Western Australian Marine Stewardship Council Report Series
No. 8, 2017

Marine Stewardship Council Full Assessment Report Western Australian Abalone Managed Fishery

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Government of **Western Australia**
Department of **Fisheries**

Fish for the future

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Overview

This report provides a comprehensive description of the Abalone Managed Fishery (AMF) in Western Australia (WA) and contains information relevant to assist with the assessment of this fishery against the Marine Stewardship Council (MSC) standard (v2.0) for sustainable fishing. Fishers in the AMF harvest three species; Roe's abalone (*Haliotis roei*), Greenlip abalone (*H. laevigata*) and Brownlip abalone (*H. conicopora*), through hand collection by diving in shallow waters off the south-western and southern coasts of WA.

The first part of this document (Sections 1 – 6) provides an overview of the fishery and the aquatic environment in which it operates, including information about the biology of the target species, development of the fishery, fishing methods and gear used, the management system in place, and external factors that may influence fishery operations and / or target species populations. The remainder of document provides more detailed information for assessing the fishery against the performance indicators under MSC Principles 1, 2 and 3.

MSC Principle 1 (Sections 7 – 10) provides information to assess the status of the target species' stocks. These sections provide information on the current stock status of the three abalone species, which includes a description of the stock assessment approach and harvest strategies employed for ensuring the sustainability of these stocks. A summary of the management measures in place to ensure that the genetic structure of the wild abalone populations is not impacted by fishing or aquaculture activities is also provided.

MSC Principle 2 (Sections 11 – 15) relates to the impact of the AMF on the marine environment in which it operates. These sections include, or point to, all currently available information on bycatch species, interactions with endangered, threatened and protected (ETP) species, as well as a description of habitats and ecosystem within which the fishery operates, and a summary of fishery-related impacts on habitat and ecosystem structure and function. Where detailed quantitative data are not available, a risk assessment approach has been used to assess the level of risk associated with any identified fishery-specific issues. The issues identified and their associated risk ratings are provided throughout the Principle 2 sections, where relevant.

MSC Principle 3 (Sections 16 – 20) provides information to assess the governance and management in place for the AMF. Governance information provided includes an overview of the local, national and international legal frameworks relevant to the management of the fishery, a description of the roles, responsibilities and consultation processes undertaken with fishery stakeholders, the long-term objectives and the incentives in place for sustainable fishing. These sections also include information on the fishery-specific management system, including fishery-specific objectives, the decision-making process, compliance and enforcement, ongoing research and an evaluation of the performance of this management system in recent years.

Although this document has been divided into MSC Principle-specific sections, it should be considered in its entirety as many sections provide supporting and complementary information. While this document is intended to provide a comprehensive account of these fisheries, it is by no means meant to be the only source of information for assessing the fisheries. If there is uncertainty regarding any parts of the descriptions and information herein, stakeholders should contact the WA Department of Fisheries (DoF) so that any such issues can be addressed in subsequent updates of this document. This document should also be read in conjunction with the *Abalone Resource of Western Australia Harvest Strategy 2016 – 2021*.

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List of Abbreviations

AMF	Abalone Managed Fishery
AAC	Aquaculture Advisory Committee
AFMA	Australian Fisheries Management Agency
AFZ	Australian Fishing Zone
AIAWA	Abalone Industry Association of Western Australia
AIMS	Australian Institute of Marine Science
AMM	Annual Management Meetings
AQWA	Aquarium of Western Australia
ARMA	Aquatic Resource Management Act
ARMS	Aquatic Resource Management Strategy
ARUP	Aquatic Resource Use Plan
CAES	Catch and Effort Statistics
CALM	Conservation and Land Management
CoA	Commonwealth of Australia
CDR	Catch Disposal Record
CEO	Chief Executive Officer
CITES	Convention on International Trade in Endangered Species
CPUE	Catch Per Unit Effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CWCE	Central West Coast Ecosystem
DEC	Department of Environment and Conservation
DEH	Department of Environment and Heritage
DEWHA	Department of Environment, Water, Heritage and the Arts
DG	Director General
DotE	Commonwealth Department of the Environment
DoF	Western Australian Department of Fisheries
DPaW	Department of Parks and Wildlife
DPC	Daily Patrol Contact
EBFM	Ecosystem Based Fisheries Management
EMS	Environmental Management Services
ENSO	El Niño/Southern Oscillation

EPA	Environmental Protection Authority
EPBC	Environment, Protection and Biodiversity Conservation
ERA	Ecological Risk Assessment
ESD	Ecological Sustainable Development
ETP	Endangered, Threatened and Protected Species
EUC	Eucla
FHPA	Fish Habitat Protection Areas
FMA	*Fisheries Management Act 1991*
FMP	Fisheries Management Papers
FMO	Fisheries and Marine Officers
FOP	Fisheries Occasional Papers
FRDC	Fisheries Research and Development
FRMA	Fish Resources Management Act
FRMR	*Fish Resources Management Regulations 1995*
GFC	Global Financial Crisis
GCB	Gascoyne Coast Bioregion
GLM	Generalised Linear Model
GPS	Global Positioning System
GVP	Gross Value of Production
IFAAC	Integrated Fisheries Advisory Allocation Committee
IQ	Individual Quota
IUCN	International Union for the Conservation of Nature
IFM	Integrated Fisheries Management
ITQ	Individual Transferable Quota
LADS	Laser Airborne Depth Survey
LC	Least Concern
LENS	List of Exempt Native Specimens
LNG	Liquefied Natural Gas
MAC	Management Advisory Committee
MCS	Monitoring, Control and Surveillance
MPG	Ministerial Policy Guidelines
MPRA	Marine Parks and Reserves Authority

MoU	Memorandum of Understanding
MSC	Marine Stewardship Council
NCB	North Coast Bioregion
NCMP	Ngari Capes Marine Park
NGO	Non-Government Organisation
NSW	New South Wales
OCP	Operational Compliance Plan
OCS	Offshore Constitutional Settlement
PAP	Prosecution Advisory Panel
PER	Public Environmental Review
RFBL	Recreational Fishing from Boat Licence
RFW	Recfishwest
RMAD	Research, Monitoring, Assessment and Development (Plan)
RSD	Regional Services Division
SAT	State Administrative Tribunal
SCB	South Coast Bioregion
SCE	South Coast Ecosystem
SCPUE	Standardised Catch Per Unit Effort
SHL	Sustainable Harvest Level
SOF	State of Fisheries Report
SSBA	Surface Supplied Breathing Apparatus
TACC	Total Allowable Commercial Catch
TAE	Total Allowable Effort
UoA	Unit of Assessment
UoC	Unit of Certification
VMS	Vessel Monitoring System
WA	Western Australia
WAFIC	Western Australian Fishing Industry Council
WAMSI	Western Australian Marine Science Institute
WCB	West Coast Bioregion
WTO	Wildlife Trade Operation

1 Background to MSC Initiative

In March 2012, the (then) Western Australian (WA) Minister of Fisheries announced that the State Government had committed to a four-year program to seek third-party sustainability certification for WA's commercial fisheries. This initiative has involved all WA commercial fisheries being put through the pre-assessment stage of the Marine Stewardship Council (MSC) certification process. Funding is also available to support the certification process for those fisheries that choose to move to a full MSC assessment.

This document provides a cumulative description of the AMF in WA for assessment against the MSC Principles and Criteria for Sustainable Fishing. There are three units of certification (UoC) included in this document for assessment, as follows:

UoC 1: Abalone Managed Fishery

Species:	Roe's abalone (*Haliotis roei*)
Geographical Area:	West and South Coast of WA (South of Moore River, Areas 1, 2, 5, 6 and 7 of the AMF)
Method of Capture:	Hand collection

UoC 2: Abalone Managed Fishery

Species:	Greenlip abalone (*Haliotis laevigata*)
Geographical Area:	South Coast of WA (Areas 1, 2, and 3 of the AMF)
Method of Capture:	Hand collection

UoC 3: Abalone Managed Fishery

Species:	Brownlip abalone (*Haliotis conicopora*)
Geographical Area:	South Coast of WA (Areas 1, 2, and 3 of the AMF)
Method of Capture:	Hand collection

2 Aquatic Environment

With the adoption of the ecosystem-based fisheries management (EBFM) approach, the Department of Fisheries (DoF) utilises a bioregional structure to manage the waters of WA. A 'bioregion' refers to a region defined by common oceanographic characteristics in its marine environment or by climate / rainfall characteristics in its inland river systems (Fletcher and Santoro 2015). The DoF identifies four major marine bioregions in WA (Figure 2.1):

1. North Coast Bioregion (NCB);
2. Gascoyne Coast Bioregion (GCB);
3. West Coast Bioregion (WCB); and
4. South Coast Bioregion (SCB).

Each bioregion is further subdivided into one or more meso-scale ecosystems (Figure 2.1), based on those ecosystems defined by the Commonwealth Government's Integrated Marine and Coastal Regionalisation of Australia (IMCRA v4.0)[1].

Although the AMF extends across the whole state of WA, from South Australia to the Northern Territory border, abalone occur mostly in the WCB and SCB. Roe's abalone are most abundant on the south-west coast around Perth and Cape Naturaliste, whilst Greenlip and Brownlip abalone are caught primarily on the south coast of WA.

1 http://www.environment.gov.au/coasts/mbp/publications/imcra/pubs/imcra4.pdf

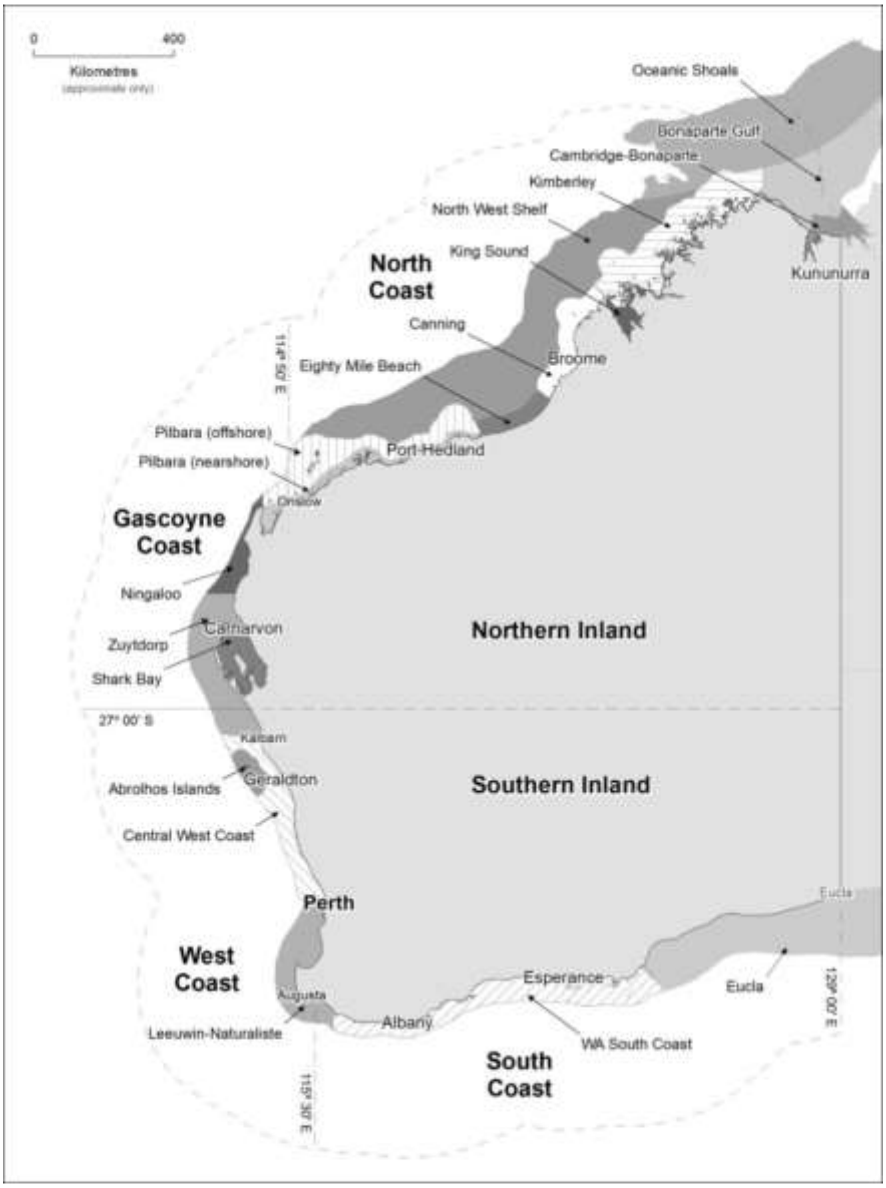


Figure 2.1. Map of WA showing general boundaries of the Departmental management bioregions and meso-scale ecosystems based on IMCRA v4.0 boundaries (Source: Fletcher and Santoro 2015)

2.1 West Coast Bioregion

The marine environment of the WCB between Kalbarri 27.7° S 114.16° E) and Augusta (34.310° S and 115.16° E) is predominantly a temperate oceanic zone, but it is heavily influence by the Leeuwin Current, which transports warm, tropical water southward along the edge of the continental shelf. Coastal water temperatures range from 18° C to about 24° C, which are generally higher than would be expected at these latitudes due to the current's influence. The Leeuwin Current is also responsible for the existence of the unusual Houtman Abrolhos Islands' coral reefs (at 29° S) and the extended southward distribution of many tropical species along the west and south coasts.

From a global perspective, the WCB is generally characterised by low levels of nutrients and high species diversity, including a large number of endemic species.

The WCB is characterised by exposed sandy beaches and a limestone reef system that creates surface reef lines, often about five kilometres off the coast. Further offshore, the continental shelf habitats are typically composed of coarse sand interspersed with low limestone reef associated with old shorelines. A significant impact of the clear, warm, low-nutrient waters of the Leeuwin Current is on the growth and distribution of the temperate seagrasses. These form extensive meadows in protected coastal waters of the bioregion, generally in depths of 20 m (but up to 30 m), and act as major nursery areas for many fish species.

Biological communities are mainly comprised of temperate species, which mix with tropical species in the northern regions of the WCB. The WCB has medium to high species diversity and is one of the global hotspots for endemism. The high number of endemic species in the bioregion is partly the product of the long period (the last 80 million years) during which the marine flora and fauna in the area have been isolated from species occurring around other land masses (CoA 2008).

2.2 South Coast Bioregion

The SCB extends east from Augusta (34.310° S, 115.16° E) to the South Australian border (see Figure 2.1).

The shelf waters of the SCB are generally temperate but low in nutrients, due to the seasonal winter presence of the tail of the tropical Leeuwin Current and limited terrestrial run-off. Sea surface temperatures typically range from approximately 15° C to 21° C, which is warmer than would normally be expected in these latitudes due to the influence of the Leeuwin Current. The effect of the Leeuwin Current, particularly west of Albany, limits winter minimum temperatures (away from terrestrial effects along the beaches) to about 16 to 17° C. Fish stocks in this region are predominantly temperate, with many species' distributions extending across southern Australia. Tropical species are occasionally found, although they are unlikely to form breeding populations.

The SCB is a high-energy environment and is heavily influenced by large swells generated in the Southern Ocean. The coastline from Cape Leeuwin to Israelite Bay is characterised by white sand beaches separated by high granite headlands. East of Israelite Bay, there are long sandy beaches backed by large sand dunes, until replaced by high limestone cliffs at the South Australian border. There are few large areas of protected water along the South Coast, the exceptions being around Albany and in the Recherche Archipelago off Esperance.

The marine habitats of the SCB are similar to the coastline, having fine, clear sand sea floors interspersed with occasional granite outcrops and limestone shoreline platforms and sub-surface reefs. A mixture of seagrass and kelp habitats occurs along the SCB, with seagrass more abundant in protected waters and some of the more marine estuaries. The kelp habitats are diverse but are dominated by the relatively small *Ecklonia radiata*, rather than the larger kelps expected in these latitudes where waters are typically colder and have higher nutrient levels (Fletcher and Santoro 2015). The benthic invertebrate communities found in the eastern part of the SCB, particularly sponges, ascidians and bryozoans, are among the world's most diverse in soft sediment ecosystems (CoA 2008).

3 Fishery Information

3.1 Abalone Managed Fishery

3.1.1 Fishery Development

Commercial fishing for abalone in WA has been undertaken since 1964. The fishery initially focused on harvesting of the Roe's abalone stocks off the Perth metropolitan area but expanded in 1969 to also target Greenlip abalone. Following this early phase of the fishery, when annual catches of each species were typically < 20 tonnes (whole weight), a substantial increase in catches was evident in 1970. The fishery peaked in 1971, with a total catch of the two species of 450 tonnes and has declined to a relatively stable level since around 1975. The first catches of Brownlip abalone were recorded in 1984 (Hart et al. 2013a).

A historical outline of key management changes in the AMF is provided in Appendix A. The first set of effort controls and minimum size limits were introduced in 1971 in response to the rapid escalation of catch and effort. The initial licences were non-transferable and owner-operated, which was designed to limit further expansion of the AMF. Formal spatial management was first introduced in 1975, with the creation of three management zones in the AMF. Zones 1 and 2 were primarily for the management of Greenlip and Brownlip abalone and Zone 3 for Roe's abalone. Total Allowable Commercial Catches (TACCs) were first introduced in the fishery as non-transferrable Individual Quota (IQ) for Zone 1 in 1975, and subsequently in Zone 2 in 1986 and Zone 3 in 1988. The initial TACC levels for Greenlip and Brownlip abalone were not deemed sustainable and were therefore reduced in 1990 (Hart et al. 2013a).

In 1999 the AMF was divided into eight new spatial areas, each with its own TACC. These new management arrangements were particularly important for Roe's abalone as they enabled fishing effort to be more evenly spread across the fishery. As the TACCs became unitised and transferable, significant trading of quota units could be undertaken between licence holders. The development of performance indicators and formal decisions rules for informing the annual TACC setting process were first introduced between 2005 and 2009 and have recently been revised (Hart et al. 2013a).

3.1.2 Current Fishing Activities

The AMF is a dive fishery, operating in shallow coastal waters along southern and western coasts of WA. The AMF covers all WA coastal waters of the Southern Ocean, Indian Ocean and Timor Sea between the Northern Territory and South Australian border and is divided into eight management areas (Figure 3.1). Although the area of the AMF is extensive, only a small portion of the area forms the functional fishery. Greenlip and Brownlip abalone are caught primarily on the south coast of WA (Areas 1, 2 and 3), whilst Roe's abalone are most abundant on the south-west coast (Areas 6 and 7).

There are currently 52 managed fishery licences in the AMF, with 29 licences endorsed to take Roe's abalone and 23 endorsed to take Greenlip and Brownlip abalone. There are 30 vessels used in the AMF; 12 of which target all three abalone species, 10 targeting only Roe's abalone and eight targeting only Greenlip and Brownlip abalone. The dispersed nature of the AMF means that small coastal towns receive income from the activities of the divers (Hart et al. 2013a).

Figure 3.1. Boundaries of management areas of the commercial Abalone Managed Fishery in WA. The Greenlip/Brownlip fishery operates in Areas 1-4 and the Roe's fishery operates in Areas 1, 2, 5, 6, 7 and 8

3.1.3 Fishing Methods

The AMF is a hand collection fishery. Harvest is carried out by divers utilising surface supplied breathing apparatus (SSBA or 'hookah') attached to a small vessel, generally less than 9 m in length (Figure 3.2). The vessel tows the divers slowly over the abalone reefs, and they harvest legal-sized abalone by hand as they are encountered. Animals are prised from the rock surfaces with an implement known as an 'abalone iron' and divers often use an underwater scooter or other motorised device such as a shark cage, to increase their efficiency and reduce fatigue from continuously swimming. Abalone are stored in large catch bags, and when it is full or the maximum bottom time for the diver has been reached (to avoid risk of the bends), the diver fills a lift bag on his equipment with air, and the unit rises to the surface. A pulley system is used to hoist the catch and equipment onto the vessel, where the abalone are counted and measured.

Fishing operations are heavily weather dependent due to the small vessels used and the potentially hazardous conditions (waves, swells, etc.) encountered. Fishing is largely confined to daylight hours and is usually completed close to shore (or offshore islands) as abalone tends to inhabit shallow water (1 – 20 m depth). Fishers do not remain overnight on board a vessel, as each day's catch mush be weighed and recorded in a Catch Disposal Record (CDR). The fishing method is species-specific with no bycatch being taken and animals are measured *in situ* prior to harvest.

For practical purposes, Greenlip and Brownlip abalone may be shucked (i.e. animals removed from the shell with the gut removed and discarded) at sea and packed into saltwater filled containers. The Department requires that the shell from these animals is kept in bags and available for inspection until the meat arrives at an approved processor. Upon arrival at shore, the weight of the catch is determined, and CDRs are completed for research and compliance purposes. The animals are then transported to the processor for weighing, cleaning, and packaging.

(a) (b)

Figure 3.2. Abalone fishing vessel (a) and abalone diver (b)

3.1.4 Catch and Effort

3.1.4.1 Roe's Abalone

The first recorded commercial catch of abalone in WA was taken from the Perth metropolitan stocks of Roe's abalone in 1964. The catches of this species peaked at 170 tonnes (whole weight) in 1971, before declining to a relatively constant level of around 100 tonnes between 1980 and 2010 (Figure 3.3). Recreational catch of Roe's abalone, currently comprises around 30% of the total catch of the species. Recreational catch estimates are available since 1992, however, considerable recreational catch also occurred in the 1980s (Figure 3.3). The decline in catch of Roe's abalone over the past five years has generally been attributed to environmental factors; with a marine heatwave in south-western Australian waters in 2010/11 causing mass mortalities of this species in the northernmost part of its distribution (see Section 6.4 for more information).

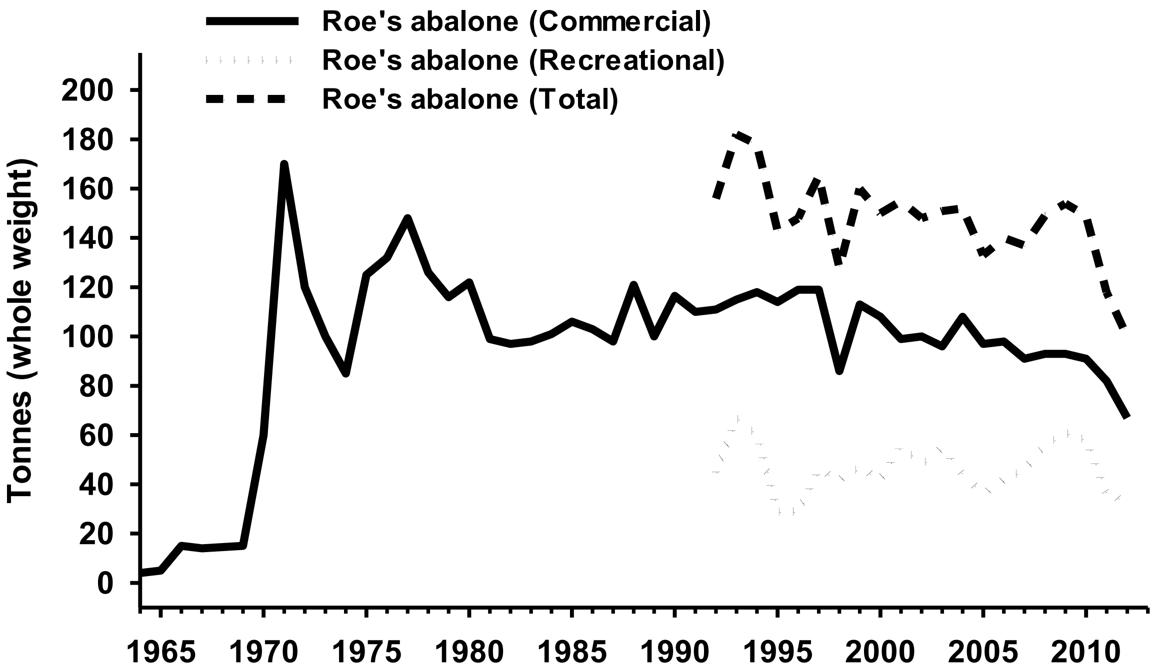


Figure 3.3. Historical commercial and recreational catches (tonnes whole weight) of Roe's abalone in WA

Commercial fishing for Roe's abalone currently occurs in Areas 1, 2, 5, 6, and 7 of the AMF. Roe's abalone are collected along the west and south coasts of WA, with the majority of catches coming from the Perth metropolitan area (Area 7) and the Capes region (Area 6) (Figure 3.4). The area north of Moore River (Area 8) has been closed to all abalone fishing since 2011.

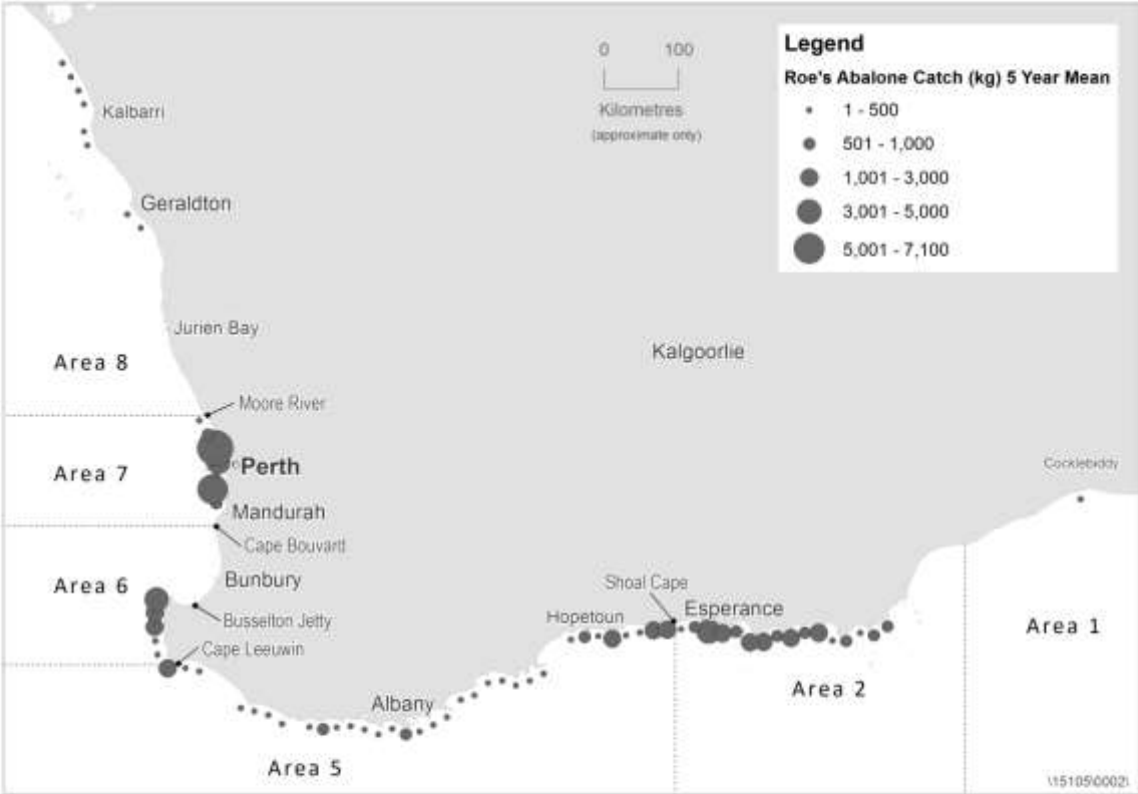


Figure 3.4. Spatial distribution of the average annual catches (in kg) of Roe's abalone in the AMF between 2009 and 2014

3.1.4.2 Greenlip and Brownlip Abalone

Commercial Greenlip abalone catches peaked at 270 tonnes (whole weight) in the first year of the fishery (1971) and oscillated between 150 and 270 tonnes during the 1970s and 1980s (Figure 3.5). With the introduction of a TACC in 1990, catches dropped and have been at lower levels ever since, averaging around 190 tonnes (Figure 3.5). Initially the catch was predominately Greenlip abalone, however, considerable amounts of Brownlip abalone have been caught since 1985 (Figure 3.5). Since 2013, the catches of Greenlip abalone have declined significantly as a consequence of TACC reductions in the fishery taken in response to low stock levels (see Section 7.1.2).

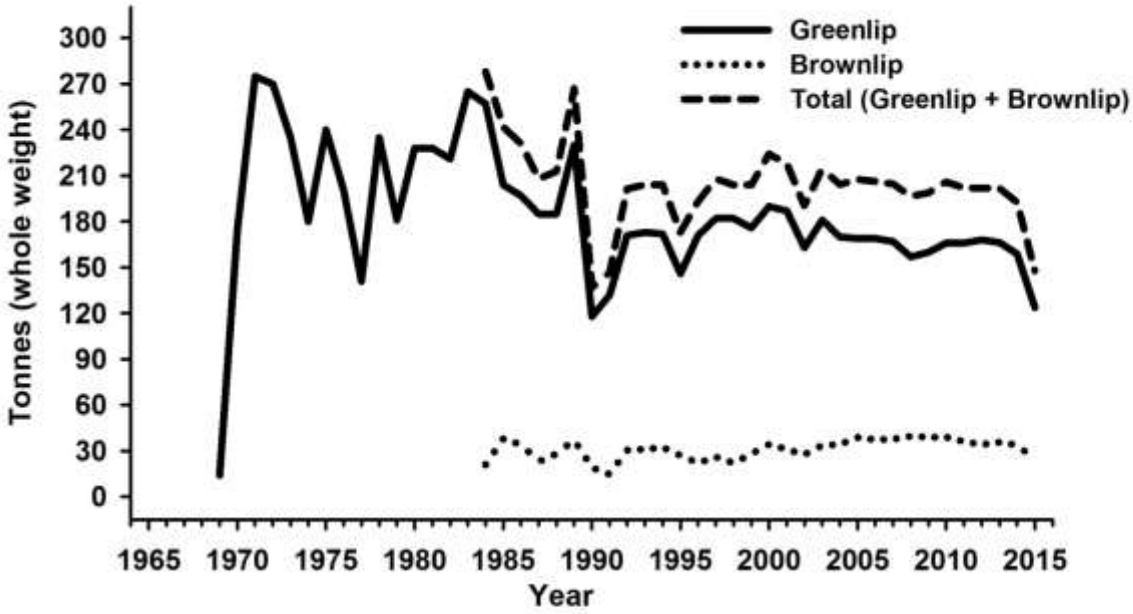
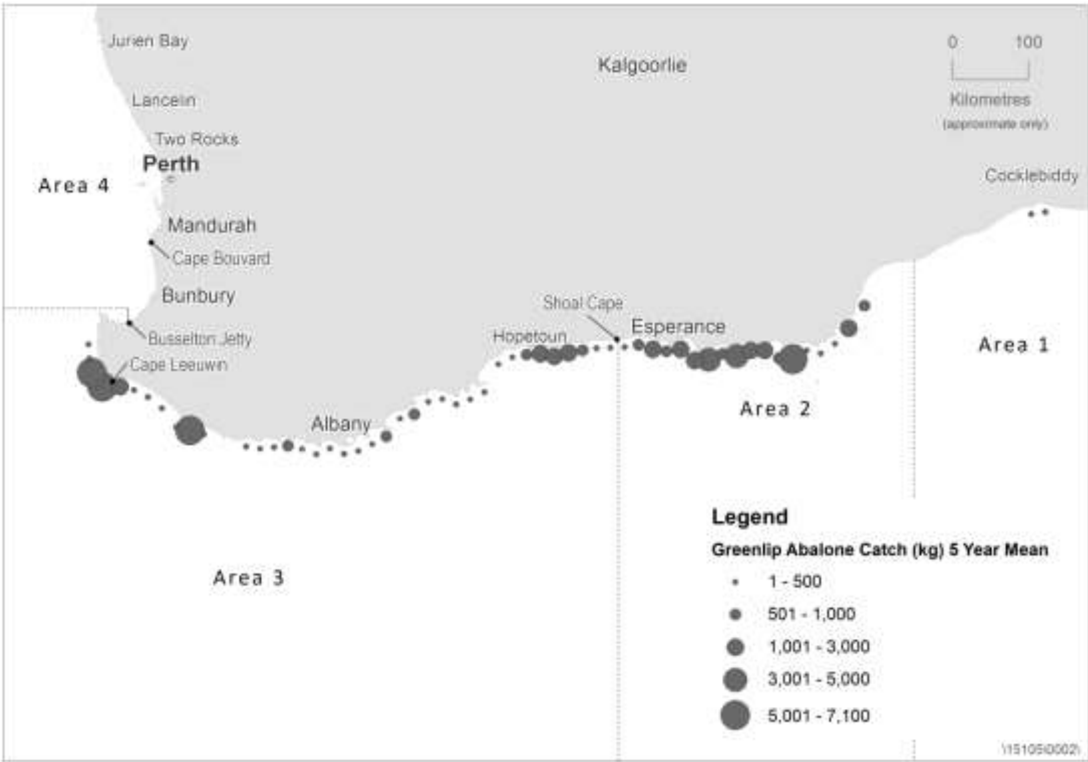


Figure 3.5. Historical commercial catch estimates (tonnes whole weight) from Greenlip and Brownlip abalone fisheries in WA. Historical commercial catches (1964 to 1985) sourced from Prince and Shepherd (1992)

Greenlip abalone are collected along the south coast of WA with the majority of catch coming from Areas 2 and 3. There is no quota allocated to Area 4 (Section 4.1.3), and catches in Area 1 are minimal. In Areas 2 and 3, catches are not evenly distributed but concentrated in certain areas such as Augusta, Windy Harbour and east of Esperance (Figure 3.6a).

