape Leeuwin northwards in W.A. and in the Northern Territory and Queensland. Migratory surface-hovering feeder, in flocks, by scooping small fish, crustaceans and small squid from the water surface. Colonial breeder under bushes, large rocks and on sheltered rocky ledges in late spring and summer. Roosts at night on land.

8.5 Brown Booby (Sula leucogaster)

Not widespread in W.A., occurring from Onslow northwards and in the Northern Territory and Queensland. Exhibits local movement only. Rests on the sea surface. High dives deep into water to catch fish and squid. Colonial breeder on islands on the ground all year round but with peaks in autumn and spring.

8.6 Buff-banded Rail (Rallus philippensis)

Found from North West Cape south to Israelite Bay in W.A. and is widespread in Australia. Feeds by foraging around islands and beach areas for insects, small molluscs and other invertebrates. Spring breeder in isolated pairs on islands placed on or close to the ground in dense vegetation.

8.7 Cape Barren Goose (Cereopsis novaehollandiae)

In W.A. it is restricted to the islands of the south coast from Albany eastwards, particularly the Recherche Archipelago, and occurs also on other islands off southern Australia. Feeds entirely ashore on plant material. Breeds in down-lined nests in grass during winter.

8.8 Caspian Tern (Hydroprogne caspia)

Widespread in W.A. and throughout Australia. Diving feeder, alone or in pairs, on fish in coastal waters or shallow freshwaters. Colonial or solitary breeder on the ground, preferably on sandy beaches, from autumn to spring in the North and during spring in the South.

8.9 Common Noddy (Anous stolidus)

Occurs in large numbers from the Abrolhos Islands northwards in W.A. and in the Northern Territory and Queensland. Surface feeder, by scooping fish and occasional cuttlefish, small molluscs and plankton. Colonial breeder on islands and coral cays on the ground or in shrubs in late spring and summer. Nests are made of seaweed.

8.10. Crested Tern (Sterna bergii)

Widespread in W.A. and throughout Australia. Sedentary feeder, in flocks, on fish and prawns by partial or total immersion when diving. Colonial breeder on offshore islands on rocky or sandy areas in autumn and spring. Roosts at night on the ground.

8.11. Eastern Reef Egret (Egretta sacra)

Widespread in W.A. and throughout Australia, except Victoria. Frequents coral reefs, beaches and rock platforms where it forages for fish, prawns, crabs and insects. Also feeds by piracy on nesting colonies of terns. Solitary breeder in a nest consisting of a simple platform of sticks in shrubs or on the ground, mostly during spring.

8.12. Fairy Tern (Sterna nereis)

Occurs from the Lacepede Islands southwards in W.A. and in southern Australia. Migratory. Diving feeder on fish and occasional gastropods and crustaceans in shallow water. Colonial breeder on sand or shingle near high water mark from early spring through summer.

8.13. Flesh-footed Shearwater (Puffinus carneipes)

Not widespread in W.A., occurring from Cape Hamelin eastwards and in New South Wales. Migratory. Feeds by fluttering over the sea in flocks and partially submerging to catch fish, shellfish and squid. Colonial breeder in burrows on islands in summer.

8.14. Great-winged Petrel (Pterodroma macroptera)

In Australia it is found only in W.A. on the south and south-west coasts. Feeds predominantly by fluttering over the sea in flocks and partially submerging to catch fish, shellfish, squid and plankton. Colonial breeder in winter on islands between Albany and the Recherche Archipelago in surface nests among rocks, tree roots and scrub or in burrows.

8.15. Least Frigatebird (Fregata ariel)

Occurs from Exmouth Gulf northwards in W.A. and in the Northern Territory and Queensland. Feeds on squid, young turtles, crabs and fish, mainly by piracy. Colonial breeder on islands using shrubs, trees and occasionally the ground in autumn through spring, often with several thousand birds forming the colony. Disperses widely from the nesting islands.

8.16. Lesser Crested Tern (Sterna bengalensis)

Occurs from Shark Bay northwards in W.A. and in the Northern Territory and Queensland. Only known breeding areas in W.A. are Adele Island and Bedout Island. Found in the open ocean, often resting or swimming on the water. Diving feeder on fish. Colonial breeder on sand, as far as is known in autumn.

8.17. Lesser Noddy (Anous tenuirostris)

Not widespread in Australia, occurring solely at the Abrolhos Islands, W.A. It is protected in W.A. as an endangered species since it breeds only on Pelsart, Morley and Wooded Islands in the Abrolhos and at the Seychelles. Is non-migratory. Sedentary feeder by scooping molluscs, jellyfish and plankton but occasionally may dive through wave crests. Colonial breeder in nests of seaweed on mangrove trees in spring and summer.

8.18. Little Penguin (Eudyptula minor)

Occurs on islands and at the foot of isolated cliffs from Carnac Island southwards in W.A. and in South Australia, Victoria, Tasmania and New South Wales. Sedentary feeder on fish and squid and may remain immersed for up to one minute. Isolated or colonial breeder in burrows, mostly on offshore islands, in spring to early summer. Usually comes ashore every night. Is flightless and does not migrate.

8.19. Little Pied Cormorant (Phalacrocorax melanoleucos)

Widespread in W.A. and throughout Australia and is much more common in fresh than marine waters. Sedentary feeder in shallow waters and dives and swims underwater to catch animals at the bottom. Feeds mainly on crustaceans, dragonfly larvae, beetles, tadpoles and small fish. On offshore islands generally breeds in isolated pairs in rocky areas in autumn and winter. Often nests in close association with the Pied Cormorant.

8.20. Little Shearwater (Puffinus assimilis)

Occurs between the Abrolhos Islands and the Recherche Archipelago in W.A. and only at Lord Howe and Norfolk Islands off eastern Australia. Feeds on fish and squid, often in flocks and up to 50 kilometres from land, by fluttering over the sea surface and partially submerging. Colonial breeder in burrows, usually in short vegetation, in winter.

8.21. Masked Booby (Sula dactylatra)

Occurs from the Dampier Archipelago north to Cambridge Gulf in W.A. and in Queensland. Rests on the sea surface. Only known breeding areas in W.A. are Adele Island and Bedout Island. Diving feeder on flying fish and occasional squid. Colonial breeder on the ground in autumn through spring.

8.22. Osprey (Pandion haliaetus)

Widespread, single or in pairs, throughout W.A. and coastal Australia, except for Victoria. Feeds on fish and carrion by diving, grasping the prey in its talons. Solitary breeder in nests usually lined with seaweed, mainly on rocky crags, in late winter and spring.

8.23. Pacific Gull (Larus pacificus)

Occurs from Shark Bay southwards and along the south coast in W.A., and in South Australia, Victoria and Tasmania. Rests on the sea surface. Sedentary feeder along reefs and shorelines for fish, squid, crabs, molluscs, echinoderms, young sea-birds, eggs and carrion. Isolated or colonial breeder in nests on rocky headlands, lagoon edges or along coastlines in spring.

8.24. Pied Cormorant (Phalacrocorax varius)

Widespread in W.A. and throughout Australia. Sedentary feeder on fish, crustaceans and molluscs and may swim up to 200 m underwater. Colonial breeder on trees, cliff ledges or islands in autumn and winter. Will alight on the sea when disturbed.

8.25. Pied Oystercatcher (Haematopus longirostris)

Widespread in W.A. and throughout Australia. Feeds along coasts, especially beaches, exposed reefs and under tidal debris, mainly on molluscs and worms. Breeds in shallow scrapes on sandy beaches above high water mark in spring.

8.26. Red-tailed Tropicbird (Phaethon rubricauda)

Not widespread in W.A., where it is considered an endangered species, occurring in the south and east to Albany. Also found in Queensland. Feeds by diving from heights up to 14 m on squid and fish and may remain submerged for about 25 seconds. Main breeding area in W.A.is at Sugarloaf Rock, off Cape Naturaliste. Isolated or loosely colonial breeder at the same site each year in scrapes in the ground, in the shade of bushes or rock ledges or in cavities in cliff faces. At Sugarloaf Rock breeding is in summer. Disperses widely and may be found several hundred kilometres out to sea. The bird is very susceptible to disturbance.

8.27. Roseate Tern (Sterna dougalli)

Occurs in W.A. from Lancelin Island northwards and in the Northern Territory and Queensland. Diving feeder in coastal waters and offshore on small fish, crustaceans and squid. Colonial breeder in sand, coral cays or cliff tops in late spring through to autumn.

8.28. Short-tailed Shearwater (Puffinus tenuirostris)

Rarely seen in W.A. but small nesting colonies have recently been found in the Recherche Archipelago. Is abundant in south-eastern Australia. Migratory. Feeds on crustacea, particularly krill, small pelagic fish and small cephalopods by partially submerging and may assemble in densely packed rafts on the sea surface. Colonial breeder in burrows on islands in late spring and early summer.

8.29. Silver Gull (Larus novaehollandiae)

Widespread in W.A. and throughout Australia. Rests on the sea surface. Diverse feeding habits, feeding on plankton or scavenging behind fishing boats in large groups floating on the sea, catching crustaceans along the shore and feeding around rubbish dumps in large numbers. Colonial and occasionally solitary breeder in lined nests on the ground, usually on islands. Breeds in autumn and spring.

8.30. Sooty Oystercatcher (Haematopus fuliginosus)

Distributed all along the W.A. coastline and throughout the Australian coastline. Feeds mainly on limpets and mussels in rocky areas. Solitary breeder in sandy scrapes close to the high water mark in spring and early summer.

8.31. Sooty Tern (Sterna fuscata)

Occurs in W.A. from the Abrolhos Islands northwards and in Queensland. Does not normally visit the mainland and rarely lands on the water. Does not dive for food like many other terns but feeds offshore in flocks by snatching fish, squid

and crustaceans from, or just below, the sea surface. Colonial breeder in a scrape in the ground in autumn and late spring.

8.32. Spotless Crake (Porzana tabuensis)

Occurs in the south-west of W.A., from Hutt Lagoon south-east to Bremer Bay, and in the south-east and eastern parts of Australia in swamps and lagoons. Feeds by foraging along shorelines and islands for molluscs, insects and aquatic vegetation. Breeds in isolated pairs at the Abrolhos Islands in nests on or near the ground in dense low vegetation during spring and early summer.

8.33. Wedge-tailed Shearwater (Puffinus pacificus)

Occurs between Carnac Island and the Dampier Archipelago in W.A., and in Queensland and New South Wales. Feeds by fluttering in small flocks across the surface and partially submerging on small fish, crustaceans and squid. Colonial breeder in summer, usually in burrows in the sand but occasionally on the surface under rocks or bushes.

8.34. White-bellied Sea-Eagle (Haliaeetus leucogaster)

Found along the entire coastline in W.A. and throughout Australia. Diving feeder on fish, sea snakes, birds, small mammals and carrion. Breeds in lined nests in trees, or on the ground in treeless islands, during winter and spring.

8.35. White-faced Storm-Petrel (Pelagodroma marina)

Occurs in the south-western and southern coasts of W.A., from the Abrolhos Islands to the Recherche Archipelago, and off South Australia, Victoria and and New South Wales. Migratory. Feeds by fluttering over the sea surface and partially submerging to catch small planktonic organisms such as euphausids, cephalopods, amphipods, nauplii of barnacles and prawns. Colonial breeder during summer in burrows in the sand which may be close to high water mark.

9. SALT WATER CROCODILES (Crocodylus porosus)

The salt water crocodile is restricted to the tropics, and in W.A. it is found in mangrove-containing rivers from the Fitzroy River northwards. Largest populations have been sighted in the Ord, Roe, Prince Regent and Glenelg tidal river systems of the north west Kimberley.

It is semi-aquatic, grows to about 6 m in length, and is a long-lived species feeding principally on fish and crabs in salt water and fish, crayfish and water rats in fresh water, but larger mammals are also eaten.

The salt water crocodile breeds wherever banks are suitable along the salt water rivers, usually away from the mouth. Between October and May about 80 eggs are laid in a nest mound of leaf mould on a hard bank, well protected by river scrub. Hatchlings are about 20 cm in length and extremely vulnerable to a host of predators. They are dispersed by the river waters and feed initially on insects, small fish and frogs.

The salt water crocodile is considered to be rare in W.A. and is a protected species.

10. TURTLES

Four species of turtle have been regularly recorded in W.A., the green turtle (Chelonia mydas), the loggerhead (Caretta caretta), the hawksbill (Eretmochelys imbricata) and the flatback (Chelonia depressa). The leatherback turtle (Dermochelys coriacea) has been occasionally sighted in the south west. The distribution of the first three species is generally from Shark Bay northwards, and the flatback from the Pilbara northwards, where suitable sandy beaches exist. However, green turtles are not uncommon in the more southerly Abrolhos Islands but their nesting areas have only been found on beaches from Shark Bay northwards. Of the four commoner species, the green turtle is the largest and may weigh over 200 kg and have a shell length exceeding 120 cm.

Their feeding habits differ. The green turtle is carnivorous when young, then mainly herbivorous on marine algae and angiosperms, the loggerhead is almost totally carnivorous on crustacea, shellfish, sponges, jelly fish and fish but occasionally algae are eaten; the hawksbill is carnivorous when young, then omnivorous on molluscs, crustacea, ascidians, jellyfish and algae; very little is known on the feeding habits of the flatback and leatherback turtles.

All species nest in burrows in the sand several times in summer. Nesting areas for the hawksbill, flatback and leatherback turtles have not been recorded in W.A. The eggs are laid in clutches at night, covered with sand and left to hatch on their own. Up to 1000 eggs may be laid in a season. After about 3 months the hatchlings emerge, dig themselves out of the sand at night, and quickly go down to the sea. At this stage they weigh less than 30 gm. Many of them are caught en route, particularly by the ghost crab, and in the sea by carnivorous fish. Very little is known about the movements of young turtles after they have entered the sea.

11. SEALS

Seals, whales, dolphins and dugongs, representing three main orders of warm-blooded mammals, are found in the marine environment off W.A.

Two seal species (pinnipeds) occur in W.A., the Australian sea lion (Neophoco cinerea) and the New Zealand fur seal (Arctocephalus forsteri). In comparison with world figures, an estimate of the populations of these two species in Australia shows that they are rare.

The sea lion is found as far north as the Abrolhos Islands and is more widely distributed in W.A. than the fur seal, which is restricted to islands off the southern coast, especially the Recherche Archipelago. The sea lion prefers sandy beaches and is occasionally found on smooth rocks whereas the fur seal prefers rocky areas close to the water's edge.

Both species feed on fish, squid, cuttlefish and sea-birds and the fur seal may forage for 2 to 5 days up to distances of 200 km.

Only one seal breeding site is known on the mainland, a small rookery of sea lions occurring just west of Twilight Cove near Esperance. All other breeding areas have been recorded on islands, the main ones being Carnac and Middle Doubtful for the sea lion and Salisbury and Middle Doubtful for the fur seal. The sea lion breeds colonially and at varied terms of year in different years. The fur seal is also a colonial breeder but does not like body contact and does not form large concentrations. It breeds between November and May with a peak in January and is less flexible in its choice of breeding sites than the sea lion. The young of both species enter tidal pools and shallows after 1 to 2 months but are still dependent on the adults.

12. DUGONGS (Dugong dugon)

In W.A. dugongs are found in Shark Bay and northwards, principally in the Bay and Exmouth Gulf but significant numbers occur in the area between the mouths of the Cane and Robe Rivers north of Onslow, in the Cape Preston - Dampier Archipelago area and around Roebuck Bay. They are classified as rare and in need of special protection.

Dugongs grow to about 3 m in length and weigh about 500 kg. They may aggregate in herds of up to 40 or more individuals and frequent shallow seas, bays and estuaries where they browse upon seagrasses which are abundant in the reef flats of the inner tropical coasts. Unlike seals, dugongs do not leave the water, but must rise frequently to the surface to breathe. Their breeding rate is slow and usually a single calf is born each time which remains close to the mother. It appears that killer whales and large sharks are the principal natural predators.

Studies in Shark Bay have shown a clear pattern of seasonal migration. In summer they are concentrated in the Wooramel Delta, feeding on rhizomes of the seagrass genus Halodule. In winter the herds move to warmer waters at the southern end of Dirk Hartog Island and northern Denham Sound where they feed on seagrass leaves of the genus Amphibolis.

13. MANGROVES

Seventeen species of mangrove have been recorded in W.A. The most diverse, luxuriant and well-zoned mangrove environments occur in the wetter portions of the tropics (sub-humid Kimberley coastline), where a maximum of 15 species occur within well-developed mangrove stands. Progressing south, mangrove diversity and luxuriance decreases, such that 11 species occur in semi-arid zones around Broome-Derby and six species occur in arid zones of the Pilbara coastline.

Mangroves are important in several respects; they are major sites of primary production along the coast, their leaf litter (transformed into detritus and a microbial assemblage) constituting the beginning of an extensive food web for coastal environments. Mangroves also function as habitats and nursery locations for numerous nearshore and tidal fauna which, in return, cause turnover of sediment and nutrient flow around the mangroves. Finally, mangroves also have a role in coastal stabilisation, the baffle effect of their subaerial and subsurface root systems retarding or controlling coastal erosion.

Substrates in mangrove areas range over mud, muddy sand, sand, gravel and boulders. Substrates composed of mud or muddy sand are the most important for best utilisation of mangrove productivity; within environments with muddy substrates there is usually an abundance of benthic fauna and a concomitant abundance of invading fish at high tide.

An assessment of the environmental importance of a mangrove stand should be based on the following considerations:

1. Area of the stand.

2. Substrate conditions (the decreasing order of importance is mud, muddy sand, sand, gravel and boulders).

3. Height of the stand relative to tides; high tidal stands are less important than mid-to high-neap tidal stands.

4. Scientific value; e.g. stands that exemplify a scientific principle or that can be utilised for research, stands that contain rare species for a particular region.

Rhizophora stylosa and Avicennia marina are probably the most common mangrove species along the W.A. coast, the southern outlier of the former occurring at Yardie Creek in the Cape Range area while the latter is the only mangrove species south of that point, existing as far south as the Bunbury area. The description of the mangroves in W.A. given below is on a map by map basis (1:250 000) and includes an indication of their environmental significance.

As evident from the mangrove areas on the Lands and Surveys maps and from recent satellite images, not all the mangrove sites are described but only those for which considerable detail is known.

Medusa Banks and Cambridge Gulf Maps

A total of 13 species of mangrove is recorded from this area of the Joseph Bonaparte Gulf. The common species are Avicennia marina, Aegiceras corniculatum, Aegialitis annulata, Camptostemon schultzii, Ceriops tagal, Excoecaria agallocha, Rhizophora stylosa and Osbornia octodonta; less common to rare species are Acanthus ebracteatus, Bruguiera exaristata, Lumnitzera racemosa, Sonneratia alba and Xylocarpus sp.

These mangroves form well-zoned broad stands fringing extensive estuarine mud flats. Locally these mangrove occur on sediment-filled small embayments that have been cut into the dissected rocky hinterland.

The combination of forest luxuriance, fairly rapid forest growth, muddy substrates and abundant benthic fauna means that these mangrove stands rank as important sites of productivity. They also function as nursery beds and feeding grounds for a variety of vertebrate and invertebrate fauna which includes barramundi, prawns and the mud (mangrove) crab.

Londonderry and Drysdale Maps

The Cape Londonderry-Drysdale area provides a variable range of habitats for mangroves, from estuarine mud flats to sandy beaches to bouldery/rocky shores. The mangroves recorded to date from this area include the common species Avicennia marina, Aegiceras corniculatum, Bruguiera exaristata, Camptostemon schultzii, Ceriops tagal, Lumnitzera racemosa, Rhizophora stylosa and Sonneratia alba and the less common species Pemphis acidula, Scyphiphora hydrophylacea and Xylocarpus sp. The species Pemphis acidula and Scyphiphora hydrophylacea are rare and are known only from few localities in tropical NW Australia; these species tend to occur on high tidal rocky shores or sandy shores and, although their importance in terms of productivity is low, their preservation is warranted because of their rarity.

The more common species occur in thick stands along the shores of smaller embayments and in estuaries such as Drysdale River and King Edward River. Here the mangroves are important as sites of productivity, functioning also as nursery beds, feeding grounds and habitats for a variety of fauna which includes barramundi, prawns, various fish and the mud (mangrove) crab.

Montague Sound Map

A total of 13 mangrove species occursin the Montague Sound area. The common species are Avicennia marina, Aegiceras corniculatum, Aegialitis annulata, Bruguiera exaristata, Camptostemon schultzii, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Osbornia octadonta, Rhizophora stylosa and Sonneratia alba; the less common species are Bruguiera parviflora and Xylocarpus sp.

Along the shores of estuaries and embayments, such as Lawley River estuary, Crystal Creek and the embayment of Port Warrender, the mangroves inhabit broad sheltered tidal flats underlain by muddy substrates or line marine-flooded deeply-incised linear fractures. Here they form well-zoned, broad luxuriant stands with all species represented. Headland and bouldery shore environments show development of narrow, shrubby mangrove stands with at least most of the common species present.

The mangrove environments in this region are important as sites of productivity as well as localities of nurseries, habitats and feeding grounds for various fishes (including barramundi, bream), prawns and the mud crab.

Prince Regent and Camden Sound Maps

Thirteen mangrove species are recorded from this area. The common species are Avicennia marina, Aegialites annulata, Aegiceras corniculatum, Bruguiera exaristata, Camptostemon schultzii, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Osbornia octodonta, Rhizophora stylosa and Sonneratia alba; less common species are Bruguiera parviflora and Xylocarpus sp.

The mangroves form dense luxuriant well-zoned stands along the shores of broad tidal flats developed in large sheltered embayments. These mangrove environments are underlain predominantly by muddy substrates.

The combination of forest luxuriance, fairly rapid forest growth, muddy substrates and abundant benthic fauna means that the mangrove stands in this region are important sites of productivity. They also function as nursery beds, feeding grounds and habitats for a variety of fauna which includes prawns, mangrove crabs, barramundi and various other fish.

Charnley and Yampi Maps

The mangrove habitats support a total of 13 species of mangrove in this area. These include the common species Avicennia marina, Aegialitis annulata, Aegiceras corniculatum, Bruguiera exaristata, Camptostemon schultzii, Ceriops tagal, Excoecaria agallocha, Osbornia octodonta and Rhizophora stylosa; the less common species include Bruguiera parviflora, Lumnitzera racemosa, Sonneratia alba and Xylocarpus sp.

The mangroves form dense luxuriant broad and well-zoned stands in northern areas in sheltered sediment-filled embayments such as Secure Bay, Walcott Inlet and Doubtful Bay and in numerous small embayments and bays within the highly indented coastline of Collier Bay-Yampi Sound-Buccaneer Archipelago. However, to the south, mangroves form narrower stands fringing broad salt flats.

Here mangroves are important as sites of productivity as well as functioning as nursery beds, habitats and feeding grounds for a variety of fauna which includes barramundi, other fishes, prawns and mud crabs.

Derby Map

This area has 11 species of mangrove. The common types are Avicennia marina, Aegialitis annulata, Aegiceras corniculatum, Bruguiera exaristata, Camptostemon schultzii, Osbornia octodonta, Rhizophora stylosa; less common species are Bruguiera parviflora and Xylocarpus sp.

The mangroves form well-zoned to poorly-zoned stands fringing broad salt flats or form narrow belts fringing eroded edges of a sandplain.

Pender and Broome Maps

A total of 12 species of mangrove occurs in this area. These include the common species Avicennia marina, Aegialitis annulata, Aegiceras corniculatum, Bruguiera exaristata, Camptostemon schultzii, Ceriops tagal, Excoecaria agallocha, Rhizophora stylosa; less common species are Lumnitzera racemosa (rare), Pemphis acidula and Sonneratia alba. The presence of Lumnitzera racemosa at Broome is significant because this locality represents the most southerly occurrence of this species.

The mangroves occur in zonated stands that fringe sediment-filled embayments cut into the sandplains and limestone/sandstone hinterland of the Dampier land Peninsula. The mangroves form important productive pockets along this coastline.

Lagrange Map

A total of 10 mangrove species occurs in this area. The most common are Avicennia marina, Aegiceras corniculatum, Aegialitis annulata, Bruguiera exaristata, Camptostemon schultzii, Ceriops tagal, Excoecaria agallocha, Osbornia octodonta and Rhizophora stylosa; Sonneratia alba occurs locally but is uncommon. The most southerly occurrence of Sonneratia alba is at Cape Bossut.

The mangroves occur in sheltered small embayments along the sand-plain coastline and a large expanse occurs along the shoreline of Roebuck Bay. The mangroves are mostly poorly-zoned. The thicker, more expansive stands appear to be important sites of productivity.

Bedout Island - Port Hedland - Roebourne - Dampier Maps

The mangrove environments within this area are similar in general physiographic setting and species diversity. There is a total of six species - Avicennia marina, Aegialitis annulata, Aegiceras corniculatum, Bruguiera exaristata, Ceriops tagal and Rhizophora stylosa.

These mangroves form narrow zoned stands along more exposed coasts and form broad dense zoned stands in larger sheltered embayments. Depending on substrate conditions and density of mangrove cover, individual stands rank as important and productive, such as those at Port Hedland, Turner River estuary, Cossack, parts of the Dampier Archipelago, Maitland River Delta and the Cape Preston area.

Elsewhere mangroves inhabit sandy substrates or rocky shores and are less important.

Onslow and Ningaloo Maps

There are five mangrove species in this area - Avicennia marina, Aegialitis annulata, Ceriops tagal, Rhizophora stylosa, and Bruguiera exaristata (rare). These form poorly-zoned low stands along the shores of sheltered embayments. Substrates are muddy and the mangrove environments are important sites of productivity for the area.

In the proposed Ningaloo Marine Park three species of mangrove occur at Mangrove Bay, Avicennia marina, Rhizophora stylosa and a few Bruguiera exaristata. Additionally, Yardie Creek is an important area since it contains the most southerly outliers of Rhizophora stylosa in W.A.

Yanrey Map

There are four mangrove species - Avicennia marina, (less common) Aegialitis annulata, Ceriops tagal and Rhizophora stylosa. These species occur in poorly-zoned stands that form extensive growths on the eastern shore of Exmouth Gulf. The substrate is muddy and the mangrove environment is an important zone of productivity.

Minilya Map

One mangrove species (Avicennia marina) exists along the shore and shoals of the inland coastal saline lake system of Lake MacLeod. Although not dense and extensive this mangrove stand is of scientific interest.

Quobba Map

Avicennia marina, the sole species in this area, occurs in Lake MacLeod and in the Gascoyne Delta area.

In Lake MacLeod the mangroves form isolated small stands that are principally of scientific interest. In the Gascoyne Delta area the stands are more extensive, inhabiting strandplain environments on muddy sand substrates, where they form a nursery and feeding ground and habitat.

Shark Bay and Wooramel Maps

Isolated stands of Avicennia marina are found in high tidal areas, e.g. near Denham, Faure Island and landwards of the Wooramel Seagrass Bank.

Abrolhos Islands Map

Avicennia marina is present on Morley, Wooded and Pelsart Islands where it serves as a breeding area for the Lesser Noddy, which is considered an endangered sea-bird species.

Collie Map

Small isolated patches of Avicennia marina occur in Leschenault Inlet (near Bollvidere) and in Koombana Bay (near Bunbury). These stands are the most southerly known outliers of mangroves in this State and warrant preservation for scientific reasons.

14. SEAGRASSES

Unlike seaweeds (macroalgae), seagrasses have true roots, produce flowers which are pollinated underwater, fruits and eventually seedlings. However, most of their growth occurs by vegetative (non-sexual) production of new shoots along an underground branching rhizome system on which the roots are borne.

This method of growth gives rise to large areas covered by dense seagrass meadows, but only where conditions are suitable. Generally the requirements are for a sediment covered bottom, with a limited degree of water movement, in depths where sufficient light penetrates. Thus the south-western and southern shorelines of W.A. between the limestone reefs and the shoreline provide an extensive area for seagrass colonization. The reefs protect the sandy floors of the inshore areas from the oceanic swell, but still allow circulation of water, and the high light intensities and clear waters provide ideal conditions for photosynthesis and high production rates.

Seagrass meadows are generally dominated by stands of one species, but there may be up to 10 minor species occurring, either as small patches or in a multispecies assembly, usually within a sand patch (known as a 'blowout') which has been caused by the removal of the dominant species during storms. Standing crops of major seagrass meadows in W.A. have an above-ground biomass of 1 to 2 kg dry weight per m^2, whereas the minor species biomass is 100 to 200 g per m^2.

The seagrasses have a very important role to play in the ecology of the nearshore systems for a variety of reasons which relate to their physical as well as their biological impact.

1. They afford protection to many juvenile fish and crustacea and are nursery areas for several commercially valuable species.

2. They act as food for a limited number of organisms, particularly dugongs and turtles in more northerly waters.

3. They serve as hosts for a large number of epiphytes and epizoa which are grazed extensively. These animals and plants which grow on the seagrasses may make up a biomass comparable to that of their hosts.

4. They are an important "sink" for nutrients, absorbing nitrogen and phosphorus from the water column and from the sediments, and provide large quantities of detrital material which serves as food for certain animal species and microbes. The detrital matter is eventually broken down to an extent where nutrients are released and made available to the living plants.

5. Seagrass leaves slow water movement, and thus cause suspended detrital matter to fall into the seagrass meadow and build up the organic detrital load.

6. Seagrasses lower the rate of water flow over the bottom, which results in the trapping of sediment within the meadow and the binding of existing sediments, thus stabilising a normally unstable environment. They therefore help to prevent erosion, and allow the establishment and maintenance of sediment communities.

Much of the W.A. coastline, particularly north of Shark Bay and south of Geographe Bay, has not been surveyed for seagrass distribution and records are patchy. Thus an absence of seagrass on the maps does not necessarily mean an absence in the field. Areas which have been well documented are Cockburn Sound and, more recently, Rottnest Island, Warnbro Sound and Shark Bay which has dense seagrass cover over about 2 600 km^2.

At least 19 species of seagrass belonging to 11 genera have been recorded in W.A.

North of Shark Bay the sub-tropical and tropical seagrasses become dominant, especially in the Exmouth Gulf area. The main species are:-

Halodule uninervis
Thalassia hemprichii
Cymodocea angustata, C. rotundata, C. serrulata,
Halophila ovalis, H. spinulosa.

The Halophila species are also found farther south.

A recent study on dugong distribution by the Department of Conservation and Land Management has revealed extensive seagrass beds in Roebuck Bay adjacent to Broome and in the One Arm Point - Sunday Island area of King Sound. One new species for W.A., Enhalus acoroides, was found near One Arm Point and Sunday Island and identified at the Botany Department, University of W.A.