Brownlip abalone are collected along the south coast of WA but in much lower numbers than Greenlip abalone. Brownlip abalone catch is predominately taken from Areas 2 and 3, with a focus of catches from certain 'hotspots' (Figure 3.6b).

(a)



(b)

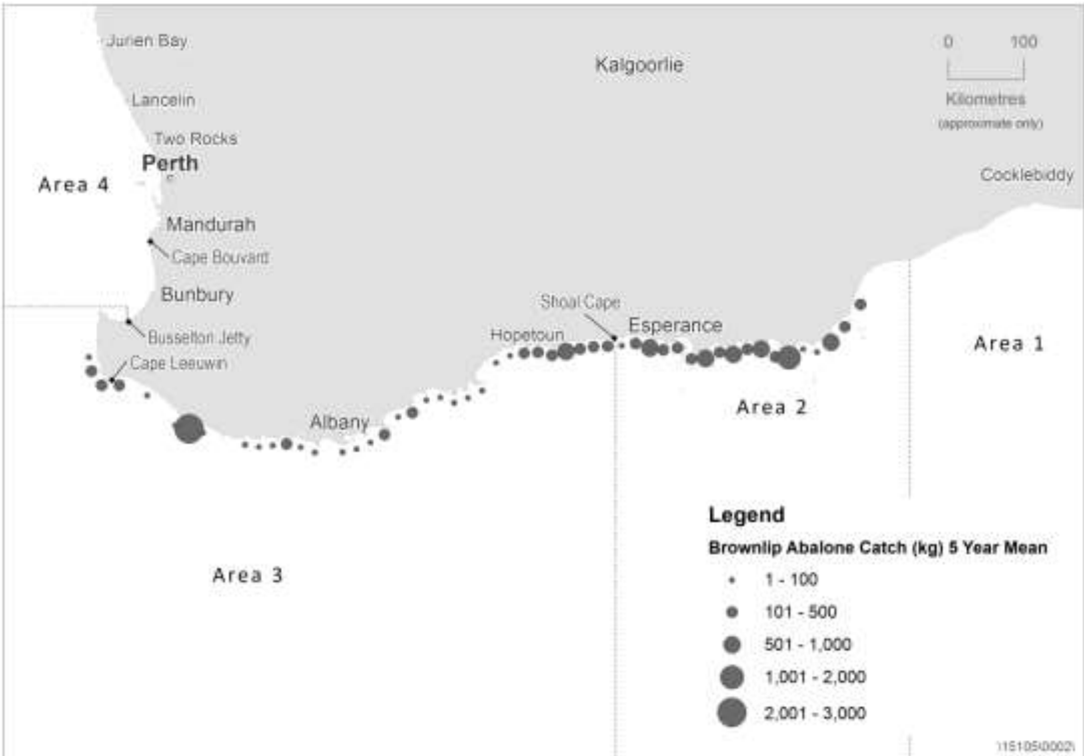


Figure 3.6. Spatial distribution of the average annual catches (in kg) of (a) Greenlip abalone and (b) Brownlip abalone in the AMF between 2009 and 2014. Note the different scale for the different species

4 Fishery Management

This section provides an overview of the commercial and recreational fisheries management arrangements for Roe's, Greenlip and Brownlip abalone. The commercial management arrangements are similar for these three species of abalone and therefore are not separated. More detailed information is provided in the MSC Principle 3 (Effective Management) sections of this report.

4.1 Commercial Management System

The AMF is managed by DoF under the following legislation:

- *Fish Resources Management Act 1994*[2] (FRMA);
- *Fish Resources Management Regulations 1995* (FRMR);
- FRMA Part 6 — *Abalone Fishery Management Plan 1992* (the Management Plan);
- FRMA Statement of Determination (see Section 4.1.4.1.4);
- FRMA Section 7 Exemptions;
- FRMA Section 43 Orders (see Section 4.1.4.1.4).

Fishers must also comply with the requirements of the:

- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- *WA Marine Act 1982*;
- WA *Wildlife Conservation Act 1950*; and
- *Conservation and Land Management Act 1984* (CALM Act).

4.1.1 FRMA

The FRMA provides the overarching legislative framework to implement the statutory management arrangements for the AMF and contains the head powers to determine a management plan (section 54 of the FRMA). Management plans (see below) are subsidiary legislation which set out the operational rules that control managed commercial fishing activities and should be viewed in conjunction with other specific relevant subsidiary legislation and strategies in place for the fishery. The management plan provides the power (pursuant to section 58 of the FRMA) to issue and restrict the number of authorisations and regulate other conditions and grounds relating to fishing. There is also power to set the capacity of the fishery under a management plan (section 59 of the FRMA). The FRMA also sets out the procedure for determining and amending a management plan (sections 64 and 65 of the FRMA). Under section 43 of the FRMA the Minister may prohibit fishing by order published in the Government Gazette.

[2] Note the FRMA will be replaced by *Aquatic Resources Management Bill* (AMRB) once enacted

4.1.2 FRMR

The FRMR contains a number of requirements pertaining to all commercial fisheries in WA. For example, regulation 64 of the FRMR requires commercial fishers to submit mandatory catch returns in the form approved for that fishery, detailing retained species catches, fishing effort, interactions with ETP species and fishing location.

The FRMR also specifies the minimum size limits for certain finfish, crustacean and mollusc species including abalone.

4.1.3 Management Plan

The Management Plan is the primary statutory management instrument for the commercial AMF. The Management Plan was established as a *Limited Entry Fishery Notice* under the previous WA *Fisheries Act 1905*; however, all existing management plans established under section 32 of the *Fisheries Act 1905* were transitioned under section 266 of the FRMA when it was established in 1994. The Management Plan implements the following set of statutory measures to meet the fishery-specific management objectives for the AMF:

- **Species restriction:** AMF is limited to the collection of Roe's, Greenlip and Brownlip abalone
- **Limited entry** –The AMF is limited entry with fishers required to hold an Abalone Managed Fishery licence, a commercial fishing boat licence and a commercial fishing licence (see Appendix B for examples). The number of commercial abalone licences is limited by the requirement that each boat hold a minimum quantity of units of entitlement (800 Roe's units or 450 Greenlip/Brownlip units). Only two people can operate on each licence. The licencing period for the fishery runs from 1 April to 31 March of the following year.

  Currently there are 51 managed fishery licences in the AMF (28 licences endorsed to take Roe's abalone, with 23 and 24 licences endorsed to take either Greenlip or Brownlip abalone respectively) in one or more of the eight specific areas.
- **Management areas**: The AMF covers all WA coastal waters and is divided into eight management areas:

  Area 1 – South Australian /WA border to Point Culver

  Area 2 – Point Culver to Shoal Cape

  Area 3 – Shoal Cape to Busselton Jetty

  Area 4 – Busselton Jetty to Northern Territory/WA border

  Area 5 – Shoal Cape to Cape Leeuwin

  Area 6 – Cape Leeuwin to Cape Bouvard

  Area 7 – Cape Bouvard to Moore River

  Area 8 – Moore River to the Northern Territory/WA border

The overlap of some of the areas (see Figure 3.1 for clarification) is due to differences in fishing for the different species of abalone. Commercial fishing for Roe's abalone is managed in six of the areas (Areas 1, 2, 5, 6, 7 and 8), whilst fishing for Greenlip and Brownlip abalone is managed across Areas 1, 2, 3 and 4.

- **Minimum size limits:** The minimum size limit for Roe's abalone is 60 mm, with the exception of Areas 1 and 7 where the minimum size for commercial catches is 75 mm and 70 mm, respectively. The minimum size limit for Greenlip and Brownlip abalone is 140 mm for both recreational and commercial fisheries. In certain areas where there are 'stunted stocks' Greenlip can be commercially fished from 120 mm under Instrument of Exemption.

- **Spatial restrictions:** Commercial fishing for Roe's abalone is not permitted in Area 7 (Cape Bouvard to Moore River) on any Saturday, Sunday or public holiday. Commercial fishers must not, when operating in the waters on the west coast of the State lying between the northern sea wall of Hillarys Boat Harbour and Cape Bouvard:

  (a) stand or remain on any reef top while fishing for abalone, or

  (b) fish for abalone other than from a boat authorised to be used in the fishery.

  Commercial fishing for Roe's abalone is not permitted between the North Mole at Fremantle and Trigg Island at any time. This is to ensure that stock levels on the shallow reef tops, which are the main areas fished by the recreational fishers, are not depleted in a way that would disadvantage recreational fishers.

  Additionally, there are a number of closed areas in the AMF where abalone fishing is prohibited at all times (See Section 13.6 for more detailed descriptions). These include the following:

  - Reef Observation Areas,
  - Fish Habitat Protection Areas,
  - Protected Reef Areas,
  - Rottnest Island Marine Reserve, and
  - Certain areas with State Marine Parks.

- **Temporal restrictions:** Roe's abalone fishing is prohibited in Area 7 on Saturdays, Sundays and Public Holidays.

- **Catch allocations:** The AMF is managed primarily through output controls in the form of TACCs, set annually for each species in each area and allocated to licence holders as Individual Transferable Quotas (ITQs). Each AMF licence has attached to it transferable units of entitlement. Each unit is given a value by dividing the TACC for a given management area and species by the total number of units allowed for that area and species. The annual quota for each zone and species is published each year as a Statement of Determination. In 2016, the maximum quantity of abalone that can be taken from the relevant management areas for each species was as follows:

Roe's abalone (whole weight):

- Area 1 – 5,000 kg
- Area 2 – 18,000 kg
- Area 5 – 20,000 kg
- Area 6 – 12,000 kg
- Area 7 – 32,000 kg
- Area 8 – 0 kg

Greenlip abalone (meat weight):

- Area 1 – 1,200 kg
- Area 2 – 18,000 kg
- Area 3 – 25,600 kg
- Area 4 – 0 kg

Brownlip abalone (meat weight):

- Area 1 – 60 kg
- Area 2 – 5000 kg
- Area 3 – 5000 kg
- Area 4 – 0 kg

- **Reporting**: Within 90 minutes of bringing abalone ashore, the personal who is the nominated operator of the licence must complete a CDR with accurate details of the weight and number of abalone caught (by species), fishing locations, diving time and any ETP interactions.

4.1.4 Notices and Orders

There are several notices and orders in place for the AMF including:

- *Statement of Determination*[3] - Published annually for each 12 month licensing period which states annual quota in the form of the maximum quantities of Greenlip, Brownlip and Roes abalone which can be harvested from each AMF management area.
- *Prohibition on taking Abalone (North of Moore River) Order 2011*[4] - Prohibits the take of any species of *Haliotis* spp. in WA waters north of 31° 21.300' S.

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[3]http://www.slp.wa.gov.au/statutes/subsiduary.nsf/0/F5D979043020BD5448257E0700279043/$file/13.03.15.+abalone+statement+of+determination+2015.pdf

- Prohibition Orders relating to commercial fishing in WA Marine Parks and Management Areas[5] - Several Orders have been published to prohibit and/or restrict fishing activities in WA Marine Parks, more detail is provided in Principle 2, Section 13.6.

4.2 Integrated Fisheries Management

Historically, the abalone resource of WA has been fished by the commercial, recreational and customary sectors without any explicit catch share allocation between sectors. In 2005, a formal sectoral allocation process known as Integrated Fisheries Management (IFM) was initiated to define and assign long-term sectoral shares of the permitted catch of abalone (Department of Fisheries 2005). Based on historical data on commercial and recreational catches, the Integrated Fisheries Allocation Advisory Committee (IFAAC) recommended that sectoral allocations for the abalone resource should consider only Roe's abalone in the Perth metropolitan area due to its high relative importance within the overall recreational abalone fishery and the availability of recreational catch information from this area (IFAAC 2009).

As part of the IFM process, an overall Sustainable Harvest Level (SHL) for the resource is set annually and used to recommend catch levels for each sector based on the proportional allocations of the recommended total catch level for the year. However, due to a limited understanding of the relationship between abalone on the platform habitats (targeted by recreational fishers) and the subtidal habitats (targeted mainly by commercial fishers) at that time, IFAAC did not recommend an immediate introduction of proportional management of Roe's abalone within an overall SHL (IFAAC 2009).

In the absence of proportional allocations, the recreational catch of Roe's abalone in the Perth metropolitan area (Zone 1 of the WA recreational abalone fishery) has been managed to an average annual catch target of 40 tonnes in conjunction with the commercial long-term SHL of 36 tonnes. Subject to recent concerns over environmental impacts on Roe's abalone stocks in this region, daily bag limits were reduced in 2014 and in season monitoring and management was introduced in 2015 to reduce metropolitan recreational catches to a catch target of 20 tonnes ± 2 tonnes.

4.3 Harvest Strategy

A resource-specific harvest strategy for AMF outlines the long- and short-term fishery-specific management objectives (DoF 2017). The harvest strategy also provide a description of the performance indicators used to measure performance against these objectives; reference levels for each performance indicator; and associated control rules, which articulate pre-defined management responses designed to maintain each resource at target levels and achieve the management objectives for the fishery (see Section 9 for more detail).

[4] http://www.slp.wa.gov.au/statutes/subsiduary.nsf/0/61660F8C572942124825791E00234085/$file/prohibition+on+taking+abalone+order+2011+(final).pdf

[5] http://www.slp.wa.gov.au/statutes/subsiduary.nsf/FisheriesO?OpenPage&Start=1&Count=30&Expand=2.1

4.4 Risk Assessments

In WA, a risk-based framework is used to assess and manage the impacts of an individual fishery on target species, retained species, bycatch (including ETP species) and habitats, as well as any potential indirect impacts on the broader ecosystem. Fishery-specific risk assessments are utilised by the DoF for the following purposes:

- As a proxy stock assessment (in the absence of sufficient data);
- As a part of export approval requirements undertaken by the Commonwealth Department of the Environment (DotE);
- Annual reporting in the *Status Reports of the Fisheries and Aquatic Resources Reports: the State of Fisheries* (e.g. Fletcher and Santoro 2015); and
- Other environmental and ecological assessments, such as MSC assessments.

Several ecological risk assessments (ERAs) have been undertaken for the AMF. The first was undertaken in 2002 as a part of an application to the (now) DotE outlining the industry's compatibility with the EPBC Act requirements for Ecologically Sustainable Development (ESD) (see Section 4.5 below). This initial comprehensive risk assessment involved a workshop with representatives from a range of stakeholder groups, including the WA Department of Environmental Protection, Abalone Industry Association of WA (AIAWA), Conservation Council of WA, Marine and Coastal Community Network, the Western Australian Fishing Industry Council (WAFIC), Recfishwest, Aboriginal Lands Trust, WA Museum, Consulting Scientists, and managers and scientists from the Department. The risk assessment framework applied during the workshop was consistent with the Australian Standard AS/NZS 4360:1999 and used a combination of the level of consequence and the likelihood to produce an estimated level of risk associated with the issues in question. The results of the 2002 ERA are presented in Table 4.1.

This ERA was updated in 2009 and 2014 as a part of the re-assessment process against the EPBC Act and for continued exemption to export native species. The re-assessment was undertaken internally by Departmental staff and the Executive Officer of AIAWA, with no changes to the 2002 risk ratings.

Table 4.1. Risk ratings of identified risks in the 2002 ERA workshop
*Note this ERA was updated in 2009 and 2014 with no changes to the risk rating

Component and Sub-component	Issue	Risk Rating
Retained species		
Greenlip abalone Area 1	Impact on breeding stock	C1 L4 - LOW
Greenlip abalone Area 2	Impact on breeding stock	C1 L4 - LOW
Greenlip abalone Area 3	Impact on breeding stock	C3 L4 - MODERATE
Greenlip abalone Area 4	Impact on breeding stock	NEGLIGIBLE
Brownlip abalone Area 1	Impact on breeding stock	C0 L3 - NEGLIGIBLE
Brownlip abalone Area 2	Impact on breeding stock	C2 L5 - MODERATE
Brownlip abalone Area 3	Impact on breeding stock	C3 L4 - MODERATE
Brownlip abalone Area 4	Impact on breeding stock	NEGLIGIBLE
Roe’s abalone Area 1	Impact on breeding stock	C2 L5 - MODERATE
Roe’s abalone Area 2	Impact on breeding stock	C2 L3 - MODERATE
Roe’s abalone Area 3	Impact on breeding stock	C3 L3 - MODERATE
Roe’s abalone Area 5	Impact on breeding stock	C3 L3 - MODERATE
Roe’s abalone Area 6	Impact on breeding stock	C3 L3 - MODERATE
Roe’s abalone Area 7	Impact on breeding stock	C3 L4 - MODERATE
Roe’s abalone Area 8	Impact on breeding stock	C3 L3 - MODERATE
Non-retained species		
Piggyback species	Impact on breeding stock	
General environment		
Removal of all organisms	Removal of abalone and piggyback species on the ecosystem	C1 L4 - LOW
Discarding undersize abalone	Impact on environment from discards	C0 L1 - NEGLIGIBLE
Discarding abalone gut	Impact on trophic structure	C0 L2 - NEGLIGIBLE
Non-native and disease introduction	Impact of translocation of organisms on vessel hulls	C4 L0 - MODERATE
Stock enhancement	Impact of stock enhancement	C4 L0 - MODERATE
Scraping abalone from rocks	Impact of scraping abalone from rocks	C0 L1 - NEGLIGIBLE
Diver/diver gear	Impact of interaction between diver gear and habitat	C0 L1 - NEGLIGIBLE
Reef walking	Impact of reef walking	C0 L1 - NEGLIGIBLE
Indirect interactions	Impact on other wildlife	C0 L1 - NEGLIGIBLE
Heatwave events	Impact of heatwave events	C5 L4 - MODERATE

4.4.1 2015 Ecological Risk Assessment of the AMF

In December 2015, an ERA workshop was held to assess the impacts of the AMF. The workshop participants included representatives from the abalone industry, the WAFIC, Department of Parks and Wildlife, Aquaculture Council of WA and, the DoF. The ERA framework applied during the workshop was based on the global standard for risk assessment and risk management (AS/NZS ISO 31000), which has been adopted for use in a fisheries context (see Fletcher et al. 2002). The risk analysis process involves the examination of the sources of risk (issue identification), the potential consequences (impacts) associated with each issue and the likelihood (probability) of a particular level of consequence actually occurring. This combination produces an estimated level of comparative risk, which can then be used to assist in determining the level of management response required (Fletcher et al. 2010).

Four aspects were considered for the risk assessment:

- Ecological sustainability — the impact of the AMF on ecological resources;
- Community well-being — the contribution of the AMF to local, regional and global social and economic well-being;
- External factors — environmental, social and economic drivers that impact the AMF's performance; and
- Governance — management processes and arrangements that impact the AMF's performance.

Issues were identified using the assistance of the component tree approach (Fletcher et al. 2002). The identification of issues was guided by the generic ESD component trees to include issues that were applicable to the AMF. Industry-specific issues were determined based on previous risk assessments undertaken for the industry and gaps identified during a MSC pre-assessment of the fishery in 2014). Scoping to clarify issues was also undertaken internal workshop involving Departmental research and management staff, and at the stakeholder's workshop in December 2015.

Twenty ecological components were identified as potentially impacted by the AMF, with 40 associated issues (Table 4.2). The majority of the issues were scored as negligible (27) or low (5) risk, and 8 were scored a medium risk (Webster et al. 2017).

Table 4.2. Overview table of Identified Components, Objectives, Sub-Components, Issues, Risk Score and Assessed Risk rakings related to the Ecological Sustainability of the AMF

Component	Management Objective	Sub-component	Issues	Management Area	Risk Score	Risk Rating
Retained Species	To maintain spawning stock biomass of each target species at a level where the main factor affecting recruitment is the environment	Greenlip Abalone	Commercial fishing	1	C1, L4 = 4	**LOW**
				2	C 2, L5 = 10	**MEDIUM**
				3	C 2, L5 = 10	**MEDIUM**
			Introduction of high risk virus	1, 2 and 3	C5, L1 = 5	**LOW**
		Brownlip Abalone	Commercial fishing	1	C1, L1 = 1	**NEGLIGIBLE**
				2	C2, L5 = 10	**MEDIUM**
				3	C2, L5 = 10	**MEDIUM**
			Introduction of high risk virus	1, 2 and 3	C5, L1 = 5	**LOW**
		Roe's Abalone	Commercial fishing	1	C1, L4 = 4, C2, L2 = 4	**LOW**
				2	C2, L5 = 10	**MEDIUM**
				5	C2, L5 = 10	**MEDIUM**
				6	C2, L5 = 10	**MEDIUM**
				7	C2, L5 = 10	**MEDIUM**
			Introduction of high risk virus	1, 2, 5, 6 and 7	C5, L1 = 5	**LOW**

Component	Management Objective	Sub-component	Issues	Bioregion or Species	Risk Score	Risk Rating
Non-retained Species	To ensure fishing impacts do not result in serious or irreversible harm to bycatch (non-retained) species populations	Commensal Species	Commensal ('Piggy back') species populations	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
			Loss of commensal ('piggyback') species habitat	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
ETP Species	To ensure fishing impacts do not result in serious or irreversible harm to ETP species' populations	Whales and Dolphin	Boat strike	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
		Marine Turtles	Boat strike	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
		Sharks and Rays	Boat strike	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
			Diver interaction	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
		Sea lion / Seals	Boat strike	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
		Shorebirds	Driving on beaches	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
		Penguins	Boat strike	WC	C1, L1 = 1	**NEGLIGIBLE**
Habitats	To ensure the effects of fishing do not result in serious or irreversible harm to habitat structure and function	Rocky Reef	Prising abalone from habitat	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
			Diver and diver equipment	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
			Anchoring	WCB/SCB	C1, L1 = 1	**NEGLIGIBLE**
			Walking on intertidal areas	SC	C1, L1 = 1	**NEGLIGIBLE**
		Seagrass	Anchoring	Roe's	C1, L1 = 1	**NEGLIGIBLE**

4.4.2 Aquaculture, stock enhancement and growout

There have been three risk assessments which examined the risks associated with aquaculture operations introducing disease to wild populations:

- Dang, C., Crockford, M and Snow, M. (2014). An assessment of the hazards and risks posed associated with abalone aquaculture (*Haliotis* spp.) in Western Australia. Dept. of Fisheries WA (in review).
- Jones, J.B. and W.J. Fletcher. 2012 Assessment of the risks associated with the release of abalone sourced from Abalone Hatcheries for enhancement or marine grow-out in the open ocean areas of WA. *Fisheries Research Report No*. 227. 24p.
- Stevens, R.N. (2012). Disease risk assessment for abalone stock enhancement. Report to Western Australian Fishing Industry council Inc. 31pp.

All of these assessments found that the risks were considered to be at an acceptable level (ranked medium or lower) providing appropriate management measures were applied.

4.5 Other Assessments and Certifications

The AMF has been assessed under the provisions of the EPBC Act (Part 13 and Part 13A) and has been found to meet the Australian Government *Guidelines for the Ecologically Sustainable Management of Fisheries* (Commonwealth of Australia [CoA] 2007). Initial assessment of the fishery took place in 2002, with the most recent reassessment and approval completed in February 2015[6]. As a decision was made to extend the maximum timeframe for EPBC Act approvals from five years to ten years, the AMF is an approved Wildlife Trade Operation (WTO) until May 2025.

[6] Full details of the current and previous assessments are available at:

http://www.environment.gov.au/marine/fisheries/wa/abalone

5 Target Species / Stock Description

5.1 Roe's Abalone

5.1.1 Taxonomy and Distribution

Roe's abalone (*Haliotis roei*; Figure 5.1) belong to the Family Haliotidae, which comprises around 75 species of shelled marine gastropods (Geiger and Owen 2012). Abalone are found along rocky shores in temparate and tropical waters, and are generally found in shallow subtidal waters 0-30 m deep. There are no abalone species of global distribution and most species have restricted ranges.

Roe's abalone can be found as far north as Shark Bay in WA and south around to Victoria, although they are not uniformly distributed throughout this range.

(a) (b)

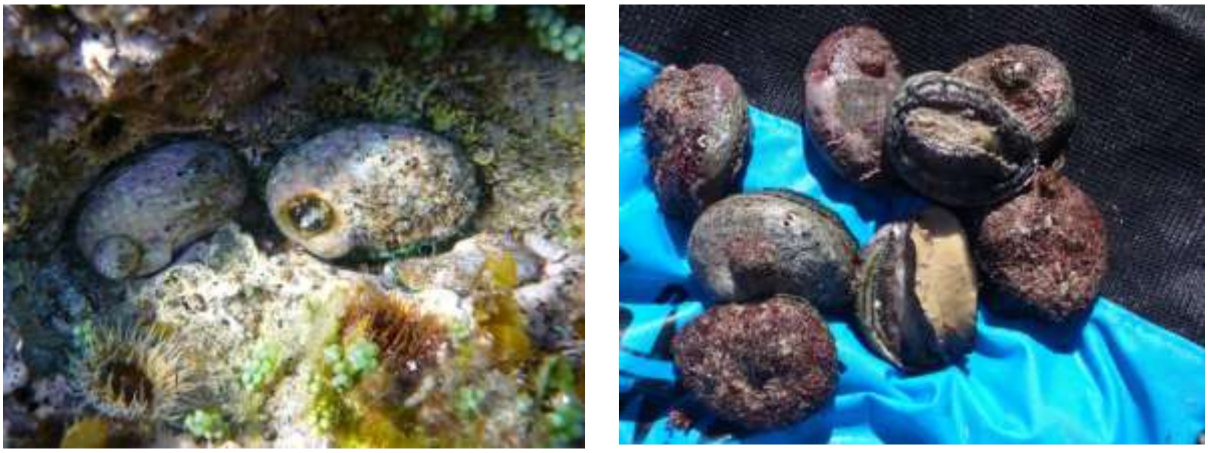

Figure 5.1. Roe's abalone in its (a) natural habitat, and (b) harvested for sale

5.1.2 Stock Structure

Standardised variance in allelic frequencies between 10 sites in south-western Australia indicated high levels of gene flow across Roe's abalone in the 3000 km sampled (Hancock 2004).

5.1.3 Life History

5.1.3.1 Habitats and Movements

All commercially targeted WA species of abalone live on exposed, high-energy coasts. Roe's abalone populations occur on semi-continuous reef complexes, each of which is generally less than 10 km of coastal length. The habitat occupied by this species is the intertidal reef platforms and shallow adjoining subtidal reef for up to 30 to 40 m beyond the reef platforms.

Abalone are sedentary animals and generally only make small-scale movements within their local habitats, primarily to feed. Long-term survey data suggests a small-scale movement from the area of settlement (outer habitat on platform reefs) to other intertidal and subtidal areas of the reef. In particular, subtidal areas have a significantly larger mean size of abalone.

Aggregative behaviour has been noted in relation to spawning (Shepherd 1986), but the primary source of movement is in the larval stage, mediated by ocean currents.

5.1.3.2 Reproduction

Roe's abalone are broadcast spawners; they release gametes (both sperm and eggs) into the water column where fertilisation occurs. The ova develop into a veliger stage and settlement usually occurs around eight to 10 days post-hatching. When they are ready to metamorphose they settle onto suitable habitat. Evidence has been found for the preferential selection onto certain habitat based on chemical cues emanating from coralline algae and biofilms that have been grazed by conspecifics (Roberts 2001).

The length at which 50% of Roe's abalone has attained maturity has been estimated as 40 mm (Table 5.1). Roe's abalone in the Perth metropolitan area have major spawning events in winter (Wells and Keesing 1989), whereas in South Australia the species appears capable of spawning all year round (Shepherd and Laws 1974).

5.1.3.3 Size-Fecundity Relationships

Egg production by a female Roe's abalone can be very high, with a fecundity of up to 8.6 million eggs measured in a large (122 mm) individual (Wells and Keesing 1989). Length-fecundity relationships for this species at two sites in WA are shown in Table 5.1.

Table 5.1. Size-at-maturity and length-fecundity relationships for Roe's abalone in WA. Length-fecundity equations are of the form $F = aL^b$, where F is fecundity (millions of eggs), and L is length (mm)

Location	Size at 50% maturity (mm)	Length-Fecundity parameters		Source
		a	*b*	
Perth (Waterman)	40	1.98×10^{-2}	4.52	Keesing (1984)
Perth (Marmion)*		9.00×10^{-8}	4.28	Unpublished data

* the fecundity parameters (a, b) for Marmion are for length-gonad weight equations of the form $GW = aL^b$, where GW is gonad weight (g).

5.1.3.4 Factors Affecting Recruitment of Juveniles

Factors affecting recruitment in juvenile Roe's abalone are not well understood. The animal lives in a highly exposed environment with a spatially limited recruitment. In Area 7 of the AMF, which encompasses the Perth metropolitan area and provides a significant recreational and commercial catch, recruitment surveys have been undertaken since 1997. Overall, density of Age 1 animals is significant positively correlated with spawning biomass (2 years previously), however there are substantial variation between sites (Figure 5.2). Recruitment over time at most sites has been stable, with the exception of Mettams, where it has declined (Figure 5.2).

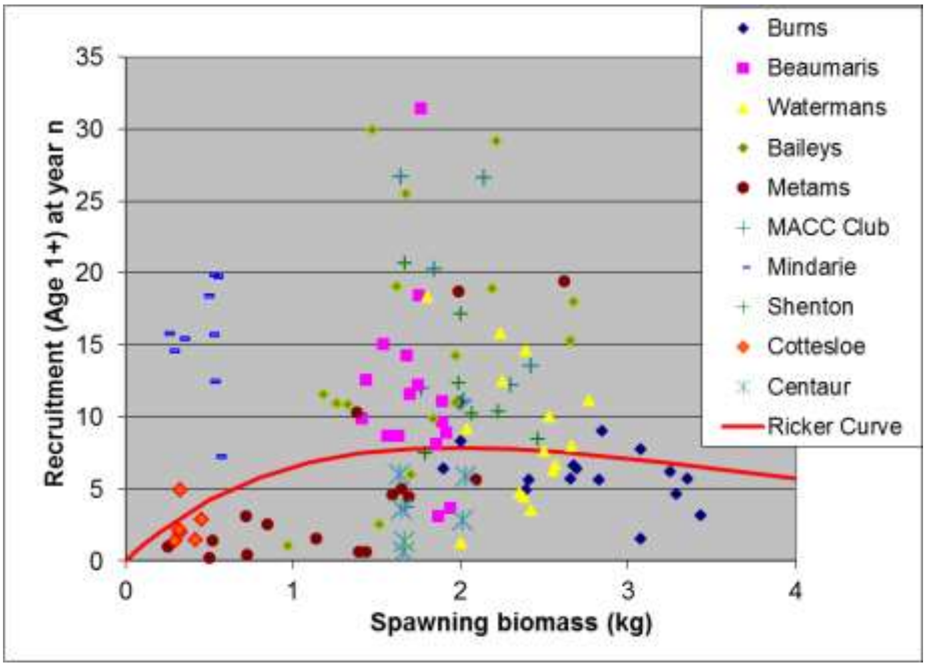

Figure 5.2. Ricker stock-recruitment equation (curved line) fitted to data for Roe's abalone in WA. Equation fitted to values of spawning biomass (Year n-2) paired with future recruitment density of Age 1+ animals (Year n) obtained from fishery-independent surveys. Density and biomass units are per m^2

5.1.3.5 Morphological Relationships

Length-weight relationships for Roe's abalone in WA are summarised in Figure 5.3.

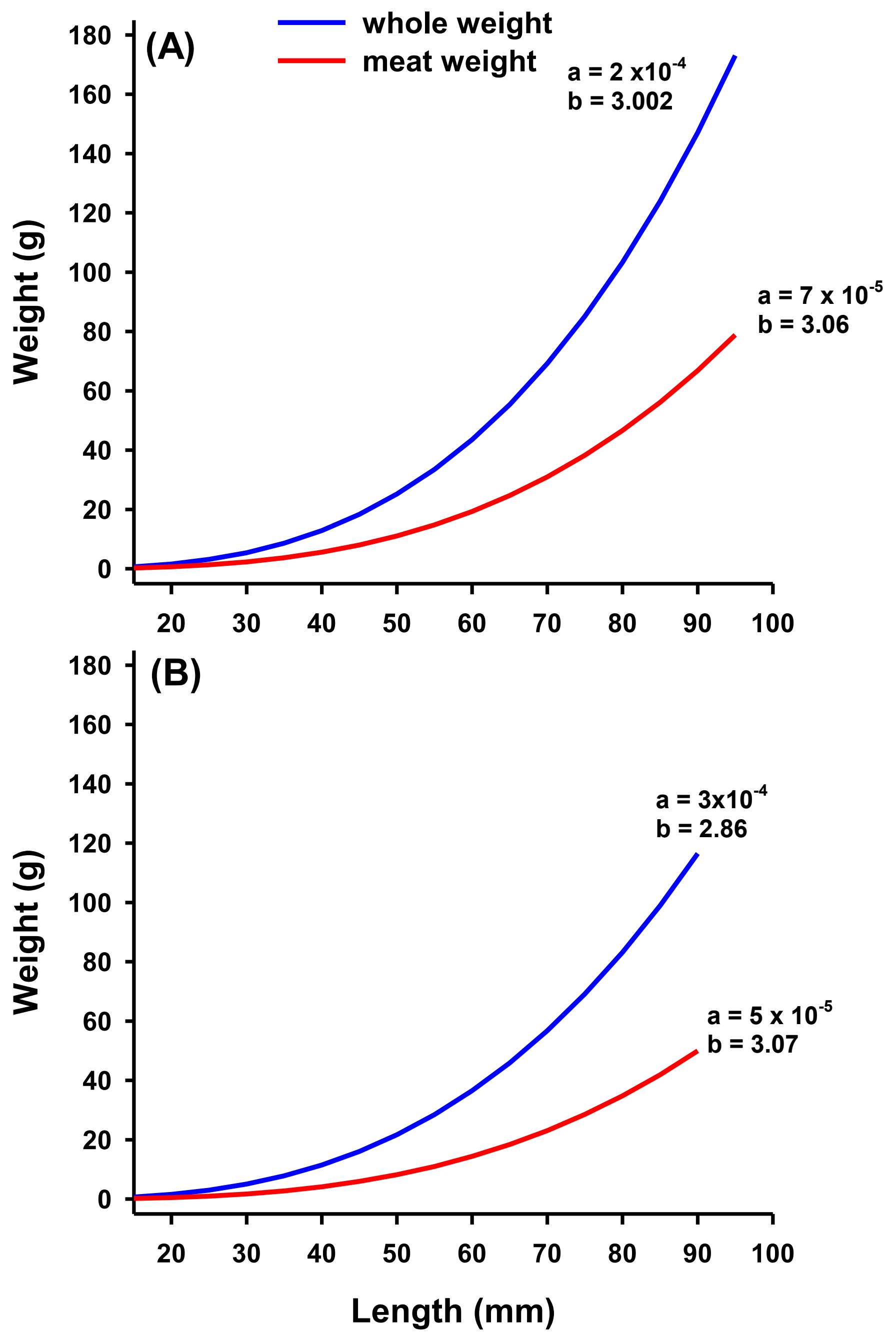

Figure 5.3. Length-whole weight (blue line), and length-meat weight (red line) relationships for Roe's abalone at 2 sites in WA: A) Perth metro (Area 7), B) Cape Naturaliste – Cape Leeuwin (Area 6). The equation is $W=aL^b$

5.1.3.6 Age and Growth

Growth of Roe's abalone varies significantly between populations. At the higher range, Roe's abalone reach an average maximum size of 89 mm shell length (Table 5.2). At the lower end of the growth spectrum, slow-growing stocks show an average maximum size of 73-75 mm (Table 5.2). This is a difference in growth of between 6 and 14 mm year^{-1} for a 40 mm animal.

Table 5.2. Growth information for Roe's abalone from WA estimated by Hancock (2004) from tag-recapture data

Location	von Bertalanffy growth parameters		Growth rate (mm year^{-1}) for a 40 mm individual
	k	L_∞	
Waterman's Reserve (North platform)	0.31	89	13
Waterman's Reserve (North subtidal)	0.40	83	14
Waterman's Reserve (South platform)	0.44	81	14
Waterman's Reserve (South subtidal)	0.34	86	13
Shag Rock (Trigg Island)	0.42	73	12
Three Bears (Margaret River)	0.20	75	6
Bald Face (Kalbarri)	0.35	73	10

5.1.3.7 Natural Mortality

Natural mortality for Roe's abalone in WA has been estimated as 0.38 year^{-1} from length-composition data in the closed Waterman's Reserve. A second unpublished estimate of 0.32 ± 0.03 (range: 0.24 to 0.40) year^{-1} has been obtained from the Kalbarri region (Area 8 of the AMF; Strain et al. in press), based on five replicate mark-release recapture experiments.

5.1.3.8 Diet

Abalone are macroalgal herbivores and feed on the most prevalent type of algae found in their particular area. All Australian abalone species feed primarily on red algae (70-80%) with small amounts of the more palatable brown algae such as *Lobospira* sp. also consumed (Shepherd and Steinberg 1992) when red algae is not as abundant. Abalone primarily feed on drift algae; the typical feeding pattern arises after sustained oceanic swells dislodge the algae and render them available to be trapped within the subtidal reef complexes and subsequently consumed by the resident abalone populations. Volumes of algae in gut contents were found to be greatest in winter, which coincides with the period of sustained oceanic swells and therefore highest food availability.

5.1.3.9 Parasites and Disease

An Australia-wide survey of diseases and parasites in abalone found a number of organisms with disease potential (Handlinger et al. 2006). The principal parasite affecting abalone and other commercial species is a protozoan parasite known as *Perkinsus* (Goggin and Lester 1995), which can cause flesh deformities and greatly reduce market value of abalone. *Perkinsus* parasites have been found in over 30 species of molluscs and are naturally occurring in abalone from South Australia (Goggin and Lester 1995) and New South Wales (Liggins and Upston 2010).

Perkinsus was heavily implicated in the demise of the Blacklip abalone fishery in New South Wales and evidence of substantial tissue necrosis, organ damage and haemocyte activity associated with *Perkinsus* cells in surveys between 2002 and 2005 showed that this parasite is pathogenic to abalone in this state (Liggins and Upston 2010). The parasite was found to be seasonally variable, with abalone being more susceptible to infection at high temperatures in late summer and autumn. In WA, a native *Perkinsus* species (*P. olseni*) has been found to be naturally occurring in Roe's and Greenlip abalone, as well as other molluscs such as cockles.

An extremely pathogenic herpes-like-virus (Abalone Viral Ganglioneuritis – AbHV-1) was discovered in wild abalone stocks in Victoria and Tasmania and is causing significant concern to the industry and community in all abalone-producing areas (Hooper et al. 2007; Corbeill et al. 2010; Savin et al. 2010). The Western Zone Blacklip abalone fishery in Victoria was decimated by this virus and TACC is current only around 10% of the levels experienced during pre-virus times.

5.2 Greenlip and Brownlip Abalone

As there are many similarities between Greenlip and Brownlip abalone, the taxonomy, stock structure, habitats and life history of these two species have been described together.

5.2.1 Taxonomy and Distribution

Greenlip abalone (*Haliotis laevigata*; Figure 5.4) and Brownlip abalone (*Haliotis conicopora*; Figure 5.5) belong to the Family Haliotide. Brownlip abalone is considered a sub-species of *H. rubra*, which is the primary commercial abalone species in eastern Australia (Geiger and Owen 2012).

(a) (b)

Figure 5.4. Greenlip abalone in its (a) natural habitat, and (b) harvested for sale

(a) (b)

Figure 5.5. Brownlip abalone in its (a) natural habitat, and (b) harvested for sale

Greenlip abalone and Brownlip abalone are co-occurring temperate endemic Australian species. The distribution of Greenlip abalone extends from the south-west of WA to Tasmania, whereas Brownlip extend only as far as South Australia (Figure 5.6).

(a) (b)

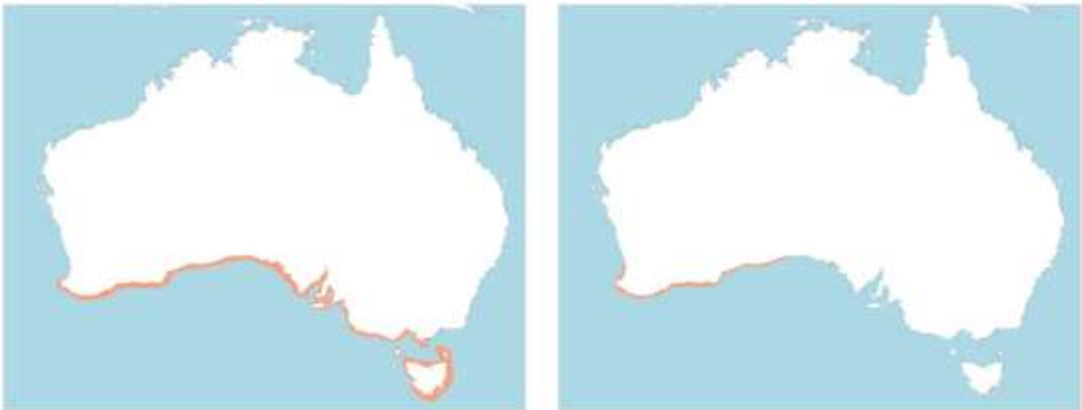

Figure 5.6. Distribution of (a) Greenlip abalone and (b) Brownlip abalone

5.2.2 Stock Structure

The genetic structure of Greenlip abalone has been investigated in south-eastern Australia (Mayfield et al. 2014) and more recently in WA (Sandoval-Castillo et al. 2016).

Studies by Mayfield et al. 2014 based on microsatellite DNA found that Greenlip and Brownlip abalone in south-eastern Australia comprise small, spatially disaggregated populations within a broader overall metapopulation structure (Shepherd and Brown, 1993). Genetic studies showed significant differences in allele structure between populations at relatively fine scale of tens of kilometres, such that stocks are composed of local populations linked by occasional larval dispersal into metapopoulations. Genetic subdivision indicated that Greenlip do not comprise a single, large, panmictic population across south-eastern Australia. Differentiation was evident at the two scales: among biogeographic regions (i.e.

hundreds of kilometres) and among locations within regions (i.e. tens of kilometres). Overall it was estimated that populations generally encompass reef areas of around 30 km^2, which are largely maintained through self-recruitment, and that distances of up to 130 km are effective barriers to larval dispersal (Mayfield et al. 2014).

Recent research on Greenlip abalone populations in WA has been undertaken using a new diagnostic genomic tool utilising Genotyping by Sequencing (GBS) (Sandoval-Castillo et al. 2016). This research found that the genetic structure of Greenlip abalone populations was similar in all populations analysed, with the highest diversity detected in the easternmost populations. The screening of genome-wide variation in Greenlip Abalone samples collected from the wild showed that "neutral" SNPs (i.e. DNA markers that are not under the influence of natural selection) exhibit a pattern of high connectivity, indicating the existence of one single abalone population across the geographic range sampled. When only a section of genome under selection (outlier SNPs) was considered, five genetically distinct groups can be clearly defined. These are: 1) the western part of the Greenlip Abalone distribution (from Outback to Windy Outside); 2) the Albany sub-area (Parrys Bay and Whalebone Port); 3) the Hopetoun sub-area (from Inner Island to Mason); 4) the West sub-area (Fanny Cove and Burton Rocks); and 5) the eastern sampling area (from Rob Island to Gulch). These corresponded to geographic regions characterised by differences in oceanography, particularly differences in oxygen. The genetic differentiation detected is likely to be adaptive so that the fitness/performance of the abalone in those locations, in relation to dissolved oxygen in the water, is likely to be superior (Sandoval-Castillo et al. 2016).

The genetic structure of Brownlip abalone is unknown.

5.2.3 Life History

5.2.3.1 Habitats and Movements

Greenlip and Brownlip abalone inhabit suitably exposed hard surfaces (usually granite or limestone) on subtidal rocky reefs between 1 and 40 m depth, however, the commercial fishery primarily targets the 5 to 25 m depth range. The habitats need to be firm enough to provide a suitable substrate for attachment, be capable of trapping floating seaweed which the abalone feed on, and be sufficiently endowed with a supply of certain types of red algae (Rhodophyta) which are the preferred food source for these species (Shepherd and Steinberg 1992). The delicate structure and susceptibility of red algae to wave exposure ensures that the highest swell-exposed areas are usually sub-optimal habitat. The largest populations of Greenlip abalone are found in the Augusta and Cape Arid regions of WA, which are characterised by small island complexes and headlands that buffer the southerly swells, create localised hydrodynamics that promote recruitment, and allow sufficient seagrass meadows and Rhodophyte communities to develop. Seagrass meadows are particularly important due to the prevalence of epiphytic red algae that are the sought after food species; the typical feeding pattern arises after sustained oceanic swells dislodge the algae and render them available to be trapped within the reef complexes and consumed by the resident abalone populations. Although inhabiting the same general reef areas, Brownlip abalone have more specialised habitat requirements. They are a far more cryptic species, generally requiring a complex boulder structure that they shelter underneath, typically known as "caves".

A recent habitat survey of 32 hectares of commercially productive Greenlip abalone reefs in the Augusta region established that abalone-specific habitat comprised only about 2-3% of the total area. The surrounding seagrass and associated macroalgal communities comprised around 30% of the total area. Within the rocky-reef complexes, abalone abundance is positively correlated with area of available habitat and density of other co-occurring invertebrates such as the purple sea-urchin (Hart et al. 2013c), indicating that the structural complexity of a reef dictates its carrying capacity and diversity for both abalone and the reef community in general. Photographs of "typical" Greenlip abalone habitat are provided in Figure 5.7a (gutter habitat) and Figure 5.7b (boulder habitat).

As with Roe's abalone, both Greenlip and Brownlip abalone are sedentary animals and generally only make small-scale movements within their local habitats, primarily to feed. Experimental investigations of stock enhancement in Greenlip abalone tracked cohorts for over 6 years and found that 90% of animals moved less than 5 m from the point of release (unpublished data).

(a) (b)

Figure 5.7. Examples of two habitat types found in the Greenlip abalone fishery (a) "gutter" habitat, and (b) "boulder" habitat

5.2.3.2 Reproduction

Greenlip and Brownlip abalone are broadcast spawners. The ova develop into a veliger stage and settlement usually occurs around eight to 10 days post-hatching. When they are ready to metamorphose they settle onto suitable habitat. Evidence has been found for the preferential selection onto certain habitat based on chemical cues emanating from coralline algae and biofilms that have been grazed by conspecifics (Roberts 2001).

Size at-maturity for Greenlip abalone varies with growth and averages between 78 and 97 mm in WA (Hart et al. 2013a; Table 5.3). Based on growth rate, age-at-maturity is around three years, although there is some evidence that maturation is not entirely age dependent and can be accelerated under optimal conditions (McAvaney et al. 2004). Size at-maturity for Brownlip abalone is less well known. Wells and Mulvay (1992) showed that maturation occurs rapidly between 110 and 130 mm, but all animals below 110 mm were immature. An approximate figure of 120 mm is assumed (Table 5.3).

The breeding season of Greenlip abalone varies between locations but is generally confined to the spring/summer months. Shepherd et al. (1992a) found an extended season from September to March at one location, and a restricted season (December) at another location in South Australia. In WA the spawning months were also confirmed as between October and December, with a peak in December (Wells and Mulvay 1992). Some sites showed evidence for partial spawning during the late summer months and it is likely that the exact timing within a season varies from year to year and location to location depending on the food availability (primarily dictated by swell) and temperature regime. There is no published information on the spawning season of Brownlip abalone.

5.2.3.3 Size-Fecundity Relationships

Egg production by an individual female can be very high. Individual fecundity of large females has been measured at up to 8 million eggs in Greenlip abalone from both WA (Wells and Mulvay 1992), and South Australia (Shepherd et al. 1992a), and 6 million eggs for Brownlip abalone (Wells and Mulvay 1992). The size-fecundity relationships for populations of Greenlip and Brownlip abalone in WA are shown in Table 5.3.

Table 5.3. Size-at-maturity and length-fecundity relationships for Greenlip and Brownlip abalone in WA. Length-fecundity equations are of the form $F = aL^b$, where F is fecundity (millions of eggs), and L is length (mm). The words “fast”, “normal” and “stunted” refer to the growth characteristics of assemblages at the different sites

Species / Location	Size at 50% maturity (mm)	Length-Fecundity parameters		Source
		a	b	
Greenlip abalone				
Augusta (fast)	97	1.00×10^{-6}	5.48	Hart et al. (2000)
Augusta (normal)	87	1.49×10^{-3}	4.29	Wells and Mulvay (1992)
Augusta (stunted)	78	1.39×10^{-4}	4.70	Wells and Mulvay (1992)
Hopetoun (normal)		6.91×10^{-4}	4.42	Wells and Mulvay (1992)
Hopetoun (stunted)	81			Wells and Mulvay (1992)
Cape Arid (normal)	88	4.95×10^{-5}	4.99	Wells and Mulvay (1992)
Cape Arid (stunted)	85	6.19×10^{-4}	4.42	Wells and Mulvay (1992)
Brownlip abalone				
Augusta	120	1.34×10^{-2}	3.74	Wells and Mulvay (1992)
Esperance	120	1.69×10^{-3}	4.15	Wells and Mulvay (1992)

5.2.3.4 Factors Affecting Recruitment of Juveniles

Recruitment of two-year old juveniles in Greenlip abalone has been shown to be density dependent, with the likely mechanism hypothesised to be limitation in appropriate crevice habitat for sheltering juveniles (Dowling et al. 2004). However the degree to which this occurs is location-specific, with areas carrying a higher proportion of suitable juvenile habitat exhibiting less density dependence. For example, Hart et al. (2013b, c) experimentally increased recruitment of Greenlip abalone through a series of stock enhancement experiments, which resulted in significantly increased adult densities in the short-term, indicating that density dependence had not limited survival of recruits at those sites. Dixon (2011) experimentally examined density dependence in juvenile Greenlip abalone by constructing and modifying experimental boulder habitats and found a strong density dependence effect on growth, and a significant, but weaker, density dependent effect on survival. An environmental signal affecting recruitment of both Greenlip abalone and invertebrates in general on the west coast of South Australia was also postulated by Dowling et al. (2004) but the mechanism remains unconfirmed. Allee effects (or depensation) have also been implicated in the collapse of recruitment due to the importance of aggregation for fertilisation success and Dowling et al. (2004) constructed a stock-recruitment curve that incorporated a parameter (the x-intercept) for depensation in Greenlip abalone in South Australia. A preliminary fit of this curve to WA stocks of Greenlip abalone did show a positive x-intercept (evidence for depensation; Figure 5.8) but the data needs to be interpreted with caution as it comprises different populations due to lack of long-term data within populations.

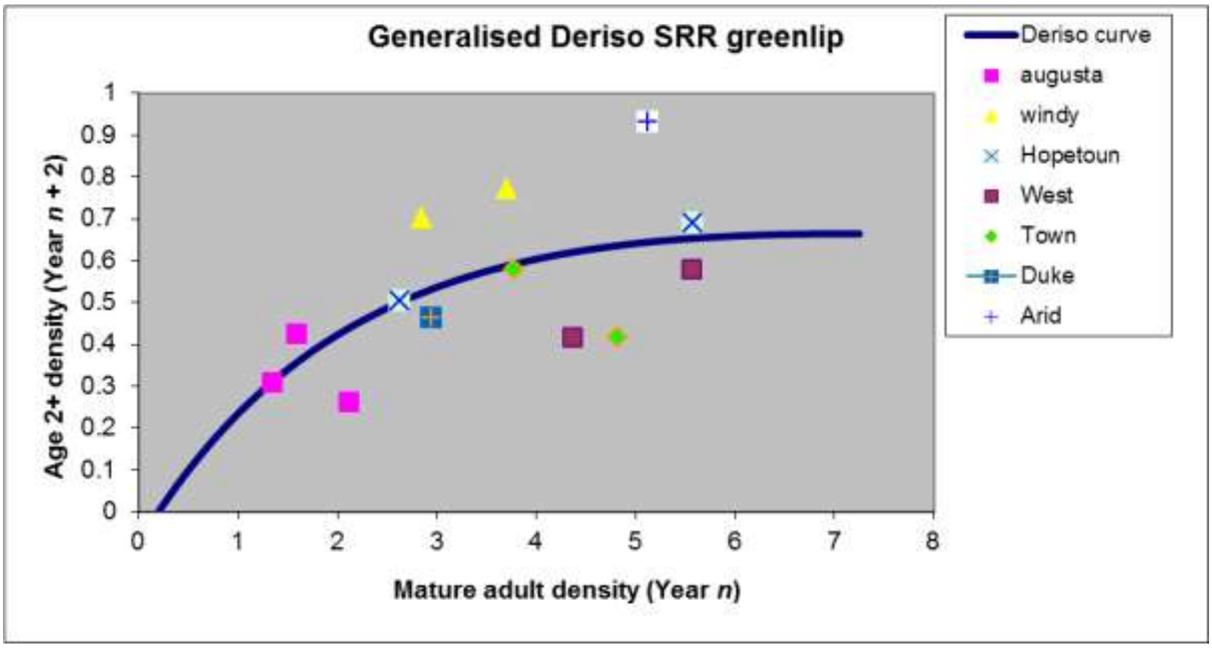

Figure 5.8. Generalised Deriso stock-recruitment equation (curved line) for Greenlip abalone in WA. Equation fitted to mature adult densities at Year *n* paired with future recruitment density of Age 2+ animals (Year *n*+2). Due to the lack of long-temporal data, curve is fitted to mean densities from different populations (Augusta, Windy, etc.). Data obtained from fishery independent surveys and density units are animals per m^2

5.2.3.5 Morphological Relationships

Length-weight relationships for Greenlip abalone in WA are summarised in Figure 5.9. Relationships vary slightly between areas. For example, a 160 mm animal at Flinders Bay, Augusta has an average meat weight of 230 g, compared to 186 g for the same-sized animal at Windy Harbour (Figure 5.9).

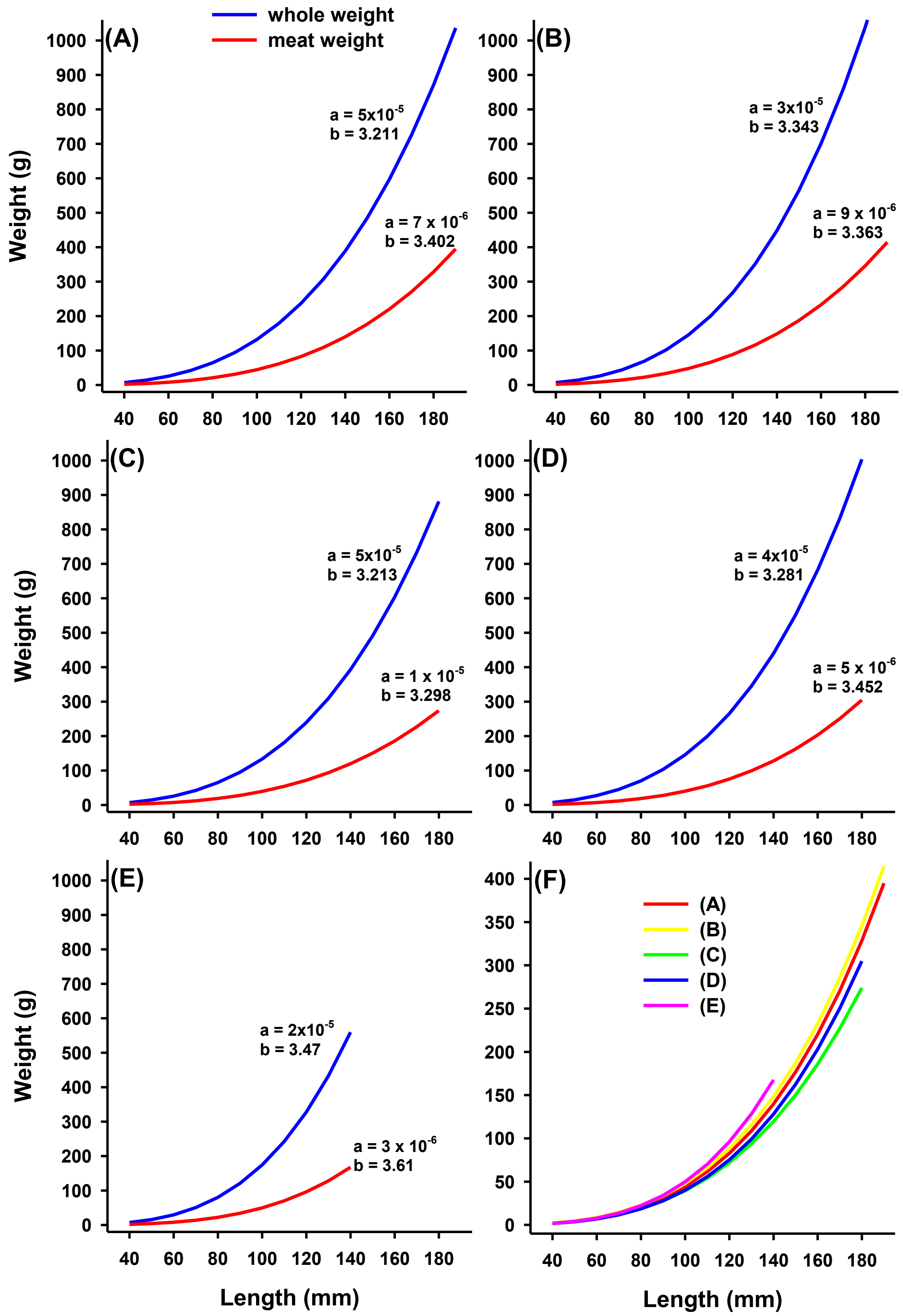

Figure 5.9. Length-whole weight (blue line), and length-meat weight (red line) relationships for Greenlip abalone at 5 sites in WA: A) Augusta (outback); B) Augusta (Flinders Bay); C) Windy Harbour; D) Hopetoun; E) Point Malcolm, F) comparison of length - meat weight relationships between areas. The equation is $W=aL^b$

Length-weight relationships for Brownlip abalone in WA are not as well-known as for Greenlip abalone. Data is available for one site at Cape Leeuwin, as summarised in Figure 5.10.

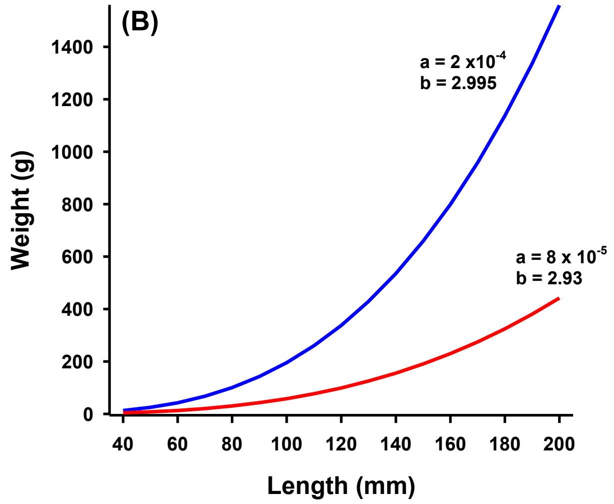

Figure 5.10. Length-whole weight (blue line), and length-meat weight (red line) relationships for Brownlip abalone at Cape Leeuwin in WA. The equation is $W=aL^b$

5.2.3.6 Age and Growth

Abalone exhibit large spatial heterogeneity in growth and "stunted" populations occur in all abalone fisheries (Wells and Mulvay 1992). In the case of Greenlip abalone, comparisons of growth parameters from tag-recapture studies across Australia reveal wide variability within and between fisheries (Figure 5.11).