Shark Bay is the northernmost extent of the major seagrass meadows of W.A. and is an overlap area which supports both temperate and tropical seagrasses. Up to 17 species have been recorded, of which Amphibolis antarctica is dominant followed by Posidonia australis. The broad distribution of the two major species in Shark Bay is given in Figure 10 at a scale of 1:1000 000, while known occurrences of the minor species are shown separately (Figure 11) at the same scale.

The presence of seagrass has highly modified Shark Bay, causing the development of geological structures such as the Faure Sill. These sedimentary banks have accumulated from the skeletal fragments of associated calcareous organisms, which have been trapped by the meadows. The high rates of leaf turnover by these plants, and hence the shedding of their calcareous epiphytes, combined with their baffling

effects on currents have accelerated these processes to rates greater than those of coral reefs.

The build up of these barrier banks and sills has restricted the circulation of oceanic seawater, leading to the increase in salinity observed in the inner reaches of the bay. This has been a self-limiting process, in that these higher salinities are now greater than the seagrasses can tolerate, and so few live plants are found in Hamelin Pool.

Seagrasses in Shark Bay support major food chains, largely through detrital pathways, contributing to the large amateur and commercial fisheries of the area. They are directly grazed by large populations of turtles and dugongs. Shark Bay is the sole locality where dugongs feed on Amphibolis antarctica, as this is the only place where this species and Posidonia australis overlap in distribution. Halodule uninervis is also utilized by dugongs, particularly in summer.

There are patches of seagrass within the Bay which are the most diverse ever recorded, with up to 10 species within a few square metres in contrast to the one or two species usually found in other parts of the world in such small areas. These areas of great diversity are mainly within blowouts, and contrast with the almost monospecific stands of Amphibolis which characterise much of Shark Bay.

Below Shark Bay the seagrass species found are:

Posidonia angustifolia, P. coriacea, P. ostenfeldii, P. sinuosa, P. australis, Amphibolis antarctica, A. griffithii, Heterozostera tasmanica, Syringodium isoetifolium, Thalassodendron pachyrhizum, Halophila ovalis, H. spinulosa, Zostera mucronata.

The main distinction between the seagrass meadows is whether they are made up of Posidonia or Amphibolis. The other species grow in small localised areas; e.g. Zostera mucronata is in estuaries and Thalassodendron pachyrhizum occurs in clumps near reefs. Collectively these other species constitute less than 5% of the seagrass area covered by the maps. Of the Posidonia species, P. sinuosa and P. australis are the most abundant. P. coriacea grows in small clumps in blowout patches and P. ostenfeldii forms fairly large beds along the south coast from Albany to the South Australian border.

Off Perth, seagrasses occur between about 15 m from the shoreline surf zone and the line of limestone reefs, up to 6 km offshore. This area is usually about 4-6 m deep.

Amphibolis antarctica, A. griffithii and Thalassodendron pachyrhizum are to be found on the edge of the inner reef, with Posidonia sinuosa and Halophila ovalis between the

reefs. The outer reefs also have Thalassodendron and Amphibolis, grading into Posidonia sinuosa. P. sinuosa forms large continuous stands of seagrass up to 50 ha in area, with blowouts containing A. antarctica and A. griffithii.

P. australis occurs in areas where sand is accreting, particularly in the lee of islands.

Detailed maps of the seagrasses around Rottnest Island and in Cockburn Sound and Warnbro Sound at 1:25 000 and 1:50 000 scales have been pepared at the Botany Department, University of W.A.

In areas along the south coast and in Geographe Bay a number of species may be found in dense beds down to 20 m depth. Thalassodendron pachyrhizum has been found at a depth of 37 m near Carnac Island.

The mapping of the seagrasses in W.A. marine waters is based largely on aerial photography at a scale of 1:50 000, supplemented with ground truth observations from herbarium records, published reports, divers, fishermen and scientists from the University of W.A. Botany Department and the CSIRO. Little information on distribution is available for the tropical areas north of Shark Bay and these have not been mapped.

The resources maps at 1:250 000 show seagrass distribution where the cover represents more than 25% of the area. For the three regions Shark Bay, Perth and Albany more detailed maps at a scale of 1:50 000 have been produced, and with Shark Bay the cover is separated into 5 levels:

>10%	= 1
10-30%	= 2
30-50%	= 3
50-70%	= 4
>70%	= 5

15. SEAWEEDS

A very large range of seaweed (macroalgae) species is found along the coastline of W.A. but, as yet, the population is poorly documented.

North of Shark Bay a fairly typical tropical macroalgal flora exists and the coral reefs are covered with encrusting coralline algae and the genus Halimeda but some of the tropical taxa, e.g. Sargassum and Halimeda species, are found in temperate waters, particularly from Geraldton and the Abrolhos Islands south to Perth and Rottnest Island. In the hypersaline zone of Shark Bay the green algae Acetabularia peniculus and Acetabularia calyculus are common.

South of Shark Bay the seaweed flora is probably the most diverse in the world for any comparable coastline within a relatively uniform temperature zone, with many endemic species and a large standing crop. This may be due to the abundance of shallow waters and reef systems which allows adequate light for photosynthesis and provides a stable surface for attachment.

Within the phylum Chlorophyta (green algae), the large genera Codium and Caulerpa are prominent in the southern part of W.A. Of the Phaeophyta (brown algae), the kelp Ecklonia radiata is abundant south of Kalbarri and dominates all reef systems. In summer, Sargassum is important while other Fucales are abundant in local areas.

The third phylum of macroalgae, the Rhodophyta (red algae), is well represented on the south coast and includes numerous endemic species particularly within the large order Ceramiales. Three types of red algae are found; encrusting, foliose calcareous and fleshy.

In addition to their presence on hard substrates, a considerable diversity of macroalgal species, mainly red algae, exists as epiphytes attached to seagrasses. It is probable that macroalgae attached to Amphibolis contribute about two-thirds of the productivity of its standing crop, while with Posidonia species they contribute much less. In eutrophic situations, for example Cockburn Sound, growth of epiphytes may be so thick that death of the host seagrass results.

The macroalgae, along with the microscopic algae or phytoplankton and the seagrasses, are the basis of many food webs in the marine environment, being grazed by numerous animals including finfish and shellfish. Certain macroalgae also contribute to reef structure and to sediment formation by deposition of calcium carbonate. With some green and brown algae it is in the form of aragonite while with calcarous red algae calcite is deposited. Information on the whereabouts of many species in W.A. waters is limited, but as a group representatives will always be found where shallow reefs and seagrasses occur.

16. ALGAL MATS

Although some of the macroalgae form algal mats, the term is used here for algal mats which are formed by filamentous and unicellular blue-green algae (Cyanophyta). These organisms are now considered to be bacteria (Cyanobacteria). Such mats are usually found in the intertidal areas of rocky coasts where they may be conspicuous and enter food chains via grazing animals. On the W.A. coast the algal mats occur from Cape Keraudren south to Shark Bay and are common behind

mangrove stands in arid climatic areas. They mainly consist of the genus Oscillatoria.

In the hypersaline zones of Shark Bay at Hamelin Pool and Lharidon Bight the algal mats are widespread. In the many rocky intertidal environments of these zones they serve as sediment-binding and trapping agents and are responsible for formation of reeflike clusters of stromatolite structures (see below). In the sand-flat environments the mats are thin, incoherent and impermanent and do not have a sediment-binding function.

17. STROMATOLITES

Stromatolites have been defined as organosedimentary structures produced by sediment trapping, binding and/or precipitation as a result of the growth and metabolic activity of micro-organisms, principally blue-green algae (Cyanophyta or Cyanobacteria, see above). Living stromatolites are rare but they occur in abundance in the intertidal and sub-tidal areas of Hamelin Pool at Shark Bay where the high salinities of 56-70%, almost twice that of normal seawater, have favoured their formation and persistence. The varied shapes of the stromatolites appear to result from interaction of the algal mat - sediment complexes with the physical environment.

Fossil stromatolites are widely distributed in rocks of all ages dating back as far as 3 billion years and are some of the few indications of early life in Precambrian times. Living stromatolites are of considerable geological interest since they closely resemble Precambrian stromatolites and thus may be regarded as living fossils. Hamelin Pool is the most significant locality in the world where these structures are forming.

18. REEFS

Reef structures are numerous on the shores and continental shelf of W.A. and have a profound influence on coastal hydrology, flora and fauna. Coral reefs are found off the west coast, mainly in the northern parts, limestone reefs occur off the west and south coasts and granite reefs are predominantly off the south coast, particularly in the Recherche Archipelago.

Coral reefs are formed of calcium carbonate, deposited predominantly by corals and macroalgae through a number of poorly-understood mechanisms. They mainly occur in warm clear waters north of Carnarvon and at the Houtman Abrolhos Islands but a few coral species exist as far south as Rottnest Island and Geographe Bay. On the inner part of the Sahul and North West Shelves, patch and platform coral reefs, such as Lacepede Islands and Adele Island, are abundant, while on the outer parts of these shelves are the large

perfect atolls of Scott and Seringapatam Reefs and the Rowley Shoals. Fringing coral reefs are found along the shores of the mainland and nearshore islands of the Kimberley and Pilbara coasts, and a part barrier, part fringing reef is the main feature of Ningaloo Marine Park, extending some 250 km from North West Cape south to Amherst Point.

Studies of the Abrolhos, Ningaloo, Rowley Shoals and Dampier Archipelago coral reefs, mainly by the W.A. Museum, have shown that each contain a rich diversity of corals, mostly reef-building, including some previously unknown species.

Associated with all reef structures are communities of flora and fauna, notably macroalgae, echinoderms, molluscs and fish. Some of the fish species, such as the north-west snapper and emperor of northern coral reefs, are of commercial importance. The western rock lobster, which forms the most important fishery in Australia, is found in reef systems, particularly at the Abrolhos Islands. Although the Abrolhos Islands reefs have the appearance of typical coral reefs, they do not support the diverse communities of organisms which are normally associated with coral reefs of such magnitude. Instead there is an impoverished fauna of tropical and temperate species, with the tropical species dominant.

Limestone reefs provide a variety of structural forms which ensures a diversity of habitats. Those in W.A. are found onshore and offshore and some of the best examples of both types occur at the west coast in the Perth area. Off the south coast major areas of limestone reefs are at D'entrecasteaux and east of Point Culver.

The surfaces of granite reefs are harder and smoother than those of coral and limestone reefs and this, along with other environmental factors, ensures a different flora and fauna. Boring animals and algae found on limestone and coral reefs are not present on these reefs and the protective niches essential for growth and survival of some communities are less numerous.

The presence of unicellular algae (zooxanthellae) within corals, growth of algae and cyanophytes on all reefs and the frequent presence of seagrass in adjacent sheltered sediment-containing sites ensures that reef systems are highly productive. Associations between reef-dwelling species leads to recycling of nutrients within such systems.

19. COQUINA BEDS

In Hamelin Pool and Lharidon Bight, the hypersaline areas in Shark Bay, the small mollusc Fragum hamelini is present in large numbers and is the dominant organism on the sub-littoral platform. This pelecypod varies in abundance and

contributes large numbers of disarticulate valves to the sea floor which form sediments called coquinas. This material, along with ooid sands, which consist of grains formed by precipitation of calcium carbonate, is carried shorewards and deposited in beach ridges. Where the deposition rate exceeds the capacity of algal mats to bind the sediment, beaches of coquina and ooid sands develop.

The coquinas are unique deposits of geological interest. However, limited small-scale mining of lithified and unlithified coquina beds has taken place around the shore of Hamelin Pool and Lharidon Bight for construction purposes and consumption by poultry.

20. RECREATION

Areas which are considerably used for coastal recreation are indicated on the map by the prevalent recreational pursuits.

In addition to usage by local residents, coastal areas are visited by a large number of tourists. According to the W.A. Tourism Commission about 90% of the tourists are intra-state and, as expected, the preferred region is the south west. As measured by commercial accommodation bookings the most favoured coastal towns are Busselton, Bunbury, Geraldton and Albany. Since tourism is purportedly a burgeoning industry in W.A., the impact on coastal areas, particularly in the south west and at Shark Bay, will undoubtedly increase.

21. SCIENTIFIC RESEARCH AND EDUCATIONAL AREAS

Marine research in W.A. is done mainly by the Western Regional Laboratory of the CSIRO Division of Fisheries, the Fisheries Department, the Museum, the Department of Conservation and Environment, the University of W.A., Murdoch University and the W.A. Institute of Technology. Organisations outside W.A. which have an interest in certain W.A. marine areas are the CSIRO Division of Fisheries, Hobart and the Bureau of Mineral Resources, Canberra.

Additional information on the marine environment is also produced by private consultants via Environmental Review and Management Programmes required by Government for assessment of various coastal development proposals.

Large areas of the coastal marine environment are visited infrequently or regularly for identifying and collecting data on flora, fauna, sediment and hydrological characteristics and for monitoring purposes but there are only a few sites where the research projects are of an experimental and manipulative nature. Research areas will change as new proposals or new developments arise. But the principal well-defined areas currently (1985) utilised by the above organisations are as follows.

1. Rowley Shoals and Scott and Seringapatam Reefs

These are atypical shelf atolls, about 300 km west (Rowley Shoals) and 450 km north (Scott and Seringapatam Reefs) of Broome, which are biologically and geomorphologically unusual in W.A. and contain spectacular coral reefs in a pristine environment.

They have been visited by workers from the Museum who have recorded a large diversity of tropical marine fauna, including rare species and new genera of corals and fish.

2. Dampier Archipelago

The Archipelago is a shallow environment bordering a region where the population is expanding considerably. Some of the islands are large and of "A class" status. Dugongs, turtles, sea-bird nesting areas, coral reefs, mangroves, gamefish, and sand flats supporting a rich intertidal fauna are found there. Mermaid Sound, in particular, is under increasing pressure from industrial and recreational users and this has been partly instrumental in its selection as a research area.

Marine research projects in the Archipelago are mainly directed by the Department of Conservation and Environment and Murdoch University. They are (i) studies of marine habitats and the distribution of fauna and flora, particularly marine algae; (ii) the effects of man-induced stress on mangroves; (iii) growth rates of corals; (iv) heavy metals in organisms, water and sediments; (v) sediment types and sediment deposition; (vi) an examination of water characteristics, especially content of particulate matter and circulation patterns in Mermaid Sound.

CSIRO Division of Fisheries, Hobart recently completed a study of species composition and broad trophic structure of the mangrove creek and open shore fish communities of the region. Kendrew Island is a Museum research area.

3. Ningaloo Reef

This extensive coastal area, off Cape Range, has been proposed for marine park status and contains large accessible barrier coral reefs with a rich association of flora and fauna. Surveys of the fauna and flora around the reefs and coastline are conducted by the Museum and the W.A. Department of Conservation and Land Management, and the CSIRO Western Laboratory has investigated the distinguishing characteristics of nesting beaches of the green turtle from North West Cape southward to Yardie Creek.

4. Shark Bay

Much of the Shark Bay region has been recommended for aquatic reserve status by the W.A. Environmental Protection Authority. Notable features are stromatolites, dugongs, breeding areas for turtles and sea birds, seagrass meadows, mangroves, hypersaline areas and prawn, scallop and scalefish fisheries.

Geological studies in Shark Bay are carried out by the University of W.A. and the State Department of Mines, while the Bureau of Mineral Resources is interested in the geobiological significance of primary productivity, sulphate reduction and sulphur isotope fractionation in algal mats and sediments at Hamelin Pool.

The University of W.A., the Department of Conservation and Environment, CSIRO Division of Mineralogy, W.A. and the Fisheries Department are contributing to an understanding of the distribution and levels of heavy metals in sediments, waters, pearl oysters and other molluscs at many sampling sites throughout the Bay.

A collaborative long-term study of the ecology and natural history of Shark Bay, organised principally by the Marine Biological Laboratory of the University of W.A., was recently concluded. It included studies on water and sediment nutrient relationships, marine molluscs (including factors affecting growth rates of clams), seagrass distribution, measurements of photosynthesis in seagrasses and the distribution of biogenic alkenes.

The area is important for fisheries and the Fisheries Department is currently investigating the biology of prawns, scallops and the pink snapper (Chrysophrys unicolor), including stock definition of this commercially important fish species in collaboration with the University of W.A.

Proposals to create a marine park at Shark Bay and to increase tourist facilities will probably cause further research in the area.

5. Abrolhos Islands

These groups of islands, situated about 75 km west of the coast opposite the Geraldton region, are surrounded by the most southerly coral reefs in the Indian Ocean. They are important sea-bird nesting areas and are also used by sea lions. The marine habitat around the islands supports a major rock lobster fishery and a scallop fishery. There is a high diversity of flora and fauna in the reef areas, and both temperate and tropical species are found.

The Museum has accommodation and research facilities at Beacon Island in the Wallaby Group and the CSIRO Western

Laboratory has accommodation at Rat Island in the Easter Group. The former organisation is interested in the sea-bird species, in coral reef fauna and flora and in maritime archaeology (shipwrecks), while the latter, along with the Fisheries Department, is concerned with rock lobster larval recruitment at the Easter Group of islands and the biology of the rock lobster breeding stock. The larval recruitment is being investigated by means of settlement collectors off Rat Island and is part of a larger study along the west coast. Other collector points are at South Passage (Shark Bay), Horrocks Beach, Seven Mile Beach (Dongara), Jurien Bay, Cervantes, Alkimos, Warnbro Sound, Dunsborough and Cape Mentelle.

The University of W.A., also working at the Easter Group, is using manipulative studies to evaluate the role played by macroalgal (seaweed) detritus in supporting secondary production of the marine communities on the reefs and to analyse the effect of competition between corals and algae on benthic community structure.

6. Dongara (Seven Mile Beach)

Research at Seven Mile Beach is centred on the western rock lobster and is mainly the province of the CSIRO Western Laboratory. It is directed towards an understanding of the biology of juvenile rock lobsters, the trophic ecology and habitat associations of local species, particularly their predation on young rock lobsters, and the ecology of seagrass epifauna. As mentioned in the section on the Abrolhos Islands, rock lobster puerulus larvae settlement collectors are situated at Seven Mile Beach.

In addition, CSIRO and Murdoch University studies sited close to Dongara are on productivity in the seaweed Ecklonia radiata, colonisation patterns of seagrasses, and biomass and community structure of epiphytes on species of the seagrass Amphibolis.

7. Metropolitan Coast

Due to its proximity to Perth, this region supports the most diverse range of research interests. Much of the work is done in the area which forms the proposed Marmion Marine Park between Burns and Trigg on the coast and three nautical miles out to sea. A broad survey of the fauna and flora of the proposed reserve's sea floor, including reef areas, has been made by the Department of Conservation and Environment.

The Marine Biological Laboratory of the University of W.A. is engaged in two areas of reef research. It is examining canopy structure of the kelp Ecklonia radiata in terms of the light budget and community structure on Marmion Reef and is interested in erosion of reefs resulting from kelp tear-off. It is also surveying the benthic fauna and flora of

several reefs, Whitford, Wreck, Little Island, Wanneroo, Cow, Boyinaboat and Marmion, to determine percentage cover of family groups, including encrusting sponges and solitary and colonial ascidians. The stability of the shore lines at Sorrento, North Beach and Scarborough is continually under study by the University of W.A.

The CSIRO Western Laboratory is attempting to determine the cause of short-term irregular levels in dissolved nitrate concentrations in the inshore waters. Additionally, it is engaged in work at Little Island involving use of a remote control unit to follow the response of the reef ecosystem to added nitrate concentrations and to determine the effect of such additions on epiphytes of the seagrass genus Amphibolis.

The Fisheries Department is studying the importance of detached algae and seagrasses to fish communities in the surf zone of sandy beaches from Two Rocks to Trigg Island.

Between Whitfords and Garden Island, the Museum is examining reef top molluscs, including the effects of fishing pressure on species numbers and distribution, particularly of Roe's abalone.

8. Rottnest Island

The classification of "A Class" reserve for this island includes adjacent rocks and islands. There is a rich and varied marine flora and fauna around the island, including coral species.

The University of W.A. has a field station on the island. Projects include classification and distribution of local seaweed and seagrass species and manipulative experiments to examine the effect of perturbations on population densities of gastropods and sea-urchins at various sites. The sites are vertical rock walls and horizontal reef platforms at Radar Reef, Cape Vlaming, Strickland Bay and Salmon Point.

Museum workers frequently dive on the reefs to determine the fauna present, and Pocillopora reef is a site for studies on recruitment of tropical reef fishes.

9. Cockburn Sound and Warnbro Sound

Cockburn Sound was the site of a major study, directed by the Department of Conservation and Environment, on the environmental effects of industrial and domestic effluents. That Department still monitors industrial effluent components in Cockburn Sound and periodically carries out fish tainting tests. Additionally, it is collaborating there with the University of W.A. in a study of recolonisation by seagrasses.

The importance of seagrass and phytoplankton-based food

chains is being compared between Cockburn and Warnbro Sounds by the University of W.A. The seagrass epiphyte research previously mentioned for Dongara also employs Warnbro Sound as a study site.

10. Princess Royal Harbour, Albany

The cycling of mercury and lead in sediments and the water column in Princess Royal Harbour is currently being investigated by the Department of Conservation and Environment while the Fisheries Department is concerned with the flow of mercury in food chains leading to fish.

As in Shark Bay the University of W.A. is working on various factors which influence the growth rates of clam species.

For educational purposes, schools in population regions close to the coast conduct regular visits to easily accessible reef sites as part of their biological field work curricula. In the Perth metro area, for example, such sites are found in the reefs at Trigg, Waterman and Cottesloe and in those at Rottnest Island. Similar visits are made to dune areas for biological and geographical teaching purposes.

School camps which may be used for marine biology education are situated at Point Samson (Pilbara), Carnarvon, Bluff Point (Kalbarri) and Point Peron (Perth metro region). The latter is used considerably, and adult courses are also run there.

The W.A. Outdoor Education Association has a 17 metre schooner at the Fishing Boat Harbour in Fremantle which is used in the teaching of marine biology and marine skills. Visits of up to three days duration are made to Cockburn Sound and to Rottnest and Carnac Islands.

In addition the Association runs a wave ski centre at Trigg and has a fleet of small sailing boats at East Fremantle which are used for teaching technical skills of seamanship to secondary school pupils.

22. SHIPWRECKS

Up to the end of 1983 a total of 69 shipwrecks off the W.A. coast had been gazetted as historic by the Commonwealth Government. Most of them occurred in the 19th century in the early years of settlement but one English and four Dutch vessels were wrecked in the 17th and 18th centuries. The main areas were the Houtman Abrolhos Islands, Rottnest Island/Garden Island region and Cape Leeuwin.

The earliest of these shipwrecks, and the first recorded in Australian waters, was the English East Indiaman 'Trial'

which left Plymouth for Java and was lost on rocks north of the Monte Bello Islands in 1622. Seven years later the Dutch vessel 'Batavia' was wrecked on Morning Reef in the Wallabi Group of the Houtman Abrolhos Islands, and the resultant mutiny, massacres, voyage to Java by the commander and subsequent trial on the islands upon his return make up an epic and grisly tale. The vessel 'Vergulde Draeck' (Gilt Dragon) foundered off Ledge Point in 1656 with considerable loss of life, whilst on a voyage from Holland to Java. In 1712 the 'Zuytdorp' was wrecked on the Zuytdorp Cliffs north of Kalbarri, and 15 years later the Abrolhos Islands was the site of another shipwreck, the 'Zeewijk' on Half Moon Reef in the Pelsart Group.

Artefacts from several of the wrecked ships, including those from the earliest, are on display at the W.A. Maritime Museum in Fremantle.

23. ANCHORAGES, MARINAS, PORTS

The approximate location of numerous anchorages, including jetties, wharves, moorings, harbours and yacht clubs, used by recreational boats or commercial fishing boats, may be found in a recent consultants' report on recreational boating facilities from Exmouth Gulf to Esperance prepared for the Public Works Department and in lists of fishing locality codes provided by the Australian Bureau of Statistics. Of these, the principal anchorages are shown on the maps. With the advent of the America's Cup Yachting Races in 1987 the number of marinas in the metropolitan area will increase in the latter half of the 1980's.

Twenty-three ports between Wyndham and Esperance are listed in the W.A. Shipping and Pilotage Act 1967. Included in this Act are descriptions of the boundaries of the ports and the powers and duties of the harbour masters.

24. INDUSTRIES, OFFSHORE PIPELINES

About 30 industries on the W.A. coast from Cockatoo and Koolan Islands south to Albany impinge upon the marine environment. Most have jetties for export or import purposes or discard effluents into the sea via short pipelines but only a few use seawater as part of their production processes.

At Port Hedland, Dampier and Shark Bay, salt is produced from seawater by Leslie Salt, Dampier Salt and Shark Bay Salt. The North West Shelf offshore gas and condensate production platform at North Rankin uses seawater for cooling turbines. South of Perth in the coastal industrial area, four other industries, Australian Iron and Steel (AIS), CSBP and Farmers, BP and the Kwinana Nitrogen Company (KNC), use seawater for cooling purposes, and the State Electricity Commission power stations at South Fremantle, Kwinana and

Bunbury also have offshore cooling water intakes.

At Jurien Bay, Fremantle Fishing Boat Harbour and Coogee, flowing seawater is used in tanks to keep western rock lobsters alive for export to Japan.

Three offshore domestic sewage pipelines exist in the metropolitan area, at Beenyup, Swanbourne and Point Peron.

At present there are only two offshore pipelines carrying oil and gas, a 135 km pipeline from the North Rankin platform to the Burrup Peninsula and a 10 km pipeline from Barrow Island to the tanker terminal. With the development in 1986 of the Harriet oil field, situated 20 km north east of Barrow Island, two further pipelines will be laid, from the platform to Lowendal Island and then from the island to an offshore loading terminal.

25. MARINE RESERVES AND PARKS

Three marine reserves have been declared in W.A., at Coral Bay south of Point Maud in the Ningaloo Reef area, at Point Quobba north of Carnarvon and at Waterman in the metropolitan area. They are administered under the Fisheries Act and are closed to the taking of any form of aquatic animal or plant life except for oyster fishing by hand at Point Quobba and rod or line fishing from the shore at Waterman.

Four marine areas were recommended by the W.A. Environmental Protectional Authority (EPA) in 1983 for the protection of reefs in System 6 (the system nomenclature in W.A. is given in the 1974 report of the Conservation through Reserves Committee). Of these areas, the M10 has become the Marmion Marine Park, extending from Burns to Trigg and three nautical miles seaward, while those at Cape Peron (M101), at the western and south-eastern ends of Rottnest Island (C45) and at Carnac Island (C46) are awaiting further consideration by the recently-formed W.A. Department of Conservation and Land Management (CALM). Management of them and future marine and estuarine protected areas and their designation as marine parks, marine nature reserves or marine multiple use management areas will be provided under the CALM Act.

The recommendation by the EPA for a large marine park at Ningaloo Reef has been endorsed by the State Cabinet and administration procedures are being formulated by the Department of CALM.

A number of National Parks have boundaries down to low water mark. They are:

Kalbarri, Nambung, D'entrecasteaux, Walpole-Nornalup, William Bay, Fitzgerald River, Stokes, Cape le Grand, and Cape Arid. It is expected that this number will increase.