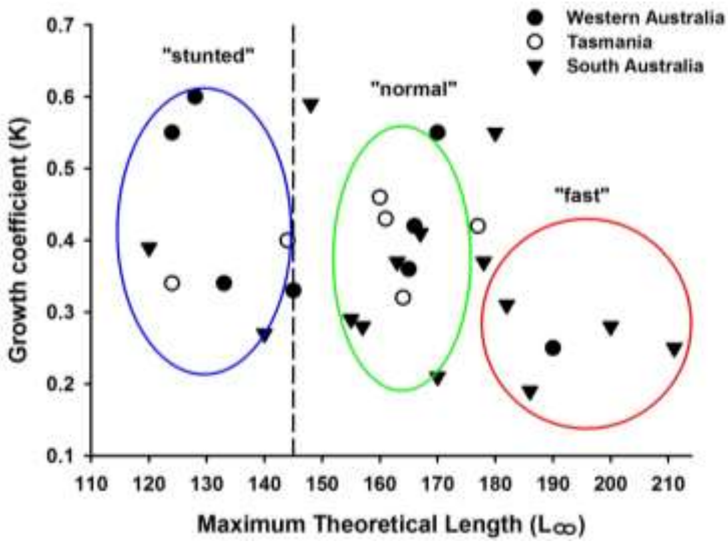

Figure 5.11. von Bertalanffy growth parameters (K, L_∞) for Greenlip abalone populations within and between states in Australia. Data have been grouped into "stunted", "normal" and "fast" growth stocks. Growth parameters sourced from: Shepherd and Hearn (1983), Wells and Mulvay (1992), Shepherd et al. (1992b), Officer (1999), Mayfield et al. (2003) and Hart et al. (2013a)

At the larger end, Greenlip abalone populations in WA reach an average maximum size of about 175 mm (Table 5.4). At the lower end of the growth spectrum, stunted stocks grow only to about 125-133 mm shell length, which is below the legal minimum length (Table 5.4). This is a difference in growth of between 12 and 38 mm year^{-1} for an 80 mm animal in different areas. Estimates of growth parameters for Brownlip abalone in Area 2 of the AMF are presented in Table 5.5. Note that additional information on growth of Greenlip and Brownlip abalone, from analyses undertaken as part of a recent stock assessment, is presented in Appendix C.

Table 5.4. Growth information for Greenlip abalone in WA. Growth is estimated from tag-recapture data using the maximum likelihood method of Francis (1988)

Location	Growth parameters (von Bertalanffy)		Growth rate* (mm yr^{-1})	Source
	K **(yr^{-1})**	**L_∞ ±SD (mm)**		
Augusta (Outback)	0.55	170 (14)	38	Hart et al. (2000)
Augusta (Flinders Bay)	0.36	165 (10)	34	Wells and Mulvay (1992)
Hopetoun (2 Mile) – main stocks	0.33	145 (14)	29	Unpublished data
Hopetoun (2 Mile) – stunted	0.34	133 (13)	12	Unpublished data
Station Island (Duke of Orleans Bay) – stunted	0.60	128 (12)	22	Unpublished data
Pt Malcolm (Israelite Bay) – stunted	0.55	124 (9)	18	Unpublished data

Table 5.5. Growth information for Brownlip abalone WA. Growth is estimated from tag-recapture data using the maximum likelihood method of Francis (1988)

Location	Growth parameters (von Bertalanffy)		Growth rate* (mm y^{-1})	Source
	K **(yr^{-1})**	**L_∞ ±SD (mm)**		
Area 2 of AMF	0.59	167 (14)	38	Unpublished data

5.2.3.7 Natural Mortality

Natural mortality (M, year^{-1}) in Greenlip abalone has been well studied and long-term mark-recapture experiments are available for wild populations in both South Australia (Shepherd 1990) and WA (Hart et al. 2013a). A summary for estimates of natural mortality in South Australian Greenlip abalone is found in Mayfield et al. (2003), and Dixon et al. (2006) present additional experimental results of juvenile mortality rates. Greenlip abalone exhibit size-dependent mortality, with M being initially high and declining with increasing size, levelling out at around 0.15 to 0.25 year^{-1} for large adults (Figure 5.12).

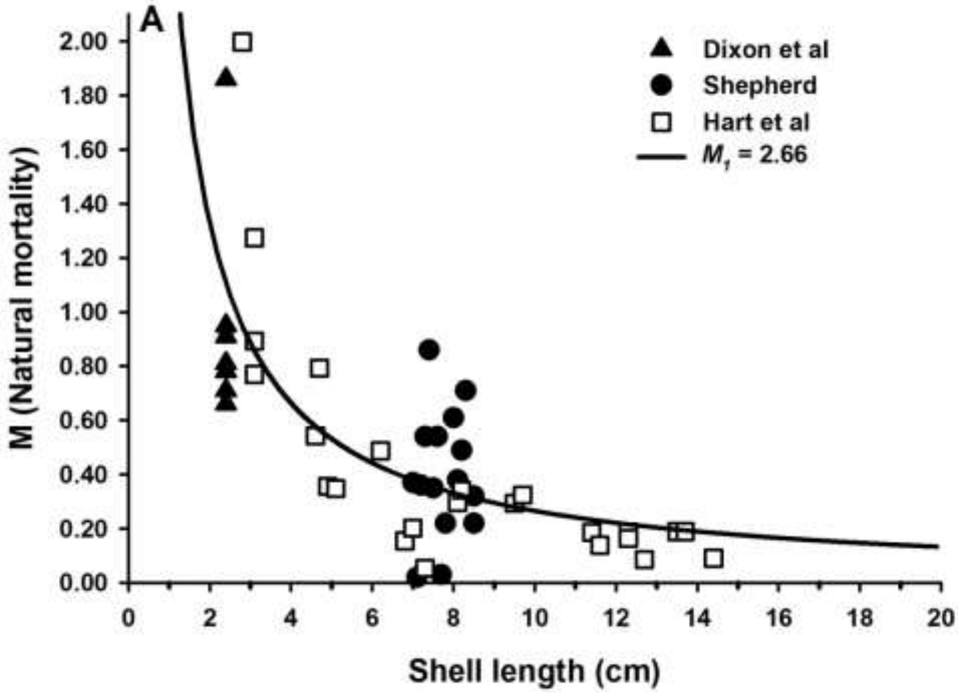

Figure 5.12. Natural mortality (*M*) in Greenlip abalone as a function of shell length, with the least-squares solution (2.66) for the mortality model $M_L = M_1 / L_{cm}$, where M_1 is *M* at 1 cm length. Mortality data derived the literature (Shepherd 1990; Dixon et al. 2006; Hart et al. 2013b). Figure modified from Hart et al. (2013d)

5.2.3.8 Diet

As described in Section 5.1.3.8, abalone are macroalgal herbivores and feed on the most prevalent type of algae found in their particular area. The plasticity in growth in Greenlip abalone is hypothesized to be primarily caused by food limitation as their relatively sedentary nature renders them susceptible to the localised algal productivity and habitat complexity.

5.2.3.9 Parasites and Disease

A summary of parasites and diseases affecting abalone is provided in Section 5.1.3.9.

6 External Influences

External factors include other activities and factors that occur within the WA state waters that may impact on the productivity and sustainability of the abalone resources and their ecosystems.

Other activities within the WA state waters include State commercial and recreational fisheries, aquaculture, mining exploration and production, ports, shipping and marina development. Other important external factors also discussed here include introduced marine species and climate change.

The WA population is concentrated in and around the major urban centre of Perth and a number of other regional centres including Broome, Karratha, Geraldton, Albany and Esperance. Outside the capital city of Perth, the distribution of the population is linked largely to primary industries, particularly agriculture, mining and fisheries.

6.1 Aquaculture

Greenlip abalone is considered a key species for aquaculture development in the south-west of WA and there are currently eight licenced abalone aquaculture farms, of which only two are operational; one land-based and the other ocean-based.

6.1.1 Land-Based Facility

The land-based facility located in Bremer Bay currently cultivates Greenlip, Brownlip and Roe's abalone. Greenlip abalone are cultivated for sale as seafood and are also sold as juveniles to the ocean-based facility (see below). Brownlip abalone are mainly cultured for research and development, with no commercial sales. Roe's abalone are cultured to restock the reefs north of Kalbarri which were devastated in the 2011 heatwave.

6.1.2 Ocean-Based Facility

The ocean-based facility, or sea ranch, which is located in Flinders Bay near Augusta, utilises artificial structures on the sea floor to grow juvenile Greenlip abalone to market size adults. The facility is located in approximately 14-20 m of water, 4 km offshore and covers an area of 12 km^2. The artificial structures are dome shaped concrete blocks weighing 900 kg and the owners of the company have called the structures 'abitats' (Figure 6.1). The lease area currently has 5000 'abitats' which can hold up to 400 abalone each. By the end of 2016 the sea ranch will be fully stocked with 2 million Greenlip abalone.

The juvenile Greenlip abalone are sourced from the land-based hatchery in Bremer Bay. The spat, which are produced from local brood stock are raised for 18 months in the hatchery prior to seeding on the 'abitats' when they are 40 mm in size. Once seeded the abalone rely on drift seaweed from the surrounding ocean and do not require any additional feeding. The abalone are grown on the structures for three years prior to harvest at around 100-145 mm. The current survival rate is around 80% with some lost to predation and others moving off the structures. In 2016 which was the first year of harvest 12 t of abalone were harvested from the artificial reefs, it is anticipated that 60 t will be harvested in 2017 reaching full capacity by 2018 with 100 t annually.

Figure 6.1 Example of typical 'abitat' structure showing layout and stocking density (Photograph Ocean Grown Abalone).

6.2 Other Fishing Activities

6.2.1 WA Commercial Fisheries

There are 47 different state-managed commercial fisheries that operate within the WA state managed waters, which target a variety of species including finfish, crustaceans, molluscs and echinoderms, with additional species being captured as byproduct and bycatch.

The AMF is the only WA commercial fishery which is permitted to harvest Greenlip, Brownlip and Roe's abalone.

6.2.2 Recreational Fishing

Approximately 30% of the WA population engages in recreational fishing, targeting a wide range of fish and invertebrate species. Recreational fishers catch abalone through wading, snorkelling and diving. The main focus for the recreational abalone fishery is the Perth metropolitan stocks of Roe's abalone (Zone 1), with recreational fishers currently landing around 41 % of the total catch of this species in WA (15-25 tonnes in the metropolitan area and 14 tonnes in the remainder of the state) (Hart et al. 2015a). The recreational take of Greenlip and Brownlip abalone off the southern coast is much smaller at around 8 tonnes, which represents approximately 3 – 4 % of the total catch of these two species (Hart et al. 2015b).

Recreational fishing for Greenlip, Brownlip and Roe's abalone can only be undertaken by a person holding a current recreational abalone fishing licence. There are no restrictions on the number of recreational licences issued and in 2014/15 there were 16,429 licences. The WA recreational abalone fishery is managed under a mix of input and output controls, including bag and size limits[7]. To control catches of Roe's abalone in the densely populated Perth metropolitan area, the recreational fishing season in this region is restricted to a total of five hours, between 0700 and 0800 hours on the first Sunday of each month between November and March in any year.

[7] See the http://www.fish.wa.gov.au/Documents/recreational_fishing/licences/rec_licence_abalone.pdf for more information on abalone recreational fishing rules

6.2.3 Customary Fishing

Although there is no quantitative information available on the customary catch of abalone in WA, there is evidence available that indicates Indigenous people have traditionally taken abalone for food and continue to do so (DoF 2005). Based on available data on the Indigenous proportion of the population inhabiting coastal areas in the south-western regions of the state, however, customary catches of abalone are likely to be negligible.

As part of the IFM process undertaken for Roe’s abalone, an annual catch of 0.5 tonnes was allocated to the customary fishing sector in the Perth metropolitan area (IFAAC 2009).

6.2.4 Illegal Fishing

The AMF has been intensively targeted by illegal fishers at certain periods in its history. The quantity taken depends on the species. Overall, intelligence operations have revealed that Greenlip abalone is the most desirable black market abalone and is easily sold and on sold; Roe’s is of limited desirability, with some local black market trade in the Perth metropolitan area, and Brownlip abalone is not highly sought and has a very limited black market.

It is estimated that at least 3 tonnes of Greenlip abalone per year is taken for the black market on the South Coast of WA. On the West Coast, small quantities of excess possession limit Roe’s abalone are taken overseas as hand luggage or baggage to Hong Kong, and Singapore (Hart et al. 2013a). For more information on compliance, see Section 17.3.

6.3 Market Influences

The majority of Roe’s, Greenlip and Brownlip abalone are exported overseas, mainly to Asian markets. The economic value of the abalone fishery is strongly affected by the value of the Australian dollar, with a decreased volume of sales when the dollar value is high.

The world market for abalone is strongly affected by numerous factors. The global financial crisis in 2007 depressed the demand for high priced fisheries products, including abalone and overall during this period prices were significantly reduced, sometimes by as much as 30%.

Large increases in illegal catches have also affected the world abalone market. It has been estimated that in 2008 the worldwide illegal catch totalled about 5300 tonnes. The availability of illegal catch has had and continues to have a destabilizing effect on the world market (Cook 2014).

The dramatic increase in production of abalone from aquaculture over the past 10 years has had a large effect on the dominant species available on the world market, product availability and prices (Cook 2014).

6.4 Environmental Factors

6.4.1 Climate Change

A risk assessment of WA’s key commercial and recreational finfish and invertebrate species has demonstrated that climate change is having a major impact on some exploited stocks (Caputi et al. 2014). This is primarily occurring through changes in the frequency and intensity of El Niño Southern Oscillation (ENSO) events, decadal variability in the Leeuwin

Current, increase in water temperature and salinity, and change in frequency and intensity of storms and tropical cyclones affecting the state (Caputi et al. 2014).

In 2010/11, a very strong Leeuwin Current resulted in unusually warm ocean temperatures in coastal waters of south-western WA (Pearce et al. 2011). This "marine heatwave" was associated with one of the strongest La Niña events ever recorded, with sea surface temperatures of up to 3° C above average. The effects of the heatwave were widespread and significant, with mortalities of Roe's in the northern reaches of the species' distribution in WA estimated at 99.9%. As a consequence, the area north of Moore River (Area 8 of the AMF) has been completely closed to all commercial and recreational fishing since 2011. The heatwave also appears to have negatively affected recruitment and growth of abalone in other areas of the fishery.

6.4.2 Weather

Weather can significantly influence fishing operations in the AMF. Area 1 is particularly vulnerable to weather, which in combination with the remoteness of the location results in low levels of fishing pressure. Poor weather mainly affects the operational effectiveness of the fishery, due to decreased efficiency; however, there have been some seasons where the quota for Roe's abalone has not been caught due to poor weather.

6.5 Other Activities

6.5.1 Oil and Gas Industry

The majority of the offshore oil and gas industry in WA is focused in the northern part of the state and thus overlap with abalone fishing operations are considered minimal. The main disturbances associated with oil and gas exploration and production include noise pollution from seismic surveys, potential for fish movement/impact arising from seismic surveys, disturbance to the marine habitat through drilling and/or dredging activities, release of produced formation water, shipping and transport activities and oil spill accidents.

The petroleum industry is regulated through the *Petroleum (Submerged Lands) Acts 1967,* the *Petroleum (Submerged Lands) (Management of Environment) Regulations 1999* and the EPBC Act. A key feature of the Environment Regulations is the requirement that an operator submit an Environment Plan before commencing any petroleum activity (CoA 2006).

6.6 Shipping and Ports

Shipping plays an important role in WA's economy, with major ports distributed along the WA Coast (Figure 6.2). The exports and imports at each port vary in accordance to proximity to different resources with major exports including: oil and petroleum, iron ore, agricultural products and salt.

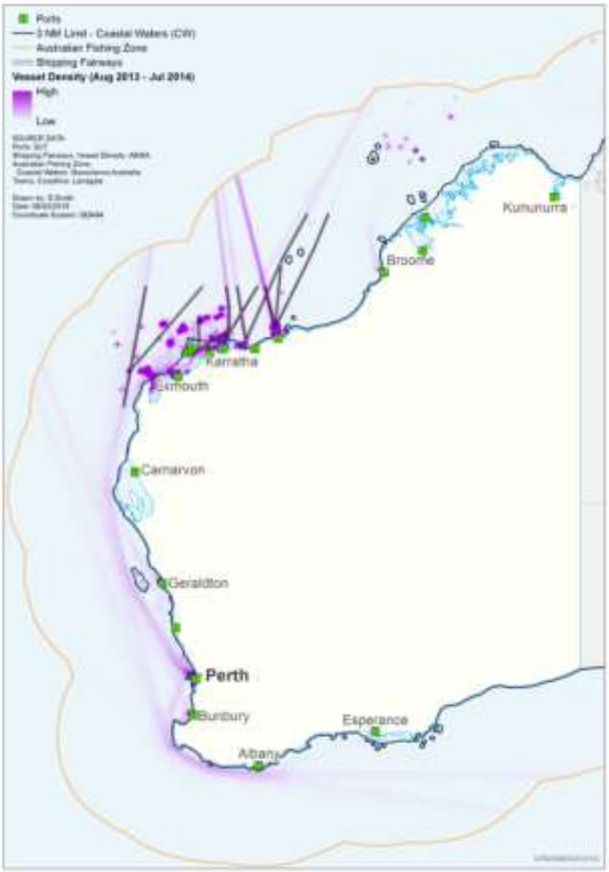

Figure 6.2 Major ports, port areas and shipping activities (based on 2013 to 2014 ship density data) for WA

In the main area of the abalone fishery in south-western WA, major ports include Fremantle, Bunbury, Albany and Esperance. Although shipping activity from these ports is low compared to activities in the north-west of the state associated with the mining industry, an increase in shipping and port expansion associated with growth of the resources sector has potential implications for the marine environment. Potential threats include loss or contamination of marine habitats as a result of dredging and sea dumping, oil spills, interactions between vessels and protected species and the introduction of marine pests. The environmental management of shipping is governed by a range of national and international agreements, regulations and codes of practice (CoA 2008).

6.7 Marina Development

A new marina has been proposed at Ocean Reef (northern metropolitan area) by the local council; the City of Joondalup (Figure 6.3). A concept plan has been developed for the marine including the following facilities:

- boat pens and boat storage;
- family leisure and recreation amenities;
- commercial and retail (including food and beverage);
- short-stay accommodation;

- residential;
- provision for the Ocean Reef Sea Sports Club and the Whitfords Volunteer Sea Rescue Group; and
- community buildings.

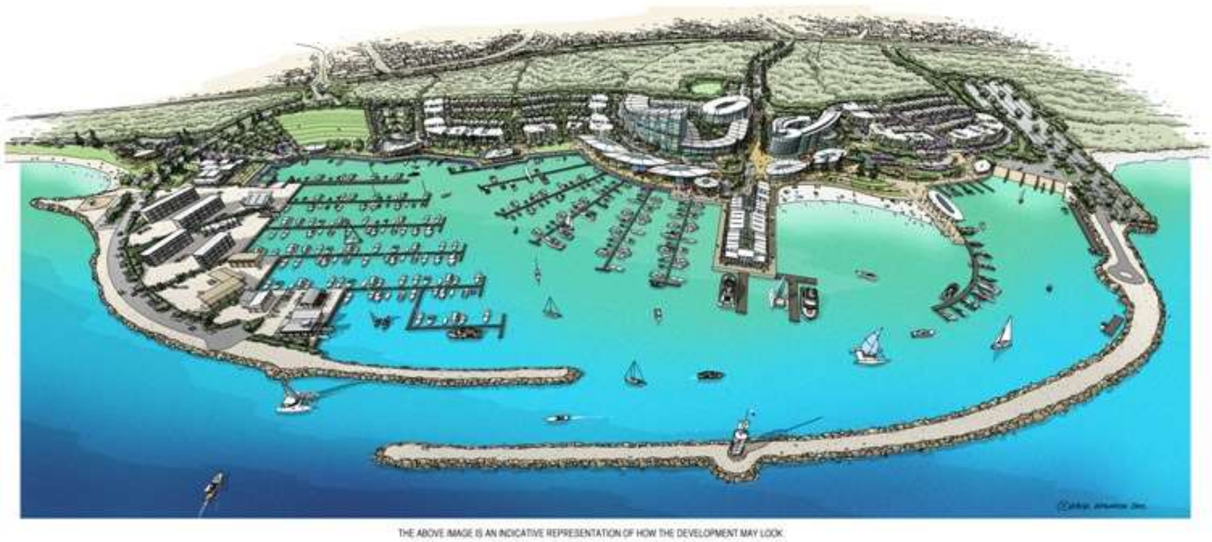

Figure 6.3. Proposed Ocean Reef marina development (Source: http://www.joondalup.wa.gov.au/Develop/MajorProjects/OceanReefMarina/Imagegallery.aspx)

The City of Joondalup is currently progressing environmental and planning approvals in collaboration with the WA State Department of Planning and the Office of the Environmental Protection Authority. Following the City's referral of the marine based components of the development to the Environmental Protection Authority (EPA) for assessment, the level of assessment was determined as a Public Environmental Review (PER). The City is progressing the PER in accordance with statutory process, which includes an assessment of impacts to marine fauna including abalone. It is anticipated that the environmental and planning assessments will be advertised for public comment in mid-2016[8].

The Ocean reef marina has the potential to impact on a large area of reef in which is important habitat for Roe’s abalone. A recent ecological risk assessment rated the potential impact of habitat modification on fishery performance as a severe (Webster et al. 2017). DoF’s role to date has been to facilitate discussions between the AIAWA and the City of Joondalup regarding direct and indirect impacts on the AMF and seeking avenues to pursue a mechanism for compensation.

[8] Information relating to the project can be found on the City of Joondalup website: http://www.joondalup.wa.gov.au/Develop/MajorProjects/OceanReefMarina.aspx.

MSC Principle 1

7 Stock Status

The status of Roe's, Greenlip and Brownlip abalone in WA is assessed using a weight-of-evidence approach that considers all available information about the stocks (see Wise et al. 2007). This assessment, which is described in more detail in Section 8, is primarily based on annual monitoring of standardised commercial catch rates in the different management areas of the AMF in which fishing effort on each species is concentrated (Table 7.1). No catch rates are calculated for Greenlip and Brownlip abalone in Area 1 (Point Culver to the South Australian border) or Area 4 (north of Busselton Jetty) due to the low levels of fishing for these species. For each species and relevant management area, a three-year moving average of the standardised catch rate (SCPUE) indicator is compared annually to species- and area-specific reference points calculated from historical fishery-dependent and fishery-independent data from a period of stability in the AMF (see Section 8.1.2).

The section below provides a summary of the current stock status of Roe's, Greenlip and Brownlip abalone in WA, including a comparison of the SCPUE indicator relative to the specified reference points in each relevant management area, and an overall weight-of-evidence summary for each species considering all available data and information. A more detailed description of the analyses and associated outputs that are incorporated in the overall weight-of-evidence assessment of each species is provided in Appendix C.

Table 7.1. Management areas of the AMF in which standardised catch rates are used as the primary performance indicator to assess the status of Roe's, Greenlip and Brownlip abalone stocks. Note that standardised catch rates are not calculated for Area 1 due to very low levels of fishing in this area

Management Area	Roe's abalone	Greenlip abalone	Brownlip abalone
Area 2	√	√	√
Area 3		√	√
Area 5	√		
Area 6	√		
Area 7	√		
Area 8	√*		

*As Area 8 is currently closed to abalone fishing due to low stock abundance, recovery is monitored through fishery-independent surveys

7.1 Current Stock Status

7.1.1 Roe's Abalone

In general, the standardised commercial catch rates for Roe's abalone in the key management areas in which this species is targeted have remained relatively stable since the early 1990s but show some decline since the 2010/11 (Figure 7.1). The three-year moving average

SCPUE used as the primary indicator for monitoring the status of this species has always remained above the target reference level specified for each management area (Figure 7.1).

The declining catch rates of Roe's abalone have generally been attributed to environmental factors, for example, the marine heatwave that caused catastrophic mortalities in Area 8 of the AMF and a closure of the fishery north of Moore River in 2010/11. This heatwave has also been implicated in growth stunting and other sub-lethal effects in other areas of the fishery (see Caputi et al. 2014). As a result, TACC has been reduced accordingly, and the latest predictions forecast further declines in harvest-sized animals in some areas. Overall, multiple lines of evidence indicate that the Roe's abalone stock in WA is above the point at which fishing may cause recruitment to be impaired (Table 7.2).

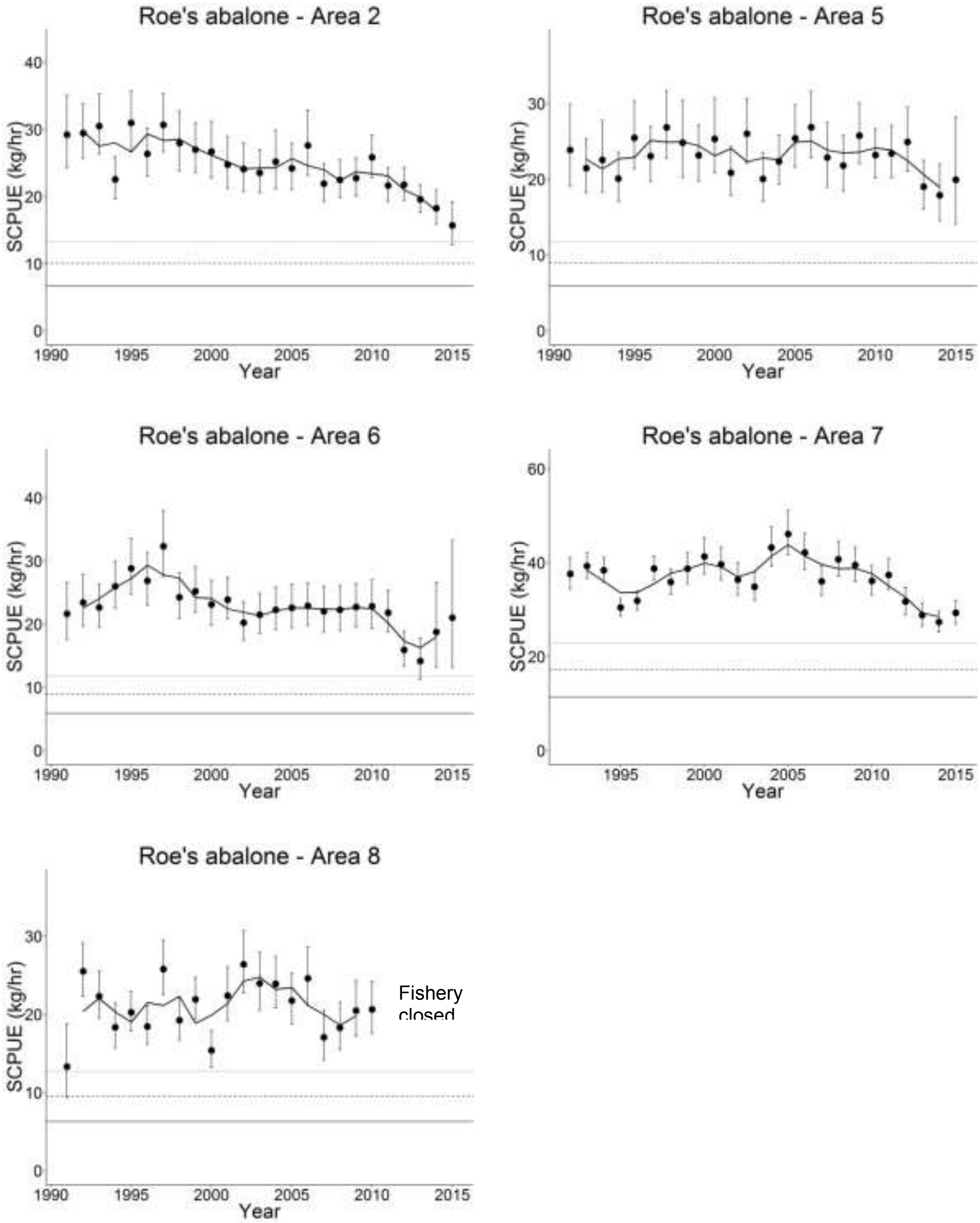

Figure 7.1. Annual standardised catch rates, SCPUE (kg/hr; ±95% confidence levels), and the three-year moving average of SCPUE (black line; i.e. the primary performance indicator) for Roe's abalone in Areas 2, 5, 6, 7 and 8 of the AMF relative to area-specific reference levels. The target, threshold and limit reference levels are denoted as the dotted (upper), dashed (middle) and solid (lower) horizontal lines, respectively. Note that the fishery north of Moore River (Area 8) has remained closed since 2011

Table 7.2. Weight-of-evidence assessment summary for stock status of Roe's abalone in WA, with each source of information available for this species/stock considered as a separate line of evidence

Category	Lines of evidence (Consequence/Status)
Catch	Currently, around 70% of the total catch of Roe's abalone is taken by the commercial fishery, with the remaining catch retained by recreational fishers. The estimated total catch in 2015 of 70 tonnes whole weight was the lowest recorded over the past 25 years, with only 58% of the TACC taken. Reductions in catch are driven mostly by economic reasons as there are few economically viable markets for this species, and fishery closures implemented in 2010/11 after a heatwave severely impacted abundance in the northernmost parts of the fishery. This does not provide any indication of stock depletion.
Catch distribution	The majority of the commercial and recreational catch of Roe's abalone is currently taken in Area 7 of the AMF, with smaller catches landed in Areas 2 and 5. Distribution of both commercial and recreational catches has remained stable over the last 20 years, with the exception of Area 8. There have been no catches in Area 8 and the northern parts of Area 7 since the 2010/11 marine heatwave caused a catastrophic mortality in this area. This provides no evidence of fishing-related stock depletion.
Catch rates	The standardised catch rates since 2010 show a declining trend in most areas, with signs of a recovery in three of the four fished areas over the last year. Although this provides some evidence of currently lowered stock levels, the performance indicator (three-year moving average of the standardised commercial catch rate) is currently above the target reference point in all areas monitored.
Vulnerability (PSA)	As a result of its sedentary nature and ease of accessibility, Roe's abalone is considered to have a high inherent vulnerability to fishing. However due to the high minimum length at first harvest, relative to length at maturity, and stringent catch controls, a low vulnerability PSA score was obtained (2.23; see Section 21.3 in Appendix C). This is equivalent to an MSC score of >80 and provides no evidence of stock depletion.
Size composition (Area 7)	Fishery-independent size composition data from the most heavily fished area (Area 7) indicate a reduction in proportion of larger abalone between 2007 and 2012, followed by stabilisation between 2012 and 2014, and an increase between 2014 and 2016 (see Section 21.1.2.1). This provides no evidence of stock depletion.
Total mortality (*Z*) (Area 7)	Time series of estimates of total mortality (*Z*) for Roe's abalone in Area 7 of the AMF, derived from a catch curve model that simultaneously estimates growth and mortality from tag-recapture and length frequency data, are linked to the trends in size-composition. Z increased between 2006 and 2012, oscillated between 2012 and 2014, and declined between 2014 and 2016 (see Section 21.1.2.1).
Index of recruitment (Area 7)	Fishery-independent (Age 1+) settlement densities of Roe's abalone in fished and unfished regions of Area 7 over the period 1997 to 2016 are not significantly different from each other (see Section 21.1.3). This indicates that recruitment variability is primarily environmentally controlled. The data show a declining trend in recruitment since the 2010/11 heatwave, with an increase occurring in 2016 after reaching the lowest level in 2015. This provides no evidence of fishing-related stock depletion.
Index of vulnerable biomass (Area 7)	Fishery-independent data on the density of fully-recruited (≥71 mm, Age 5+) Roe's abalone in Area 7 show a small decline since 2008 (see Section 21.1.3), however, the recent impact of the low Age 1+ recruitment is yet to be felt at this size class. The prediction model anticipates a significant reduction in the vulnerable biomass of this species in 2019 to 2020.
Index of spawning stock biomass (Area 7)	Estimates of spawning biomass of Roe's abalone for 2006 to 2009 are lower for the platform habitat (87 t; 95% CL 51-172 t) than for the subtidal habitat (174 t; 95% CL 85-759 t) (see Section 21.1.4). A time series trend from fishery-independent surveys provides no indication of a significant change (increase or decrease) since this time. The average annual harvest between 2006 and 2015 (64 t) was 25% of the estimated spawning stock biomass, but average catch in recent years (2013 – 2015) has been even lower (53 t or 20% of spawning biomass). This provides no evidence of stock depletion.

7.1.2 Greenlip Abalone

The three-year moving average SCPUE indicator for Greenlip abalone in Areas 2 and 3 (i.e. the key management areas on the south coast of WA in which this species is targeted by the AMF) has typically fluctuated around, or slightly below, the target reference level since the early 1990s (Figure 7.2). As with Roe's abalone, however, the effect of the 2010/11 marine heatwave on Greenlip abalone is evident in the declining catch rate trend observed over the past five years (Figure 7.2). Although the three-year average SCPUE indicator has remained just above the threshold level for Area 2, the indicator fell below the threshold level in Area 3 in 2014 (i.e. the 2012-2014 average SCPUE of 9.1 kg/hr and the 2013-2015 average SCPUE of 8.3 kg/hr have been below the threshold level of 9.9 kg/hr). In response to these breaches, TACCs have been reduced accordingly, particularly in the last couple of years. Currently, TACCs for the new season (2016/2017) have been reduced to 45% in Area 2, and 30% in Area 3, of their long-term averages. Overall, multiple lines of evidence indicate that the Greenlip abalone stock in WA is above the point at which fishing may cause recruitment to be impaired (Table 7.3).

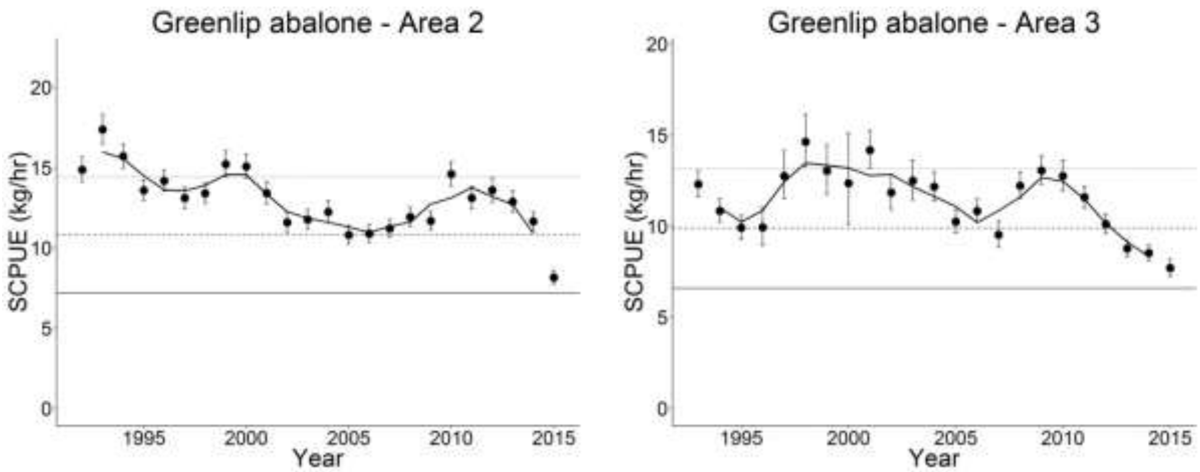

Figure 7.2. Annual standardised catch rates, SCPUE (kg/hr; ±95% confidence levels), and the three-year moving average of SCPUE (black line; i.e. the primary performance indicator) for Greenlip abalone in Areas 2 and 3 of the AMF relative to area-specific reference levels. The target, threshold and limit reference levels are denoted as the dotted (upper), dashed (middle) and solid (lower) horizontal lines, respectively

Table 7.3. Weight-of-evidence assessment summary for stock status of Greenlip abalone in WA, with each source of information available for this species/stock considered as a separate line of evidence

Category	Lines of evidence (Consequence/Status)
Catch	Currently, around 95% of the total catch of Greenlip abalone is taken by the commercial fishery, with the remaining catch retained by recreational fishers. The estimated total catch in 2015 of 46 tonnes meat weight (123 t whole weight) was the lowest recorded over the past 25 years. Reductions in TACC have been driven by lower SCPUE triggering harvest control rules. The fishery is considered to be in a low period of stock abundance, primarily due to environmental conditions.
Catch distribution	The vast majority of catches come from Area 2 and Area 3. The spatial distribution of this catch has remained consistent over the history of the fishery.
Catch rates	The three-year moving average of the standardised commercial catch rate is currently above the limit reference point in all areas monitored. However it has breached the threshold in Area 3, and substantial reductions in TACC have been implemented.
Vulnerability (PSA)	As a result of its sedentary nature, Greenlip abalone is considered to have a high inherent vulnerability to fishing. However due to the high minimum length at first harvest, relative to length at maturity, and stringent catch controls, a low vulnerability PSA score was obtained (2.23) (see Section 21.3 in Appendix C). This is equivalent to an MSC score of >80 and provides no evidence of stock depletion.
Size composition	Fishery-dependent length frequency data for Greenlip abalone show oscillations in length at 50% selectivity (L_{50}), but no consistent trend (see Section 21.2.2.1). This provides no indication of stock depletion.
Total mortality (*Z*)	Estimates of total mortality (Z) from fishery-dependent length frequency data since 2004 for Greenlip abalone indicate that *Z* has remained relatively stable (see Section 21.2.2.1). This provides no indication of increasing stock depletion over this time period.
Index of recruitment	Fishery-independent juvenile densities (< 85 mm) of Greenlip abalone in fished regions of Area 2 and 3 over the period 2005 to 2016 show a lower recent period, from 2012 to 2016 (see Section 21.2.3). It is hypothesised that, as with Roe's abalone, this is an environmentally driven response to warming waters. There is no evidence of fishing related stock depletion.
Index of vulnerable biomass	Fishery-independent data on the density of fully-recruited (≥145 mm, Age 6+) Greenlip abalone has remained relatively stable since 2005 (see Section 21.2.3), however it would be expected that the period of low juvenile recruitment would be entering the fishery over the current and next few seasons. There is no evidence of fishing related stock depletion.
Spawning biomass estimate	Estimates based on fishery-independent density data indicate that spawning biomass is between 540 to 640 t (see Section 21.2.4.1). Catches have been estimated to be approximately 9 – 11% of spawning biomass, which translate to a level of exploitation that is well within commonly used *F*-based target reference levels.

7.1.3 Brownlip Abalone

The three-year average SCPUE indicator for Brownlip abalone in Areas 2 and 3 has typically fluctuated above or around the target levels since 1999 but has declined to historically low levels since the 2010/11 marine heatwave (Figure 7.2). Despite this reduction, the primary performance indicator is currently above the threshold level in both areas. In response to this decline the TACC for this species has been reduced in accordance with the harvest control rules. Overall, multiple lines of evidence indicate that the Brownlip abalone stock in WA is above the point at which fishing may cause recruitment to be impaired (Table 7.2).

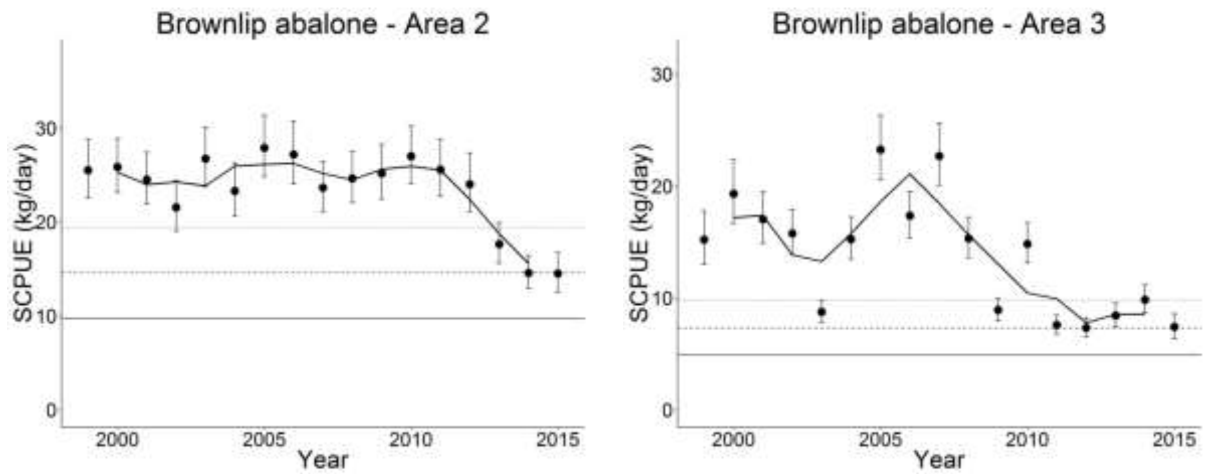

Figure 7.3. Annual standardised catch rates, SCPUE (kg/day; ±95% confidence levels), and the three-year moving average of SCPUE (black line; i.e. the primary performance indicator) for Brownlip abalone in Areas 2 and 3 of the AMF relative to area-specific reference levels. The target, threshold and limit reference levels are denoted as the dotted (upper), dashed (middle) and solid (lower) horizontal lines, respectively

Table 7.4. Weight-of-evidence assessment summary for stock status of Brownlip abalone in WA, with each source of information available for this species/stock considered as a separate line of evidence

Category	Lines of evidence (Consequence/Status)
Catch	Currently, around 97% of the total catch of Brownlip abalone is taken by the commercial fishery, with the remaining catch retained by recreational fishers. The estimated total catch in 2015 of 9.9 tonnes meat weight (24.6 t whole weight) was the lowest recorded over the past 15 years. Reductions in TACC have been driven by lower SCPUE triggering harvest control rules. The fishery is considered to be in a low period of stock abundance, primarily due to environmental conditions.
Catch distribution	All catches come from Area 2 and Area 3. The spatial distribution of this catch has remained consistent over the history of the fishery.
Catch rates	The three-year moving average of the standardised commercial catch rate is currently above the threshold reference point in both areas.
Vulnerability (PSA)	As a result of its sedentary nature, Brownlip abalone is considered to have a high inherent vulnerability to fishing. However due to the high minimum length at first harvest, relative to length at maturity, and stringent catch controls, a low vulnerability PSA score was obtained (2.23; see Section 21.3 in Appendix C). This is equivalent to an MSC score of >80 and provides no evidence of stock depletion.
Size composition	Fishery-dependent length frequency data for Brownlip abalone show a decline in length at 50% selectivity (L_{50}), from 158 mm (2004 to 2006) to 150 mm (2013-2015) (see Section 21.2.2.2). This indicates a reduction in larger sized animals.
Total mortality (Z)	Estimates of total mortality (Z) from fishery-dependent length frequency data since 2004 for Brownlip abalone indicate that Z has remained relatively stable (see Section 21.2.2.2). This provides no indication of increasing stock depletion over this time period.
Female spawning biomass	Results produced by a preliminary sex- and length-structured integrated model suggest that female spawning biomass has declined by about 30% from 1988 to 2015 (see Section 21.2.4.2). Given that catches in the early phase of the fishery (mid-1970s to mid-1980s) are likely to have been lower than those in 1988 to 2015, it is unlikely that female spawning biomass has declined to an unacceptable level.

8 Stock Assessment

8.1 Assessment Description

The range of methods used by the Department to assess the status of aquatic resources in WA have been categorised into five broad levels (Fletcher and Santoro 2015), which are typically used together with a weight-of-evidence approach to consider all available information for a resource. This includes objective interpretations of the inherent vulnerability of a species to the impacts of fishing, considering factors such as longevity, recruitment patterns and stock structure, in conjunction with the operational characteristics of the fishery and the potential influences of environment (Wise et al. 2007). The level of assessment and monitoring in place for each target species is thus determined based on the current risk to the sustainability of the species and the size and value of the fishery (DoF 2011).

In accordance with the weight-of-evidence approach, abalone stocks in WA are assessed using a wide range of available data, including fishery-dependent catch and effort statistics, size composition data and estimates of growth and fishing mortality, and fishery-independent survey information on the size and density of abalone in different areas of the fishery. As outlined in more detail in Section 9.3, the type and amount of data available for assessment differs between species and areas depending on their importance and contribution to the overall catches within the fishery.

For each of the three species (Roe's, Greenlip and Brownlip abalone), the primary performance indicator used for monitoring stock status is a three-year average of the annual standardised catch rates in each of the relevant management areas (see Table 7.1). This indicator, which is considered a proxy for stock abundance, is compared annually to species- and area-specific reference points (target, thresholds and limits). Following the harvest control rules detailed in the abalone harvest strategy, this assessment is then used as the basis for providing recommendations for the setting of TACCs each year.

The sub-sections below provide (1) an outline of the process undertaken to standardise the commercial catch rates used as the primary performance indicator for stocks and (2) a description of the reference points against which the three-year average of this indicator is compared to determine current stock status.

8.1.1 Catch Rate Standardisation

Standardisation of catch rates is an integral part of the stock assessment and is the primary performance indicator used to inform the annual setting of TACCs for each management areas in the AMF (Hart et al. 2009). The current standardised catch rate (SCPUE; standardised catch per unit effort) model applied to data for each of the three species takes into account technology and environmental effects on catching efficiency. Estimates of technology correction factors (Internet Weather Prediction, or IWP) were established by Hart et al. (2009), and applied to the raw CPUE data prior to the generalised linear model (GLM) analysis.

For each species in each management area, the GLM model fitted to the raw CPUE data after correcting for catching efficiency is

$$\ln(CPUE+1) = \mu + \beta_1(Year) + \beta_2(month) + \beta_3(subarea) + \beta_4(Diver) + \varepsilon\ ,$$

where *CPUE* is the corrected CPUE data (kg whole weight/hr) from each fishing day of an abalone diver; β_1 (*Month*) is the effect of monthly variation in the fishing efficiency arising from changes in seasonally varying factors, such as meat condition, swell, visibility; β_2 (*Sub-area*) is the effect of spatial differences on abundance of abalone; β_3 (*Diver*) is the effect of diver differences on the catch rate of abalone. The least squares mean of the *Year* factor was used to produce an annual index of the relative abundance (SCPUE) of abalone.

8.1.2 Reference Points

Catch rate-based reference points have been in place to guide the management of Roe's and Greenlip abalone in WA since the first harvest strategy was implemented in 2005 (Hart et al. 2009). These initial target, threshold and limit levels specified for each species and management area did not, however, constitute conventional biological reference points but rather aimed to ensure catch rates were maintained over levels at which it was economically feasible for fishers to operate.

Following a review of the abalone harvest strategy in 2015, updated (biologically-based) target, threshold and limit reference points were calculated for each of the three abalone species and their relevant management areas. These new reference points were based on historical catch rate information from reference periods of stability in the AMF (Table 8.1) and, where possible, utilised available fishery-independent data from fished and unfished areas to determine appropriate catch rate levels.

Table 8.1. Species-specific reference periods used for setting appropriate harvest strategy reference levels for the abalone resources

Species	Reference period	Justification
Roe's abalone	1997-2010	Period prior to marine heatwave event for which fishery-independent survey data in Area 7 are available. Note that the same reference period is applied across all other management areas for Roe's abalone.
Greenlip abalone	1992-2006	As described by Hart et al. (2009).
Brownlip abalone	2000-2014	Period prior to TACC change in 2015 for which fishery-dependent data for this species are considered most reliable.

8.1.2.1 Roe's Abalone

The reference points for Roe's abalone have been calculated based on commercial catch rate data for the specified reference period of 1997-2010 (Table 8.1), using fishery-independent survey indices of abundance in the fished and unfished areas of Area 7 of the AMF from the same time period to determine the catch rate levels that would be expected when stock abundance is at 40%, 30% and 20% of unfished biomass levels (i.e. which correspond to the target, threshold and limit reference points, respectively). Specifically, the fishery-independent data for the fished and unfished areas were applied to relate the standardised catch rate data to estimates of spawning biomass in this management area using the following procedure.

1. The average spawning biomass of Roe's abalone in unfished areas of Area 7 for the period 1997 to 2010 (i.e. B_0) was estimated as 2.61 kg per m^2. This is used as a measure of unfished biomass for the stock in this management area.
2. The average spawning biomass of Roe's abalone in fished areas during the same time period (B_F) was estimated as 1.97 kg per m^2.
3. The year in which the annual spawning biomass index for the fished area was the closest to B_F (1.9 kg per m^2 in 2004) was set as the reference year.
4. Given the ratio between the average fished and unfished spawning biomass during the reference period (B_F/B_0 = 0.755), the standardised commercial catch rate expected to relate to an unfished stock level was calculated as $\mathrm{SCPUE}_0 = \mathrm{SCPUE}_{2004}/(B_F/B_0)$. Based on a standardised catch rate in the reference year (SCPUE_{2004}) of 43.2 kg/hr in Area 7, the unfished catch rate level (SCPUE_0) in this management area was estimated as 57.2 kg/kr.
5. The SCPUE-based target, threshold and limit reference points for Roe's abalone in Area 7 were then calculated as 20%, 30% and 40% of SCPUE_0.

As no fishery-independent survey indices for abundance are available for Roe's abalone in areas other than Area 7 (i.e. which represents the key area of the fishery for this species), it has been assumed that the ratio between the average fished and unfished spawning biomass of the stock during the reference period is consistent across all Roe's abalone fisheries. For Areas 2, 5, 6 and 8, SCPUE-based reference points were thus determined from steps 4 and 5 of the above procedure. The reference points calculated for each management area, based on SCPUE values estimated by the catch rate standardisation model using data including the 2014/15 fishing season, are presented in Table 8.2. Note that the values for these reference points may change marginally when the catch rate standardisation is annually updated as new data becomes available.

Table 8.2. Biologically-based target, threshold and limit reference points for Roe's abalone in relevant management areas

	Standardised catch rate-based reference points (kg whole weight/hr)		
Management Area	**Target**	**Threshold**	**Limit**
Area 2	13.3	10.0	6.7
Area 5	11.8	8.9	5.9
Area 6	11.8	8.9	5.9
Area 7	22.9	17.2	11.4
Area 8	12.7	9.5	6.3

As an independent check of the validity of using the unfished area biomass of Roe's abalone as an index for virgin biomass in the fished areas, the mean settlement densities of Age 1+

(17-32 mm) abalone since 1997 were statistically compared between fished and unfished areas (Figure 8.1). The two data sets were highly correlated (r = 0.78; P < 0.001; Figure 8.1a), and there was no statistical difference in the mean Age 1+ density in the different areas (9.6 per m^2 for fished areas; 8.1 per m^2 for unfished areas).

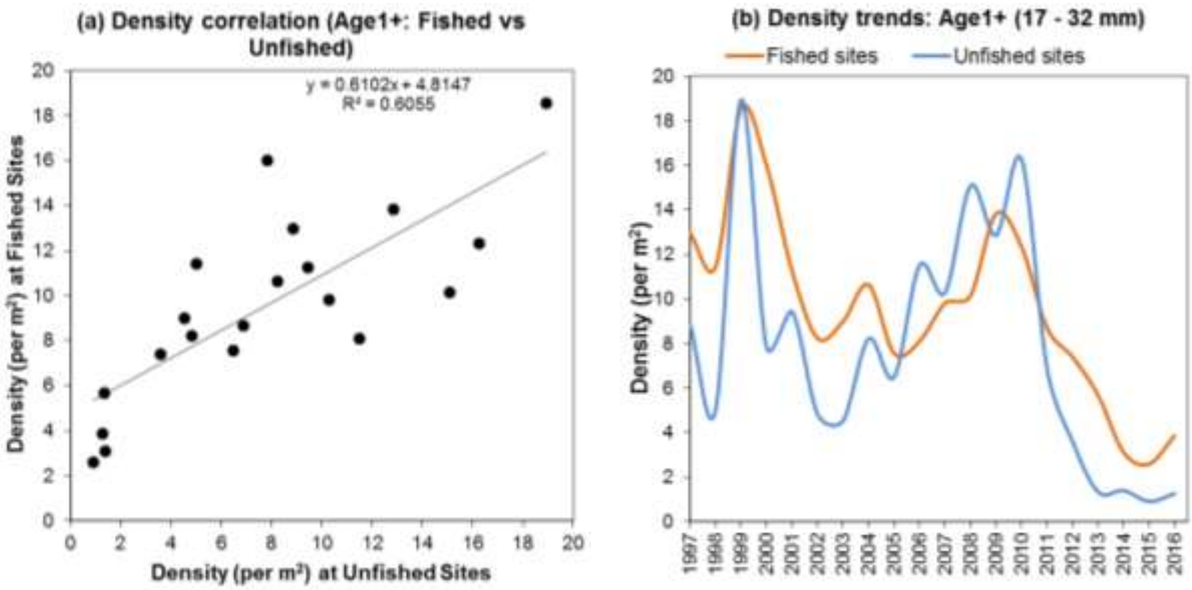

Figure 8.1. Mean density (individuals per m^2) of Roe's abalone recruits (Age 1+; 17-32 mm) for fished and unfished areas, based on fishery-independent survey data from 1997 to 2016. (a) presents the correlation between densities in fished and unfished areas and (b) shows the time series of data

8.1.2.2 Greenlip and Brownlip Abalone

Establishing a relationship between catch rate data and biologically-important parameters such as unfished biomass is challenging when fishery-independent data are limited, which is the case for Greenlip and Brownlip abalone. Theoretical analyses of egg per recruit relationships have established that, at the minimum size limits for these two species in WA, egg conservation is well above the traditional target fishing mortality of 40% of unfished egg production (Hart et al. 2013a), based on the assumption of constant recruitment.

Due to a lack of robust estimates of spawning biomass relative to unfished levels for Greenlip and Brownlip abalone, reference points for these species have been determined based on the historical values of the commercial catch rates observed in each relevant management area during their reference periods (1992-2006 for Greenlip abalone and 2000-2014 for Brownlip abalone, see Table 8.1). Based on the data showing that the fisheries were operating at sustainable levels during these reference periods (i.e. recruitment was not impaired), threshold reference levels for each species have been set as the lowest catch rate observed in each management area (assuming this level corresponds to catch rates at 30% of unfished stock levels, see Johnston et al. 2015 for an example of this approach being applied to the harvest strategy for a blue swimmer crab fishery). Associated target (40%) and limit (20%) reference level were then determined (Table 8.3).

Table 8.3. Biologically-based target, threshold and limit reference points for Greenlip and Brownlip abalone in relevant management areas

Species – Management Area	Standardised catch rate-based reference points (kg meat weight/hr for Greenlip, kg meat weight/day for Brownlip)		
	Target	Threshold	Limit
Greenlip – Area 2	14.4	10.8	7.2
Greenlip – Area 3	13.2	9.9	6.6
Brownlip – Area 2	19.4	14.6	9.7
Brownlip – Area 3	9.8	7.3	4.9

8.2 Appropriateness of Assessment

The weight-of-evidence assessment incorporates all available information for Roe's, Greenlip and Brownlip abalone in WA (including both fishery-dependent and fishery-independent data, see Section 9.3) and takes into account important features relevant to the biology of each species and the nature of the fishery. The process undertaken for each species to standardise the commercial catch rates (i.e. the primary performance indicator for the stocks) takes into account a range of factors known to influence the catch rates of abalone divers, including technological and environmental effects on their catching efficiency. The assessment also accounts for evidence of relatively localised recruitment in abalone through monitoring of standardised catch rates in each of the key management areas in which the species are targeted (Table 7.1; see also Hart et al. 2013a). To reduce the influence of annual fluctuations in abundance resulting from natural recruitment variability, a three-year moving average of the standardised catch rates for each species and relevant area is used as the indicator that is compared annually to the species- and area-specific reference points.

In addition to annual monitoring of standardised catch rates, the overall weight-of-evidence assessment of each abalone species also incorporates a range of other available data, including estimates of commercial and recreational catches, estimates of growth and fishing mortality, and indices of recruitment and harvest-size abundance derived from fishery-independent surveys of abalone densities (see Appendix C for more information). A probabilistic *F*-based reference point analysis based on these data has also been undertaken to demonstrate that catches of the each species have been sustainable (see Section 8.5.1).

8.3 Assessment Approach

The assessment approach is directly focused on ascertaining that abalone stocks remain above the level at which fishing may cause recruitment to be impaired. This is pursued through a careful and robust annual assessment of standardised commercial catch rates (for each species in each relevant management area) relative to specified reference points (see Section 8.1.2).

8.4 Uncertainty in the Assessment

Several sources of uncertainty are accounted for in the weight-of-evidence assessment of the abalone stocks. The process undertaken to standardise commercial catch rates to provide reliable proxies for the abundance of abalone in each management areas considers a range of factors that are known to influence these catch rates (Hart et al. 2009). Impacts of important factors influencing diver catch rates are routinely discussed with commercial fishers at Annual Management Meetings, leading to the ongoing identification of new factors to incorporate into the catch rate standardisation model. An example is the Internet Weather Prediction (IWP) factor, which allows for fishers to plan harvest around multiple days of low ocean swells. It was found to have a significant effect on fishing efficiency and is therefore now accounted for in the catch rate standardisation process (Hart et al. 2009). Measures of variability (uncertainty) around the standardised catch rates are presented as 95% confidence intervals around the estimated mean values for each year.

Although estimates of fishing mortality derived from length-based analyses for moderately long-lived species such as abalone are much less certain than those based on age, the difficulty of ageing abalone precludes age-based assessments. Application of length-based methods is made more difficult by the influence of substantial variability in growth among individuals, within and between management areas. Recent research has therefore been focused towards deriving more reliable methods for estimating growth and mortality for abalone (see Appendix C), as well as incorporating uncertainty into assessments. For example, as described in Section 21.1.2, simultaneous fitting of catch curves and growth curves has enabled uncertainty in growth to be accounted for when estimating mortality. Comparisons of using this approach to assuming a “fixed” growth curve demonstrate that uncertainty in mortality is grossly underestimated if uncertainty in growth is not accounted for. This uncertainty has then been accounted for in subsequent analyses undertaken to estimate spawning biomass, and in the *F*-based reference point analysis undertaken to ascertain sustainable levels of annual catch for each species (see below).

The reference point analysis described below in Section 8.5.1, which was undertaken to estimate the sustainable catch of Roe’s and Greenlip abalone, accounted for uncertainties in the various data inputs, such as in growth, total and natural mortality and estimates of spawning biomass. The analysis is probabilistic in that it identifies the catch that has the greatest probability of being within 10% of the target catch, whilst having a low (<10%) chance of exceeding catch limits, according to *F*-based reference points. Two different estimates of natural mortality were considered in the analyses for each species to explore the extent to which this influences results.

8.5 Evaluation of Assessment

The current assessment has indicated that abundance of harvest size Roe’s abalone in the different management areas have remained relatively stable over the past two decades, apart from Area 8, which suffered a catastrophic collapse due to the effects of a marine heatwave in 2010/11, resulting in closure of this area to abalone fishing. Fishery-independent data from the important Perth metropolitan area indicate that, since the heatwave, Roe’s abalone in the platform habitat has been impacted more by fishing pressure than those in the subtidal habitat. As would be expected, there has been a progressive decline in the density of harvest-sized animals in the platform habitat, which is also reflected in the trend in fishing mortality estimates for this period (see Section 21.1.2.1). In contrast, catch rate indices of the abundance of harvest-sized animals, fishing mortality and catches are all more stable in the subtidal habitat. The similarity of recruitment trends observed in fished and unfished areas provide strong evidence that the recent downturn in recruitment of Roe's abalone is driven by the environment and was not caused by excessive fishing on the stock.

In the case of the Perth metropolitan fishery for Roe's abalone, a probabilistic reference point analysis in 2013 (see section below) demonstrated that the level of commercial and recreational catches of Roe's abalone between 2006 and 2013 was marginally too high but that maintaining the 2013 TACC would result in a very low (8%) probability of breaching the F-based limit reference point. The result of that analysis is consistent with the indication from other available data that fishing at that time, particularly on the platform habitat, was too high. As a result, the recreational bag limit of Roe's abalone in the Perth metropolitan area has been reduced from 20 to 15 and the TACCs for this species have also been reduced. This has resulted in a substantial reduction in catches, the average total catch (recreational + commercial) of around 50 tonnes for 2012 to 2015 was 32% lower than the average catch for 2006 to 2011 (73 t).

For Greenlip abalone, analyses assuming realistic estimates of parameters such as natural mortality have yielded viable estimates of spawning biomass, with the average catch of this species from 2007 to 2012 (60 ± 2.3 t; meat weight) reflecting 9 to 11% of the median biomass estimate (see Section 21.2.4.1). Although the reference point analysis undertaken in 2013 for Greenlip abalone (see section below) concluded that the level of harvest of this species between 2007 and 2012 was highly likely to be sustainable, with <5% probability of exceeding the limit reference points, the current assessment shows a recent decline in the annual standardised catch rate in Area 3 to a level that is now below the threshold value. A similar pattern has been observed for Brownlip abalone. These declines are hypothesised to have been caused by environmental drivers, as is the case for Roe's abalone. In accordance with the harvest control rule, the TACC for Greenlip and Brownlip has been reduced over the past few years.

8.5.1 Reference Point Analysis

For Roe's and Greenlip abalone, an approach adapted from that detailed by Hesp et al. (2008) was applied in 2013 to estimate the level of sustainable catch for each species, based on fishing mortality (F)-based reference points and an analysis involving the Baranov catch equation. Although analyses for both species considered a target level of $F = 0.75M$, there is some debate about which F-based limit reference points are most appropriate for abalone. For Roe's abalone, a limit level of $F = 1.5M$ was specified as the estimate for M for this species of 0.43 year^{-1} indicates that it has moderate longevity and productivity. This is consistent with F-based reference points used by the Department for other species with similar life history traits. For Greenlip abalone, a limit reference point of $F = 1.2M$ was specified because fishing is focused on only large individuals that attained maturity several years earlier and therefore, the stock is likely to support a higher level of F than if smaller individuals were fished.

The reference point analysis for each species involved:

1) calculating the values of F that correspond to the specified F-based target and limit reference points by drawing a random value of F and M from their respective distributions;
2) calculating the catch corresponding to the target and limit values of F using the Baranov catch equation and available estimates of spawning biomass for each species; and
3) scoring selected levels of catch (i.e. over the range of possible catches) depending on whether they (a) exceed the F-based limit values and (b) lay within 10% of the target value.

This process was repeated multiple times (1000 for Roe's abalone and 5000 for Greenlip abalone) to determine the probabilities of each level of catch exceeding the limit level, and being within 10% of the target. The analysis takes into account uncertainty in estimates of spawning biomass, F and M. The sustainable catch is considered as that which maximises the probability of being within 10% of the target, but which still has a low probability (e.g. no greater than 5%) of exceeding the limit level. For Roe's abalone, the catch associate with a threshold level of fishing mortality, corresponding to that at which $F = M$, was also considered to provide an approximation for the maximum sustainable yield (MSY).