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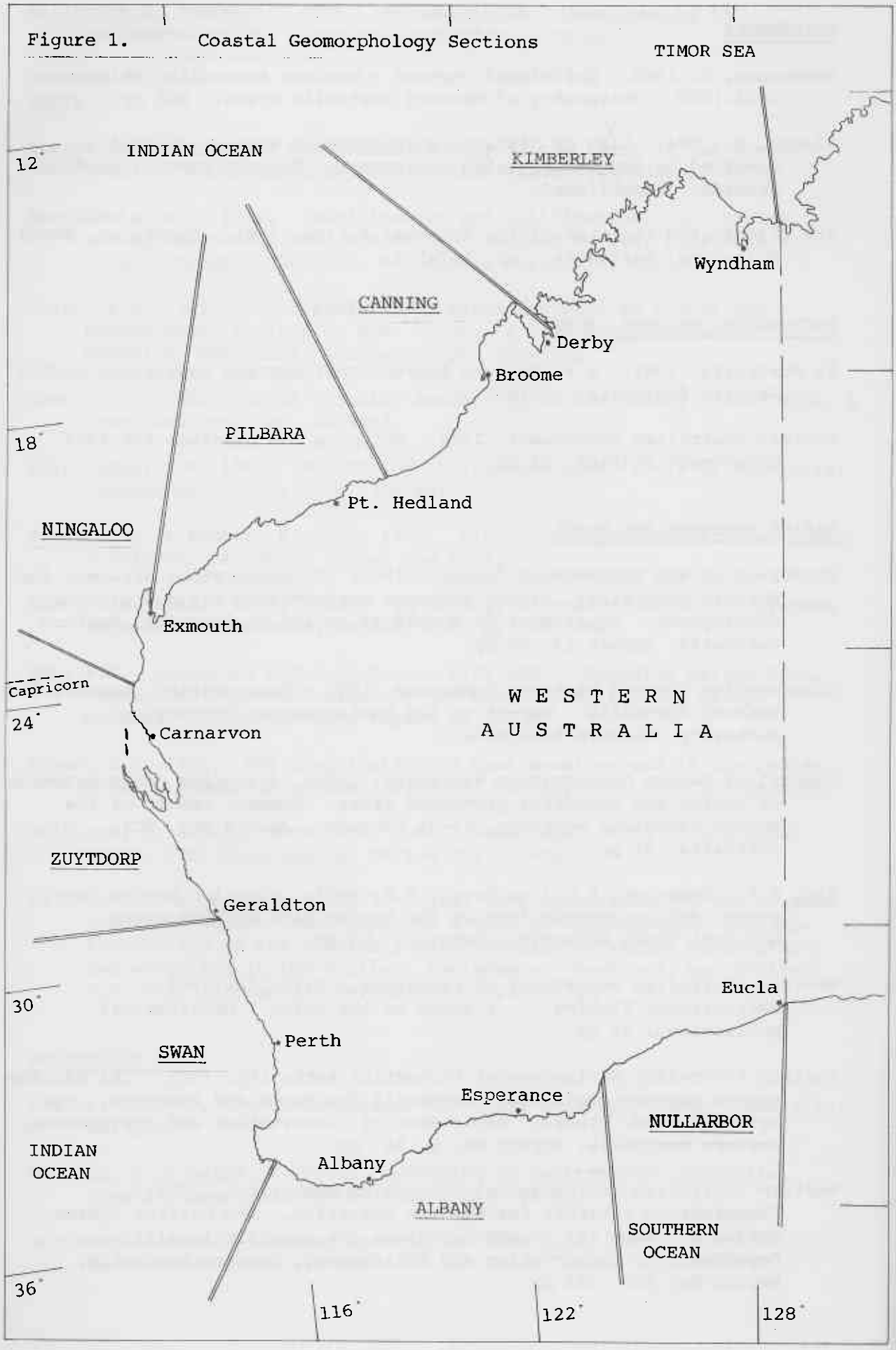
Figure 1. Coastal Geomorphology Sections



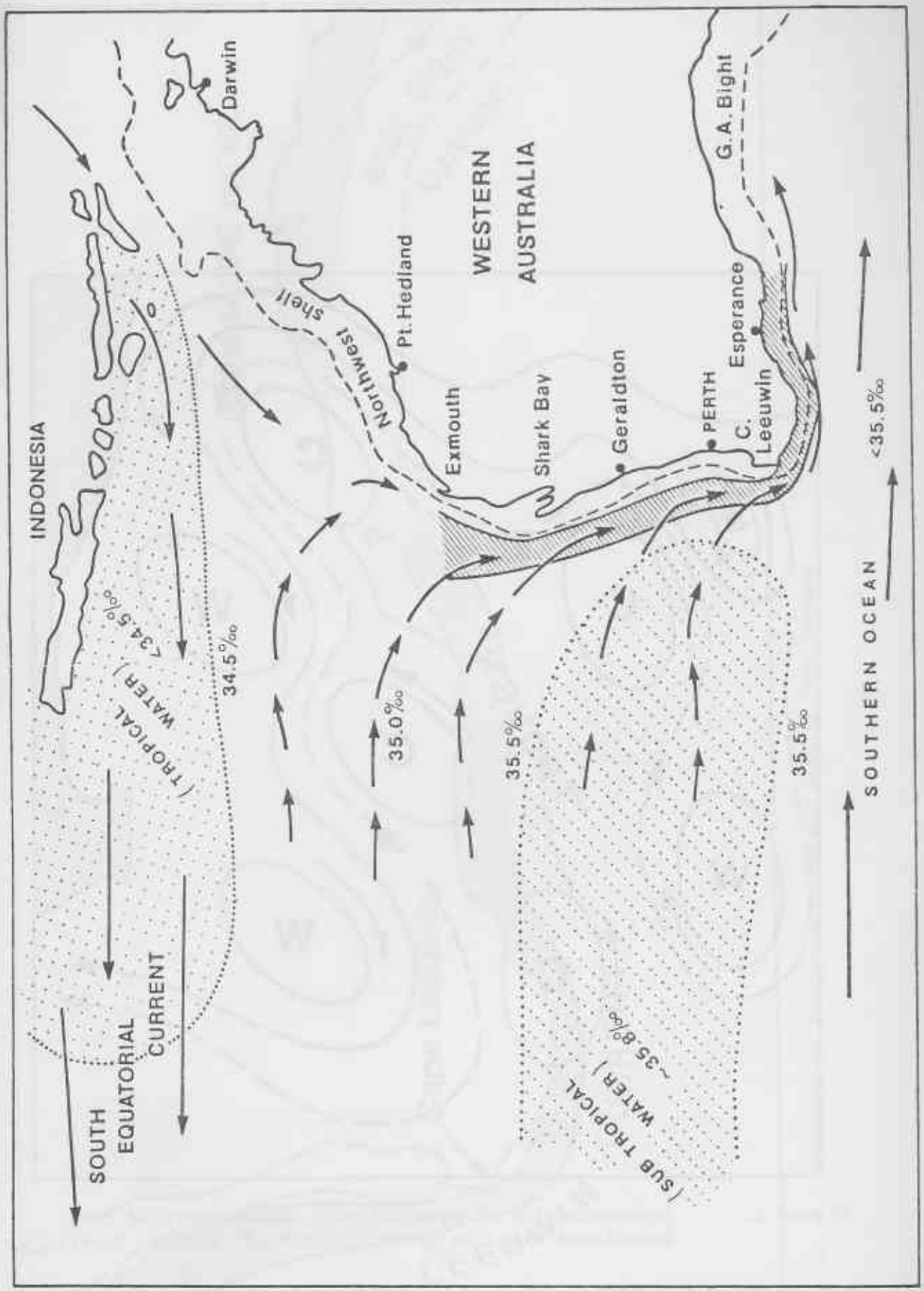


Figure 2. Gross circulation in the south-east Indian Ocean

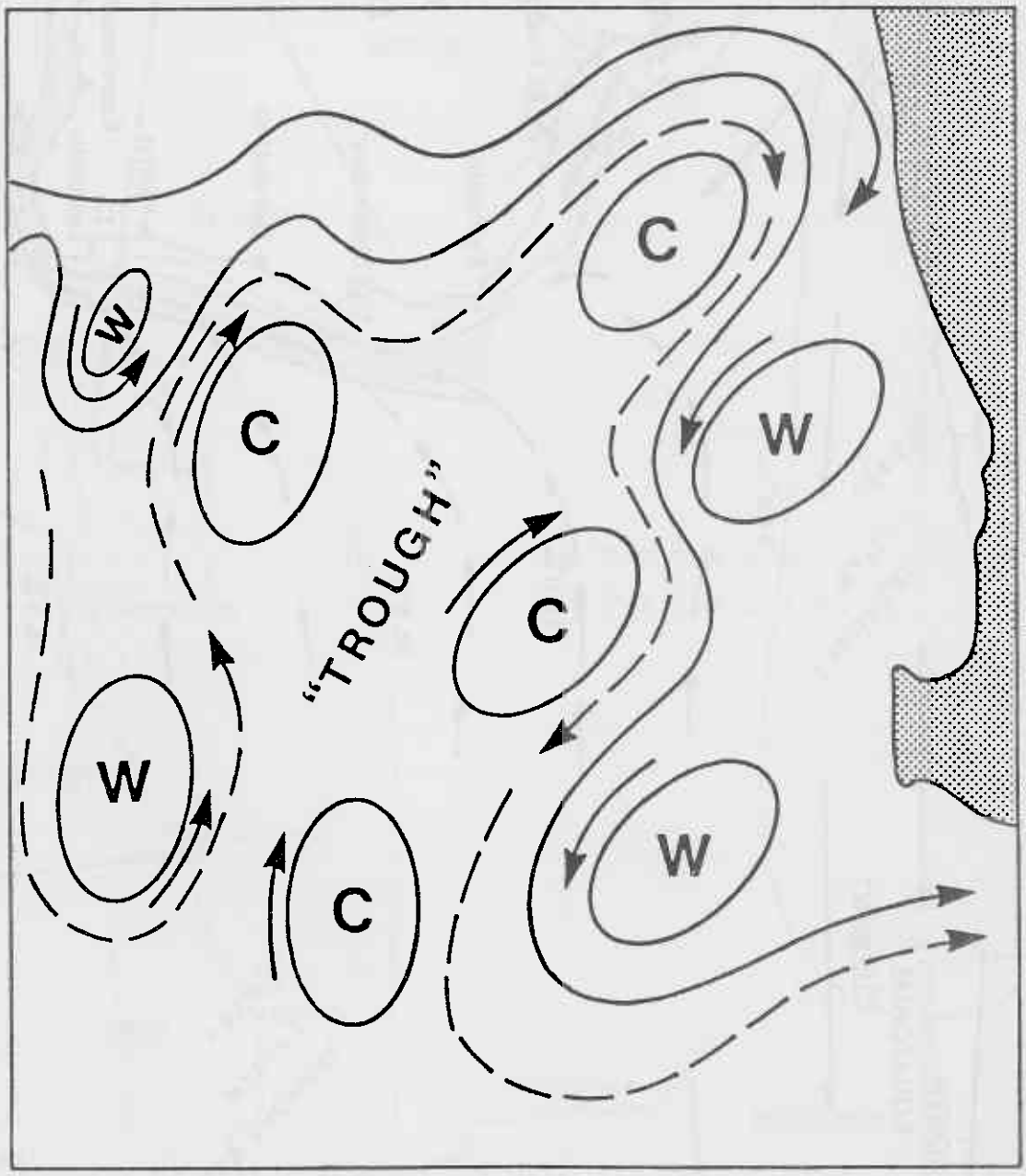


Figure 3. Representation of warm and cool eddies south of 30°S associated with the dynamic trough off Western Australia.

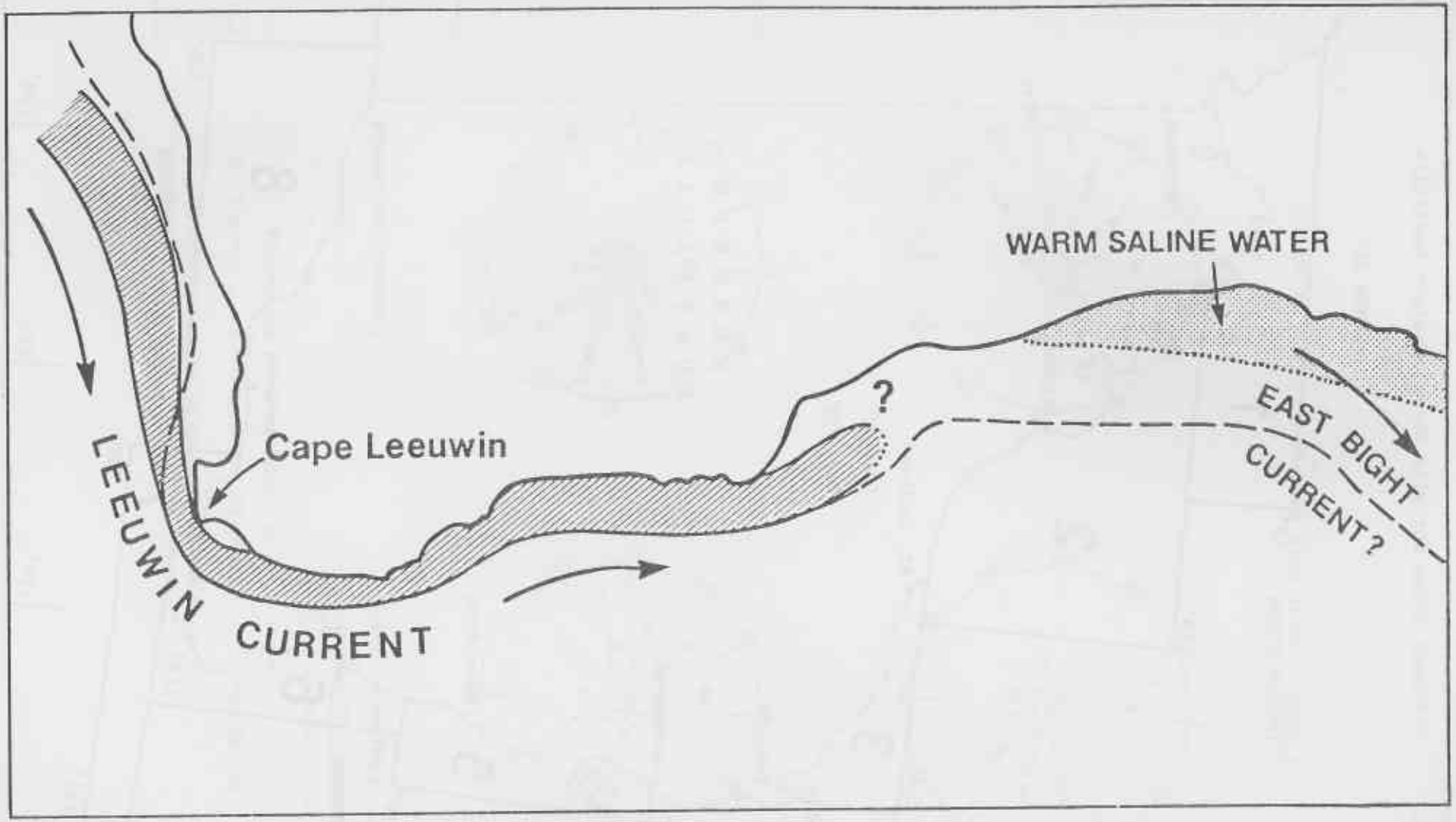


Figure 4. Behaviour of the Leeuwin Current east of Cape Leeuwin.

Figure 5. Offshore areas for wind roses, Western Australia

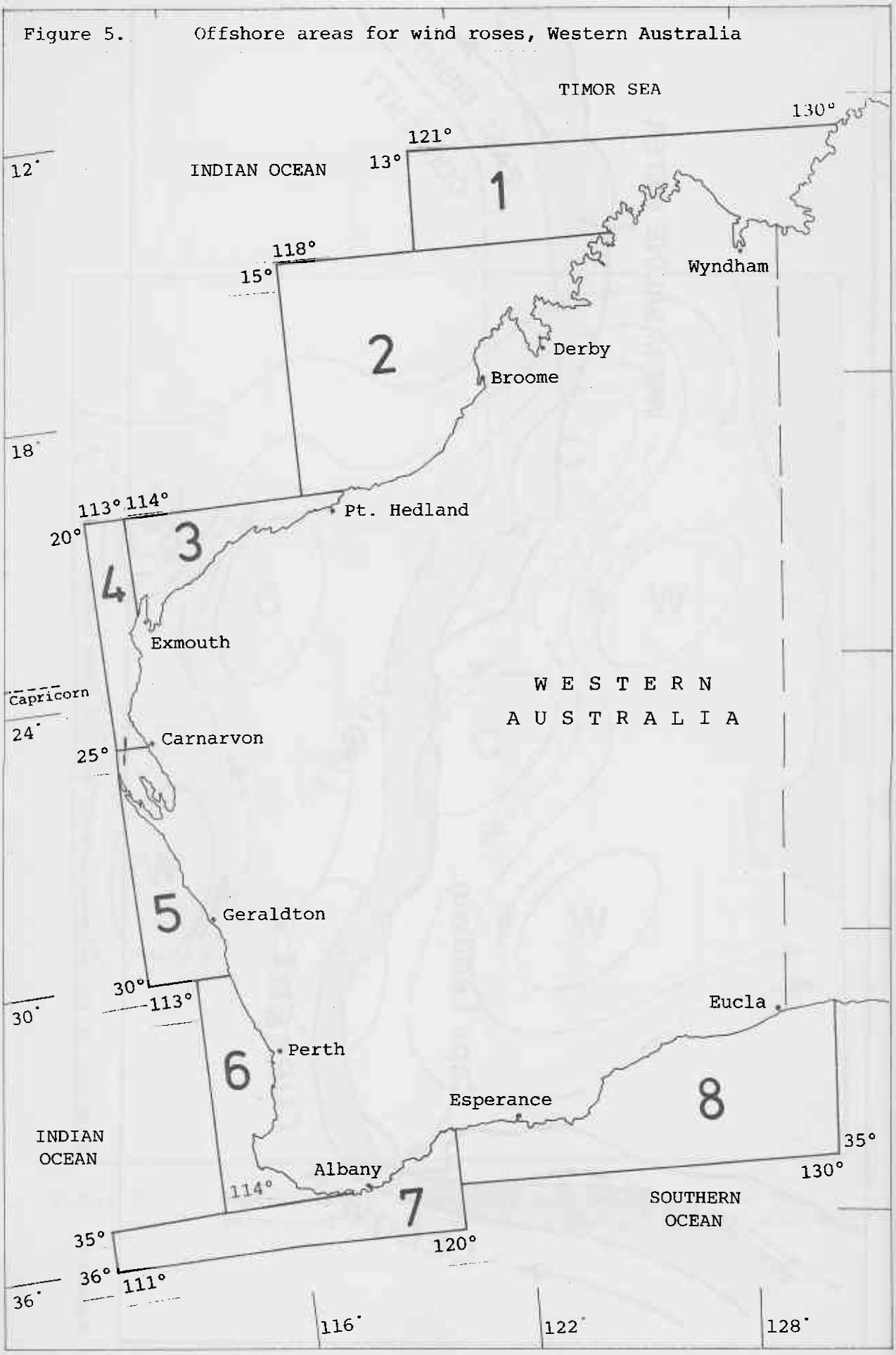


Figure 6. Offshore wind roses. Area 1

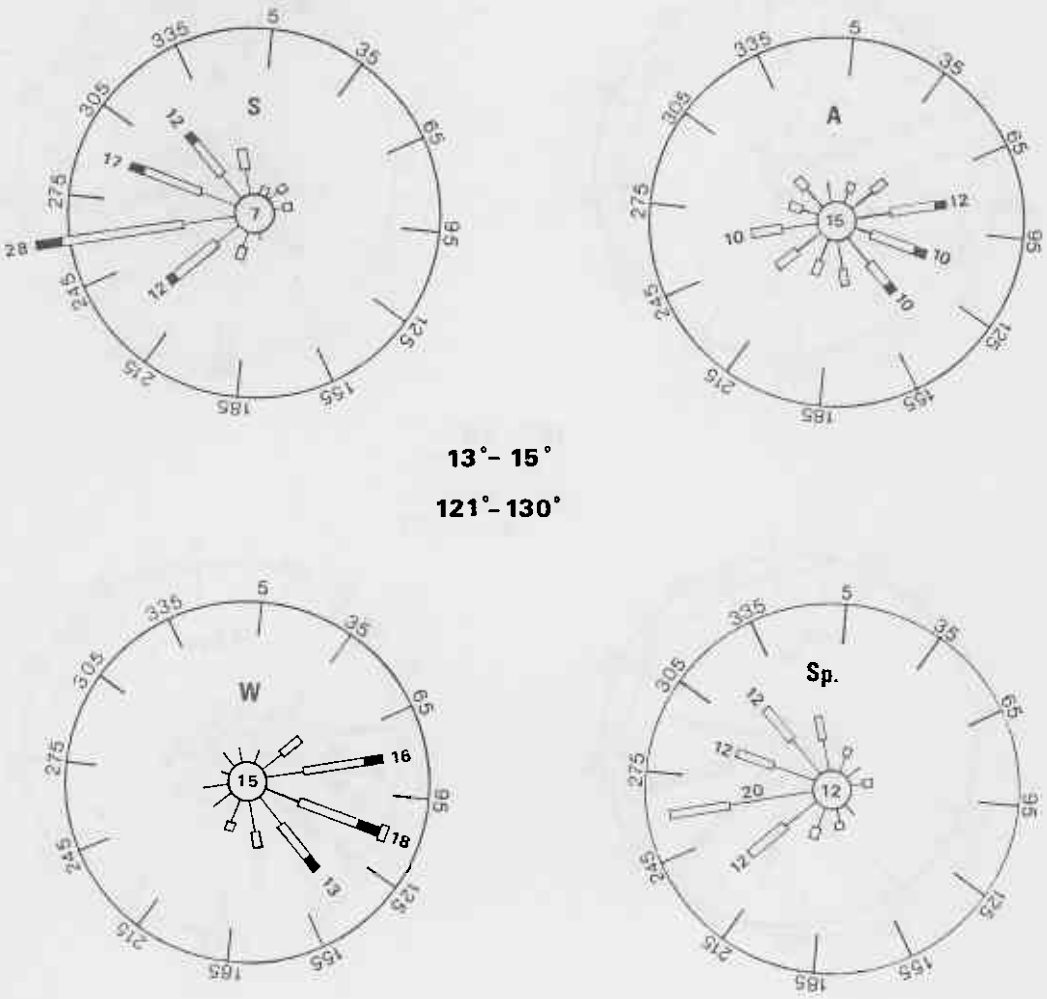


Figure 6. cont. Offshore wind roses. Area 2

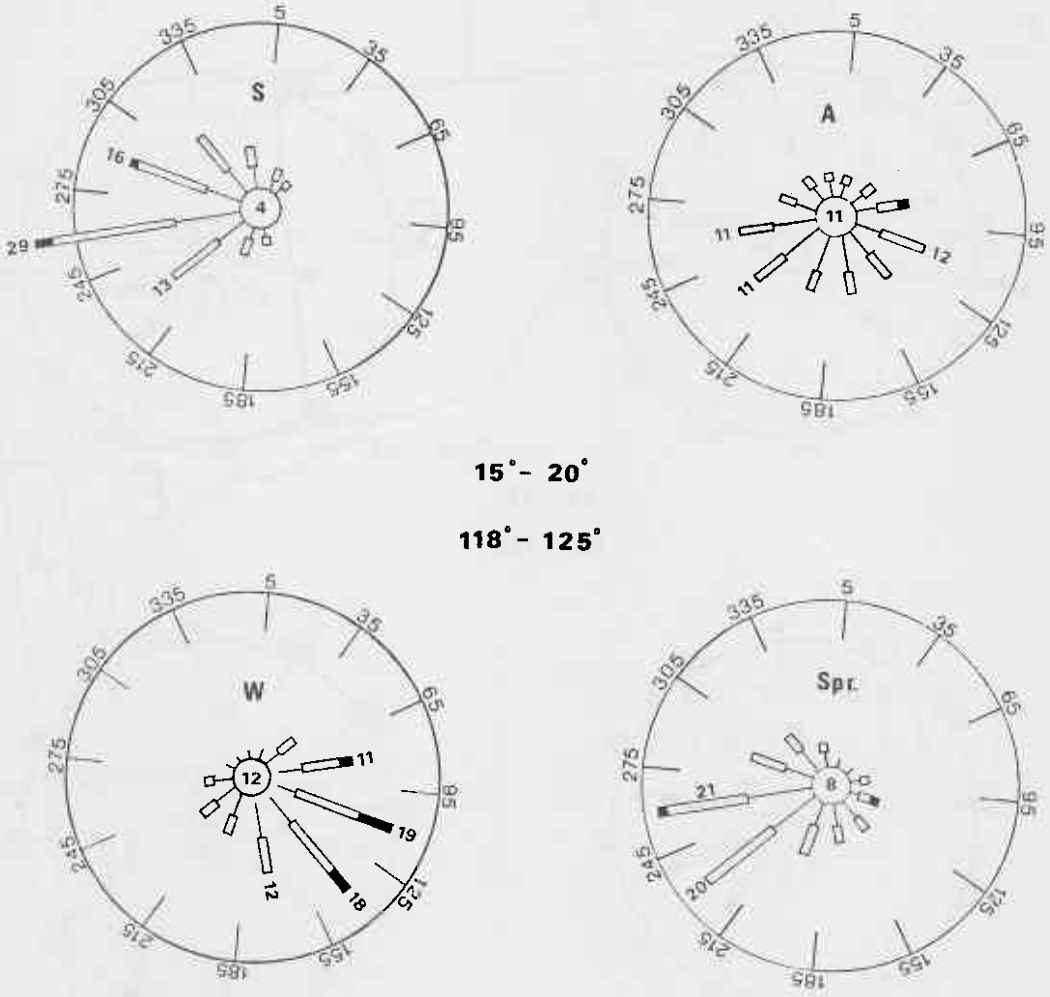
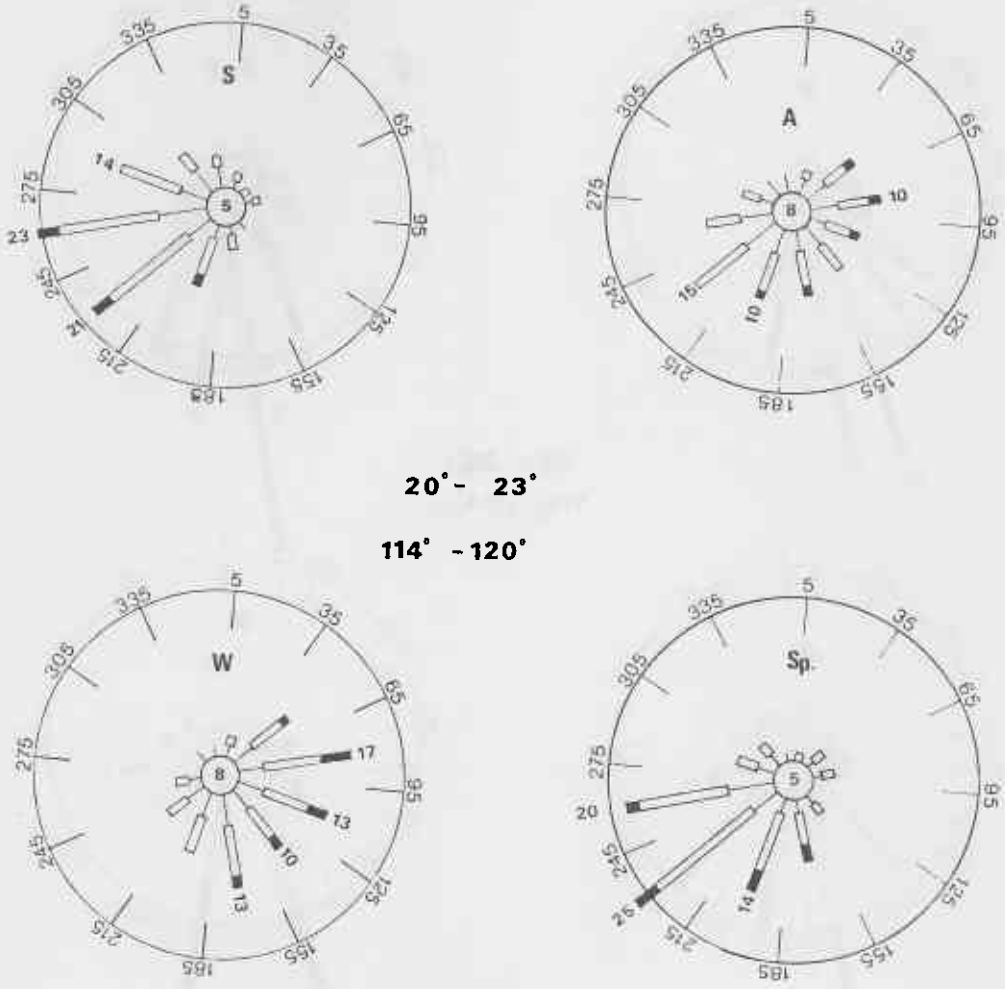