8.5.1.1 Roe's Abalone

Assuming a value for M of 0.43 $year^{-1}$ for Roe's abalone, the average catch observed between 2006 and 2013 in the key area of the fishery for this species (68 t, including commercial landings in Area 7 and recreational catch estimates for the West Coast Zone) had a low chance (<10%) of exceeding the limit reference point of $F = 1.5M$ (Figure 8.2a). Under this scenario, the catch that has the greatest probability of meeting the target reference point of $F = 0.75M$ was 50 t, and the catch that is most likely to correspond to the threshold level of MSY ($F = M$) is 58 t. As the curves describing the probabilities of different levels of catch being within 10% of the threshold and target levels are relatively flat near their peaks, an average annual catch as large as 78 t is estimated to still have relatively low (<20%) probability of exceeding the limit (Figure 8.2). These results would indicate that the average catch has been slightly too high for some years, which would be consistent with the observations of a progressive decline in the abundances of larger individuals in the platform habitat (and accompanying catch curve estimates for "mortality" in this habitat). Given the recent downturn in recruitment, which appears mainly environmentally driven, the TACC has been reduced accordingly.

Under the scenario with a more conservative value for M of 0.3 $year^{-1}$ (i.e. assuming lower stock productivity), the values of catch that maximised the probability of being within 10% of the target and threshold values for F were 30 t and 38 t, respectively (Figure 8.2b). Given that the fishery for Roe's abalone has sustained catches of well above these levels for over three decades, the values suggested by this latter analysis appear unrealistically low.

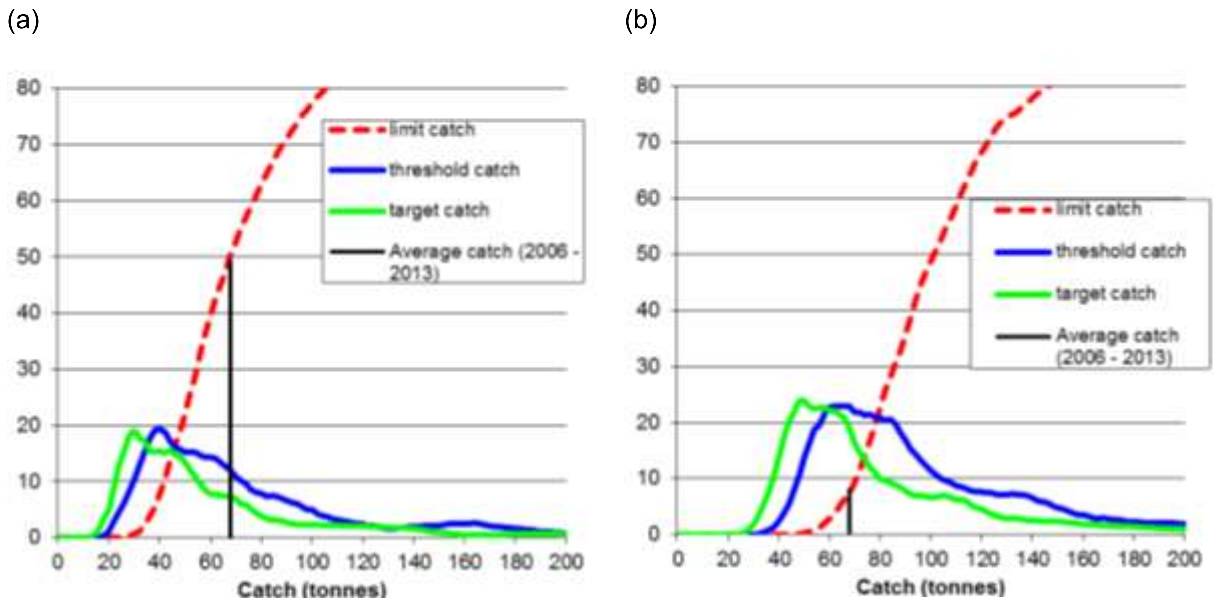

Figure 8.2. Sustainable catch estimates for Roe's abalone in the Perth metropolitan fishery (Area 7 commercial + West Coast recreational) calculated from reference point analysis. Horizontal lines refer to the probabilities (expressed as a %) of each level of catch exceeding the limit reference point (F = 1.5M) and being within 10% of the target reference point (F = 0.75M) and threshold reference point (F = M). M is assumed at 0.3 year^{-1} in (a) and 0.43 year^{-1} in (b)

8.5.1.2 Greenlip Abalone

Assuming a value of M for Greenlip abalone of 0.2 year^{-1} in the reference point analysis showed that the average catch between 2007 and 2012 (60 ± 2.2 t) had a <1% probability of exceeding the limit reference point (Figure 8.2a). Under this scenario, the catch that has the greatest probability of meeting the target reference point is 80 t (Figure 8.2a).

If an M of 0.15 year^{-1} is assumed for Greenlip abalone, which may be considered as a "worst-case scenario" of low stock productivity, the average catch between 2007 and 2012 (60 ± 2.2 t) had a 7% chance of exceeding the limit reference point (Figure 8.2b). Under this scenario, the catch that has the greatest probability of meeting the target reference point, but only a 1% chance of exceeding the limit, was 52 t, i.e. 8 t less than the average harvest between 2007 and 2012 (Figure 8.2b). These findings provide support that the historical catches of Greenlip abalone in WA have been sustainable.

(a) (b)

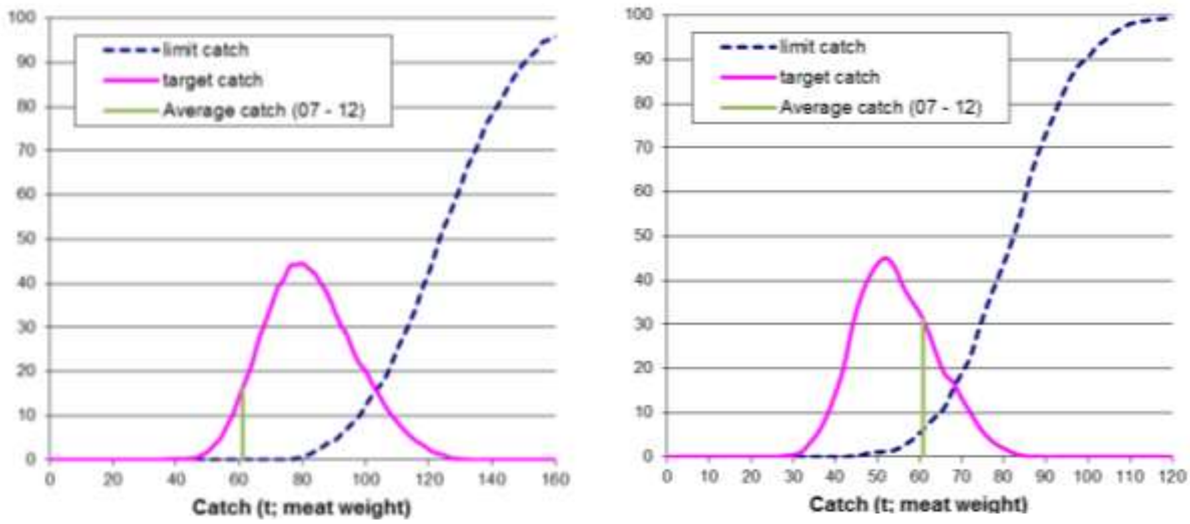

Figure 8.3. Sustainable catch estimates for Greenlip abalone calculated from reference point analysis. Horizontal lines refer to the probabilities (expressed as a %) of each level of catch exceeding the limit reference point (F = 1.2M) and being within 10% of the target reference point (F = 0.75M). M is assumed at 0.2 year^{-1} in (a) and 0.15 year^{-1} in (b)

8.6 Peer Review of Assessment

Prior to the third-party certification initiative that involved the MSC pre-assessment of all WA fisheries, the Department adopted a schedule for the periodic peer review of assessments for all fisheries in WA. This "rolling" schedule aimed to generate major reviews of 5 – 8 fisheries per year, employing a mix of internal and external fisheries experts (e.g. from universities, CSIRO and interstate fishery departments). The abalone fishery assessment was peer reviewed in 2010, and a copy of that review can be obtained upon request. Significant independent peer-review of all aspects of AMF, including the stock assessment components, has also been conducted through the assessments of the fishery to meet the Commonwealth's requirements for export accreditation under the EPBC Act (see Section 4.5).

Internal review of the abalone assessment approach and the catch rate standardisation process was undertaken as part of the publication of the first harvest strategy for abalone as a Fisheries Research Report (Hart et al. 2009). The outcomes of the annual assessment of the standardised catch rates are reviewed each year as part of the process for completing the annual *Status Reports of the Fisheries and Aquatic Resources in Western Australia* (e.g. Fletcher and Santoro 2015). Assessment results and annual trends in data are also examined and conveyed to fishers during regular meetings with a Research Group comprising members of the Abalone Industry Association of Western Australia (AIAWA), including those discussing recommendations provided for the annual setting of TACCs for the upcoming fishing season.

9 Harvest Strategy

The harvest strategy for the abalone resources of WA make explicit the management objectives, performance indicators, reference levels and harvest control rules for the resource, which are taken into consideration by the Department when preparing advice for the Minister for Fisheries. The harvest strategies have been developed in line with the Department's over-arching Harvest Strategy Policy (DoF 2015) and relevant national policies / strategies (ESD Steering Committee 1992) and guidelines (e.g. Sloan et al. 2014). In addition, to target species (i.e. Roe's, Greenlip and Brownlip abalone) they also incorporate bycatch and ETP species, habitats and ecosystem components to ensure the risks to these elements are effectively managed.

9.1 Framework

This section provides a summary of the harvest strategy framework in place for managing the abalone resources of WA (see also DoF 2017). Additional information about the harvest control rules is provided in Section 9.2, with a summary of the information and monitoring undertaken to inform the assessment and harvest strategy of these resources outlined in Section 9.3.

9.1.1 Design

The harvest strategy for the abalone resources of WA is based on a *constant exploitation approach*, where the annual catch varies in proportion to variations in stock abundance. In line with this approach, the commercial fishery is primarily managed through TACCs, which are set annually for each management area based on a three-year average of the primary performance indicator for abalone (i.e. standardised commercial catch rates) relative to species- and area-specific reference points (Table 9.1).

As the catch rates are considered to represent adequate proxies for abundance of abalone in the different management areas, the harvest strategy is responsive to the status of the stocks and is designed to achieve the key management objective *to maintain spawning stock biomass of each target species at a level where the main factor affecting recruitment is the environment*. This long-term objective has been operationalised as short-term (annual) objectives aimed to maintain each stock close to a target level and above a threshold level (see Table 9.1).

Harvest control rules define what management actions should occur annually in response to the value of the catch rate indicator compared to reference points (see Section 9.2). This involves, for each species in each relevant management areas, determining an annual (commercial) sustainable harvest level (SHL), which is then provided to managers and industry as the recommended TACC for the upcoming fishing season. The extent of management actions taken (e.g. TACC reduction from the long-term level) will be determined by the extent to which the performance indicator has breached a threshold or limit reference point.

Table 9.1. Summary of the harvest strategy for Roe's, Greenlip and Brownlip abalone in WA

Management Objective	Performance Indicator	Reference Points	Control Rules
To maintain spawning stock biomass of each target species at a level where the main factor affecting recruitment is the environment	Three-year moving average of the standardised catch rate in each relevant management area	**Target** Roe's abalone (kg whole weight/hr): Area 2- 13.3, Area 5- 11.8, Area 6- 11.8, Area 7- 22.9, Area 8- 12.7 Greenlip abalone (kg meat weight/hr): Area 2- 14.4, Area 3- 13.2 Brownlip abalone (kg meat weight/day): Area 2- 19.4, Area 3- 9.8	1. If the performance indicator is ≥ the Target, set SHL to long-term level (or above this level when indicator is well above the Target). 2. If the performance indicator is < the Target and ≥ the Threshold, set SHL at 90 % of long-term level. 3. Area 7 Roe's abalone. Set SHL as a function of stock abundance using predictive model. This control rule is in the developmental stage, and is used in tandem with existing rules, rather than as a stand-alone rule I (see Section 9.2.1).
		Threshold Roe's abalone (kg whole weight/hr): Area 2- 10.0, Area 5- 8.9, Area 6- 8.9, Area 7- 17.2, Area 8- 9.5 Greenlip abalone (kg meat weight/hr): Area 2- 10.8, Area 3- 9.9 Brownlip abalone (kg meat weight/day): Area 2- 14.6, Area 3- 7.3	If the performance indicator is < the Threshold and > the Limit, set SHL at 70 % of long-term level.
		Limit Roe's abalone (kg whole weight/hr): Area 2- 6.7, Area 5- 5.9, Area 6- 5.9, Area 7- 11.4, Area 8- 6.3 Greenlip abalone (kg meat weight/hr): Area 2- 7.2, Area 3- 6.6 Brownlip abalone (kg meat weight/day): Area 2- 9.7, Area 3- 4.9	If the performance indicator is ≤ the Limit, set SHL at 0-50 % of long-term level.

9.1.2 Evaluation

The abalone harvest strategy has evolved over time, based on a historical understanding of the catch rates achieved in the fishery at different catch levels. Using an adaptive management approach for the fishery, the annual TACCs have been modified to match the harvest level to the expected abundance. This was initially based on anecdotal observations of abalone divers that growth or recruitment of abalone was increasing or decreasing. To bring more rigour into the TACC setting process, preliminary performance indicators were first introduced into the fishery in 2005 and in the following year, the abalone management advisory committee commissioned a formal project to develop robust harvest control rules. This involved a comprehensive 7-step process with explicit industry consultation, which led to the implementation of a formal harvest strategy for Roe's and Greenlip abalone that has been operating since 2008 (Hart et al. 2009).

Since 2008, the abalone harvest strategy has been evaluated on an annual basis by assessing current stock abundance (as indicated by the standardised catch rates) against reference points based on long-term historical abundance levels in the fishery. The harvest strategy has been successful in adjusting TACCs in response to changes in the catch rate indicator, with several TACC decreases implemented for management areas when reference levels have been breached (see Section 9.2.3 on evaluation of harvest control rules). In preparation for a MSC pre-assessment of the abalone fishery in 2013, analyses were also undertaken demonstrate that the TACCs set for Roe's and Greenlip abalone at that time were sustainable (see Section 8.5.1).

Based on a review in 2015 of the reference points specified in the 2008 abalone harvest strategy, it was considered necessary to update these to better reflect biological targets, thresholds and limits (they previously corresponded to economic reference levels, which were overly conservative). In particular for Roe's abalone, for which a long time series of fishery-independent data in fished and unfished areas is available, the process for calculating reference levels now better utilises this information to determine the catch rate levels that would be expected to correspond to those when the stock is at 20, 30 and 40% of unfished stock levels (corresponding to the limit, threshold and target reference points, respectively. All revised reference levels for Roe's and Greenlip abalone, and the first ones implemented for Brownlip abalone, are described in Section 8.1.2, as well as the updated abalone harvest strategy 2016 – 2021 (DoF 2017).

The approach of continual improvement of the abalone harvest strategy has maintained stocks at levels above that needed to ensure sustainability. Despite data showing that abalone stocks have been impacted by the 2011 marine heatwave in WA, the very conservative minimum size limits for each species will ensure that sufficient stock remains in the fishery at catch rates levels above the threshold reference points. The current reference levels are considered sufficiently precautionary to deal with impacts of environmentally-driven fluctuations in stock levels but will trigger TACC reductions when needed. This is further guaranteed through the use of a weight-of-evidence approach to assessment approach, which considers all available information (e.g. fishery-dependent and fishery-independent data on abalone size compositions and densities) in management decision making.

9.1.3 Monitoring

There is a wide range of monitoring in place to determine that the abalone harvest strategy is working. Available information to support the assessment and harvest strategy include both the fishery-dependent catch and effort data used to produce the time series of standardised catch rates that comprise the key performance indicator for abalone stocks, as well as fishery-independent data that are incorporated into the overall weight-of-evidence approach for assessing stock status (see Section 9.3).

Outputs from the monitoring programs and stock assessments are presented annually to industry at Annual Management Meetings (AMMs) each December, followed by industry feedback and a TACC assessment meeting in February. The status of the WA abalone resources is also reported in the annual *Status Reports of the Fisheries and Aquatic Resources of Western Australia* report (e.g. Hart et al. 2015a, b). Through this annual review process, it is expected that the monitoring in place will continue to demonstrate that the harvest strategy is working effectively.

9.1.4 Review

The first harvest strategy formally implemented for Roe's and Greenlip abalone in 2008 was developed through extensive consultation with industry (see above) and was internally reviewed as part of the publication of Fisheries Research Report No. 185 (Hart et al. 2009). After the process undertaken in 2015 to improve the reference points for both species and to for the first time calculate reference points for Brownlip abalone, an updated harvest strategy for the abalone resources of WA was published in 2016 (DoF 2017). This current harvest strategy was reviewed by industry, the Western Australian Fishing Industry Council (WAFIC) and Recfishwest, and has also been approved by the Director General of the Department of Fisheries and the Minister for Fisheries.

It is recognised that fisheries change over time and thus a review period is built into each harvest strategy to ensure that it remains relevant. The current abalone harvest strategy will remain in place for a period of five years (2016 – 2021), after which time it will be fully reviewed; however, the document may be subject to further review and amended as appropriate within the five-year period.

9.2 Harvest Control Rules and Tools

9.2.1 Design and Application

The harvest control rules in place for abalone (see Table 9.1, Figure 9.1) are well-defined and effective in controlling the level of commercial abalone catch in each management area so that stock levels are maintained close to the targets.

For each of the three abalone species and their relevant management areas, a long-term commercial sustainable harvest level (SHL; also referred to as a sustainable TAC) has been calculated as the average catch of the species in that area over the specified reference period (Table 9.2, refer to Table 8.1 for information on reference periods). These long-term SHLs are applied in the annual process for recommending the harvest levels used for setting the TACC each year, in response to the status of the abalone resource relative to the specified reference points. As specified by the harvest control rules, an annual SHL for each target species and management area is determined as a percentage of the long-term SHL, based on the value of the performance indicator relative to the specified (target, threshold and limit) reference levels for that species/areas (see Figure 9.1).

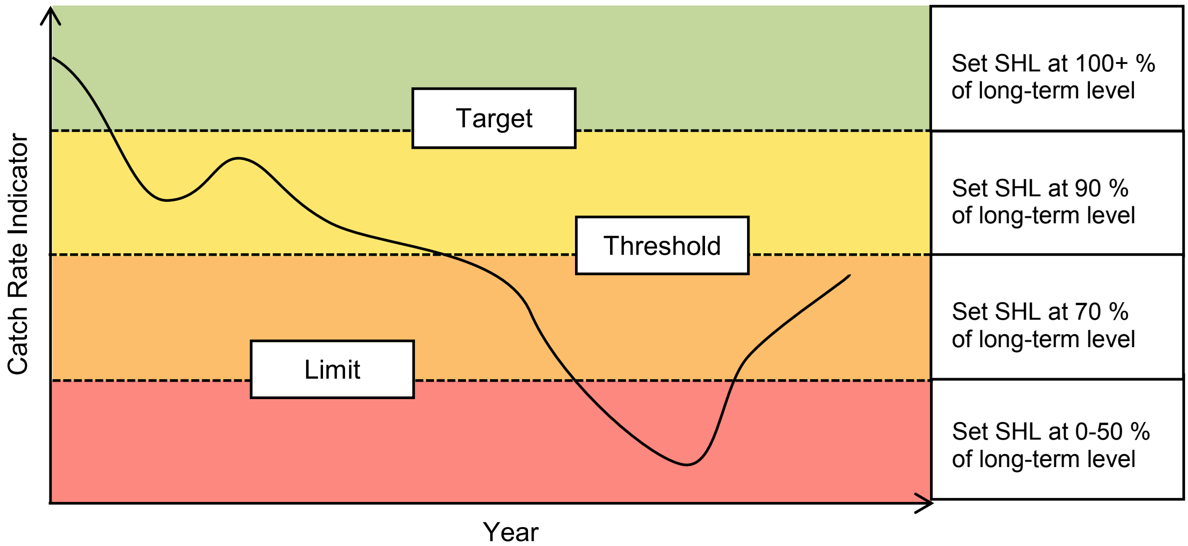

Figure 9.1. Schematic of how the harvest control rules are applied to managing the abalone resource of WA

Table 9.2. Species- and area-specific long-term commercial sustainable harvest levels (SHLs) used within the harvest control rules for abalone

Species	Area	Long-term SHL
Roe's abalone	2	18 tonnes (whole weight)
Roe's abalone	5	20 tonnes (whole weight)
Roe's abalone	6	12 tonnes (whole weight)
Roe's abalone	7	36 tonnes (whole weight)
Roe's abalone	8	12 tonnes (whole weight)
Greenlip abalone	2	30 tonnes (meat weight)
Greenlip abalone	3	35 tonnes (meat weight)
Brownlip abalone	2	7 tonnes (meat weight)
Brownlip abalone	3	6 tonnes (meat weight)

When the performance indicator in an area falls below the target reference level, the extent to which the SHL for the following year will be reduced is reflective of how far the indicator has fallen from the target level (see Figure 9.1). This allows for a precautionary approach to management, with reductions to catches addressed in a timely manner to minimise the risk of the indicator reaching the limit reference point. If an indicator falls below the limit level, a more stringent management response will be implemented, with the SHL set to 0 – 50% of the long-term SHL (i.e. potentially fully closing that area to fishing).

If the performance indicator increases beyond the target level, the control rule allows for an increase in SHL above the long-term SHL (Figure 9.1). The exact levels of the increase are usually determined via the weight-of-evidence approach for each area, using relevant extra information. As an example, in the particular case of the Area 7 Roe's abalone fishery, extra evidence on future stock abundance is obtained from a stock prediction and TAC allocation model currently being developed (Figure 9.2). This model is usually applied when the performance indicator is above the target level, but as a consequence of its unique predictive capacity, it can also be used to inform decisions on sustainable harvest levels when performance indicators are below target and threshold levels. It uses evidence from annual recruitment surveys of Age 1+ animals, combined with the average Summer SST (i.e. January – March) during the 4 year period in which the Age 1 cohort grows to harvest size, to predict the availability of harvest size stock (density of abalone ≥71 mm in length) in the target year. Such a model is only possible in Area 7 because it has a 20 year time series trend of fishery-independent survey data at both fished and unfished sites.

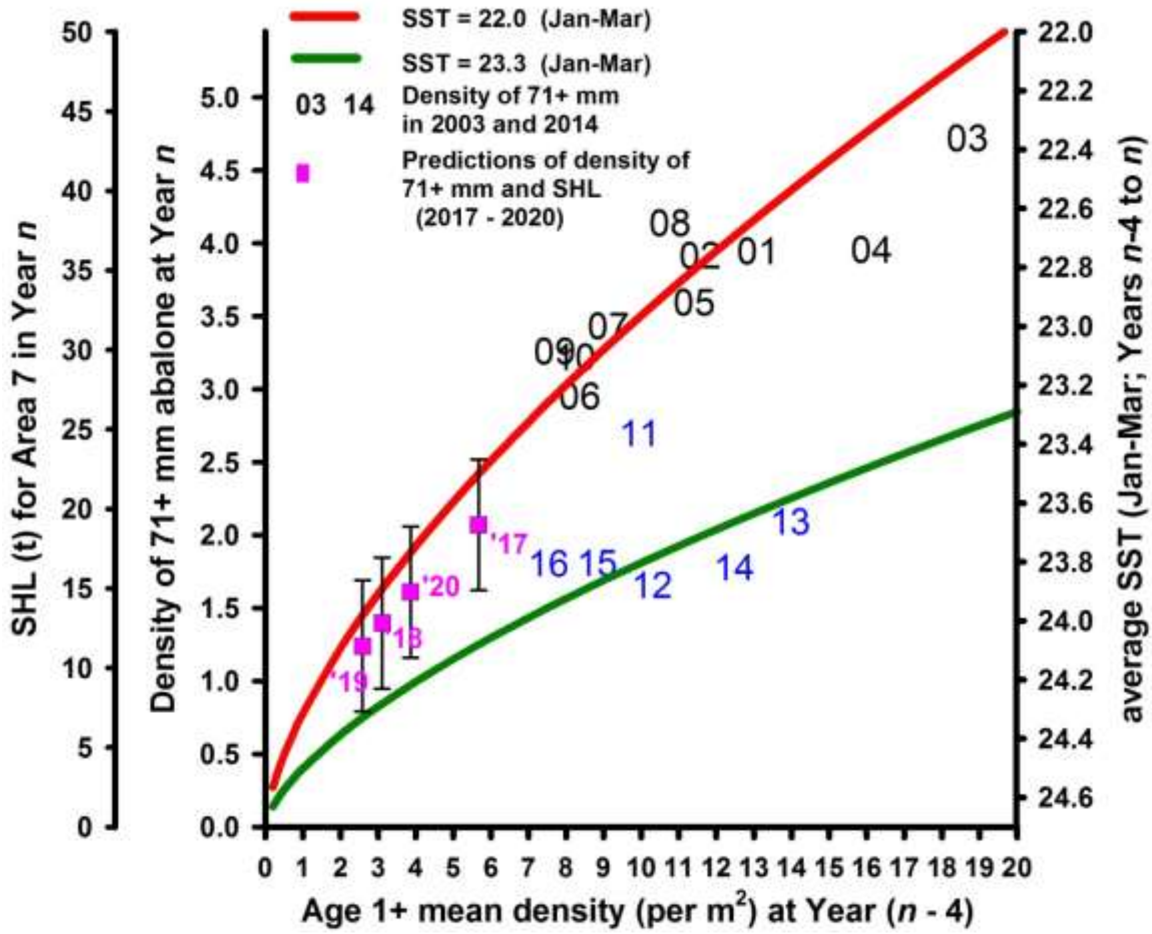

Figure 9.2. Prediction model (PM) and developmental harvest control rule for Roe's abalone in Area 7 of the Abalone Managed Fishery. This prediction model is used in tandem with the main harvest control rule, as it is still being developed. Further development and evidence of its predictive capability are needed before it can be adopted as the primary rule

9.2.2 Accounting for Uncertainty

There is considerable uncertainty around the stock-recruitment relationship for abalone and thus the particular level of spawning stock below which there is a high risk of recruitment failure is unknown. Fishery-independent data on abalone densities also provide evidence that recruitment of Roe's abalone is more closely related to the environment than stock levels. In consideration of this uncertainty, the abalone control rules are designed to be precautionary and the use of multiple of "trigger points" (i.e. when the indicator falls below the target and threshold level) ensures that catch reductions are implemented before the limit level is reached.

Whilst the commercial catch rates are used as the primary indicator to guide management, other available information (e.g. fishery-dependent and fishery-independent data on abalone size compositions and densities) incorporated into the overall weight-of-evidence assessment of the abalone resource (see Section 8.1) will also be considered in all decision making. For example, fishery-independent data on densities of Roe's abalone allows tracking of different size- and age-classes over time in both fished and unfished areas, which play an important role in understanding the effect of the environment on recruitment and spawning stock levels.

9.2.3 Evaluation

There is clear evidence that the harvest control rules for abalone are effective in controlling catches and maintaining stock sustainability. For example, the 2015 assessment of Greenlip abalone indicated that stock status has started to decline and consequently, the TACCs for the 2016/2017 fishing seasons have been reduced to 45% in Area 2, and 30% in Area 3, of their long-term averages.

There is also evidence of substantial management actions taken in the abalone fishery in situations when environmental factors rather than excessive fishing have been impacting on stock levels. In 2011, the area of the AMF north of Moore River was closed indefinitely to all commercial and recreational abalone fishing in response to the mass mortality of Roe's abalone after the heatwave in WA this year. This shows that the Department is capable of quickly implementing significant management measures when needed, even in situations where the catch rate indicator has not yet triggered.

9.3 Information and Monitoring

9.3.1 Range of Information

There is a comprehensive range of information available to support the assessment and inform the harvest strategy for abalone in WA (Table 9.3). Research and monitoring has been undertaken since the start of the fishery and has provided a broad understanding of the biological characteristics of abalone in WA.

Information on commercial abalone catch and effort is available from monthly statutory catch and effort returns and daily logbooks (Section 9.3.2.1), while estimates of recreational catches and effort are available from recreational fishing surveys (Section 9.3.2.3). Fishery-independent information on recruitment and spawning stock levels are also available through surveys of abalone densities (Section 9.3.2.4).

Table 9.3. Summary of information available to support the harvest strategy for abalone in WA

Data type	Fishery-dependent or independent	Analyses and purpose	Areas of collection	Frequency of collection	History of collection
Commercial catch and effort statistics (CAES)	Dependent	Historical catch and effort trends	AMF	Monthly	Since 1975
Commercial logbook (Catch Disposal Record, CDR)	Dependent	Catch, effort and catch rates	AMF	Daily	Since 1989 for Roe's Since 1986 for Greenlip/Brownlip
Recreational catch and effort (field surveys) for Roe's	Independent	Estimates of catch, effort, catch rates and average size caught	Perth metropolitan area	Annually	Since 1999
Recreational catch and effort (telephone surveys)	Dependent	Estimates of catch, effort and catch rates	WA	Occasional	Baseline surveys in 2004, 2006 and 2007
Recreational boat-based catch (integrated surveys)	Dependent	Estimates of catch	WA (by bioregion)	Biennial	Since 2011/12
Commercial length-frequency monitoring for Greenlip/ Brownlip	Dependent	Monitoring of trends in size composition of catch, estimation of mortality	Structured sampling design	Annually	Since 2004
Population surveys for Roe's	Independent	Density and biomass of all age classes, recruitment and spawning stock levels, growth patterns etc.	Fixed sites, stratified by area and depth	Annually	Since 1997
Population surveys for Greenlip/ Brownlip	Independent	Density and biomass of all age classes, recruitment and spawning stock levels, growth patterns etc.	Fixed sites, stratified by area and depth	Periodically (every 1-3 years)	Since 2004

9.3.2 Monitoring

9.3.2.1 Commercial Catch and Effort

There is a statutory obligation for abalone fishers to provide the Department with a daily catch and effort record, with data recorded for 10 x 10 mile statistical reporting blocks. Although daily reporting of catch and effort has been in place since 1986 for Greenlip/Brownlip abalone and 1989 for Roe's abalone, there is a longer historical time series of monthly catch and effort records for this fishery dating back to the early 1970s. Note that, prior to 1984, catches of Greenlip and Brownlip abalone were not separated.

Information recorded by fishers on the daily Catch and Disposal Records (CDRs, see Appendix D) includes catch by weight (kg) and numbers, effort in dive hours or minutes fished, the location of fishing and associated statistical reporting block (Figure 9.3). The processor unload information on the CDR is used to validate the catches recorded by the fishers and provides information for whole-meat weight conversions and estimates of drip loss between shucking and landing of the product.

Estimates of effort derived from the daily logbooks are highly accurate as fishers are dependent on pre-determined depth/time profiles to comply with safe diving limits and avoid decompression illness. The depth fished is fairly consistent from year to year as the spatial distribution of fishing effort does not change significantly.

Abalone catch and effort statistics are reported annually in the *Status of the Fisheries and Aquatic Resources of Western Australia* report published by the Department (see Hart et al. 2015a, b) and a summary of historical catch and effort trends in the fishery is presented in Section 3.1.4.

9.3.2.2 Commercial Catch Rates

The species- and area-specific commercial catch rates (and associated levels of uncertainly) used as the primary performance measure in the abalone harvest strategy are derived from the daily catch and effort information provided by fishers and processors on the CDRs and are standardised to account for variables that influence catching efficiency and abundance in the fishery (see Section 8.1.1 for more detail on the standardisation process). Time series of the standardised catch rate indices for each species are presented in Section 7.1.