Figure 6. cont. Offshore wind roses. Area 3

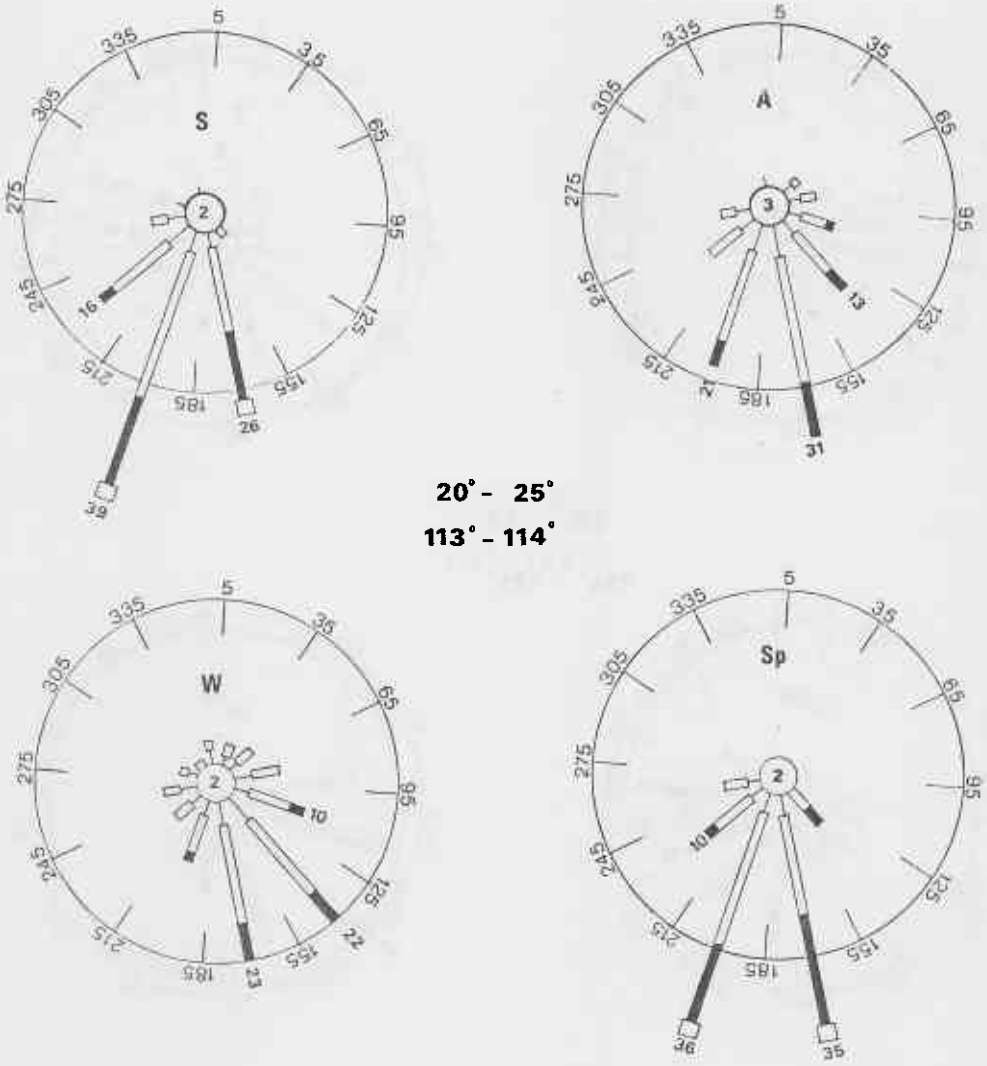


Percentage of calms given in inner circle

S = Summer A = Autumn W = Winter Sp = Spring

Wind direction is towards the inner circle

Figure 6. cont. Offshore wind roses. Area 4

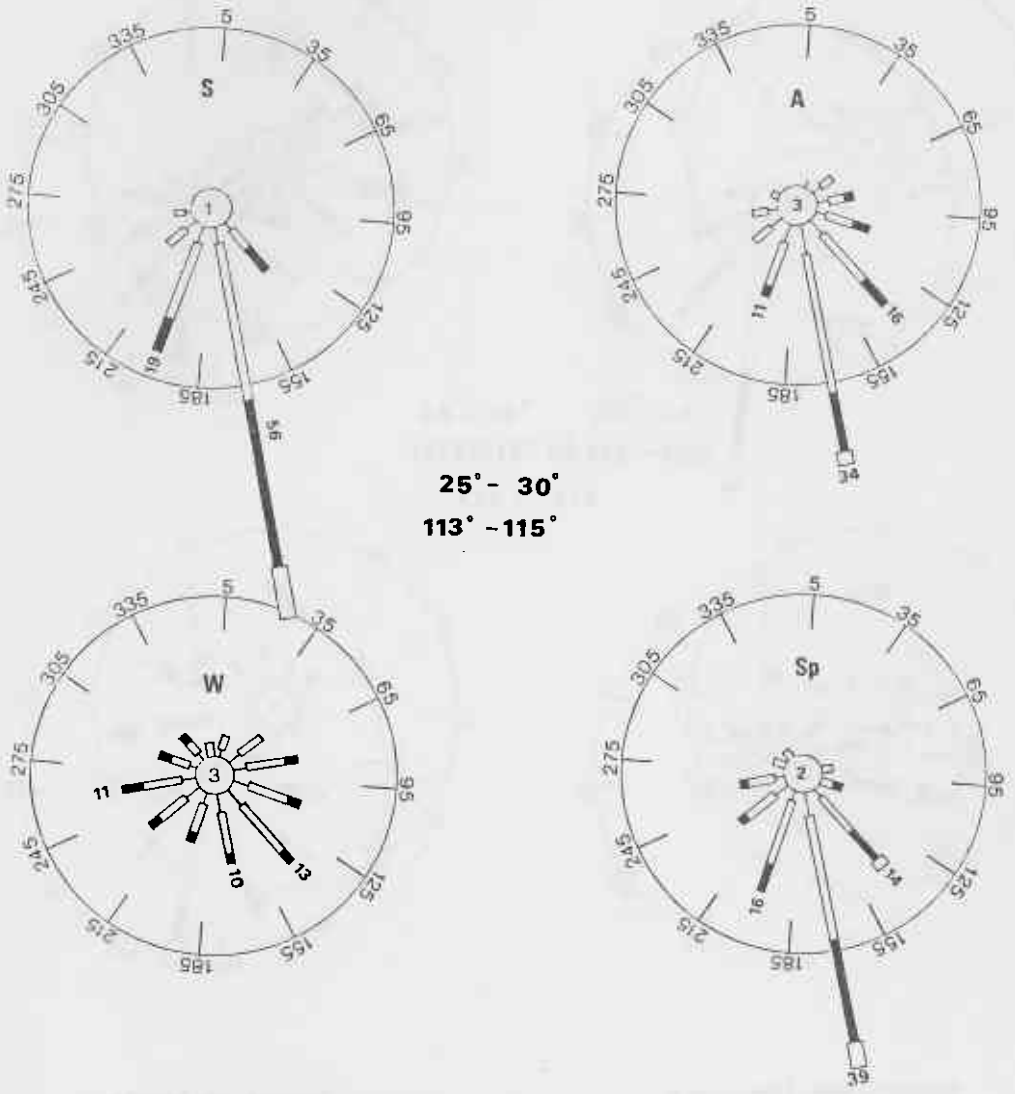


Percentage of calms given in inner circle

S = Summer A = Autumn W = Winter Sp = Spring

Wind direction is towards the inner circle

Figure 6. cont. Offshore wind roses. Area 5

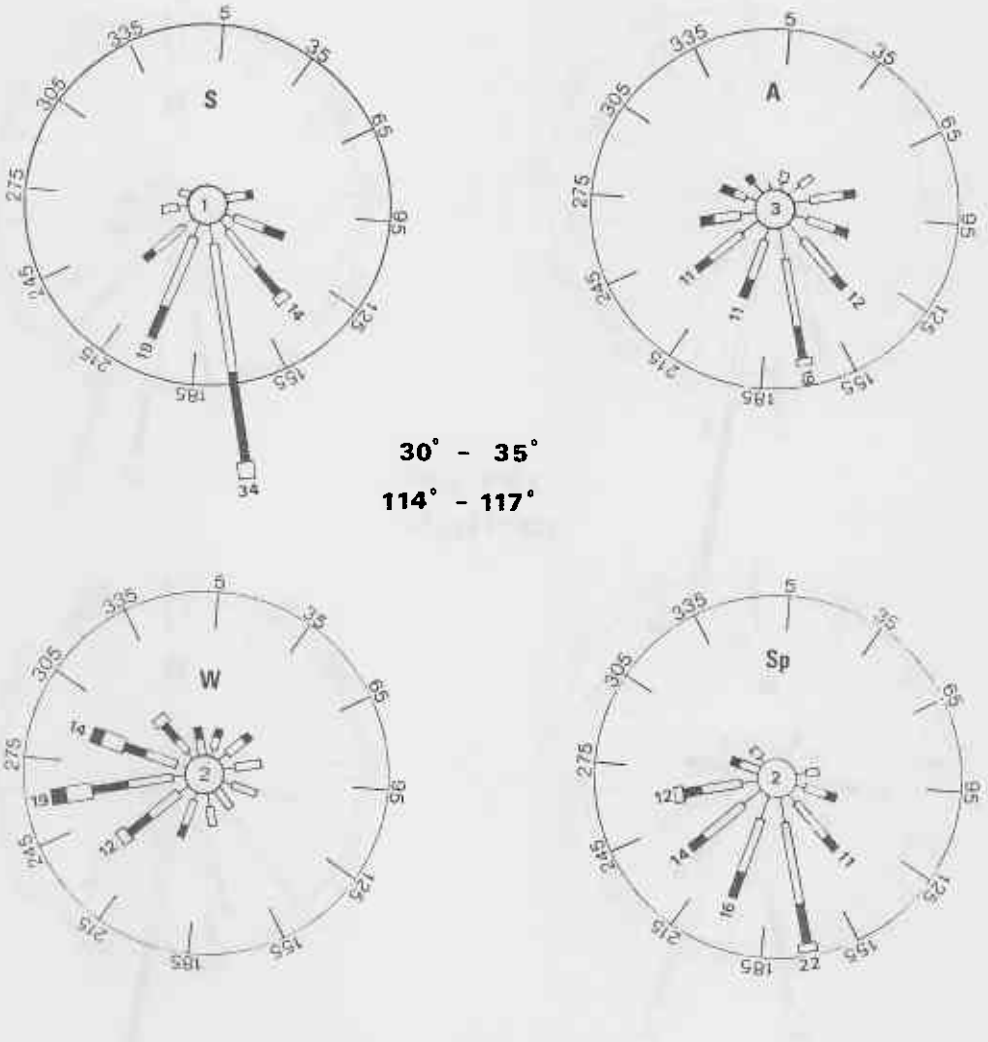


Percentage of calms given in inner circle

S = Summer A = Autumn W = Winter Sp = Spring

Wind direction is towards the inner circle

Figure 6. cont. Offshore wind roses. Area 6

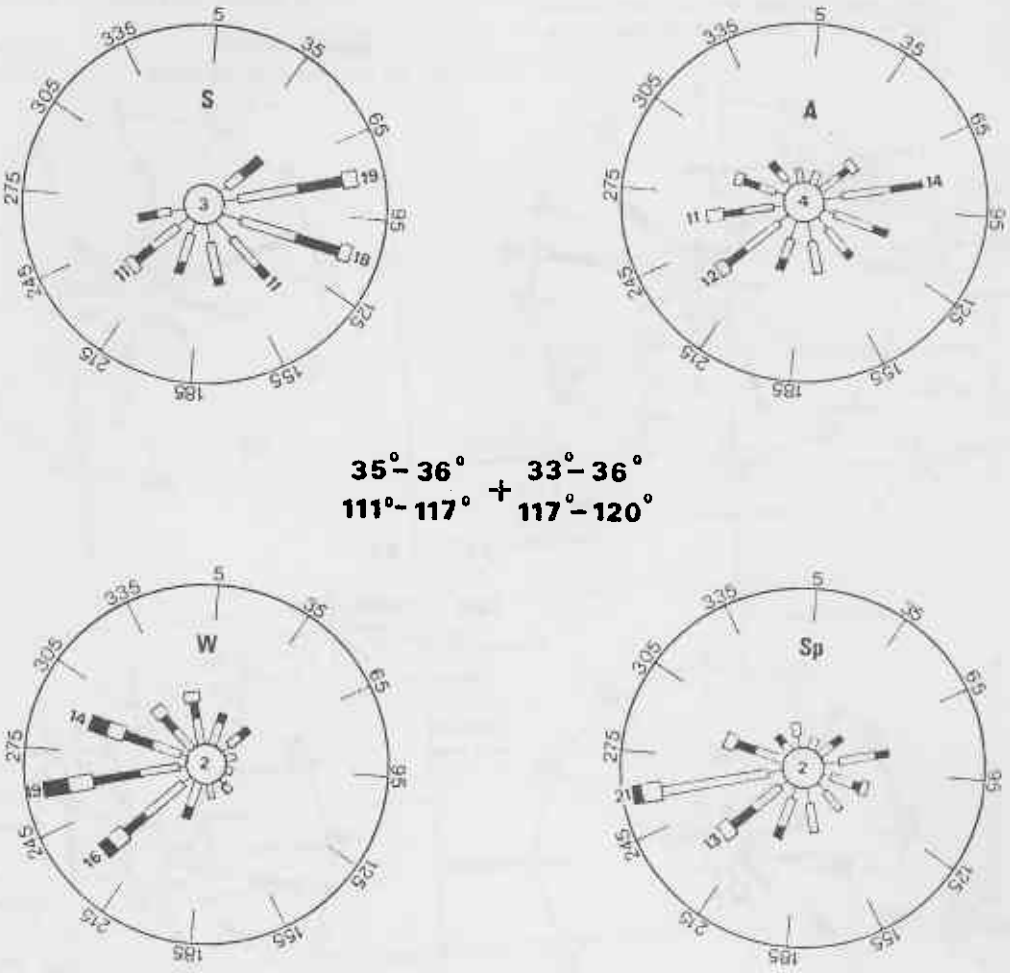


Percentage of calms given in inner circle

S = Summer A = Autumn W = Winter Sp = Spring

Wind direction is towards the inner circle

Figure 6. cont. Offshore wind roses. Area 7

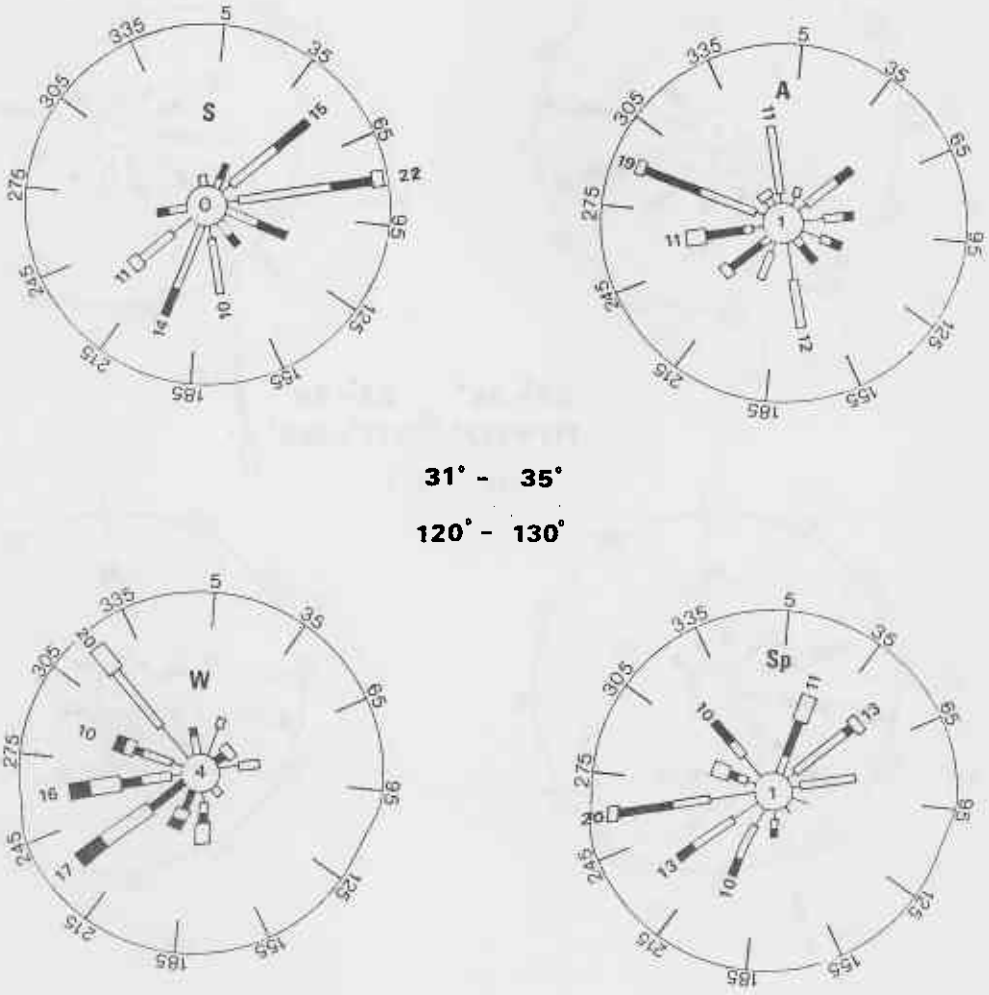


Percentage of calms given in inner circle

S = Summer A = Autumn W = Winter Sp = Spring

Wind direction is towards the inner circle

Figure 6. cont. Offshore wind roses. Area 8



Percentage of calms given in inner circle

S = Summer A = Autumn W = Winter Sp = Spring

Wind direction is towards the inner circle

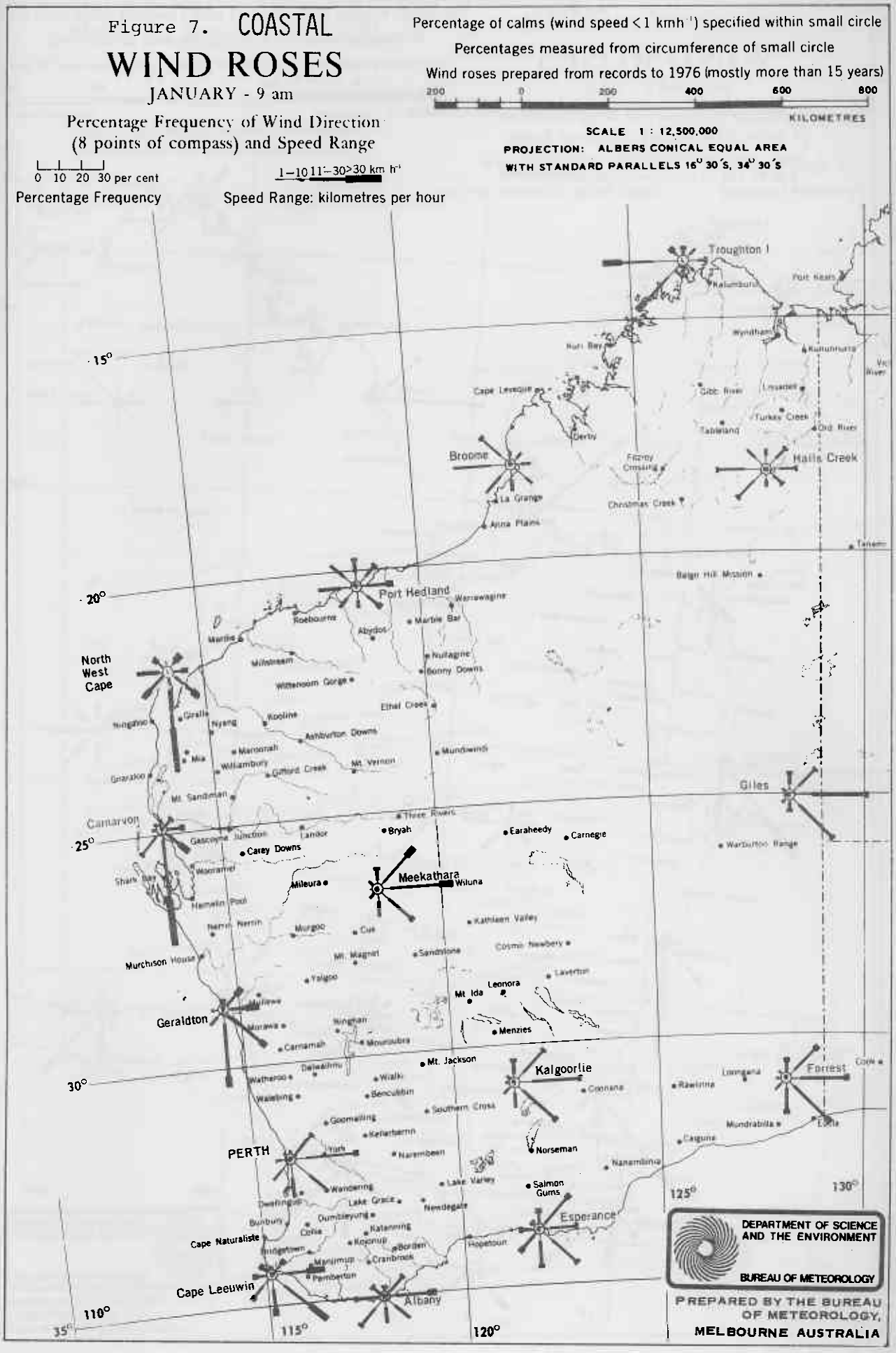


Figure 7. COASTAL
WIND ROSES
JANUARY - 9 am
Percentage Frequency of Wind Direction
(8 points of compass) and Speed Range
0 10 20 30 per cent
Percentage Frequency
1–10 11–30 >30 km h⁻¹
Speed Range: kilometres per hour
Percentage of calms (wind speed < 1 kmh⁻¹) specified within small circle
Percentages measured from circumference of small circle
Wind roses prepared from records to 1976 (mostly more than 15 years)
200 0 200 400 600 800
KILOMETRES
SCALE 1 : 12,500,000
PROJECTION: ALBERS CONICAL EQUAL AREA
WITH STANDARD PARALLELS 16° 30′S, 34° 30′S
Troughton I
Port Keats
Kalumburu
Wyndham
Kununurra
Vic River
Cape Leveque
Derby
Gibb River
Lissadell
Turkey Creek
Tableland
Ord River
Broome
Fitzroy Crossing
Halls Creek
La Grange
Christmas Creek
Anna Plains
Tanami
Balgo Hill Mission
Port Hedland
Warrawagine
Roebourne
Marble Bar
Abydos
Nullagine
Bonny Downs
Wittenoom Gorge
Ethel Creek
North West Cape
Giles
Carnarvon
Three Rivers
Bryah
Earaheedy
Carnegie
Carey Downs
Meekathara
Wiluna
Mileura
Kathleen Valley
Cue
Murgoo
Mt. Magnet
Sandstone
Cosmo Newbery
Laverton
Leonora
Mt. Ida
Menzies
Murchison House
Yalgoo
Geraldton
Mingenew
Carnamah
Mt. Jackson
Kalgoorlie
Coolgardie
Forrest
Rawlinna
Mundrabilla
Eucla
Norseman
Caiguna
Nullarbor
PERTH
York
Narembeen
Lake Varley
Salmon Gums
Esperance
Wandering
Lake Grace
Newdegate
Dumbleyung
Bunbury
Cape Naturaliste
Katanning
Kojonup
Borden
Cranbrook
Hopetoun
Pemberton
Cape Leeuwin
Albany
15°
20°
25°
30°
35°
110°
115°
120°
125°
130°
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Figure 7. cont. COASTAL

WIND ROSES

JANUARY - 3 pm

Percentage Frequency of Wind Direction
(8 points of compass) and Speed Range

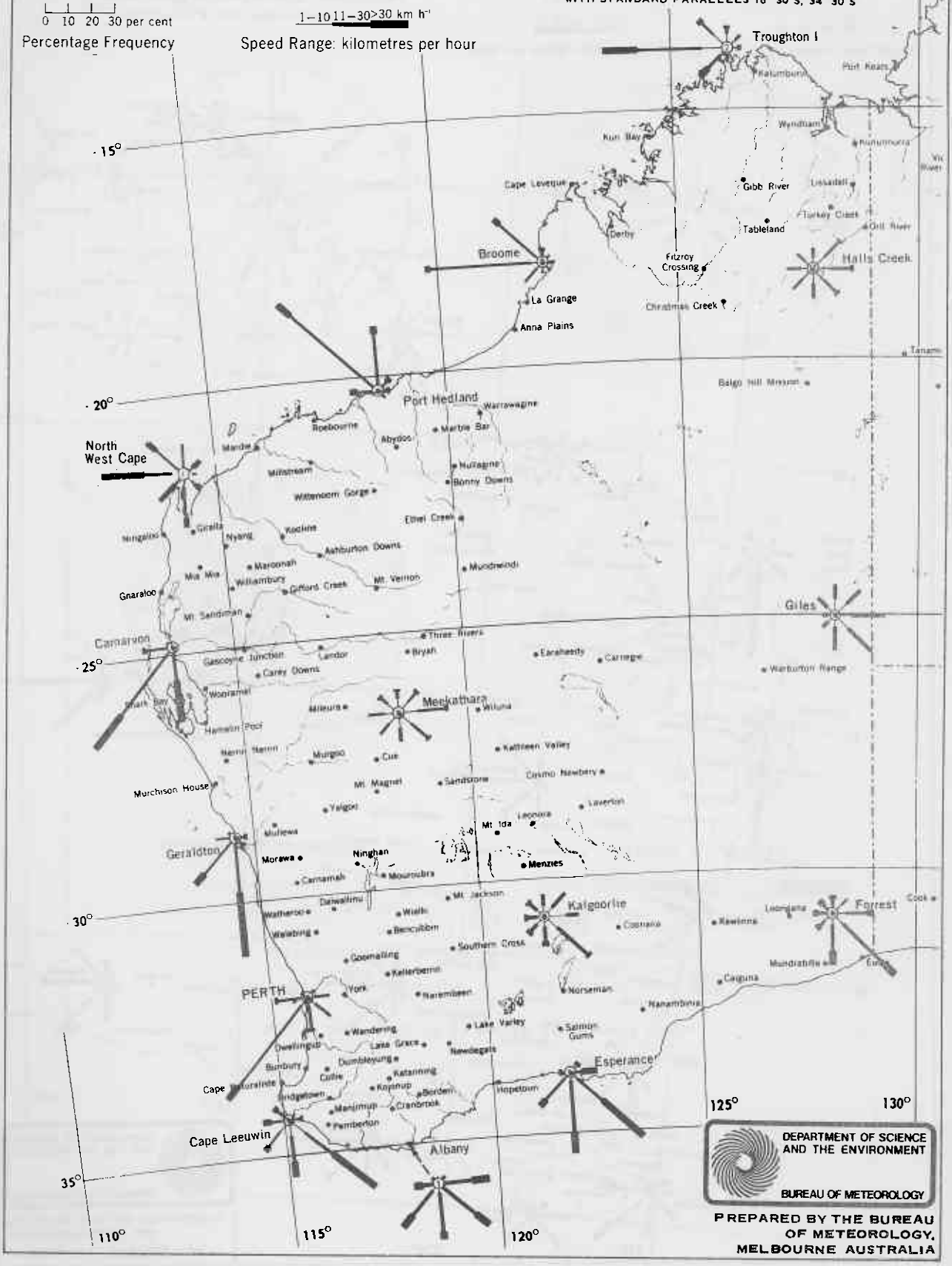

Figure 7. cont.

COASTAL WIND ROSES

APRIL - 9 am

Percentage Frequency of Wind Direction
(8 points of compass) and Speed Range

0 10 20 30 per cent
Percentage Frequency

1–10 11–30 >30 km h⁻¹
Speed Range: kilometres per hour

Percentage of calms (wind speed <1 kmh⁻¹) specified within small circle
Percentages measured from circumference of small circle
Wind roses prepared from records to 1976 (mostly more than 15 years)

200 0 200 400 600 800
KILOMETRES

SCALE 1 : 12,500,000
PROJECTION: ALBERS CONICAL EQUAL AREA
WITH STANDARD PARALLELS 16° 30′S, 34° 30′S

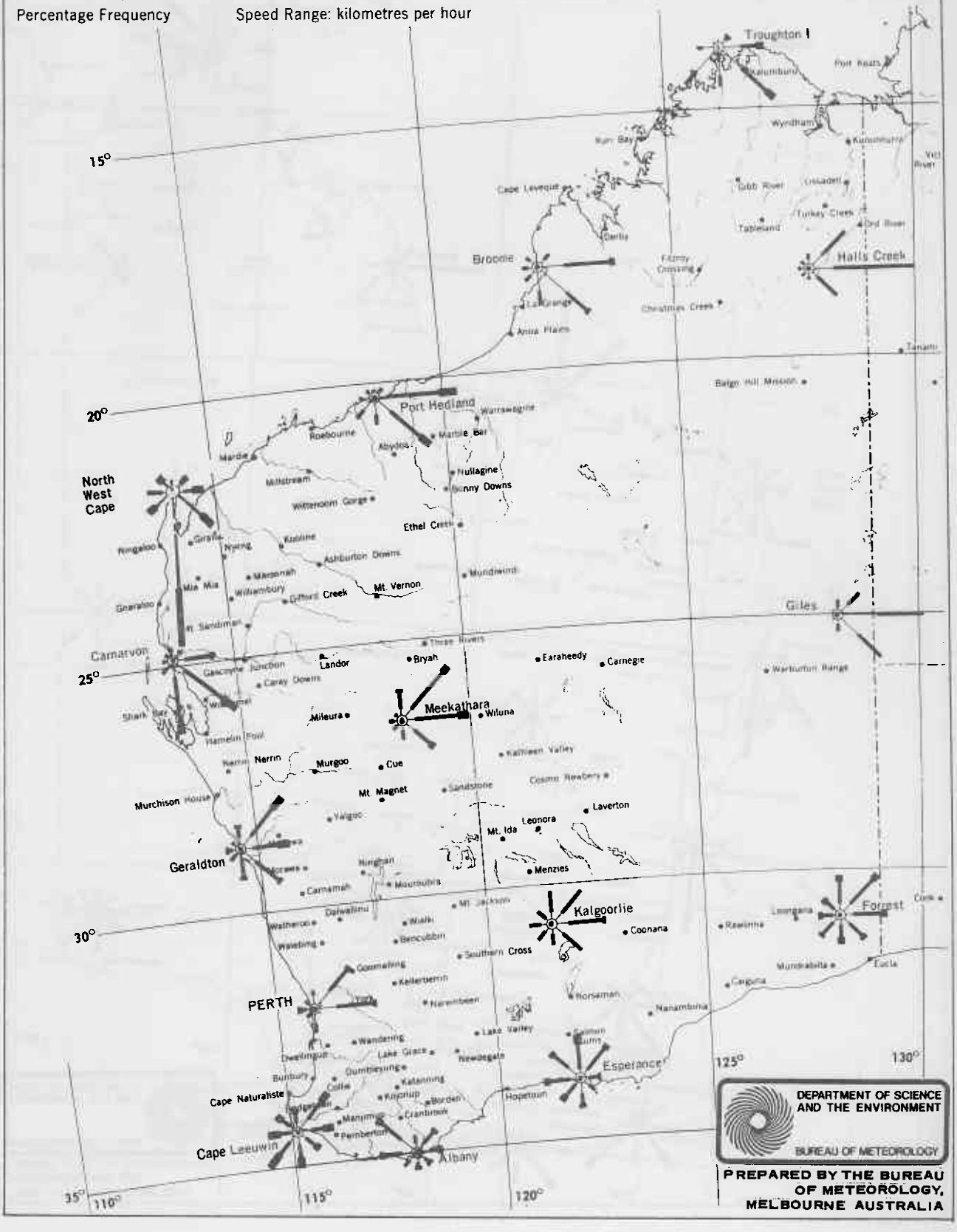

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Figure 7 cont. COASTAL

WIND ROSES

APRIL - 3 pm

Percentage Frequency of Wind Direction
(8 points of compass) and Speed Range

0 10 20 30 per cent
Percentage Frequency

1–10 11–30 >30 km h⁻¹
Speed Range: kilometres per hour

Percentage of calms (wind speed < 1 kmh⁻¹) specified within small circle
Percentages measured from circumference of small circle
Wind roses prepared from records to 1976 (mostly more than 15 years)

200 0 200 400 600 800
KILOMETRES

SCALE 1 : 12,500,000
PROJECTION: ALBERS CONICAL EQUAL AREA
WITH STANDARD PARALLELS 16° 30′S, 34° 30′S

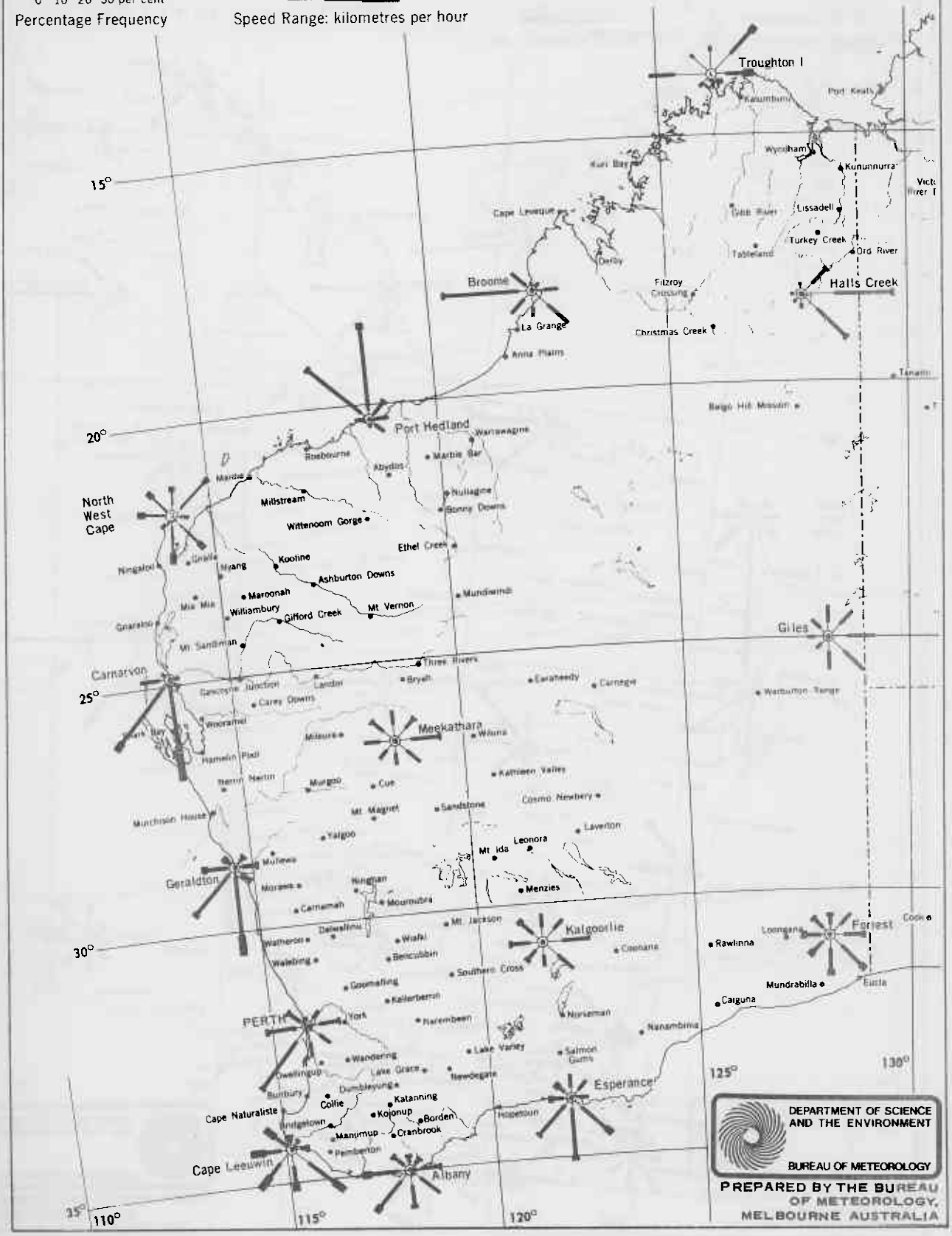

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Figure 7 cont. COASTAL

WIND ROSES

JULY - 9 am

Percentage Frequency of Wind Direction
(8 points of compass) and Speed Range

0 10 20 30 per cent
Percentage Frequency

1–10 11–30 >30 km h⁻¹
Speed Range: kilometres per hour

Percentage of calms (wind speed <1 kmh⁻¹) specified within small circle

Percentages measured from circumference of small circle

Wind roses prepared from records to 1976 (mostly more than 15 years)

200 0 200 400 600 800
KILOMETRES

SCALE 1 : 12,500,000

PROJECTION: ALBERS CONICAL EQUAL AREA
WITH STANDARD PARALLELS 16° 30′S, 34° 30′S

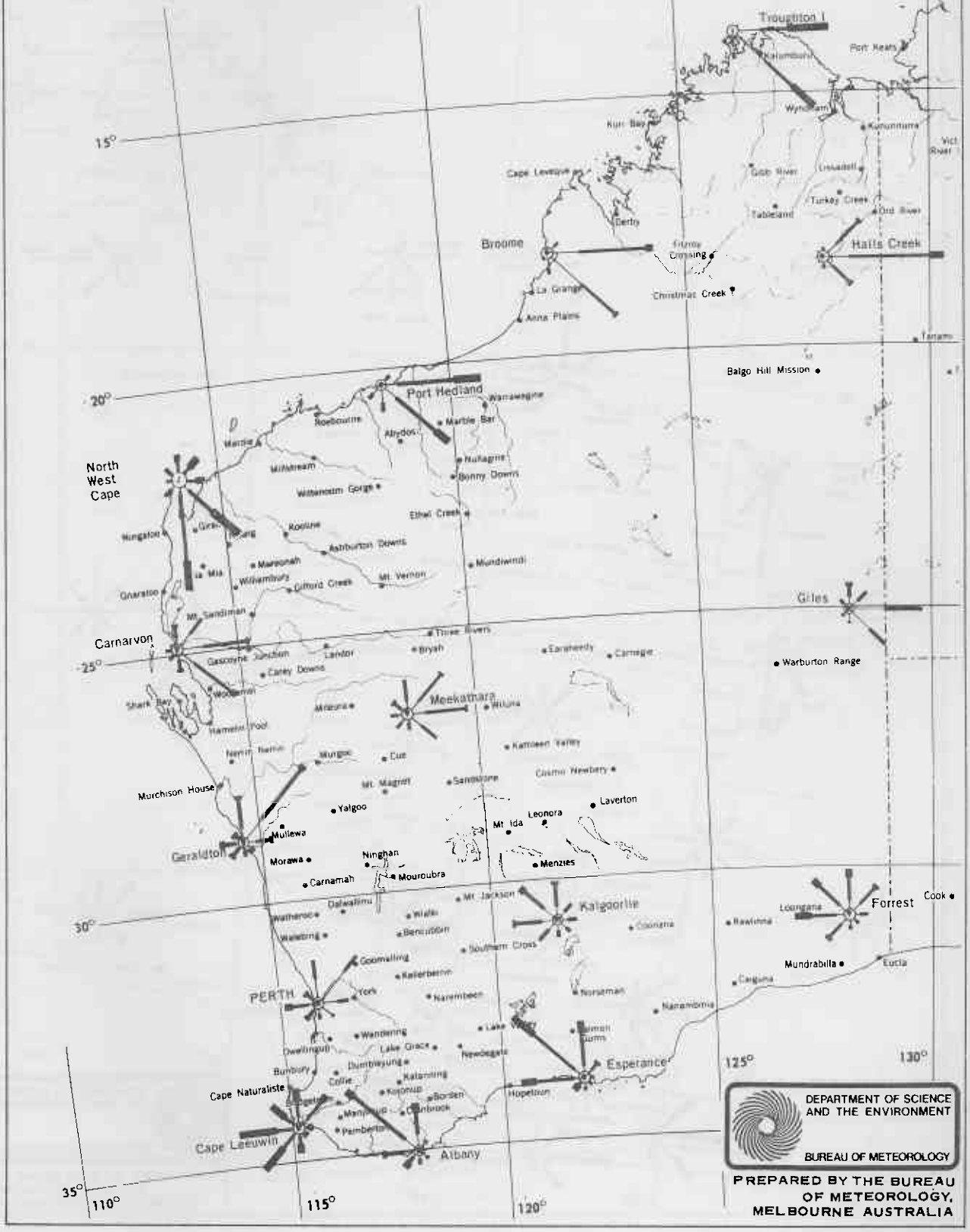

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Figure 7. cont. COASTAL

WIND ROSES

JULY - 3 pm

Percentage Frequency of Wind Direction (8 points of compass) and Speed Range

0 10 20 30 per cent

Percentage Frequency

1–10 11–30 >30 km h⁻¹

Speed Range: kilometres per hour

Percentage of calms (wind speed < 1 kmh⁻¹) specified within small circle

Percentages measured from circumference of small circle

Wind roses prepared from records to 1976 (mostly more than 15 years)

200 0 200 400 600 800 KILOMETRES

SCALE 1 : 12,500,000

PROJECTION: ALBERS CONICAL EQUAL AREA

WITH STANDARD PARALLELS 16° 30´S, 34° 30´S

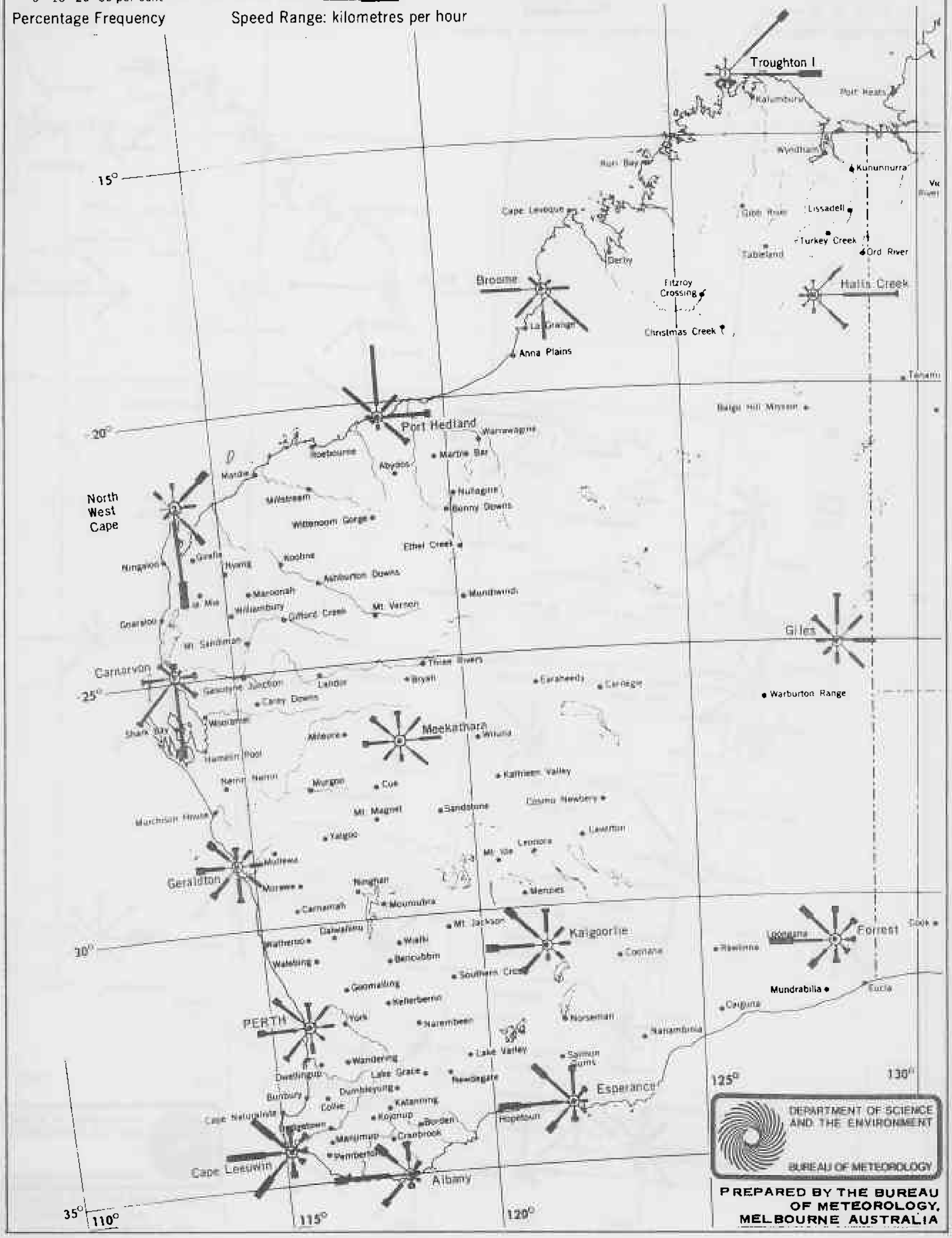

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Figure 7. cont. COASTAL

WIND ROSES

OCTOBER - 9 am

Percentage Frequency of Wind Direction
(8 points of compass) and Speed Range

0 10 20 30 per cent
Percentage Frequency

1–10 11–30 >30 km h⁻¹
Speed Range: kilometres per hour

Percentage of calms (wind speed < 1 kmh⁻¹) specified within small circle

Percentages measured from circumference of small circle

Wind roses prepared from records to 1976 (mostly more than 15 years)

200 0 200 400 600 800
KILOMETRES

SCALE 1 : 12,500,000

PROJECTION: ALBERS CONICAL EQUAL AREA
WITH STANDARD PARALLELS 16° 30′S, 34° 30′S

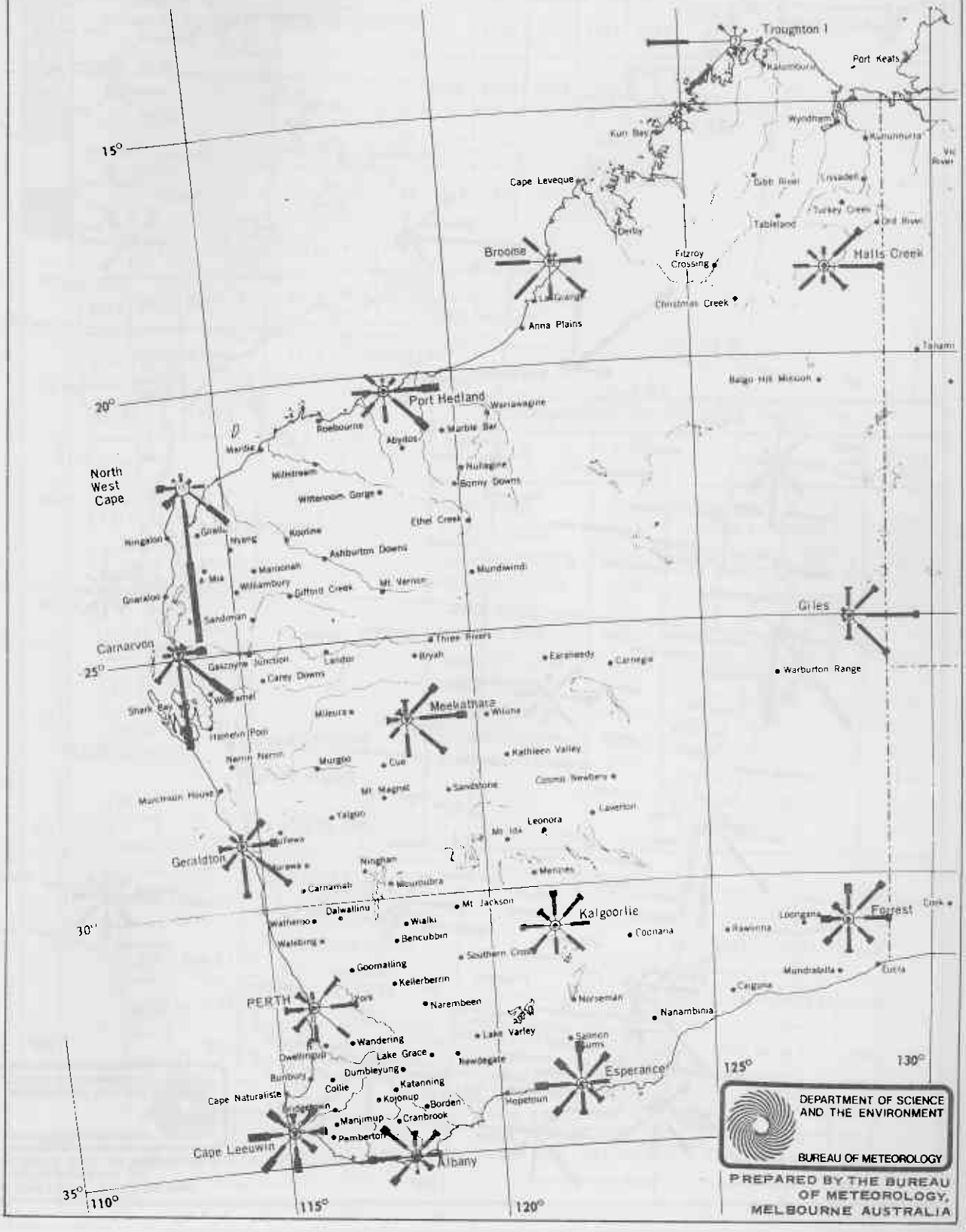

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Figure 7. cont. COASTAL

WIND ROSES

OCTOBER - 3 pm

Percentage Frequency of Wind Direction
(8 points of compass) and Speed Range

0 10 20 30 per cent
Percentage Frequency

1–10 11–30 >30 km h^{-1}
Speed Range: kilometres per hour

Percentage of calms (wind speed <1 kmh^{-1}) specified within small circle

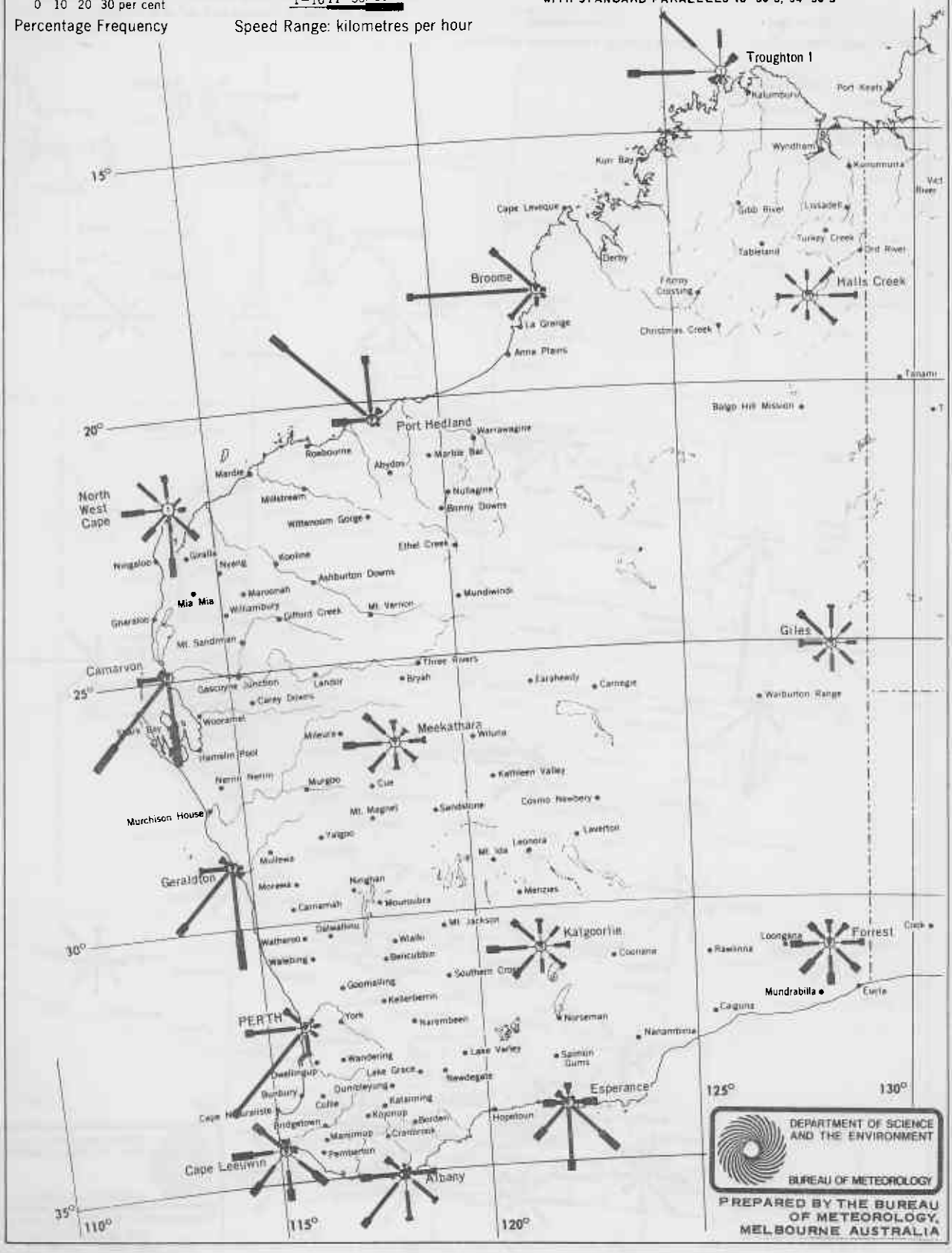
Percentages measured from circumference of small circle

Wind roses prepared from records to 1976 (mostly more than 15 years)

200 0 200 400 600 800
KILOMETRES

SCALE 1 : 12,500,000

PROJECTION: ALBERS CONICAL EQUAL AREA
WITH STANDARD PARALLELS 16° 30′S, 34° 30′S



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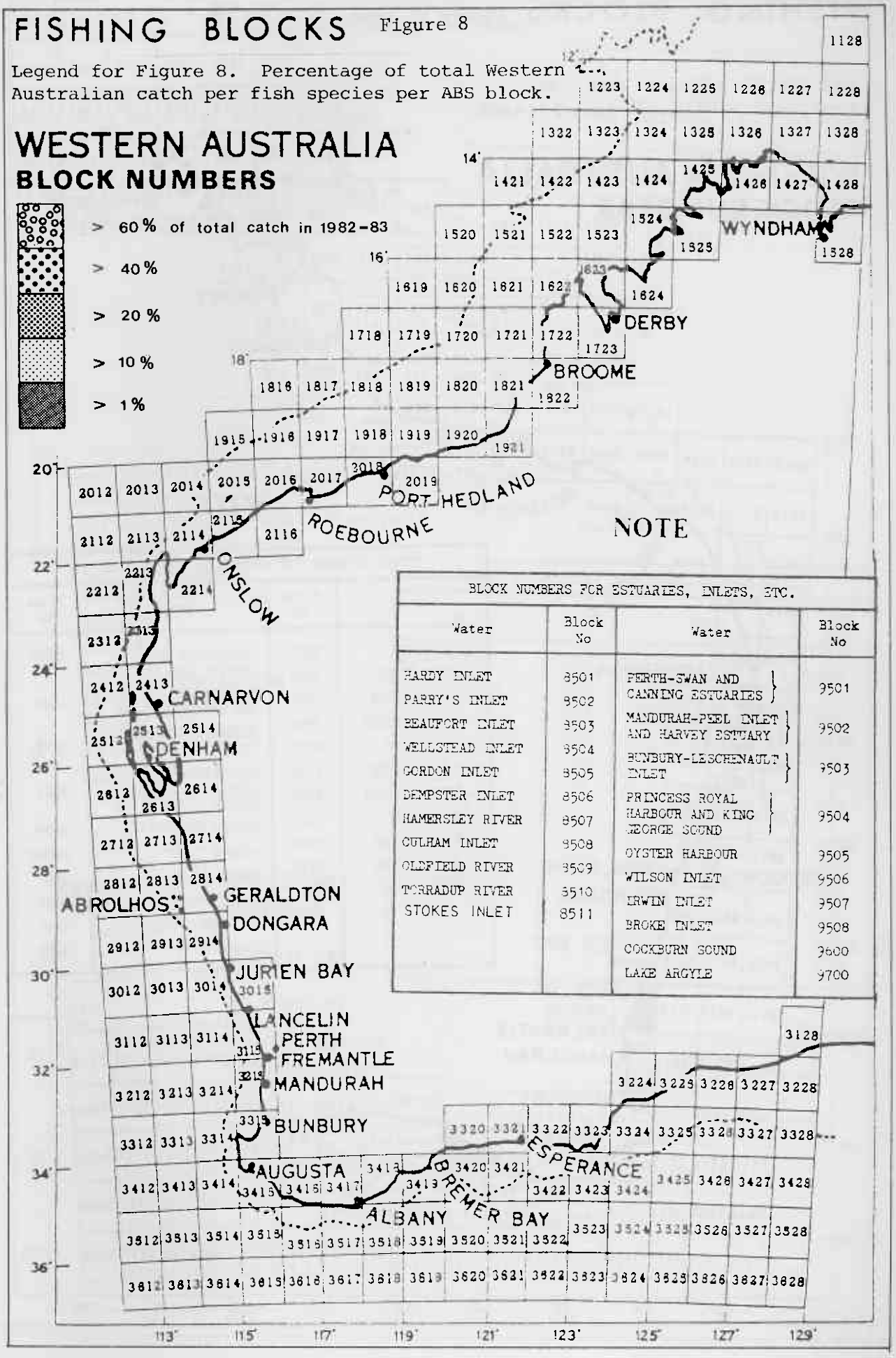
FISHING BLOCKS Figure 8

Legend for Figure 8. Percentage of total Western Australian catch per fish species per ABS block.



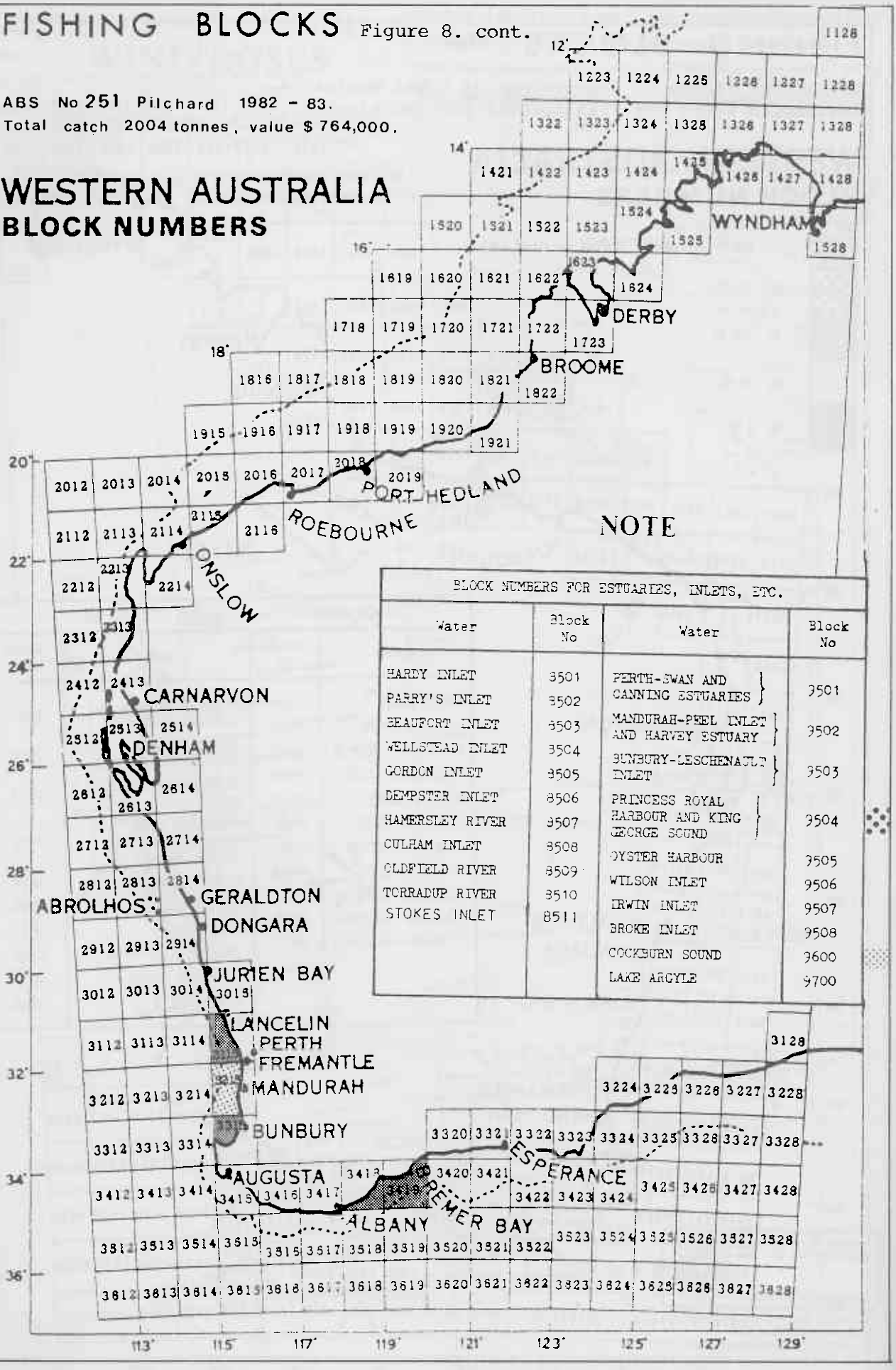
BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502		
BEAUFORT INLET	8503	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
WELLSTEAD INLET	8504		
GORDON INLET	8505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	8506		
HAMERSLEY RIVER	8507	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
CULHAM INLET	8508		
OLDFIELD RIVER	8509	OYSTER HARBOUR	9505
TORRADUP RIVER	8510	WILSON INLET	9506
STOKES INLET	8511	IRWIN INLET	9507
		BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS Figure 8. cont.

ABS No 251 Pilchard 1982 - 83.
Total catch 2004 tonnes, value $ 764,000.

WESTERN AUSTRALIA
BLOCK NUMBERS



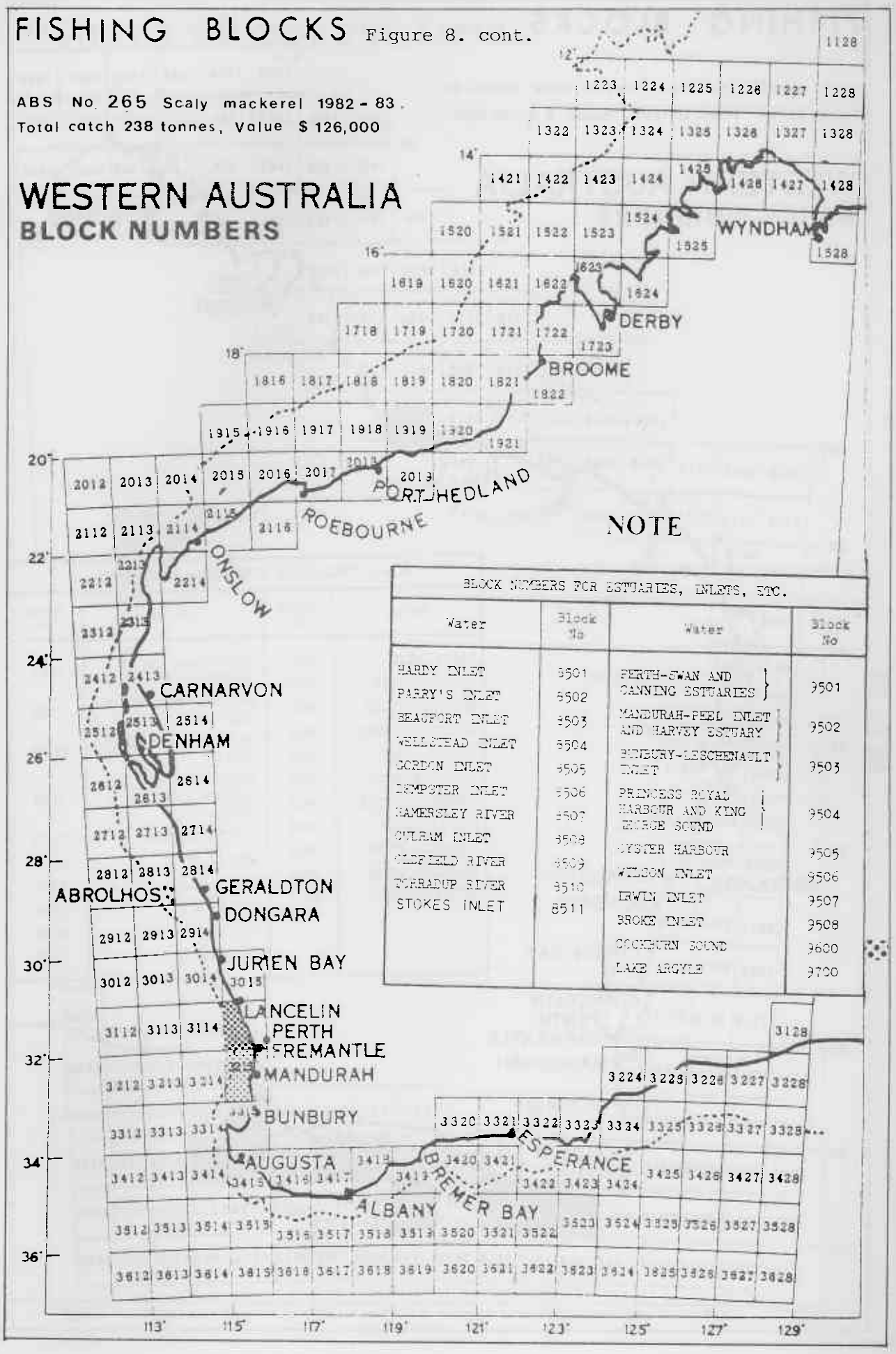
NOTE

BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502		
BEAUFORT INLET	8503	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
WELLSTEAD INLET	8504		
GORDON INLET	8505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	8506		
HAMERSLEY RIVER	8507	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
CULHAM INLET	8508		
OLDFIELD RIVER	8509	OYSTER HARBOUR	9505
TORRADUP RIVER	8510	WILSON INLET	9506
STOKES INLET	8511	IRWIN INLET	9507
		BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS Figure 8. cont.