In addition to the main catch rate indices (for the three species in the relevant management areas) used as performance indicators in the harvest strategy, some finer-scale monitoring of catches and catch rates is also conducted for abalone populations in particular sub-areas from which large proportions of the catches are taken. For example, in Area 2, the two most important sub-regions for Greenlip abalone, Arid and Town, have collectively provided an average of 29% and 23% of the total historical catches respectively, compared with Duke (21%), Israelite (15%) and West (12%). This information, although not directly supporting the harvest strategy for abalone, is included in the overall weight-of-evidence assessment of the stocks.

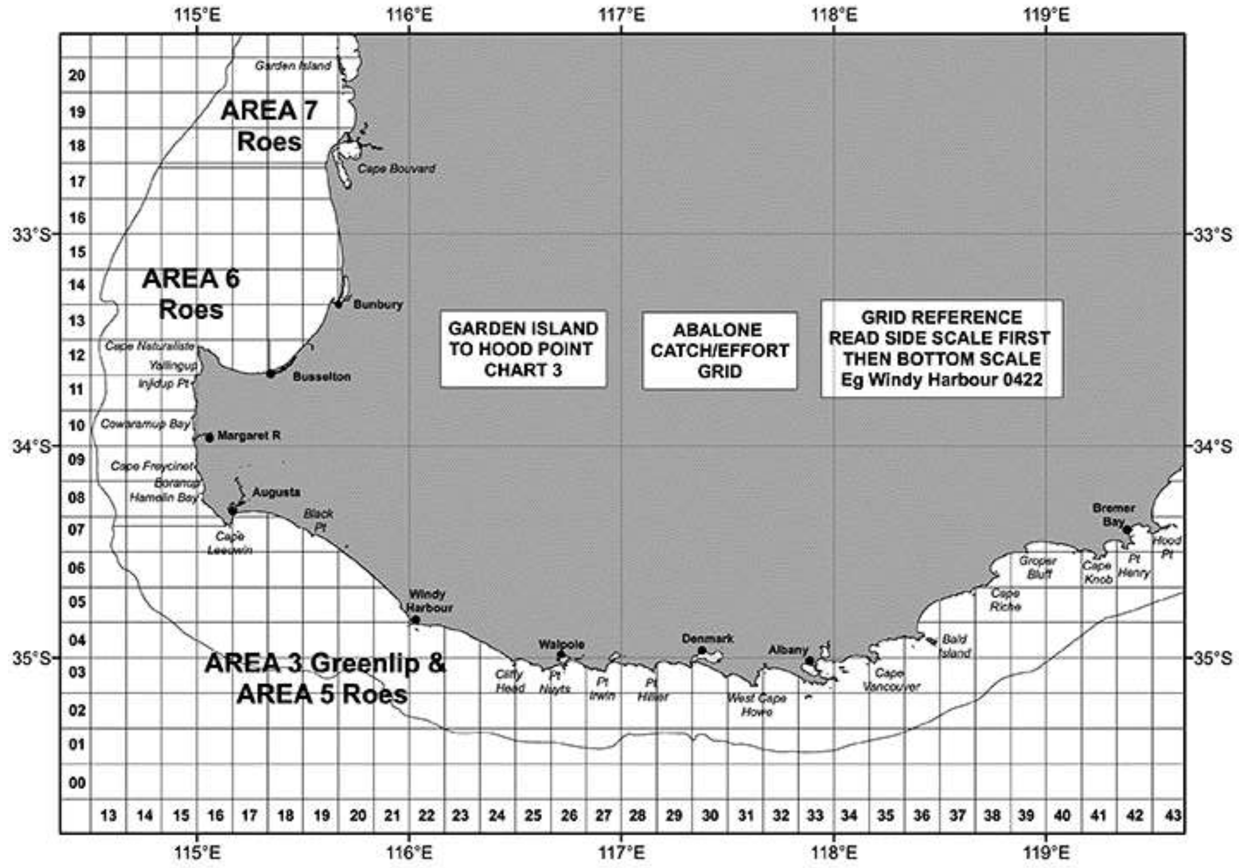

Figure 9.3. Example of statistical reporting grid map

9.3.2.3 Catch from Other Sectors

9.3.2.3.1 Recreational Catch

Estimates of recreational abalone catches are available from a number of recreational fishing surveys undertaken in WA since the late 1990s. Although catch estimates are available for all three abalone species, most surveys have focused on the fishery for Roe's abalone in the Perth metropolitan area, where the majority of recreational abalone catches are landed. Recreational surveys include annual field surveys of the Perth metropolitan fishery for Roe's abalone, as well off-site (typically phone diary) surveys that use recreational fishing licence holders as a sampling frame.

Information collected during the Perth metropolitan field surveys for the Roe's abalone recreational fishery includes average catches (weight and numbers), catch rates (derived from 1,000+ interviews), and fisher counts from shoreline vantage points and aerial surveys (Hancock and Caputi 2006). Although the survey method provides a comprehensive assessment of the 5-hour metropolitan area fishery, it is too resource-intensive to be applied routinely outside of this area.

Three telephone diary surveys were carried out in 2004, 2006 and 2007 to provide estimates of the catch of all three abalone species on a state-wide basis. The survey methodology was to randomly select around 500 licence holders from the licensing database, with the selection stratified by licence type (abalone or umbrella, which also covered fishing for other species such as rock lobster) and respondent location (Perth metropolitan area or other). The selected licence holders were sent a diary to record their fishing activity and were contacted every three months by telephone for the duration of the abalone season.

More recently, a state-wide integrated survey has been implemented to collect information on (licenced) boat-based recreational fishing in WA every two years (Ryan et al. 2013). This survey system uses three complementary components, including an off-site phone diary survey, on-site boat ramp surveys and a remote camera survey, to collect information on catch, effort, location and other demographic information. Two such integrated surveys have been completed to date, in 2011/12 (Ryan et al. 2013) and 2013/14 (Ryan et al. 2015), using this methodology and the third survey is currently underway. Note that these surveys do not provide estimates of total recreational catches as shore-based fishers do not require a licence and therefore are not included in the survey sample frame.

Estimates of recreational catch and effort for the three abalone species are reported in the *Status of the Fisheries and Aquatic Resources of Western Australia* report (Hart et al. 2015a, b). The recreational catch of Roe's abalone from the Perth metropolitan area in 2014 was estimated as 20.2 t, compared to an estimated (from phone diary surveys) catch of this species in the rest of WA of 14 t (Table 9.4). Based on these estimates, recreational catches of Roe's abalone in WA represented about 41% of the total (commercial and recreational) catch (83 t) in 2014. An estimated 8 t of Greenlip and Brownlip abalone was caught by recreational fishers in 2007 (Table 9.4), which corresponds to approximately 3-4% of the total (commercial and recreational) catch of these species in WA.

Table 9.4. Recent estimates of recreational boat- and shore-based catches of abalone in WA

Species	Area	Survey	Shore- / boat-based	Year	Catch (tonnes, whole weight)
Roe's abalone	Perth metropolitan	Field	Shore	2014	20.2
	Perth metropolitan	Phone diary	Shore + boat	2007	24 (19-29)
	West Coast (excl. metro)	Phone diary	Shore + boat	2007	9 (6-12)
	South Coast	Phone diary	Shore + boat	2007	5 (1-9)
Greenlip abalone	West Coast	Phone diary	Shore + boat	2007	3 (0-6)
	South Coast	Phone diary	Shore + boat	2007	4 (0-8)
Brownlip abalone	West Coast	Phone diary	Shore + boat	2007	<1 (0-1)
	South Coast	Phone diary	Shore + boat	2007	<1 (0-1)

9.3.2.3.2 Illegal Catch

Greenlip abalone is the most desirable black market abalone species in WA and is easily sold. Brownlip and Roe's abalone are not as highly sought after and has a very limited black market. It has been estimated that at least 3 t (whole weight) of Greenlip abalone is illegally caught each year for the black market on the south coast of WA (Hart et al. 2013a).

9.3.2.4 Other Monitoring

9.3.2.4.1 Commercial Monitoring

9.3.2.4.1.1 Greenlip and Brownlip Abalone

Commercial abalone fishers undertake annual length-frequency monitoring of Greenlip and Brownlip abalone according to a sampling protocol which is described in detail by Hart et al. (2013a). In brief, divers provide a random sample of 10 Greenlip abalone shells and five Brownlip abalone shells harvested from each day of fishing. The individual shells are measured by research observers who are highly experienced and use the equipment required to accurately record the abalone lengths. Over the around 200 dive days per year, 1300-4500 Greenlip and Brownlip abalone are measured and the data are combined with (tag-recapture) growth data to estimate trends in total mortality and fishing mortality (see Section 21.2) used to inform the weight-of-evidence assessment of these two species.

9.3.2.4.2 Fishery-Independent Monitoring

Fishery-independent population surveys to monitor trends in recruitment and spawning stock levels have been undertaken since 1996 for Roe's abalone and since 2004 for Greenlip abalone. Surveys involve repeated (annually or periodically) sampling at fixed sites stratified by area, habitat and/or depth (see below) to represent all areas of the fishery. Data on the density and size of abalone collected during these surveys are used to estimate biomass and also provide an independent index of abundance to compare against the fishery-dependent catch rates that are used as the primary performance indicator for monitoring stock status.

9.3.2.4.2.1 Roe's Abalone

Population surveys for Roe's abalone are undertaken annually at 13 sites between Yanchep and Penguin Island. The sites cover the important Perth metropolitan area, which is accessed by the Area 7 commercial and West Coast recreational abalone fisheries for Roe's abalone. Eleven of the sites are fished while the other two are the Watermans Reserve Marine Protected Area (MPA) and the Cottesloe Fish Habitat Protection Zone. Although only five sites have been sampled since monitoring started in 1996, all 13 sites have been included in the survey since 2011.

Surveys are carried out on two habitats, the reef platform and the subtidal habitat (Figure 9.4), which generally correspond to the recreational and commercial fisheries, respectively. The reef platform is further subdivided into three habitats (outer, middle, inner). The survey methodology involves surveying fixed quadrats of 0.25 and 0.5 m^2 at each site (Figure 9.4) and counting and measuring all abalone within these quadrats. For further details of survey methodology, see Hancock (2004).

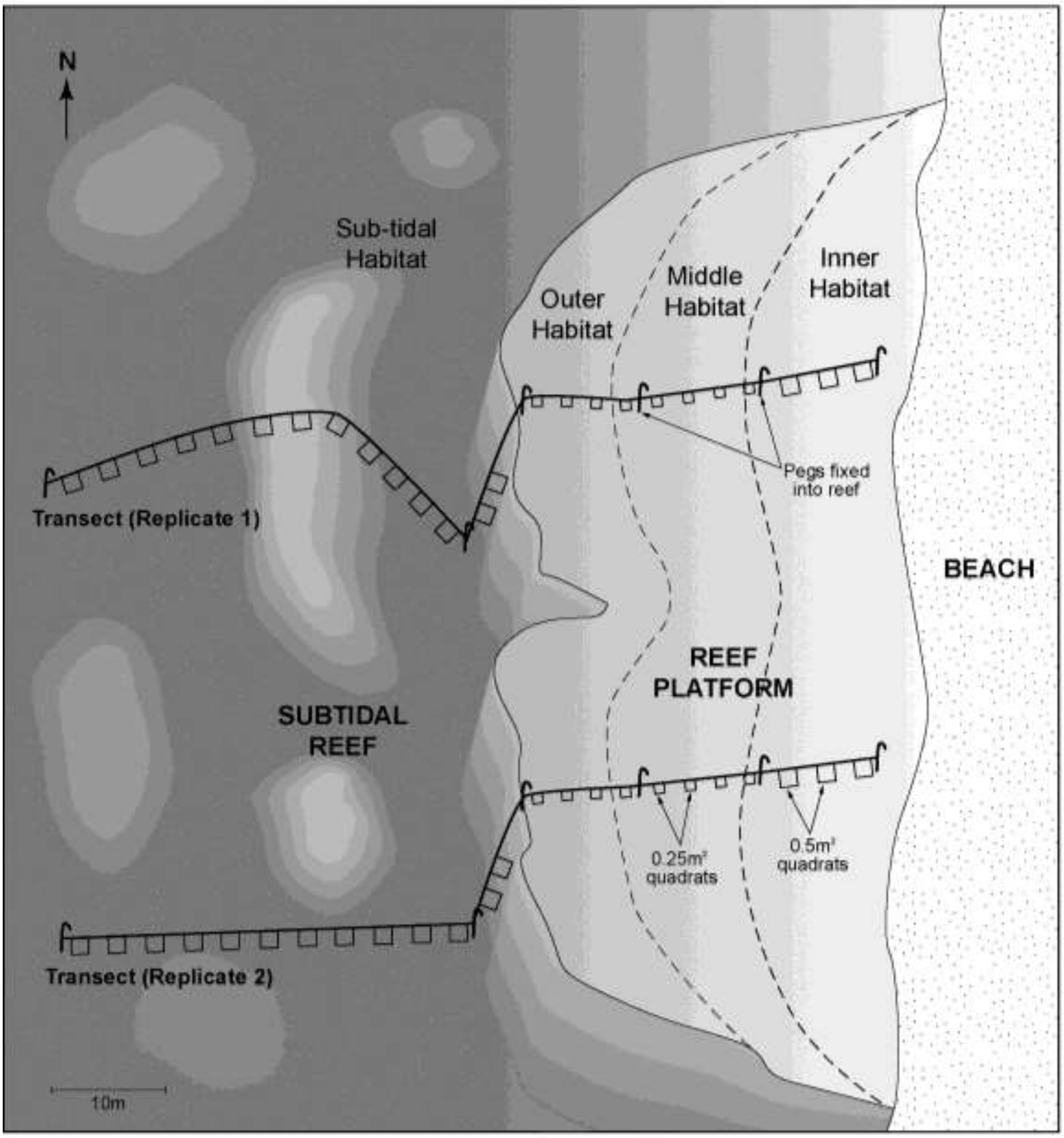

Figure 9.4. Schematic representation of Roe's abalone habitat and the survey design used to monitor the populations (Source: Hancock 2004)

9.3.2.4.2.2 Greenlip Abalone

Fishery-independent population surveys of Greenlip abalone are carried out periodically in the different management areas of the fishery in which these species are targeted. The survey method used (see Hart et al. 2013a for details) was originally developed for Blacklip abalone *Haliotis rubra* (Gorfine et al. 1996; Hart et al. 1997) and has been adapted for Greenlip abalone in WA.

Survey sites were selected on the basis of known stock distributions and currently there are 86 stock survey sites in the Area 2 fishery and 131 in the Area 3 fishery, targeting a range of sites of different productivity (Table 9.5). The two main sub-regions of the fishery (Augusta in Area 3 and Arid in Area 2) are visited annually (71 sites), while other regions are visited once every 2 - 3 years. Another 28 sites have been surveyed and used for stock enhancement experiments, and a further 150 sites have been set up as baseline survey sites to examine the effects of proposed marine parks (Table 9.5). Further details for abalone surveys in proposed marine parks are found in Hesp et al. (2008).

At each site, two survey transects of 30 m^2 (30 x 1 m), divided into 1 m^2 quadrats, are surveyed. Observers swim out a rope marked at 1 m intervals and record the number and size of individual Greenlip abalone within each 1m^2 quadrat. The area of suitable abalone habitat is quantified according to criteria presented in Table 9.6 and utilised to obtain estimates of density (i.e. the number of abalone per m^2 of habitat).

Table 9.5. Fishery-independent survey sites for Greenlip abalone

Management area	Sub-region	Stock survey sites	Stock enhancement sites	Capes Marine Park sites
2	Arid	27		
	Duke	13		
	Israelite	12		
	Town	20		
	West	14		
3	Albany	28		
	Augusta	44	28	150
	Hopetoun	44		
	Windy Harbour	15		
TOTAL		217		

Table 9.6. Habitat criteria for Greenlip abalone surveys. Codes are applied to each 1 m^2 quadrat within the larger sample unit (a 30 m^2 transect). An estimate of the total area of habitat per 30 m^2 transect is obtained by summing the mid-points for each quadrat

Code	Habitat area (m^2)	Mid-point (m^2)
0	0	0
1	0 – 0.1	0.05
2	0.1 – 0.2	0.15
3	0.2 – 0.3	0.25
4	0.3 – 0.5	0.4
5	0.5 – 1.0	0.75
6	>1.0	1.1

10 Genetics

There is a sea ranch in Augusta where artificial structures are seeded with juvenile abalone sourced from a hatchery in Bremer Bay (Section 6.1). The abalone are approximately 40 mm when seeded onto the structures, and are harvested at approximately 100-145 mm which is larger than the size at maturity. Abalone on the sea ranch could potentially affect the wild populations by either reducing genetic diversity and/or introducing new genotypes. This section examines the potential for the sea ranch operations to affect wild populations and strategies in place to manage potential risks.

10.1 Fishery Impacts

Recent research has demonstrated that the WA abalone are one large intermixing population based on neutral SNPS, however, when SNP markers under natural selection are examined five genetically distinct groups are identified (Sandoval-Castillo et al. 2016) (Section 5.2.2). The populations in Augusta and Windy Harbour are considered to be one genetic group, with next closest genetic group being Albany.

The sea ranch facility is highly unlikely to impact genetic structure of the wild fishery populations to a point where there would be serous or irreversible harm for the following reasons:

- The broodstock are taken from the Augusta area where the sea ranch is located.
- Only F1 generation abalone can be seeded onto the sea ranch. There are no F2 generations, hybrid or polyploid abalone seeded onto the artificial structures.
- The ranch is located in an area of sand and the closest reef where commercial fishing occurs is 2 km which acts as a barrier to genetic mixing.

10.1.1 Risk Assessment Outcomes

The ERA assessed the impacts of abalone hatchery and sea ranch on the genetic structure of wild populations, with the risk rating for both operations assessed as negligible (Webster et al. 2017)

Risk Rating: Impact of abalone aquaculture on the genetic structure of wild populations WC/SC – C1, L1 = 1; NEGLIGIBLE

Risk Rating: Impact of abalone ranching on the genetic structure of wild populations SC – C1, L1 = 1; NEGLIGIBLE

10.2 Genetic Management

There is a strategy in place for managing the hatchery enhancement activity such that it does not pose a risk of serious or irreversible harm to the genetic diversity of the wild population. These management measures are specified in the *FRMA 1994*, the *FRMR 1995,* Abalone Aquaculture Policy (DoF 2013a) and the Policy on Restocking and Stock Enhancement in WA (DoF 2013b). There are a number of legislated measures in place to achieve this objective, including the following requirements:

- Aquaculture licence to undertake aquacultural activities (subject to conditions see Section 10.2.3)

- Management and Environmental Monitoring Plan (MEMP)
- Aquacultural lease

10.2.1 Abalone aquaculture policy

The Abalone Aquaculture Policy (2013a) currently defines three genetic zones in WA. These boundaries were established before detailed genetic studies of WA Greenlip species had been undertaken and were based on the Management Areas.

The Department is in the process of updating the Abalone Aquaculture Policy on the management of genetic risks in relation to abalone aquaculture. This policy is likely to be formalised and published by July 2016. The new policy recognises that the use of a single strategy for managing genetics (i.e. genetic zoning) is not comprehensive enough when aquaculture progeny are grown in a diverse range of environments. For example, progeny have been grown out in enclosed on-land facilities, marine-grow-out structures, and within wild fisheries. The Department now recommends the development of specific genetic management plans, based on risk assessments of each proposed operation, using a variety of genetic management strategies. The two main strategies implemented in genetic plans are:

a) Genetic Separation: imposing a physical or other managerial barrier between low diversity aquaculture populations and high diversity wild populations. This could involve the use of an appropriate production facility design and management measures such as spatial separation (physical distance), or harvest based controls (harvesting below sexual maturity), etc.

b) Progeny diversity: using explicit broodstock collection and breeding programmes to ensure only genetically appropriate progeny are released into the marine environment.

10.2.2 Policy on Restocking and Stock Enhancement in WA

Until the Abalone Aquaculture Policy is updated the Department recommends the genetic management strategies in the Policy on Restocking and Stock Enhancement in WA (DoF 2013b) be applied to new and existing abalone sea ranch operations. The genetic principles relate to broodstock collection and maintenance, spawning management procedures, distance of sea ranching operation from significant wild stocks, potential spawning biomass of sea ranched animals and compliance procedures.

10.2.3 Aquaculture Licence Conditions

The licence conditions for the sea ranch operation specifies the following:

- Abalone cannot be stocked at the site unless they are brood stock originating from Genetic Zone 1 (Busselton Jetty to Shoal Cape).
- Selectively bred abalone produced from broodstock lines originating from outside of the genetic zone in which the site is located must not be cultured and
- Hybrid or poyploid abalone must not be cultured.

The hatchery licensees are required to provide a written record to the Department detailing the geographic location where broodstock abalone come from (including the genetic zone), the number, size, sex and species of abalone, and any mortalities of breeding stock.

10.3 Genetic Information

There is an in depth understanding of the genetic structure of abalone populations (Sandoval-Castillo et al. 2016) (Section 5.2.2), which provide good baseline information against which future trends in genetic diversity can be measured. Genetic information in relation to sea ranching activities and their potential effects on wild stocks is currently being obtained by periodic spawning biomass surveys of each sea-ranching facility. These provide an estimate of the spawning biomass of cultured populations, which can be compared to existing wild populations.

The sea ranching facility has only been in operation at a commercial scale for one year. The most recent estimate of spawning biomass from the existing sea ranch is from December 2015. The estimate was 1.7 tonnes (whole weight - unpublished data). This is less than 0.2% of the total spawning biomass for the Greenlip fishery, which is estimated at 500 to 600 tonnes meat weight (1300 – 1600 t whole weight). It therefore presents negligible genetic risk to the wild fishery. It must be noted however that 90% of the current stock of abalone on the sea ranch are below spawning size, and these are expected to grow significantly within the next two years.

It is anticipated that when spawning biomass of cultured populations in sea ranching operations reaches large enough proportions, e.g. 10% or more of wild populations, more in-depth genetic monitoring will be undertaken, which will include on-going monitoring of the diversity of wild stocks.

MSC Principle 2

11 Other Captured Species

11.1 Abalone Industry Impacts

11.1.1 Retained Species

Fishers in the AMF are only allowed to retain the target species of Greenlip, Brownlip and Roe's abalone, there are no other retained species.

11.1.2 Unwanted Catch

Bycatch in the AMF is extremely low as fishers specifically only target Greenlip, Brownlip and Roe's abalone species. Whilst unusual, undersize abalone are occasionally collected but are typically quickly replaced on the home scar after measurement.

Abalone shells are often encrusted with commensal species such as coralline algae, sponges and small invertebrates (also known as 'piggy-back' species). These organisms are harvested with the abalone and if returned to the water (some shell are kept for sale) are unlikely to survive.

11.1.2.1 Risk Assessments Outcomes

11.1.2.1.1 Piggyback Species

ERA Risk Assessment (2015): Impact of removing abalone on commensal (piggyback) species as a source of habitat (in WCB/SCB – C1, L1 = 1; NEGLIGIBLE)

ERA Risk Assessment (2015): Impact of collecting abalone on commensal (piggyback) species populations (in WCB/SCB – C1, L1 = 1; NEGLIGIBLE)

There is a high degree of certainty that the commensal species attached to abalone shells are above the biologically based limit. Adult abalone live in high-energy environments which are unfavourable for settling invertebrates. Typically the quantity of biota encrusting abalone shells is low, due to the harsh environment and there are no known species which exclusively use the abalone shell as a habitat. The commensal species on abalone shells also inhabit other hard surfaces such as rocky reefs which are widely distributed and abundant.

Whilst there are no known species dependent on Greenlip, Brownlip or Roe's abalone shell for habitat, the management of the stock results in a proportion of the population remaining unfished, providing habitat for piggy back species.

Given the relatively low levels of bycatch and the highly selective fishing method, it is considered likely that the level of interaction will continue to be only minimal with no unacceptable impacts on piggyback species' populations occurring.

11.1.4 Management Strategy

There is a strategy in place to manage the AMF impacts on the ecosystem, which utilises management measures under the FRMA, the FRMR and the Management Plan. As per the harvest strategy, the wild collection fishery has long-term objective for bycatch to e*nsure fishing impacts do not result in serious or irreversible harm to bycatch species populations*.

There are a number of measures in place to achieve these objectives (see Section 4), including:

- Species restrictions limiting fishers to the take of Brownlip, Greenlip and Roe's abalone;
- Annual catch limits in the form a TACC for abalone;
- Limited Entry
- Size limits for each species;
- Spatial management via zoning and closed areas; and
- Statutory reporting of catch and the location of fishing activities.

There is high confidence that this strategy will work, based on information directly about the fishery and species involved. Fishers are highly selective targeting only Brownlip, Greenlip and Roe's abalone. The only other potentially impacted species are commensal organisms which settle on the abalone shell. By limiting the quantity and size of abalone oysters which can be removed, there is a portion of the population which remains in the ecosystem providing substrate for commensal organisms.

There is clear evidence that the strategy is being implemented successfully and is achieving its objectives. Fishery performance against the objectives in place for bycatch species is measured via the Harvest Strategy. The short-term (annual) objective is *fishery impacts are considered to generate an acceptable level of risk (i.e. moderate risk or lower) to bycatch species populations* (DoF 2017). In the most recent risk assessment (2015), the fishery was considered to be a negligible risk to piggyback species populations.

Compliance with management measures is monitored by field officers based in the Metropolitan and regional areas who patrol the entire fishing area (see Section 17.3). Compliance officers also inspect catches at processing factories and monitor quota via the *Catch and Disposal Record Book*.

11.1.5 Information and Monitoring

The catches of all retained species are reported daily by all licensees to the Department in statutory *Catch and Disposal Record Book* (Appendix D) which specifically records accurate details of weight and number of abalone species effort (hours) spent diving for abalone, and location fished using a 10 x 10 nautical mile grid system. Data from these logbooks indicate there have been no non-target species retained by the wild collection fishery. This information has been verified through compliance checks and monitoring.

12 ETP Species

A number of endangered, threatened and protected[9] (ETP) species can be found within south WA including sea lions, seals, whales, dolphins, dugongs, marine turtles, syngnathids/solenostomids, sea snakes, sharks and seabirds. These species are protected by various international agreements and national and state legislation. International agreements include:

- Convention on the Conservation of Migratory Species of Wild Animals 1979 (Bonn Convention);
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES);
- Any other international agreement, or instrument made under other international agreements approved by the environment minister.

Primary pieces of national and WA legislation include the EPBC Act, the WC Act, and the FRMA.

12.1 Abalone Industry Impacts

The selective nature of the fishing method, e.g. hand collection by divers, minimises the risk of interactions with ETP species. The only recorded interactions with ETP species have been attacks by sharks on divers.

The AMF has been assessed under the provisions the EPBC Act 1999 (Part 13 and 13A), part of which considers the effects of the fishery on ETP species. In the most recent assessment in 2015, the fishery was considered not likely to adversely affect the survival or recovery of any listed threatened species.

12.1.1 Risk Assessments Outcomes

12.1.1.1 Whales and Dolphins

ERA Risk Assessment (2015): Impact of fishery boat strikes on whale and dolphin populations in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

There are 46 species of cetaceans listed in WA, 43 of which may be present in South and West Coast Bioregions. Most whale species are typically associated with deep water (e.g. baleen whales) or are very rarely encountered (e.g. *Mesoplodon* beaked whales). Of the dolphin species, only one the Bottlenose dolphin (*Tursiops truncatus*) is commonly encountered in southern inshore waters.

There is a high degree of confidence that the AMF has no significant detrimental direct or indirect effects on whale and dolphin populations. There are currently 52 licences in the AMF, all of which utilise vessels <9m in length. The low number of small, highly

[9] Note that being on a protected species list does not automatically indicate that a species is either threatened or endangered.

manoeuvrable vessels operating in the fishery reduces the likelihood of any interactions with protected species. Whales occasionally aggregate in certain locations on the south coast, typically mothers and calves. Abalone fishers avoid these areas due to the increased presence of white sharks associated with whales. There have been no recorded interactions with whale and dolphin species within the AMF.

12.1.1.2 Marine Turtles

ERA Risk Assessment (2015): Impact of boat strikes on marine turtle populations in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

Six species of marine turtles are known from WA waters; Loggerhead (*Caretta caretta*), Green (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), Olive Ridley (*Lepidochelys olivacea*), Flat back (*Natator depressus*) and Leatherback turtles (*Dermochelys coriacea*). All species are typically found in tropical waters but may appear as vagrants in the cooler south west coast.

There is a high degree of confidence that the AMF has no significant detrimental direct or indirect effects on turtle populations. The low number of licences and small vessels utilised in the AMF minimises the likelihood of interactions with turtle species. There have been no recorded interactions with turtle species within the AMF.

12.1.1.3 Sharks and Rays

ERA Risk Assessment (2015): Impact of boat strikes on marine shark and ray populations in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

ERA Risk Assessment (2015): Impact of interactions with divers and equipment on shark and ray populations in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

There are 38 species of shark are protected in WA with 25 of those being reported in West and South Coast bioregions. All rays are considered commercially protected species in Western Australia.

The main interactions with these ETP species is through sharks attacking AMF divers. There are reported four interactions with sharks between 2008 and 2015. One was reported as a blacktip shark, while the others were reported as White Sharks. In the cases of the White Shark interactions, animals are reported as “alive” at the conclusion of the interaction, while the blacktip is noted as “unknown”.

There is a high degree of confidence that the AMF has no significant detrimental direct or indirect effects on shark and ray populations. There have been no recorded interactions between sharks and rays and AMF vessels.

12.1.1.4 Seals and Sea lions

ERA Risk Assessment (2015): Impact of boat strikes on seal and sea lion populations in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

Two species of pinnipeds are resident in the south and west coast bioregions. The Australian Sea lion (*Neophoca cinerea*) and the New Zealand Fur Seal (*Arctocephalus forsteri*).

There is a high degree of confidence that the AMF has no significant detrimental direct or indirect effects on seal and sea lion populations. The low number of licences and small vessels utilised in the AMF minimises the likelihood of interactions with seals and sea lion species. There have been no recorded interactions with sea lion species within the AMF.

12.1.1.5 Shorebirds

ERA Risk Assessment (2015): Impact of driving beaches and disturbing shorebirds and shorebird nests on bird populations in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

There are at least 180 protected and migratory species of seabirds and shorebirds in WA, approximately 140 of which may occur in southern and western bioregions. Several shorebirds inhabit and nest on south-WA beaches, including the Hooded plover (*Thinornis rubricollis*), Red-capped plover (*Charadrius ruficapillus*), Pied oyster catcher (*Haematopus longirostris*) and Sooty Oyster catcher (*H. fuliginosus*).

There is a high degree of confidence that the AMF has no significant detrimental direct or indirect effects on shorebird populations. The low number of abalone fishers which do access remote areas typically drive on existing roads, tracks and farms. The beach areas accessed by fishers in the AMF are typically well used beaches which are also accessed by the public.

12.1.1.6 Penguins

ERA Risk Assessment (2015): Impact of boat strikes on penguin populations in WCB– C1, L1 = 1; NEGLIGIBLE

Only one penguin species, the Little Penguin (*Eudyptula minor*), is consistently present in Western Australian waters. Its Australian distribution is south of Fremantle on the west coast and it extends across the south coast to New South Wales.