ABS No. 265 Scaly mackerel 1982 - 83.
Total catch 238 tonnes, Value $ 126,000



NOTE

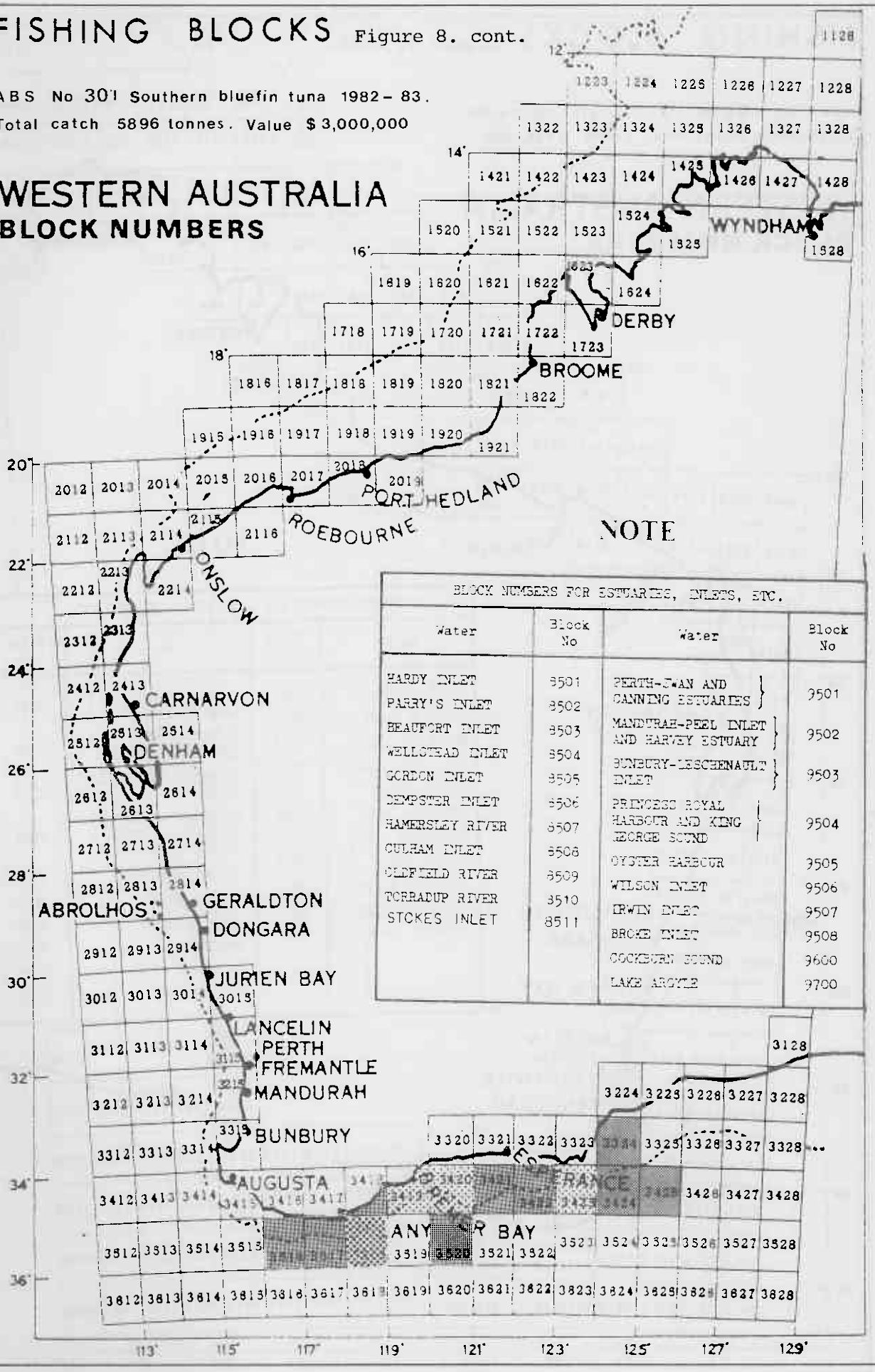
BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	9501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	9502	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
BEAUFORT INLET	9503	BUNBURY-LESCHENAULT INLET	9503
WELLSTEAD INLET	9504		
GORDON INLET	9505	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
DEMPSTER INLET	9506		
HAMERSLEY RIVER	9507	OYSTER HARBOUR	9505
OULLAM INLET	9508	WILSON INLET	9506
OLDFIELD RIVER	9509	ERWIN INLET	9507
TORRADUP RIVER	9510	BROKE INLET	9508
STOKES INLET	9511	COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS Figure 8. cont.

ABS No 301 Southern bluefin tuna 1982 – 83.
Total catch 5896 tonnes. Value $3,000,000

WESTERN AUSTRALIA
BLOCK NUMBERS



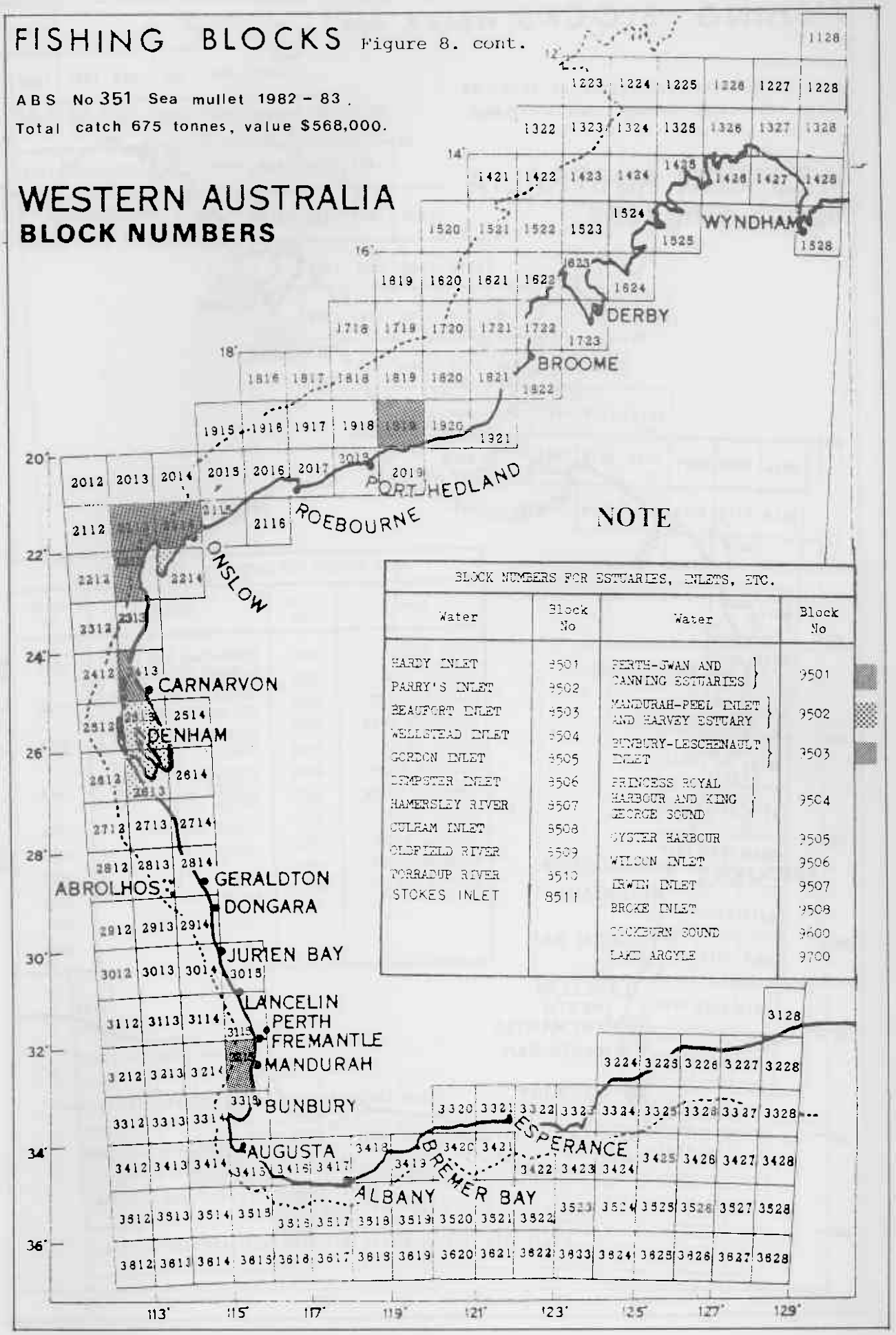
NOTE

BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502		
BEAUFORT INLET	8503	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
WELLSTEAD INLET	8504		
GORDON INLET	8505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	8506		
HAMERSLEY RIVER	8507	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
CULHAM INLET	8508		
OLDFIELD RIVER	8509	OYSTER HARBOUR	9505
TORRADUP RIVER	8510	WILSON INLET	9506
STOKES INLET	8511	IRWIN INLET	9507
		BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS Figure 8. cont.

ABS No 351 Sea mullet 1982 - 83.
Total catch 675 tonnes, value $568,000.

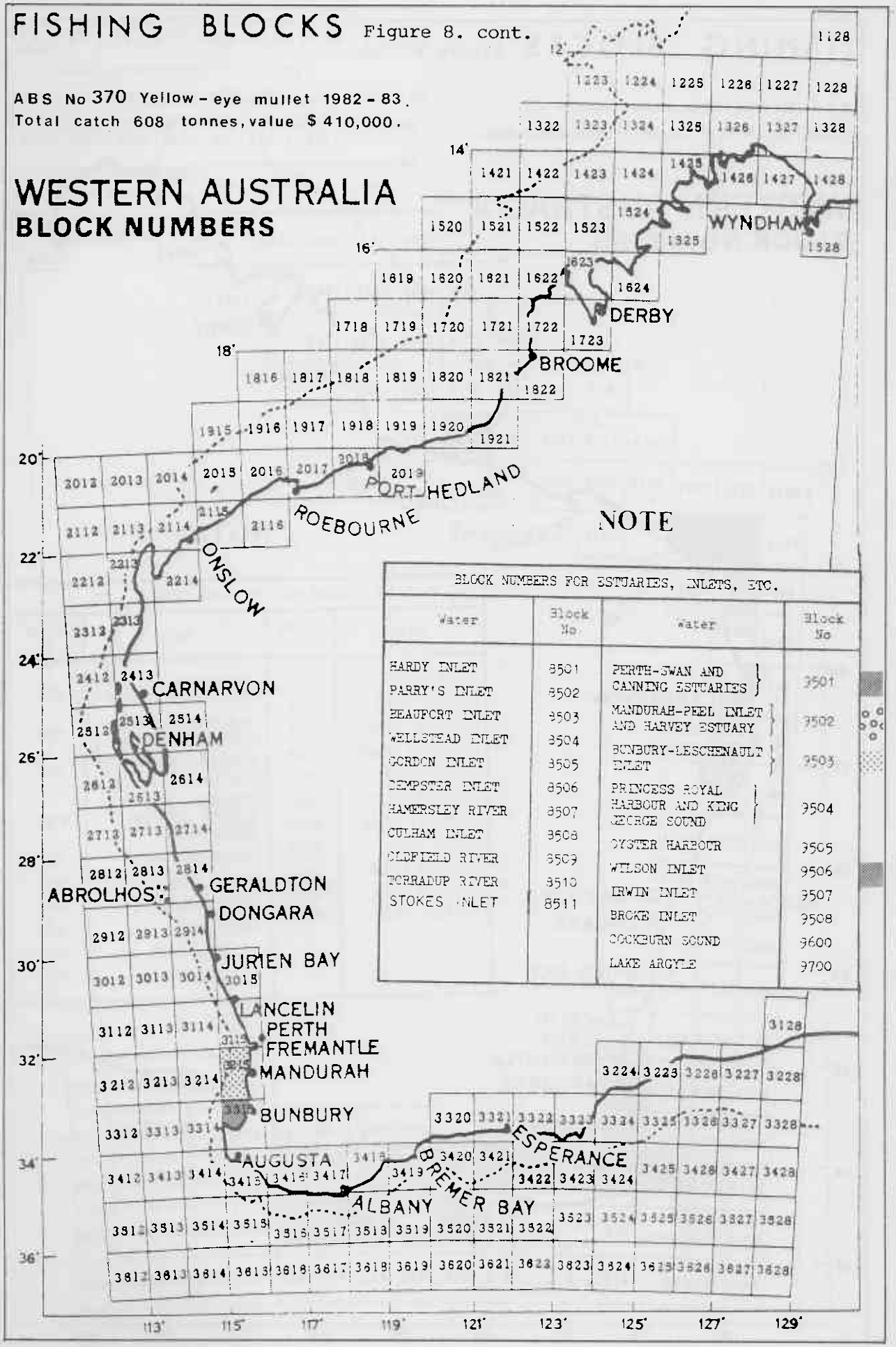


BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	9501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	9502		
BEAUFORT INLET	9503	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
WELLSTEAD INLET	9504		
GORDON INLET	9505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	9506	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
HAMERSLEY RIVER	9507		
JULIAM INLET	9508	OYSTER HARBOUR	9505
OLDFIELD RIVER	9509	WILSON INLET	9506
TORRADUP RIVER	9510	IRWIN INLET	9507
STOKES INLET	9511	BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS Figure 8. cont.

ABS No 370 Yellow-eye mullet 1982-83.
Total catch 608 tonnes, value $ 410,000.



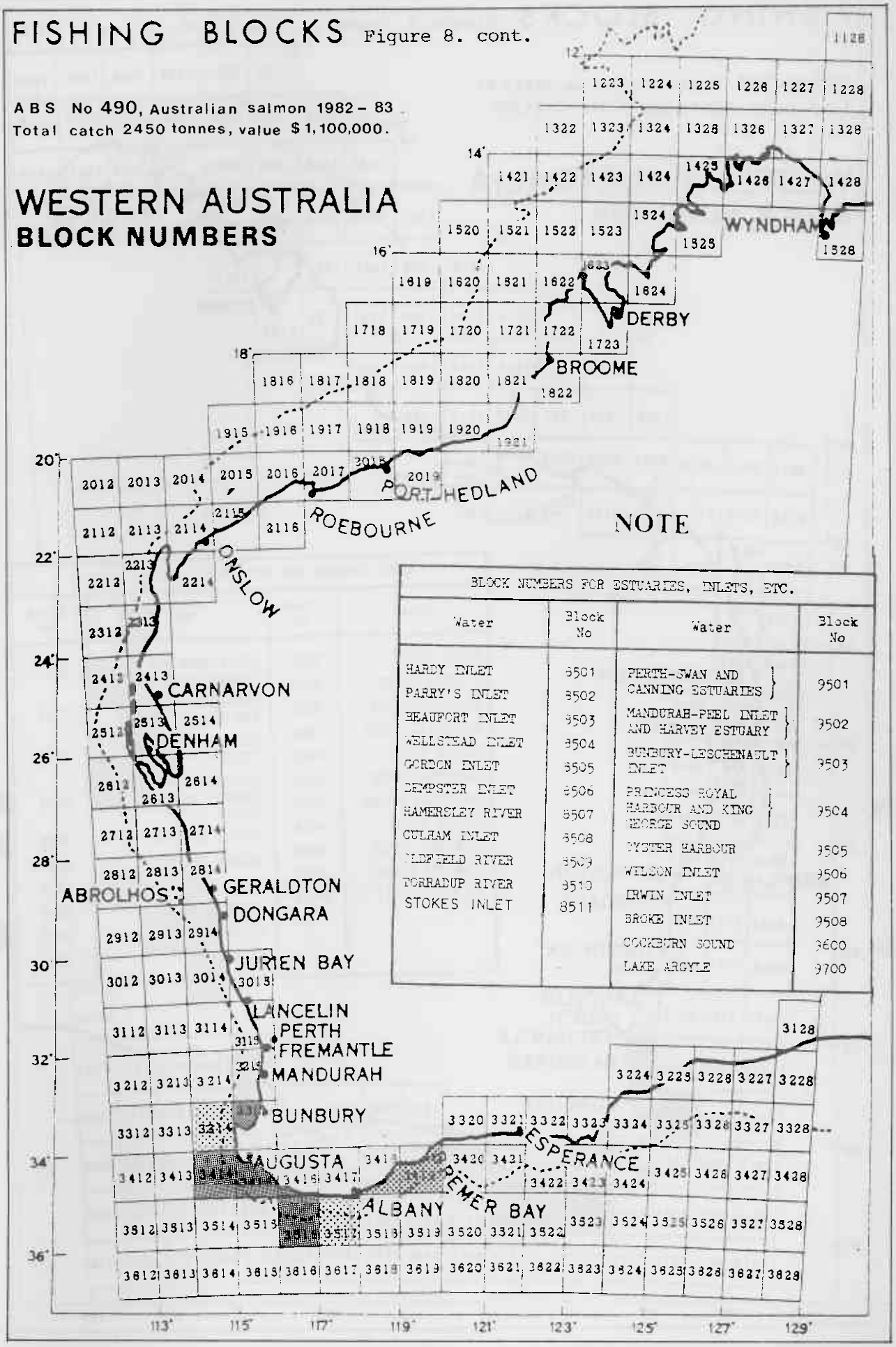
NOTE

BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No.	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502		
BEAUFORT INLET	8503	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
WELLSTEAD INLET	8504		
GORDON INLET	8505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	8506		
HAMERSLEY RIVER	8507	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
CULHAM INLET	8508		
OLDFIELD RIVER	8509	OYSTER HARBOUR	9505
TORRADUP RIVER	8510	WILSON INLET	9506
STOKES INLET	8511	IRWIN INLET	9507
		BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS Figure 8. cont.

ABS No 490, Australian salmon 1982 – 83
Total catch 2450 tonnes, value $1,100,000.

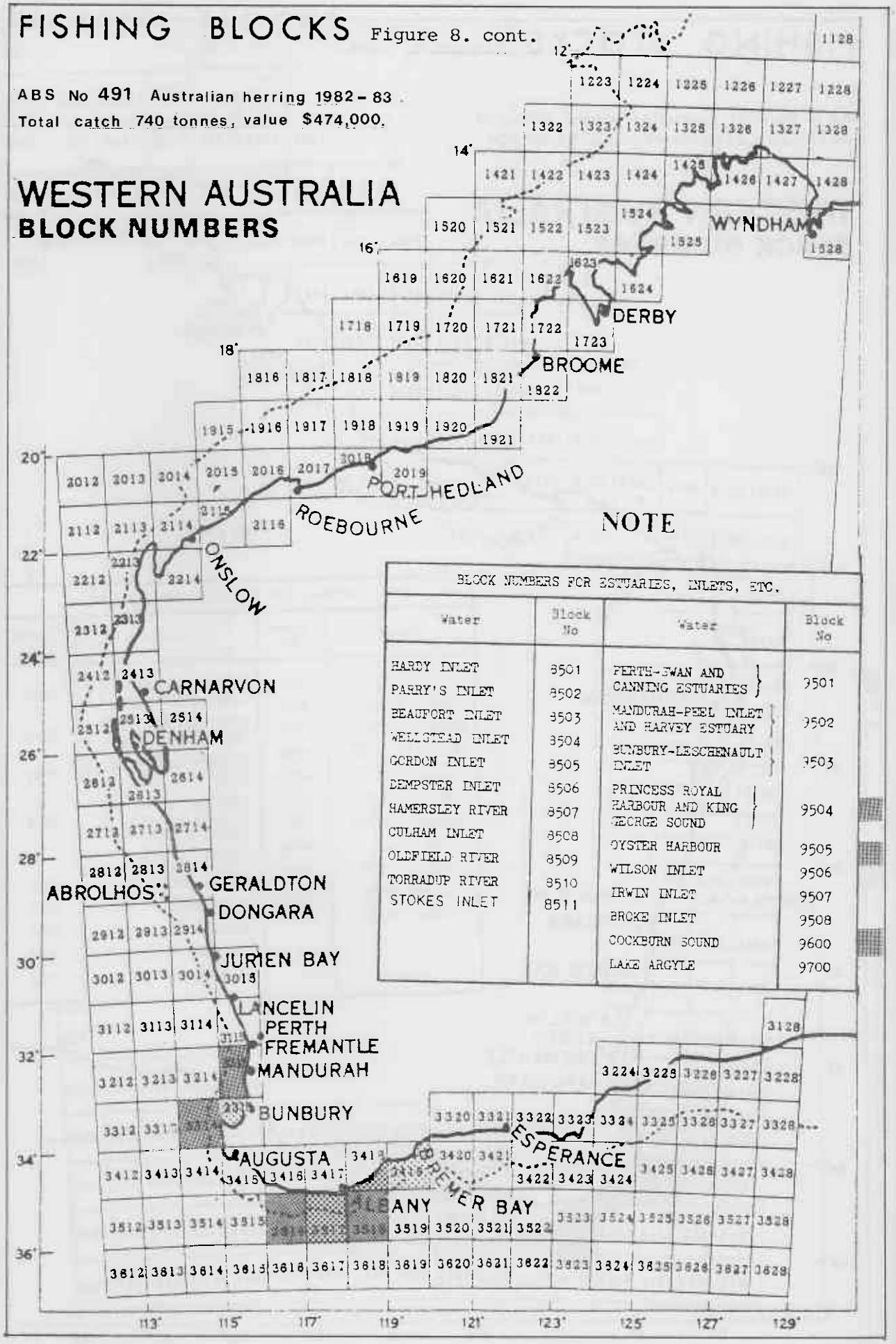


BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
BEAUFORT INLET	8503	BUNBURY-LESCHENAULT INLET	9503
WELLSTEAD INLET	8504		
GORDON INLET	8505	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
DEMPSTER INLET	8506		
HAMERSLEY RIVER	8507	OYSTER HARBOUR	9505
CULHAM INLET	8508	WILSON INLET	9506
OLDFIELD RIVER	8509	IRWIN INLET	9507
TORRADUP RIVER	8510	BROKE INLET	9508
STOKES INLET	8511	COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS Figure 8. cont.

ABS No 491 Australian herring 1982 – 83.
Total catch 740 tonnes, value $474,000.



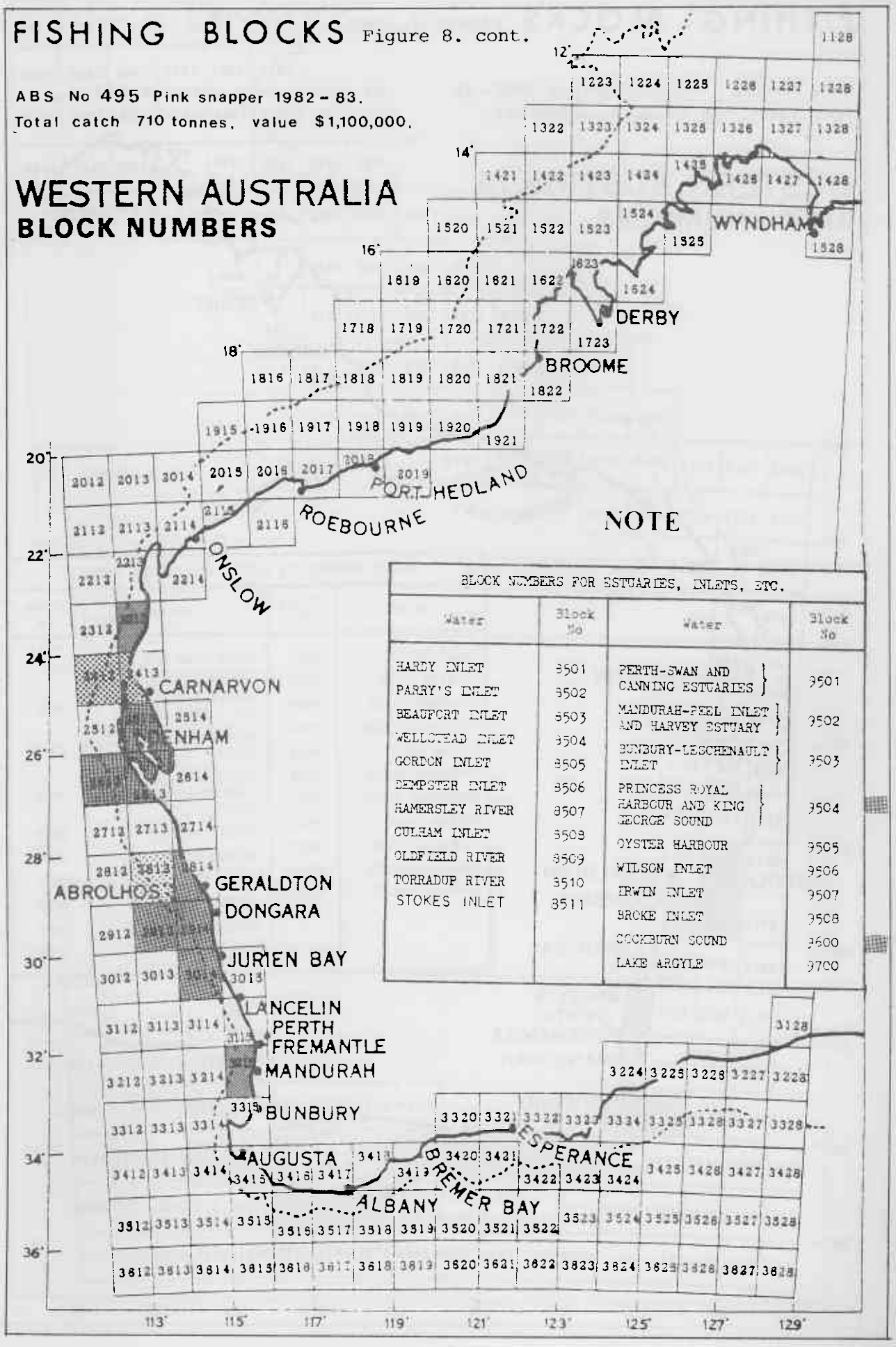
NOTE

BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
BEAUFORT INLET	8503	BUNBURY-LESCHENAULT INLET	9503
WELLSTEAD INLET	8504	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
GORDON INLET	8505	OYSTER HARBOUR	9505
DEMPSTER INLET	8506	WILSON INLET	9506
HAMERSLEY RIVER	8507	IRWIN INLET	9507
CULHAM INLET	8508	BROKE INLET	9508
OLDFIELD RIVER	8509	COCKBURN SOUND	9600
TORRADUP RIVER	8510	LAKE ARGYLE	9700
STOKES INLET	8511		

FISHING BLOCKS Figure 8. cont.

ABS No 495 Pink snapper 1982 - 83.
Total catch 710 tonnes, value $1,100,000.



NOTE

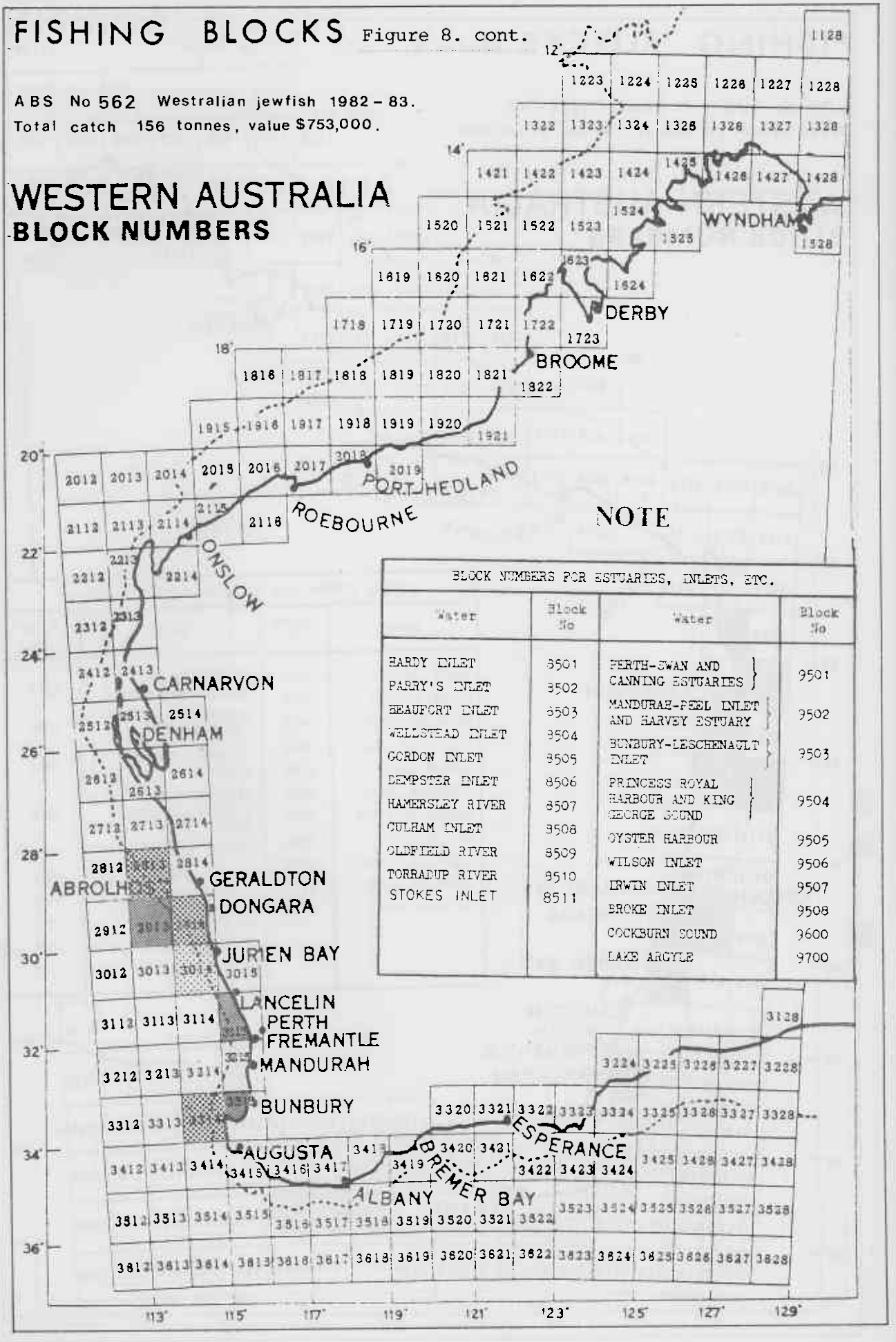
BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502		
BEAUFORT INLET	8503	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
WELLSTEAD INLET	8504		
GORDON INLET	8505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	8506		
HAMERSLEY RIVER	8507	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
CULHAM INLET	8508		
OLDFIELD RIVER	8509	OYSTER HARBOUR	9505
TORRADUP RIVER	8510	WILSON INLET	9506
STOKES INLET	8511	IRWIN INLET	9507
		BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS Figure 8. cont.

ABS No 562 Westralian jewfish 1982 – 83.
Total catch 156 tonnes, value $753,000.

WESTERN AUSTRALIA
BLOCK NUMBERS



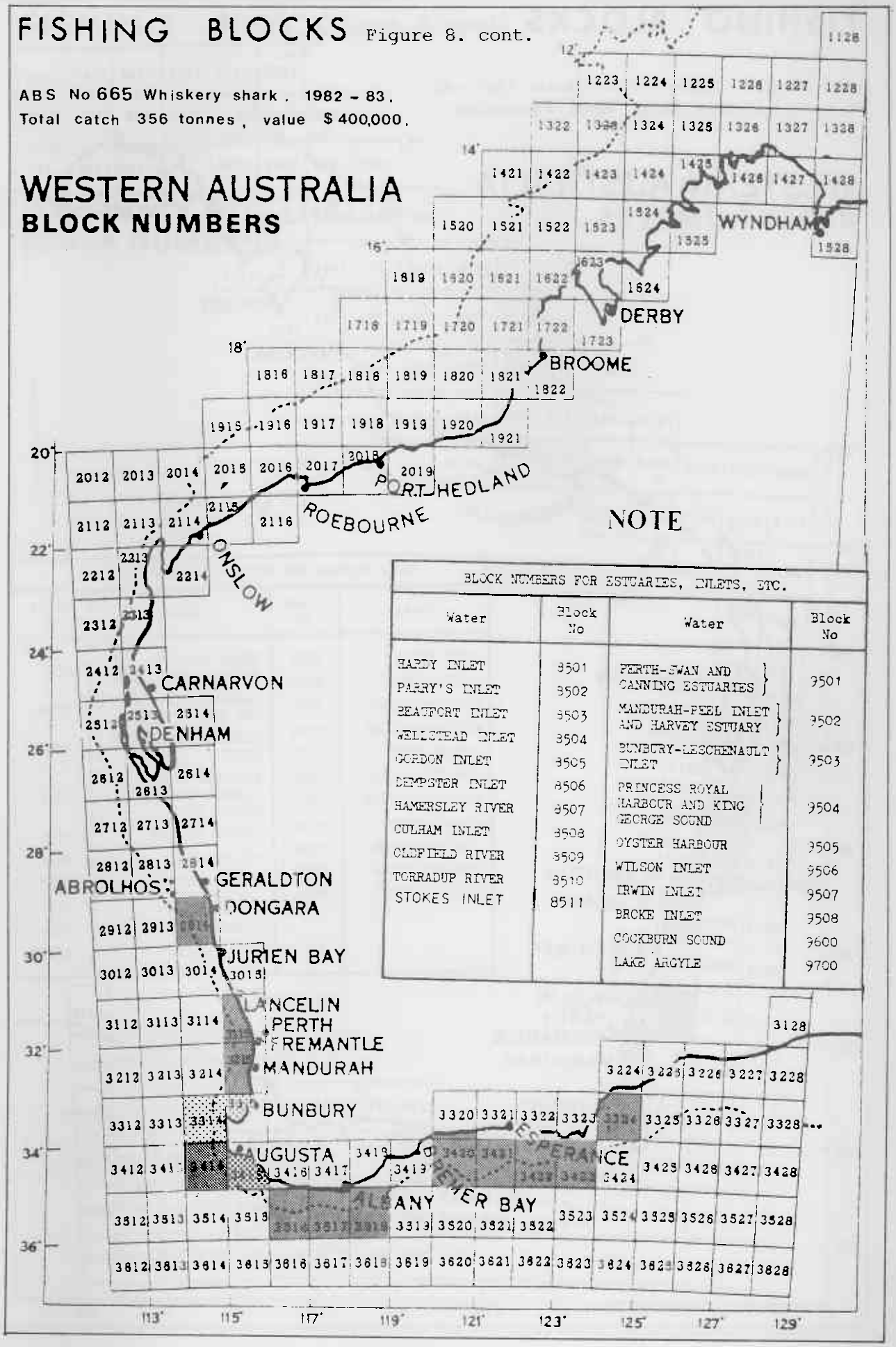
NOTE

BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502		
BEAUFORT INLET	8503	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
WELLSTEAD INLET	8504		
GORDON INLET	8505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	8506		
HAMERSLEY RIVER	8507	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
CULHAM INLET	8508		
OLDFIELD RIVER	8509	OYSTER HARBOUR	9505
TORRADUP RIVER	8510	WILSON INLET	9506
STOKES INLET	8511	IRWIN INLET	9507
		BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

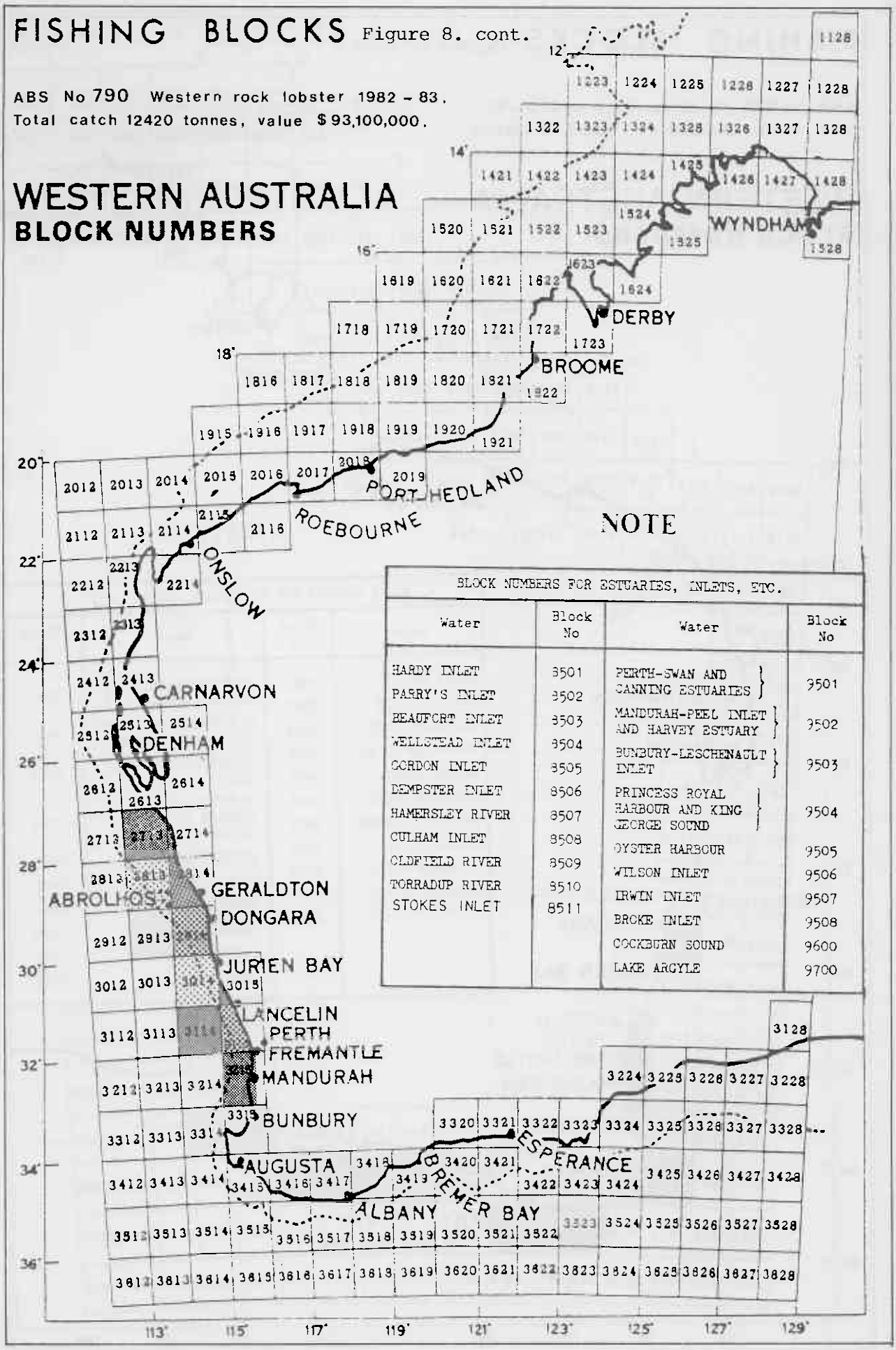
FISHING BLOCKS Figure 8. cont.

ABS No 665 Whiskery shark. 1982 - 83.
Total catch 356 tonnes, value $ 400,000.



FISHING BLOCKS Figure 8. cont.

ABS No 790 Western rock lobster 1982 - 83.
Total catch 12420 tonnes, value $93,100,000.



NOTE

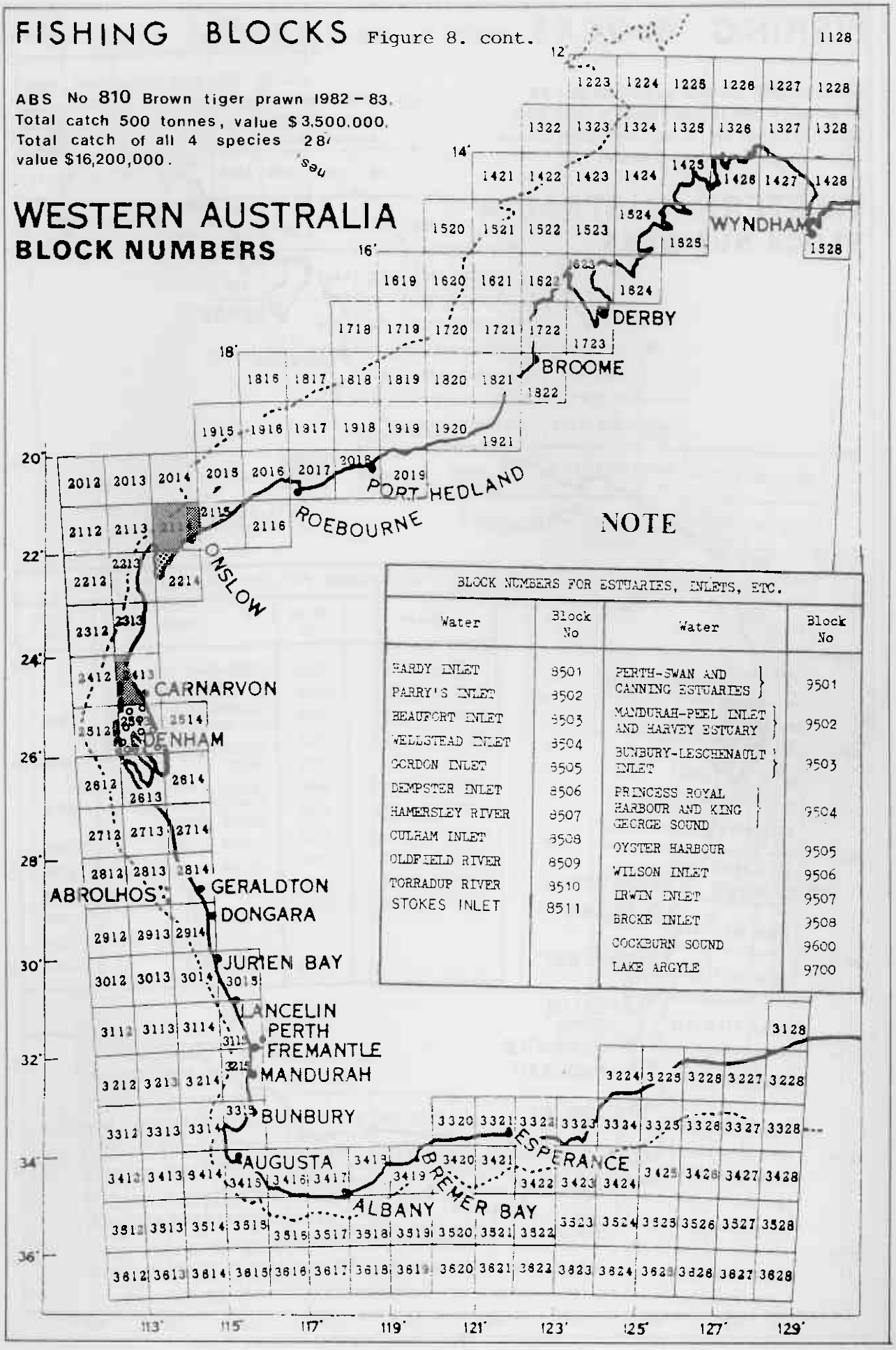
BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
BEAUFORT INLET	8503	BUNBURY-LESCHENAULT INLET	9503
WELLSTEAD INLET	8504	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
GORDON INLET	8505	OYSTER HARBOUR	9505
DEMPSTER INLET	8506	WILSON INLET	9506
HAMERSLEY RIVER	8507	IRWIN INLET	9507
CULHAM INLET	8508	BROKE INLET	9508
OLDFIELD RIVER	8509	COCKBURN SOUND	9600
TORRADUP RIVER	8510	LAKE ARGYLE	9700
STOKES INLET	8511		

FISHING BLOCKS Figure 8. cont.

ABS No 810 Brown tiger prawn 1982 – 83.
Total catch 500 tonnes, value $3,500,000.
Total catch of all 4 species 28
value $16,200,000.

WESTERN AUSTRALIA
BLOCK NUMBERS



NOTE

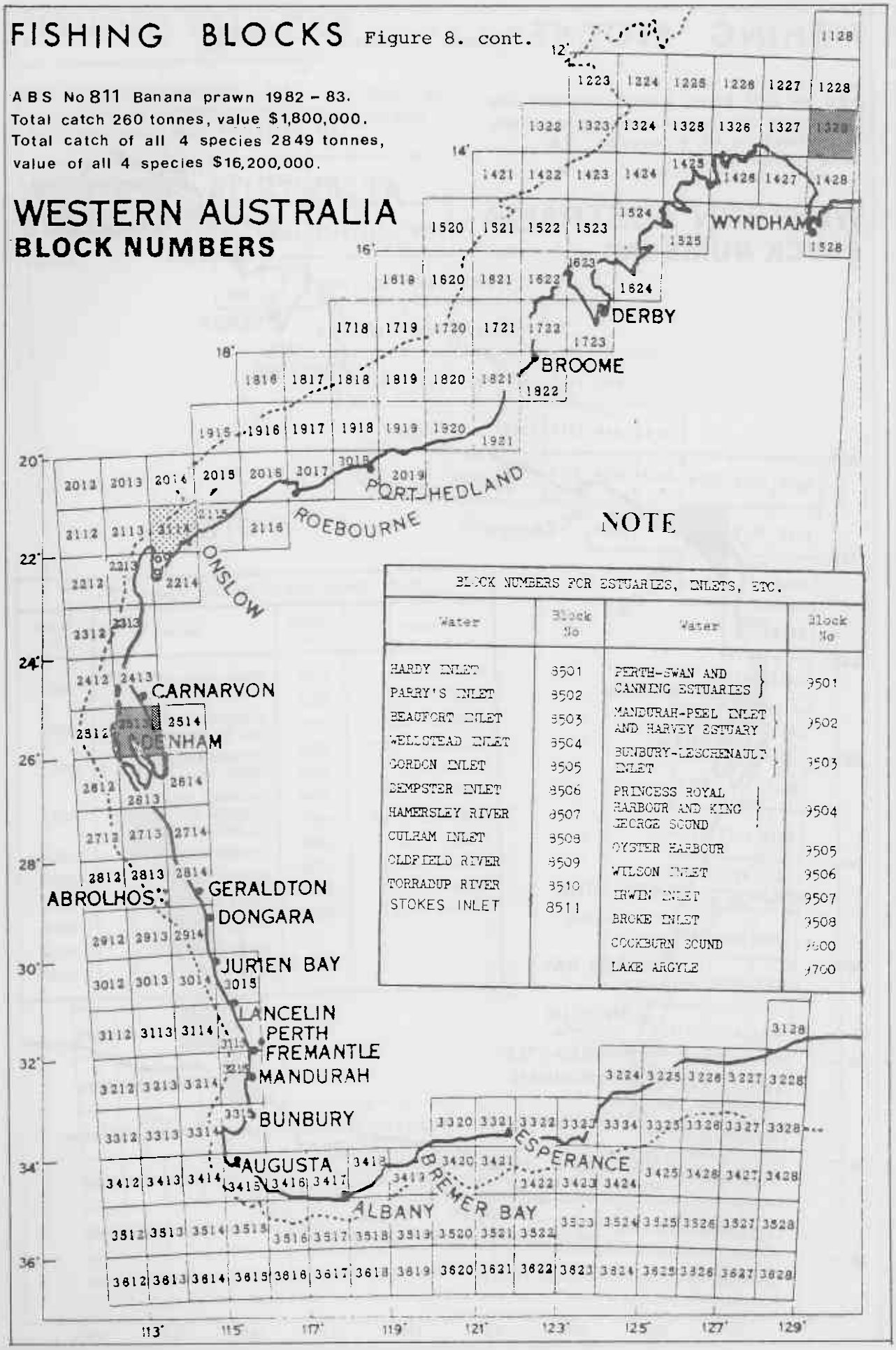
BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
BEAUFORT INLET	8503	BUNBURY-LESCHENAULT INLET	9503
WELLSTEAD INLET	8504	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
GORDON INLET	8505	OYSTER HARBOUR	9505
DEMPSTER INLET	8506	WILSON INLET	9506
HAMERSLEY RIVER	8507	IRWIN INLET	9507
CULHAM INLET	8508	BROKE INLET	9508
OLDFIELD RIVER	8509	COCKBURN SOUND	9600
TORRADUP RIVER	8510	LAKE ARGYLE	9700
STOKES INLET	8511		

FISHING BLOCKS Figure 8. cont.

A B S No 811 Banana prawn 1982 – 83.
Total catch 260 tonnes, value $1,800,000.
Total catch of all 4 species 2849 tonnes,
value of all 4 species $16,200,000.

WESTERN AUSTRALIA
BLOCK NUMBERS



NOTE

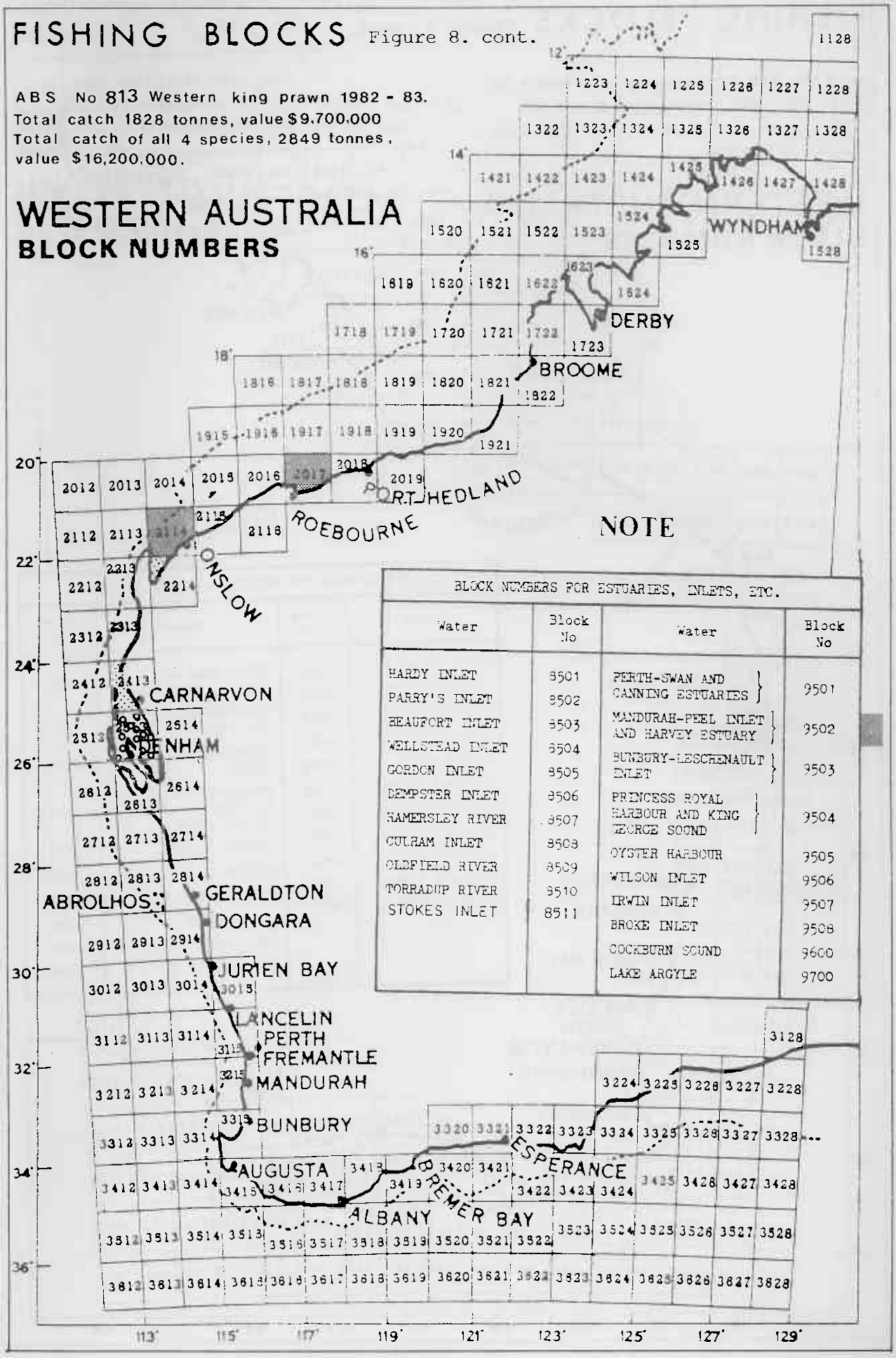
BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502		
BEAUFORT INLET	8503	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
WELLSTEAD INLET	8504		
GORDON INLET	8505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	8506	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
HAMERSLEY RIVER	8507		
CULHAM INLET	8508	OYSTER HARBOUR	9505
OLDFIELD RIVER	8509	WILSON INLET	9506
TORRADUP RIVER	8510	IRWIN INLET	9507
STOKES INLET	8511	BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS

Figure 8. cont.

ABS No 813 Western king prawn 1982 - 83.
Total catch 1828 tonnes, value $9,700,000
Total catch of all 4 species, 2849 tonnes,
value $16,200,000.



NOTE

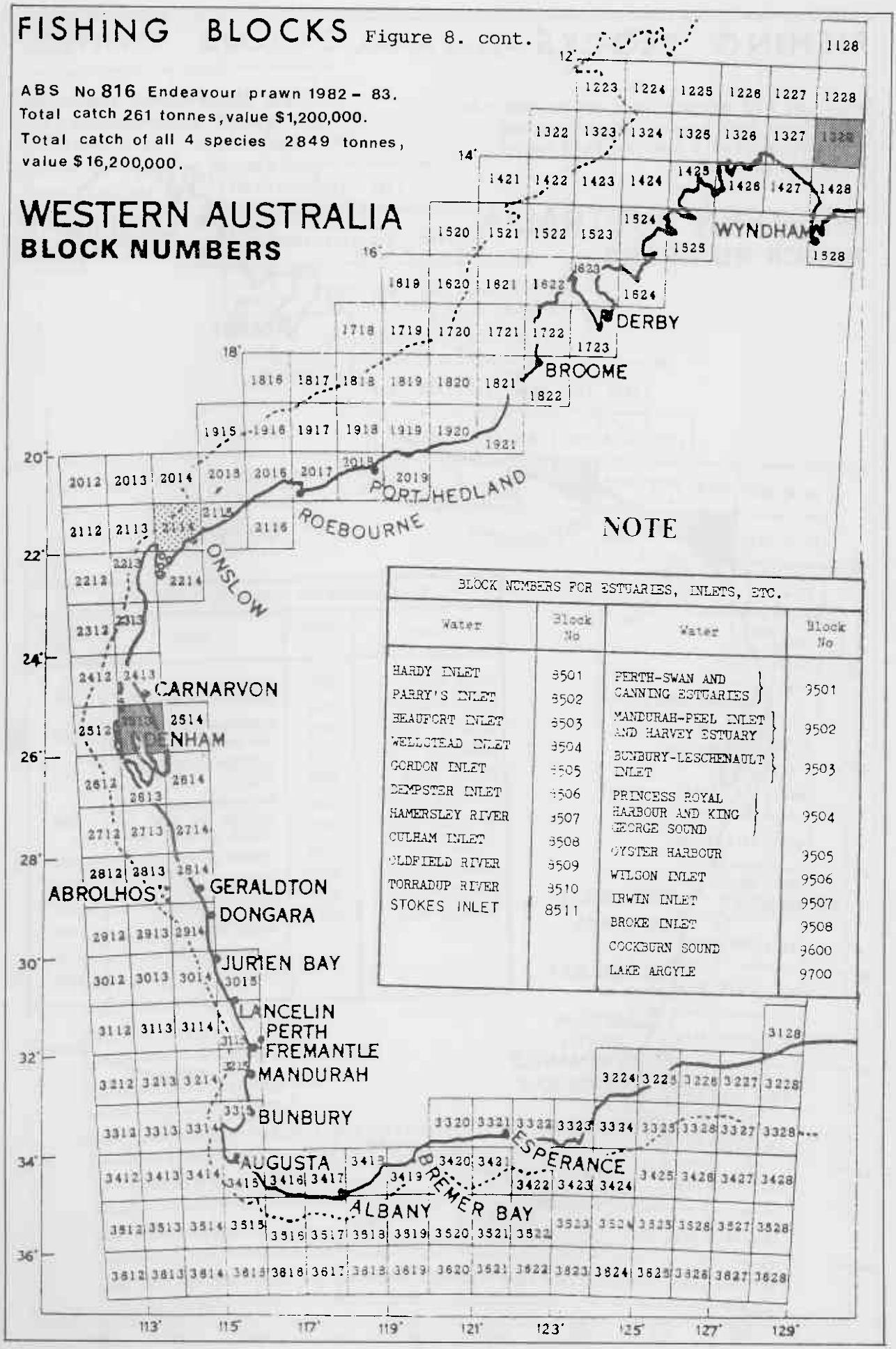
BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
BEAUFORT INLET	8503	BUNBURY-LESCHENAULT INLET	9503
WELLSTEAD INLET	8504	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
GORDON INLET	8505	OYSTER HARBOUR	9505
DEMPSTER INLET	8506	WILSON INLET	9506
HAMERSLEY RIVER	8507	IRWIN INLET	9507
CULHAM INLET	8508	BROKE INLET	9508
OLDFIELD RIVER	8509	COCKBURN SOUND	9600
TORRADUP RIVER	8510	LAKE ARGYLE	9700
STOKES INLET	8511		

FISHING BLOCKS Figure 8. cont.

ABS No 816 Endeavour prawn 1982 – 83.
Total catch 261 tonnes, value $1,200,000.
Total catch of all 4 species 2849 tonnes, value $16,200,000.

WESTERN AUSTRALIA
BLOCK NUMBERS



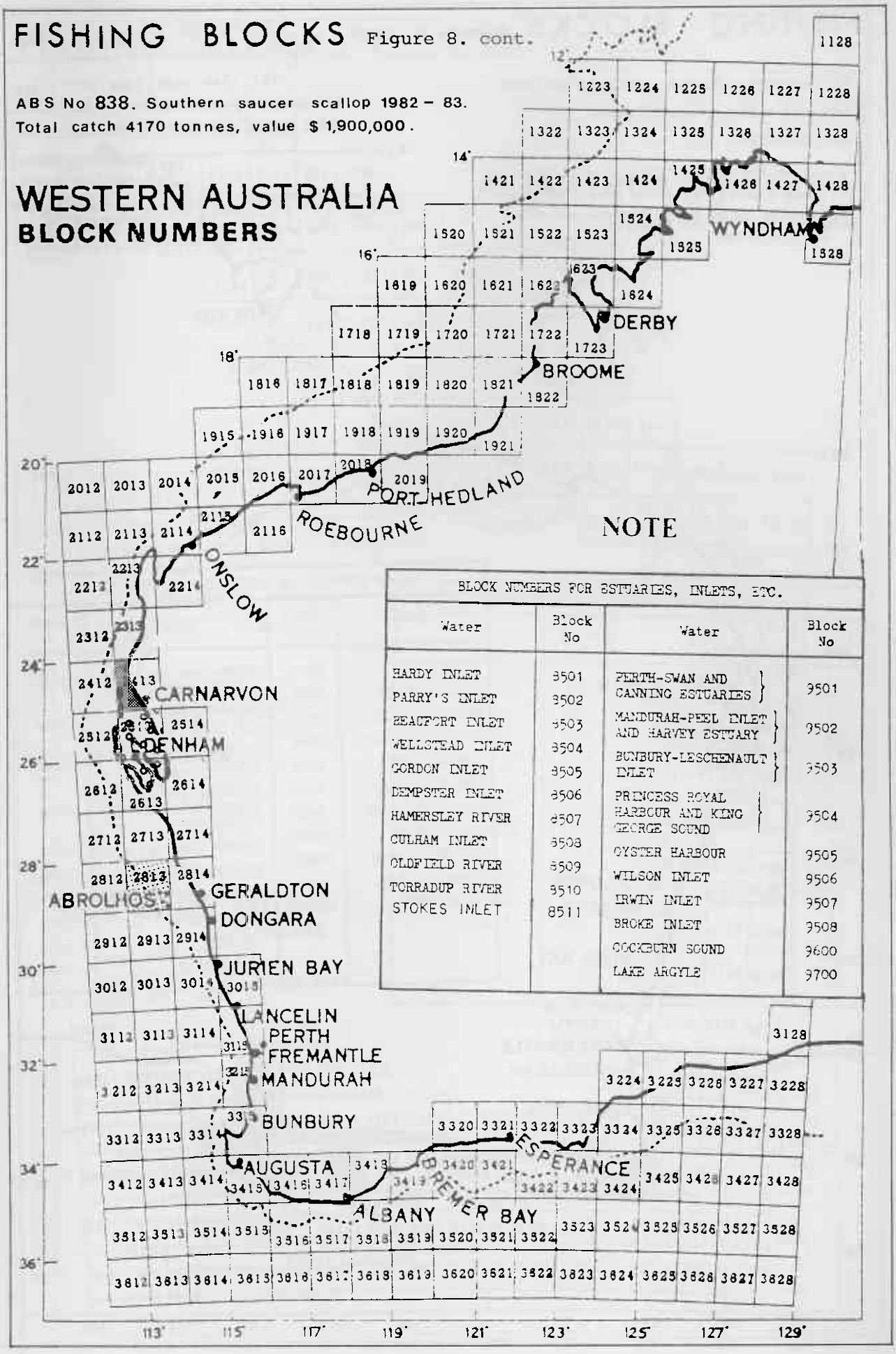
NOTE

BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
BEAUFORT INLET	8503	BUNBURY-LESCHENAULT INLET	9503
WELLSTEAD INLET	8504	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
GORDON INLET	8505	OYSTER HARBOUR	9505
DEMPSTER INLET	8506	WILSON INLET	9506
HAMERSLEY RIVER	8507	IRWIN INLET	9507
CULHAM INLET	8508	BROKE INLET	9508
OLDFIELD RIVER	8509	COCKBURN SOUND	9600
TORRADUP RIVER	8510	LAKE ARGYLE	9700
STOKES INLET	8511		

FISHING BLOCKS Figure 8. cont.

ABS No 838. Southern saucer scallop 1982 – 83.
Total catch 4170 tonnes, value $ 1,900,000.



NOTE

BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

Water	Block No	Water	Block No
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502		
BEACFORT INLET	8503	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
WELLSTEAD INLET	8504		
GORDON INLET	8505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	8506		
HAMERSLEY RIVER	8507	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
CULHAM INLET	8508		
OLDFIELD RIVER	8509	OYSTER HARBOUR	9505
TORRADUP RIVER	8510	WILSON INLET	9506
STOKES INLET	8511	IRWIN INLET	9507
		BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

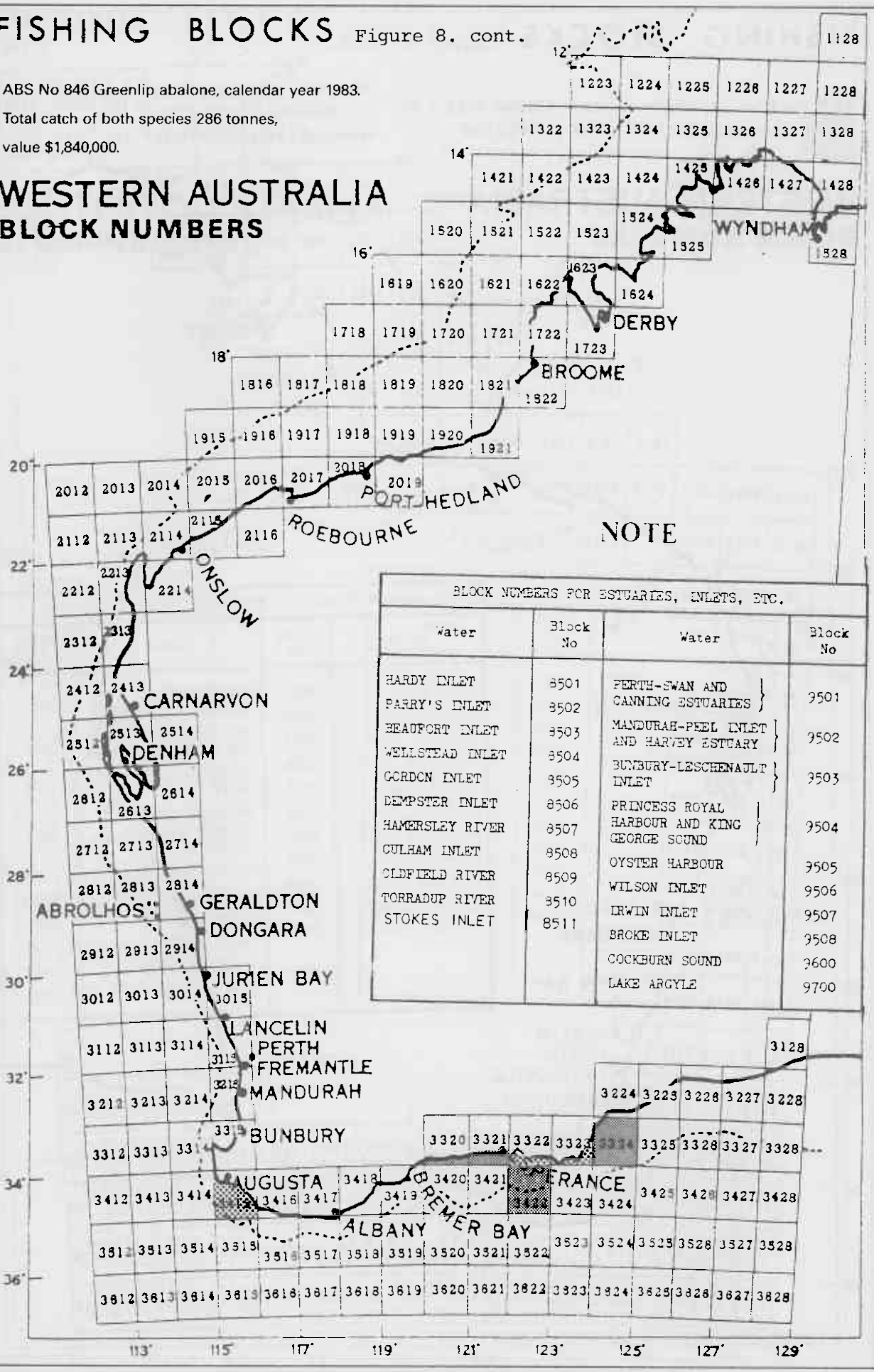
FISHING BLOCKS Figure 8. cont.

ABS No 846 Greenlip abalone, calendar year 1983.

Total catch of both species 286 tonnes,

value $1,840,000.

WESTERN AUSTRALIA
BLOCK NUMBERS



NOTE

BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

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HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502		
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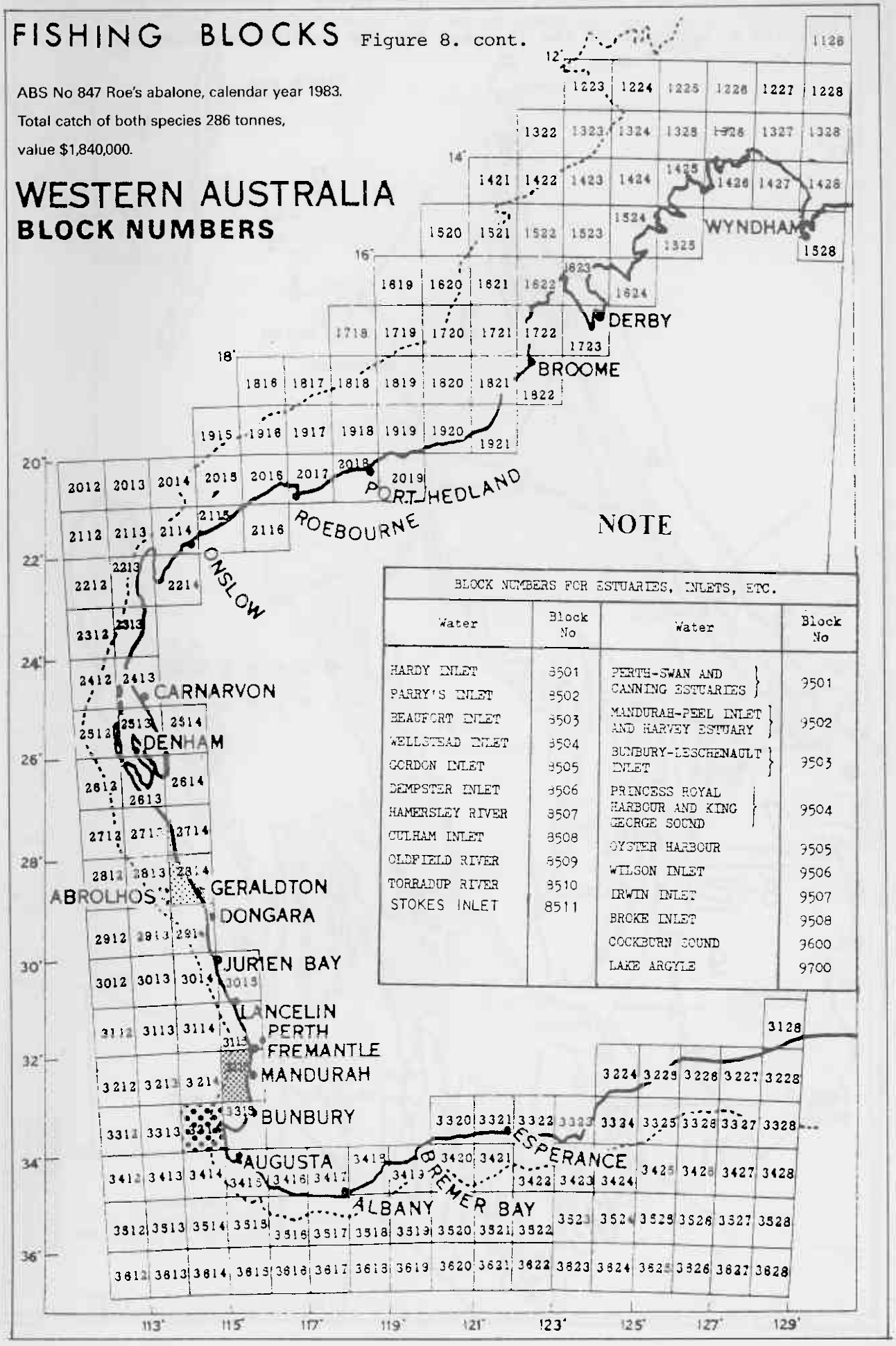
WELLSTEAD INLET	8504		
GORDON INLET	8505	BUNBURY-LESCHENAULT INLET	9503
DEMPSTER INLET	8506		
HAMERSLEY RIVER	8507	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
CULHAM INLET	8508		
OLDFIELD RIVER	8509	OYSTER HARBOUR	9505
TORRADUP RIVER	8510	WILSON INLET	9506
STOKES INLET	8511	IRWIN INLET	9507
		BROKE INLET	9508
		COCKBURN SOUND	9600
		LAKE ARGYLE	9700

FISHING BLOCKS Figure 8. cont.

ABS No 847 Roe's abalone, calendar year 1983.

Total catch of both species 286 tonnes,

value $1,840,000.



NOTE

BLOCK NUMBERS FOR ESTUARIES, INLETS, ETC.

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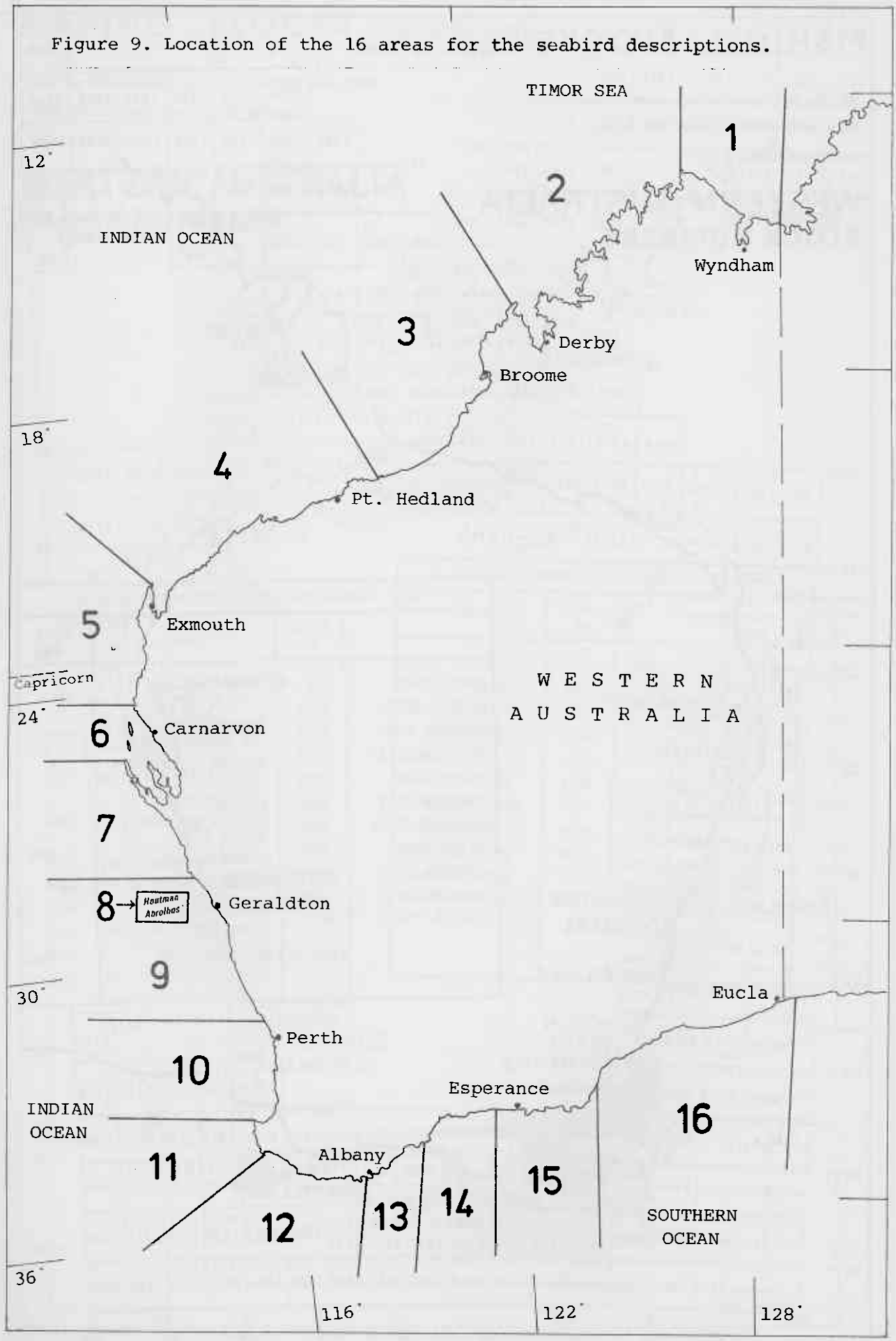
HARDY INLET	8501	PERTH-SWAN AND CANNING ESTUARIES	9501
PARRY'S INLET	8502	MANDURAH-PEEL INLET AND HARVEY ESTUARY	9502
BEAUFORT INLET	8503	BUNBURY-LESCHENAULT INLET	9503
WELLSTEAD INLET	8504	PRINCESS ROYAL HARBOUR AND KING GEORGE SOUND	9504
GORDON INLET	8505	OYSTER HARBOUR	9505
DEMPSTER INLET	8506	WILSON INLET	9506
HAMERSLEY RIVER	8507	IRWIN INLET	9507
CULHAM INLET	8508	BROKE INLET	9508
OLDFIELD RIVER	8509	COCKBURN SOUND	9600
TORRADUP RIVER	8510	LAKE ARGYLE	9700
STOKES INLET	8511		

Figure 9. Location of the 16 areas for the seabird descriptions.



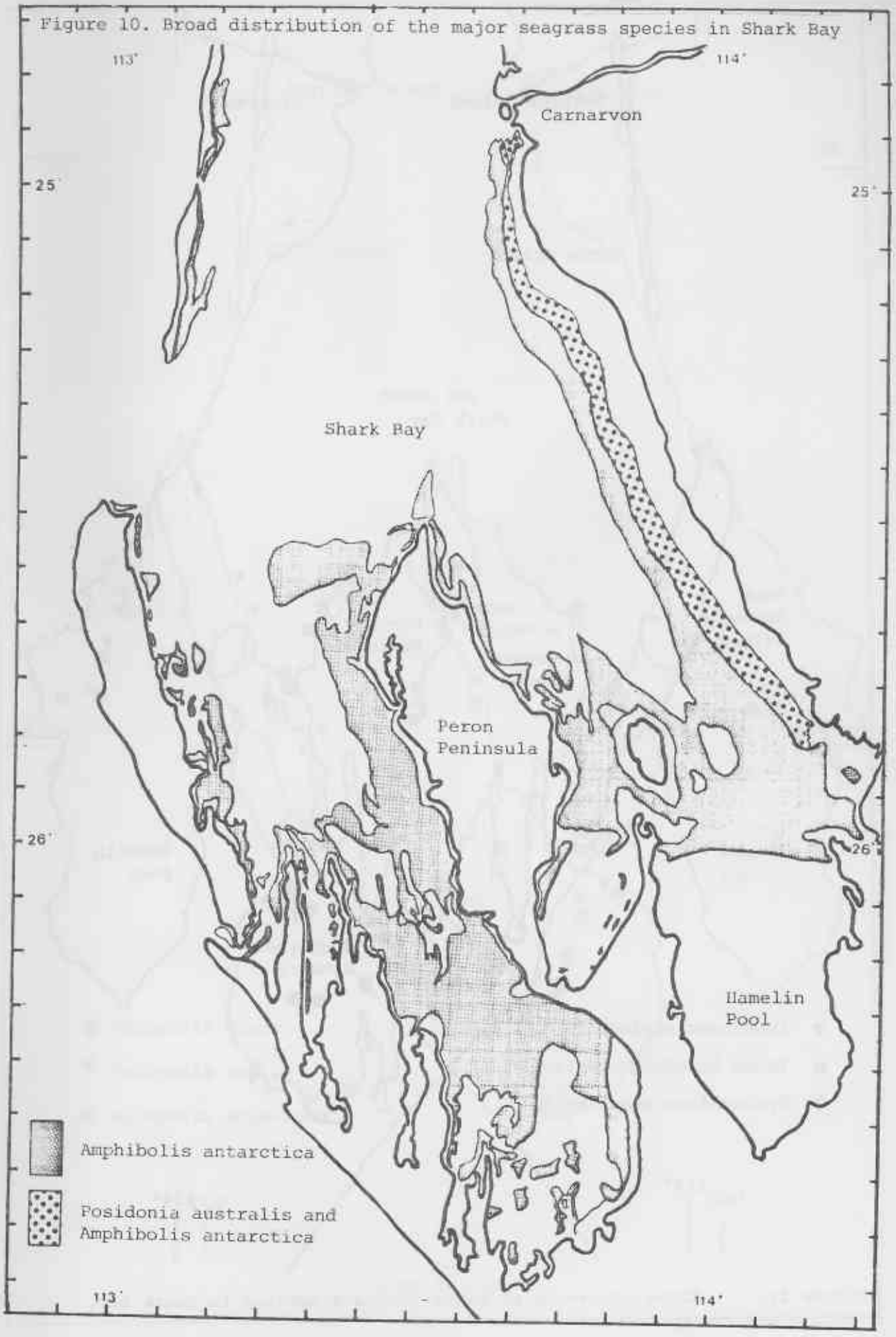


Figure 10. Broad distribution of the major seagrass species in Shark Bay
113°
114°
Carnarvon
25°
Shark Bay
Peron
Peninsula
26°
Hamelin
Pool
Amphibolis antarctica
Posidonia australis and
Amphibolis antarctica

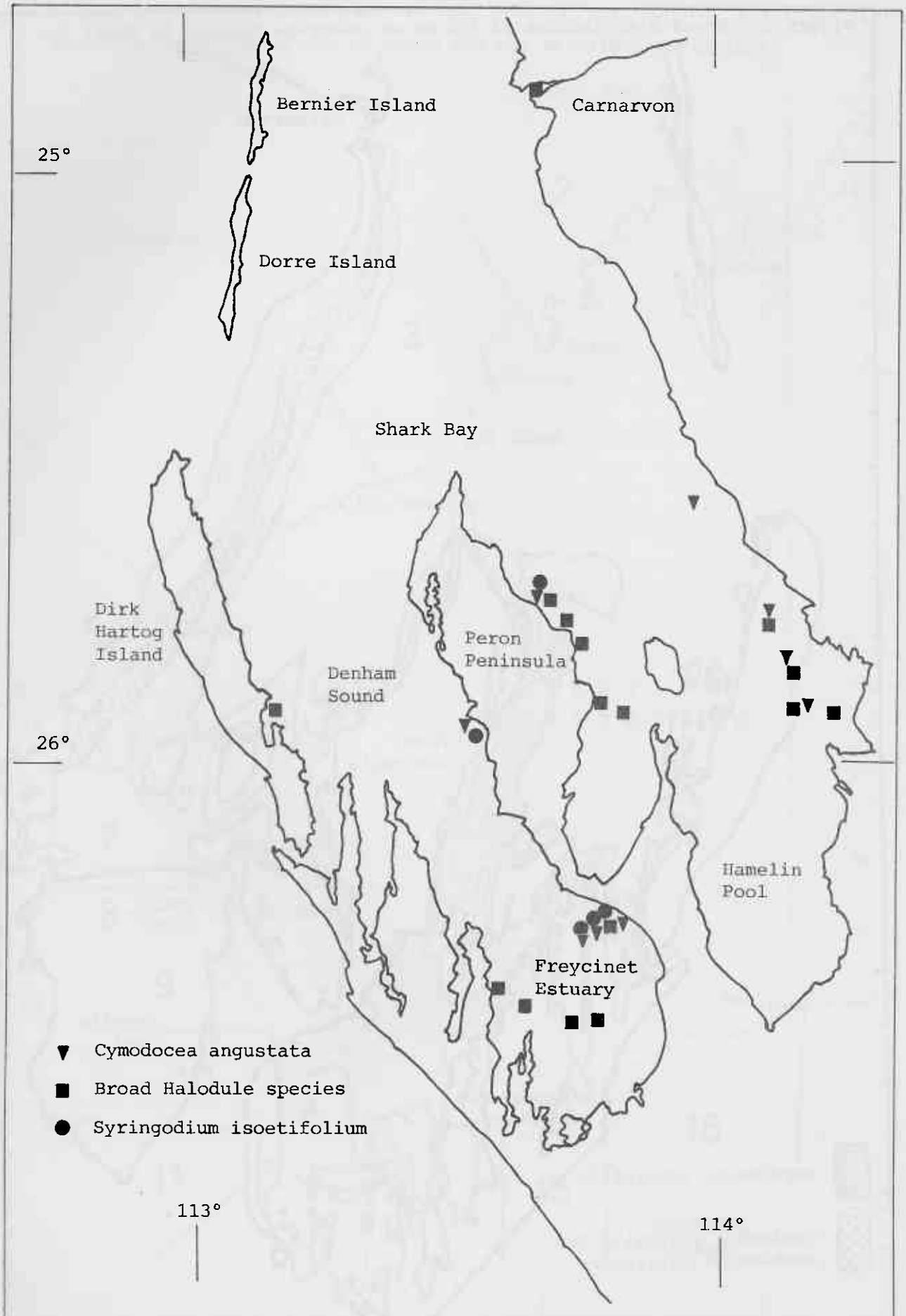


Figure 11. Known occurence of minor seagrass species in Shark Bay.

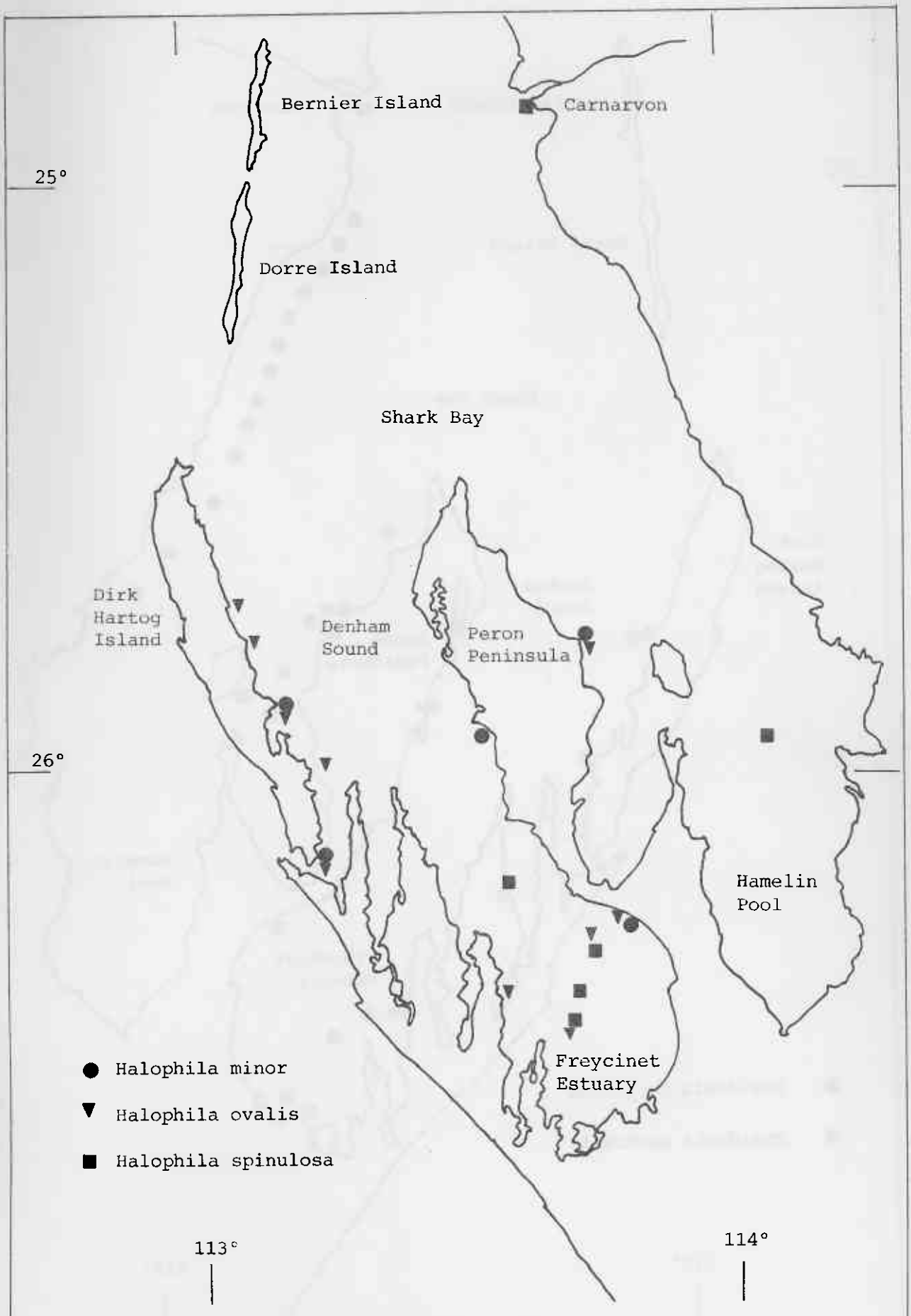


Figure 11. cont.

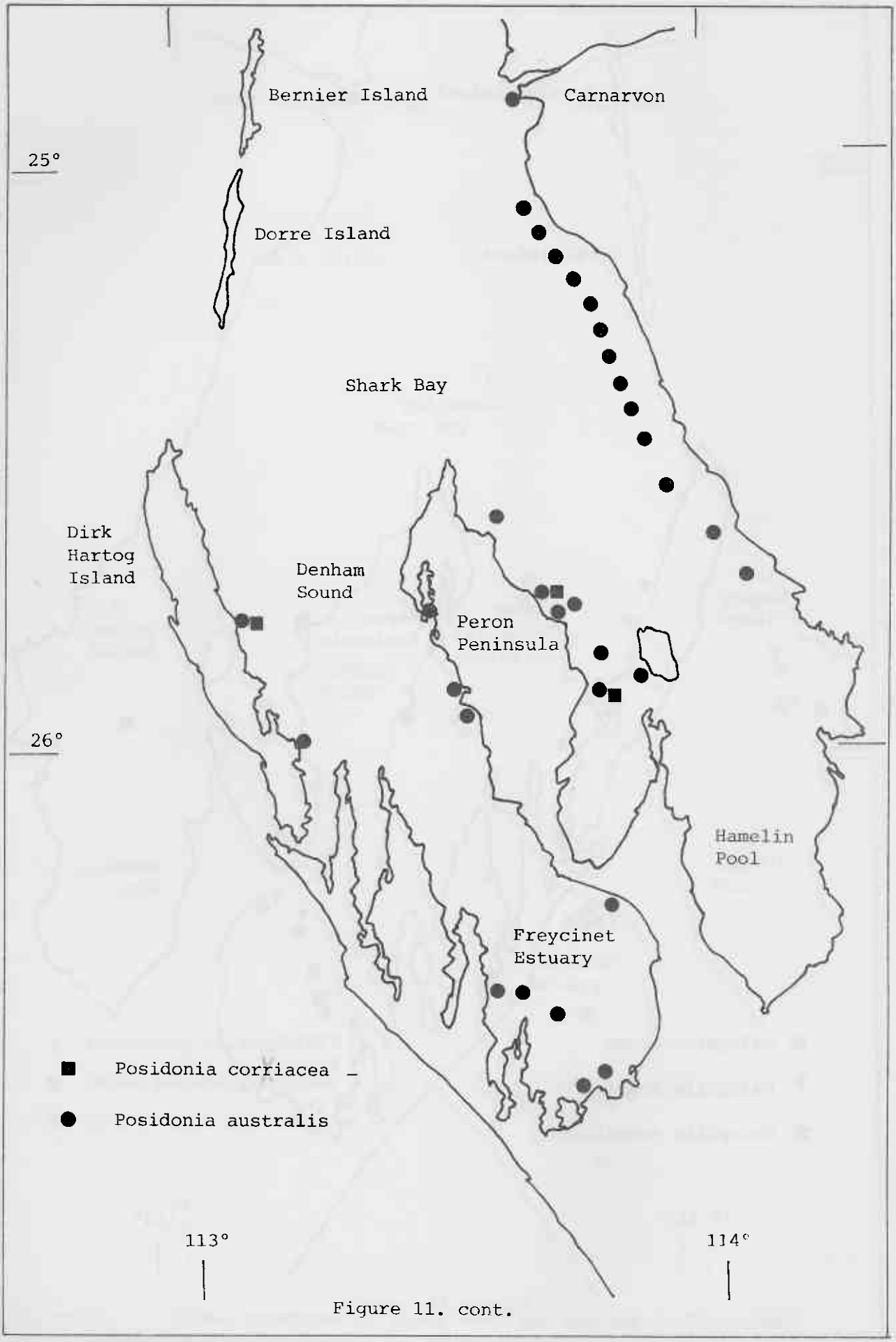


Figure 11. cont.