There is a high degree of confidence that the AMF has no significant detrimental direct or indirect effects on penguin populations. The low number of licences and small vessels utilised in the AMF minimises the likelihood of interactions with penguin species. There have been no recorded interactions with penguins species within the AMF.

12.2 Management Strategy

There is a strategy in place to manage industry-related impacts on ETP species, which utilises management measures under the FRMA, the FRMR and the Management Plan. As per the harvest strategy, the fishery has a long-term objective for ETP species *to ensure fishing impacts do not result in serious or irreversible harm to ETP species populations*. There are a number of legislated measures in place to achieve this objective, including:

- Species restrictions limiting fishers to the take of Roe's, Greenlip and Brownlip abalone;
- Limited entry and;
- Statutory reporting of all ETP species interactions.

There is high confidence that this strategy will work, based on information directly about the fishery and species involved. There are less than 52 small vessels operating in the fishery and the only reported ETP interaction has been from sharks attacking divers.

Fishery performance against the objective for ETP species is measured and monitored annually via the harvest strategy. The fishery has a short-term (annual) objective for ETP species that *fishery impacts are considered to generate an acceptable level of risk (i.e. moderate risk or lower) to all ETP species populations* (DoF 2017). In the most recent risk assessment (2015), the fishery was considered to be a negligible risk to ETP species populations.

The potential effectiveness and practicality of alternative measures to minimise industry-related mortality of ETP species is reviewed regularly and are implemented as appropriate. The Department and industry undertake regular (approximately every five years) reviews of the risk to ETP species from industry operations. Where a risk is considered undesirable (e.g. has increased from low to medium or is assessed as high), new and/or further risk control measures are investigated and implemented, with a goal of reducing the risk to an acceptable level.

12.3 Information and Monitoring

Quantitative information is available to assess the fishery-related impacts, mortalities, injuries and consequences for ETP species. Fishers in the wild collection fishery have a statutory requirement[10] to report all ETP species interactions to the Department in *Catch and Disposal Record Book* (Appendix D). All CDR's returns are checked by Departmental staff, and any possibly erroneous entries or gaps are verified directly with skippers or the fishing company.

This information is used to inform fishery performance against the ETP species component of the Harvest Strategy. Information on the number of interactions with ETP species is used to inform periodic risk assessments undertaken in the fishery, with specific control rules in place for different risk ratings. Although risk assessments are scheduled to take place every five years, they can be triggered following a substantial change in fishery operations or management or the reporting of an unusually high number of interactions, which may indicate a significant change in the previous assessment outcomes.

[10] Note prior to 2015 fishers reported any ETP species interactions in the 'comments' section of daily logbooks; recently, this has been changed to a specific section for reporting ETP species interactions.

13 Habitats

13.1 Overview

The Australian marine environment has been classified into bioregions that make ecological sense and are useful for regional planning through a collaborative effort between State, Northern Territory and Commonwealth governments. The classification system is known as the Integrated Marine and Coastal Regionalisation for Australia (IMCRA V 4.0 2006; Commonwealth of Australia 2001).

The AMF operates in the south western parts of WA across two bioregions, the West Coast and South Coast (See Section 0). Utilising the IMCRA scheme the West Coast Bioregion has been divided into three meso-scale regions: the Abrolhos Islands, the Central West Coast and the Leeuwin Naturaliste (Figure 13.1). The South Coast Bioregion is divided into two meso-scale regions, South Coast and Eucla (IMCRA V 4.0 2006).

13.1.1 Habitat Mapping in the WCB and SCB

A significant portion of the habits in the WCB and SCB have been mapped to describe both the physical substratum and the biological communities present. This is largely a result of different government agencies and private sectors undertaking habitat-mapping exercises in relation to coastal development projects and marine reserve planning initiatives. The information available spans several decades and has been collected using different methodologies (due to technical advances) and at different spatial scales. Despite these inconsistencies, habitat classification categories are similar across the regions, providing a comprehensive overview of the benthic habitats. The remainder of this section provides an overview of habitat descriptions and mapping in the SCB and WCB. Where more than one habitat map was produced for an area, the most comprehensive and detailed map was selected. Descriptions typically focused in shallower waters were abalone are found, but in cases where the only available habitat information related to deeper water, this is presented. Note that the Abrolhos Islands ecosystem is not described as abalone typically do not inhabit this area.

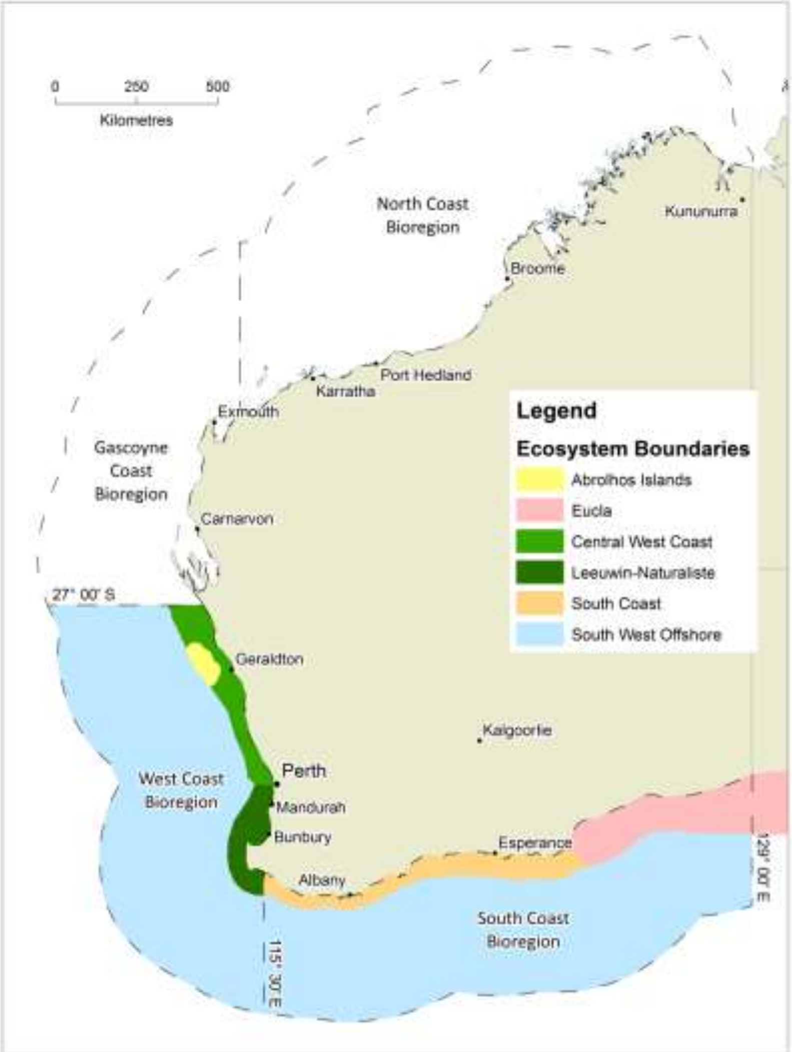

Figure 13.1. Map of the South-West Bioregions and associated ecosystems. Note: some IMCRA ecosystem boundaries have been shifted to align with DoF bioregional boundaries.

13.2 Central West Coast Ecosystem

The Central West Coast Ecosystem (CWCE) extends from the northern boundary of the WCB (27° S) to Perth (31° 60' S; Figure 13.1), excluding the area around the Houtman Abrolhos Islands.

The CWCE is a microtidal, relatively high-energy area, with clear water and few rivers. The coastline is characterised by long beaches with occasional limestone cliffs and headlands, with offshore limestone islands and reef complexes. There are many estuaries, of which the Swan, Peel-Harvey and Leschenault Inlet are large and permanently-open to the sea, while Cockburn Sound is a major semi-enclosed marine embayment (Wilson 1994).

From Geraldton to Cape Leeuwin, the shelf (Rottnest Shelf) ranges in width from 45 – 100 km and covers an area of approx. 52 000 km^2 (Harris et al. 2005). The shelf in this area can be divided into a steep shoreface (< 30 m depth), a wide, flat inner shelf plain (30 – 50 m depth), a linear ridge complex that shallows to about 40 m depth and an outer shelf that slopes seaward to the shelf edge at about 200 m (McClatchie et al. 2006).

The shelf includes a series of nearshore ridges and depressions that form inshore lagoons and supports a variety of benthic habitats including rocky substrates with prolific growths of algae and sponges, rippled sand with clumps of non-calcareous red algae and open rippled sand (which may be locally modified by burrows and surface traces). Sponges, ascidians, non-calcified red algae and *Ecklonia* are all common to depths of 40 m. Encrusting coralline algae form rhodoliths around limestone nuclei, and branching forms are present to 60 m depth (James et al. 2001).

13.2.1 Habitat Descriptions and Mapping

13.2.1.1 Kalbarri to Geraldton

Marine habitat information from Kalbarri to Geraldton is very limited for both the inshore and offshore regions. This area has a moderate- to high-energy coastline that is relatively straight with sandy beaches and occasional limestone headlands and offshore reefs. Kelp dominates the sublittoral zone on the limestone reefs, while seagrass meadows are moderately developed in sheltered lagoons and banks. Small and species-poor coral reefs occur at several locations. There are a number of small estuaries along the coast, i.e. at the Chapman, Irwin and Greenough Rivers (Wilson 1994).

13.2.1.1.1 Kalbarri

The stretch of coastline near Kalbarri is moderately high energy. Within this region, the intertidal rock platforms are dominated by algal growth. The Murchison River enters the Indian Ocean at Kalbarri and has a small estuary (Wilson 1994).

The Kalbarri Blue Holes FHPA, located immediately west of the township of Kalbarri, includes part of a near-shore limestone reef system, which stretches intermittently from the Murchison River mouth to Red Bluff in the south. As part of the FHPA planning process in April 2002, the Australian Marine Conservation Society WA conducted dive surveys (SCUBA and snorkel) to collect habitat information (DoF 2004a). Marine surveys have identified a number of habitats within 400 m of the shoreline, including intertidal and subtidal reefs platforms featuring irregular-shaped depressions (1 – 2.5 m depth) with sandy bottoms, commonly referred to as the ‘Blue Holes’ (DoF 2004).

The majority of reef lagoons in the area were characterised by broken and undulating limestone outcrops and sandstone outcrops with occasional patches of seagrass and algae. Beyond the reef platforms, the offshore area was characterised by gently undulating limestone substrate with moderately-dense rock ledges, ridges and depression/runnel (2 – 3 m deep)/trenches, eventually becoming sandy at 17 – 18 m depths. Sand in the area is fine to medium grain size; however, gravels and cobbles were also common in scour holes, gutters and depressions (DoF 2004).

Two-hundred species of marine flora and fauna were identified in the area, including 10 sponges, 11 coral, 71 fish, seven algae and four seagrass species (DoF 2004a).

13.2.1.1.2 Oakajee

Around Oakajee (approx. 20 km north of Geraldton), the marine environment can be summarised as a sandy coastline with occasional reef and exposed rocky headlands. The seabed slopes to 30 m depth at approx. 7 km offshore, and the seafloor is mainly sand, interspersed with raised limestone reef blocks and ridges. The marine environment surrounding Oakajee has been extensively assessed and mapped as a part environmental impact assessment studies for a deep water port planned for the area (ATA 1997, LeProvost Dames and Moore 1999, Oceanica 2008a and b). The marine habitat has been described as patches forming a mosaic across the sea floor. Whilst the different surveys classify the benthos to differing degrees of detail the main habitats in the area are summarised below and depicted in Figure 13.2:

- Inshore reef with algae
- Sand
- Sand with seagrass
- Reef with algae
- Reef with algae and seagrass (Oceanica 2008a).

The benthic primary producer habitat (BPPH) at Oakajee is considered to be similar and representative of BPPH on the west coast in general (Kirkman 1997). The dominant primary producers were algae, of which robust brown algae (e.g. *Ecklonia* spp.) and foliose brown appear to be most prevalent. The dominant seagrass was *Amphibolis* spp., along with *Thalassodendron pachyrhizum* (Oceanica 2008b). A high degree of temporal patchiness was detected (evident from studies undertaken during different periods of time) indicating that the habitat in the Oakajee area was highly dynamic (Oceanica 2008b).

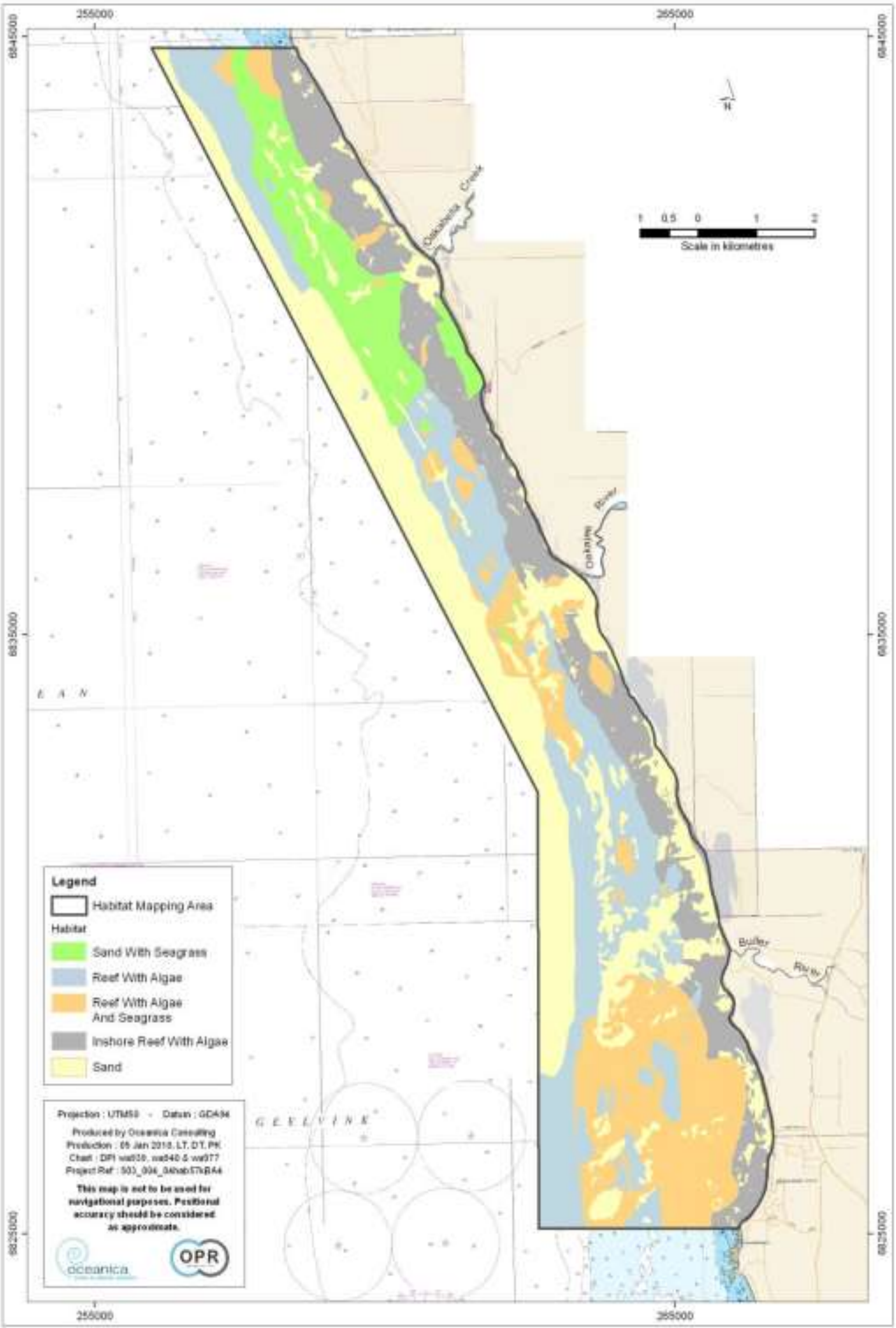

Figure 13.2. Benthic primary producer habitat (BPPH) map of the Oakajee region (Source: Oceanica 2008a)

13.2.1.1.3 Geraldton

Geraldton is located approx. 400 km north of Perth, on the north side of Point Moore peninsula and facing north into Champion Bay. A number of rivers discharge seasonally (winter) into the coastal waters of the region. The Greenough River mouth is located some 10 km south of Point Moore, and the Chapman River mouth is located some five kilometres north of Point Moore. A number of smaller rivers (e.g. Buller and Oakajee) drain the hinterland north of Geraldton (URS 2001).

The main marine habitats in the Geraldton area have been described as characterised by the following habitat types (Figure 13.3):

- Sand
- Seagrass meadow on sand
- Algae and seagrass on sand-veneered limestone pavement
- Raised limestone reef (URS 2001).

The most dominant seagrasses recorded in the area were *Amphibolis antartica* and *A. griffithi* with *Posidonia* species in the south. Other species observed include *Syringodium isoetifolium, Thalassodendron* and *Halophila spp*. The main species of macroalgae observed were brown (e.g. *Ecklonia radiata*, *Sargassum* spp.) and red (*Osmundaria rolifera*, *Dictymenia muelleri*, *D. sonderi*, *Laurencia* spp.) algae, with smaller amounts of green (*Caulerpa* sp., *Halimeda* sp.) algae (URS 2001).

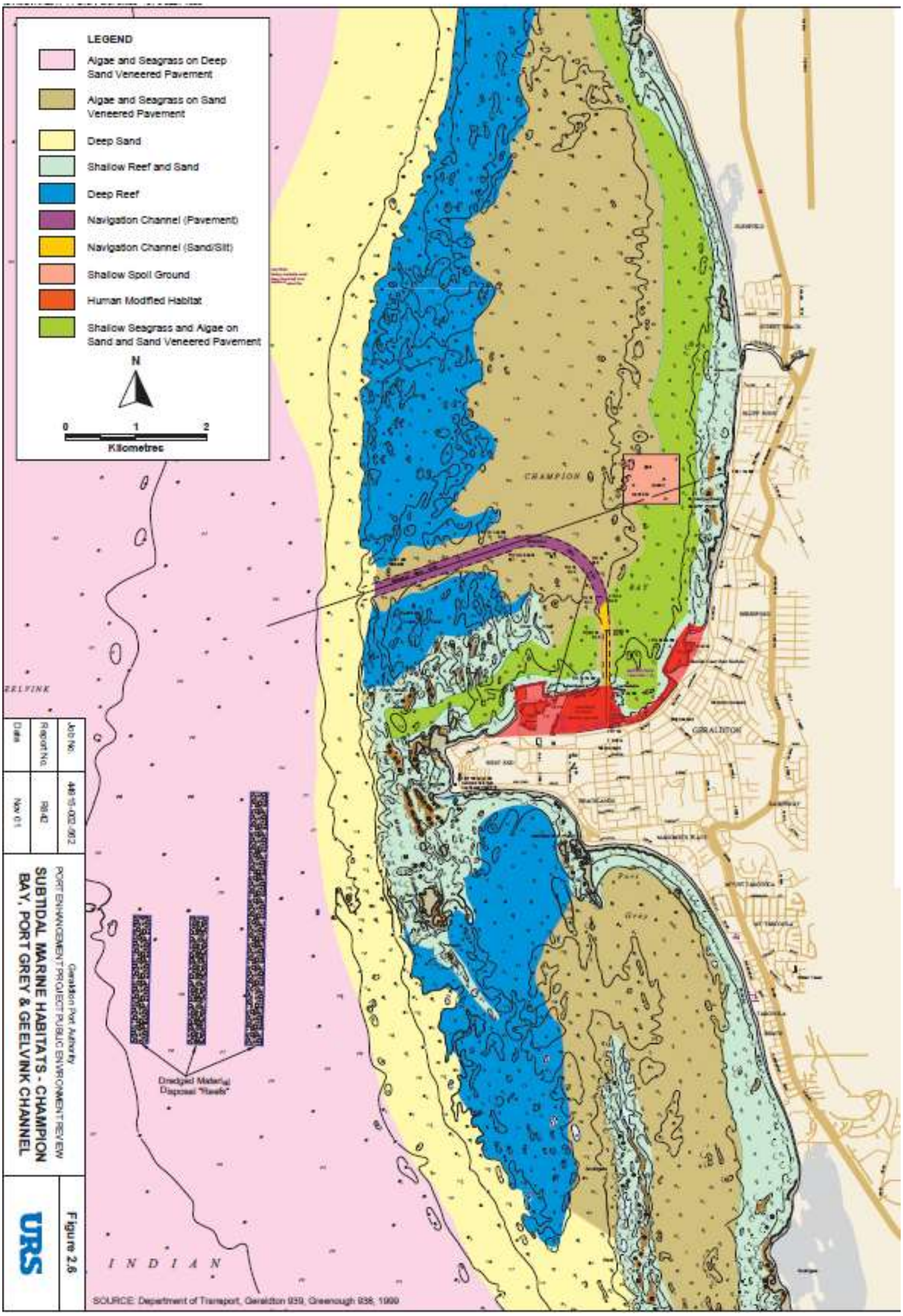

Figure 13.3. Subtidal marine habitats of Champion Bay, Port Grey and Geelvink Channel (Source: URS 2001)

13.2.1.2 Dongara to Guilderton

The central coast is comprised of a narrow ribbon of limestone and sand substrates with an extensive chain of offshore reefs. The near shore environment between these offshore reefs and the coast includes a wide range of submarine landforms and marine habitats such as reef, sand and seagrass communities (Figure 13.4). The dominant algae species on reefs < 10 m depth is *Ecklonia* spp., while *Sargassum* spp. dominates the deeper waters (Department of Planning and Urban Development 1994, Wilson 1994).

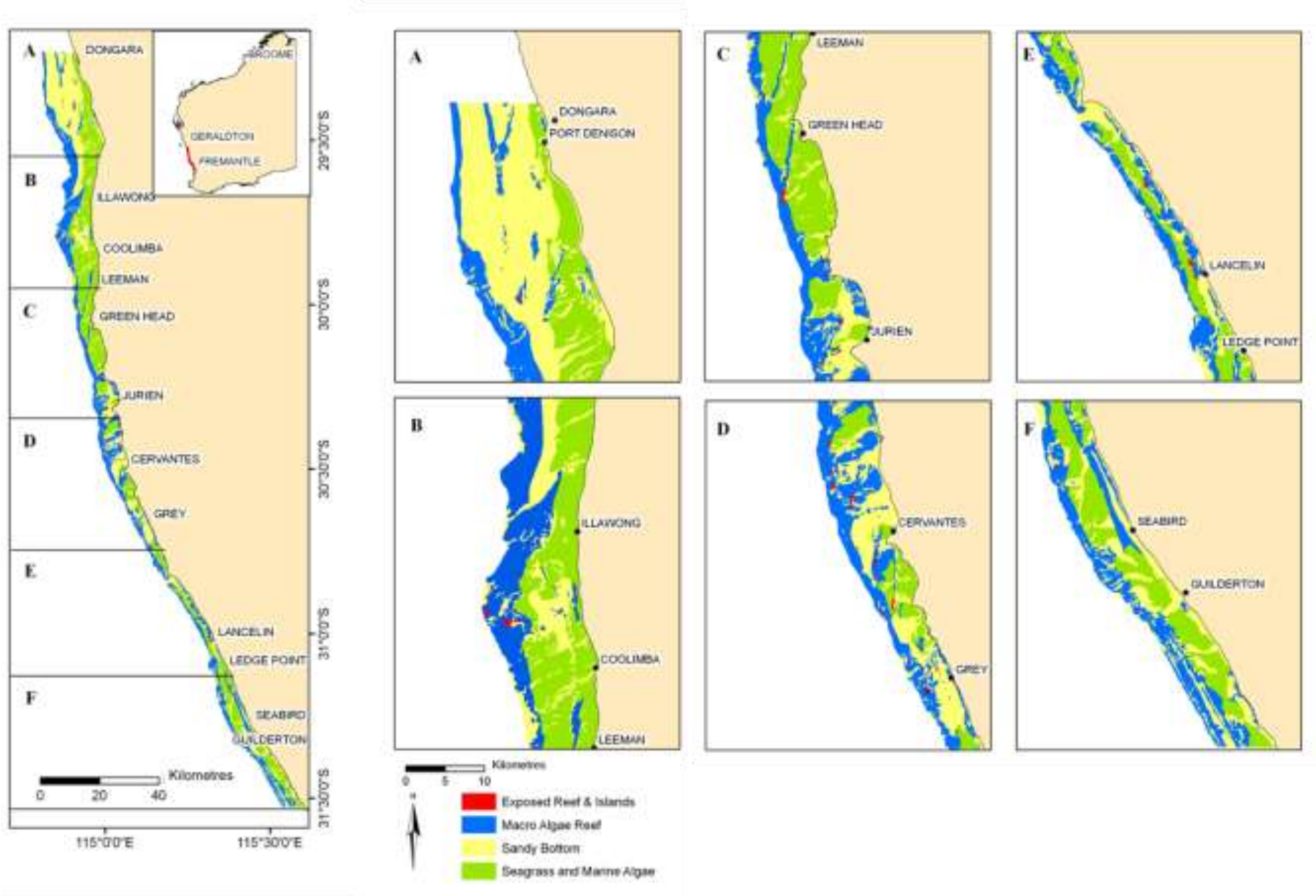

Figure 13.4. Major benthic habitats of the central west coast (Source: Department of Planning and Urban Development 1994)

13.2.1.2.1 Jurien Bay

Jurien Bay is located approx. 200 km north of Perth and has a unique combination of offshore reefs, islands and sheltered lagoons. The nearshore bathymetry of this region is complex; inside the 20 m isobath, there is a series of prominent, elongate, limestone reefs, more or less parallel to the shore, protecting inshore lagoons. Many of the reefs break in moderate water, some are exposed at low tide and some bear emergent rocks and islands. There is a series of medium-sized limestone islands along the coast (i.e. Sandland, Favorite, Boullanger, Whitlock, Escape and Cervantes), which have well-developed intertidal rock platforms, at least on their seaward sides (Wilson 1994).

The Jurien Bay Marine Park (JBMP) was established in 2003 and extends across the region from Green Head to Wedge Island. Five major habitat-types have been identified within the JBMP (Figure 13.5):

- Bare or sparsely vegetated mobile sand;
- Seagrass meadows: important habitat in the more sheltered areas in the lagoonal environments (covers ~ 25 % of the JBMP);
- Shoreline and offshore intertidal reef platforms: range from highly protected to fully exposed. Significant areas of intertidal reef platforms are located between Green Head and North Head and between Cervantes and Wedge;
- Subtidal limestone reefs: dominated by large algal species in < 20 m depths, while deeper offshore reef platforms are dominated by red algae; and
- Reef pavement (CALM 2005).

The biota of deeper-water habitats at Dongara, Lancelin and Jurien have also been assessed to evaluate the effects of western rock lobster fishing on deep-water ecosystems along the west coast (Bellchambers 2010; Bellchambers et al. 2010). Habitat type and biota were classified using towed video in depths of 35 to 75 m. Dongara was identified as a sponge-dominated ecosystem, while Lancelin was macroalgae-dominated, and Jurien Bay was a mixture of sponge and algae. The macroalgae assemblage was dominated by *Ecklonia radiata*, which is likely to be the main source of primary production in the local deep-coastal ecosystems (Bellchambers 2010).

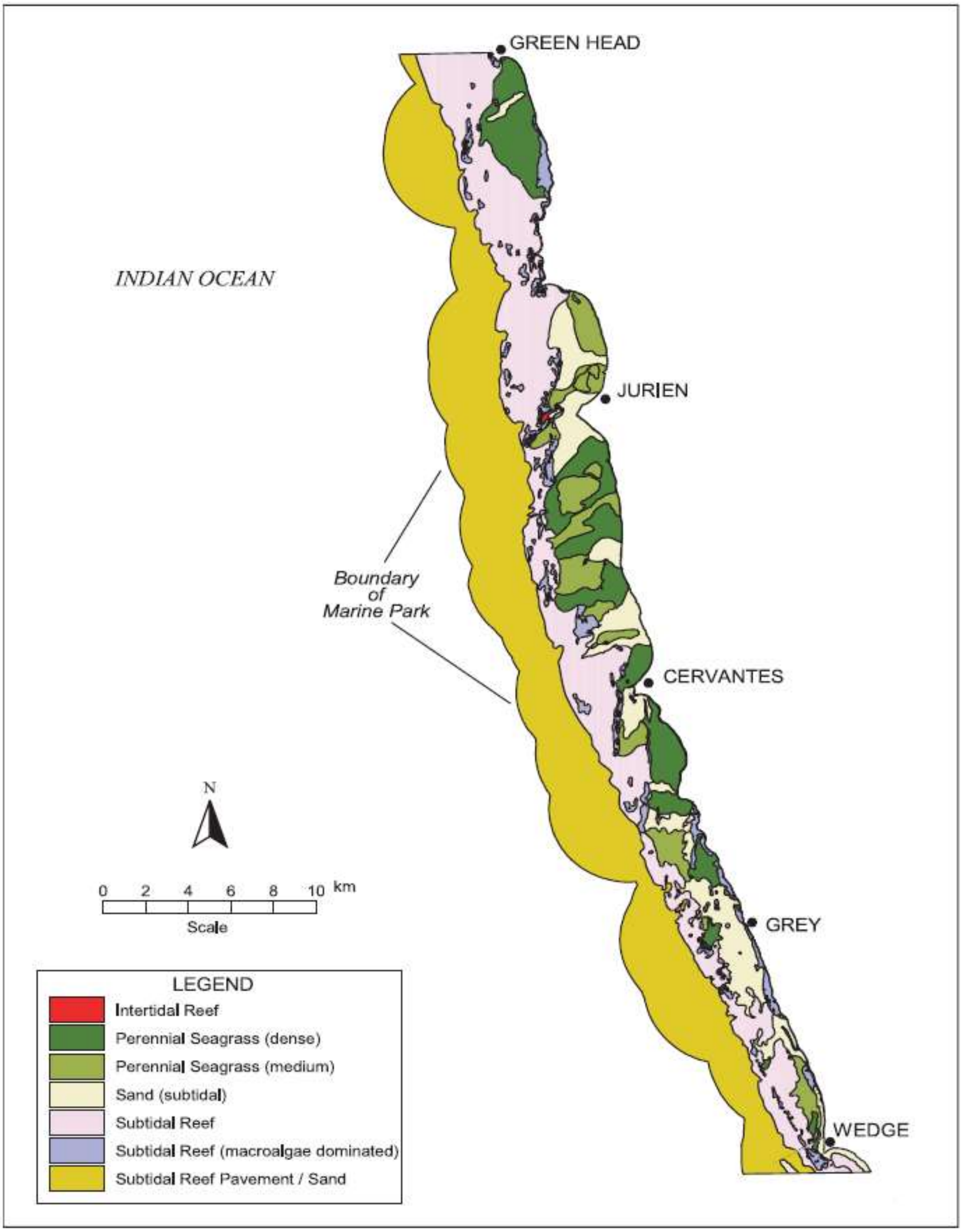

Figure 13.5. Major benthic habitat types within the Jurien Bay Marine Park (Source: CALM 2005)

13.2.1.3 Northern Perth Metropolitan Region

Benthic habitats in the Perth metropolitan region (Yanchep to Mandurah) comprise platforms, nearshore and offshore reefs, as well as sandy and silty areas. The reefs support numerous macroalgal species, a variety of sponges and some corals, which in turn sustain both tropical and temperate fish and invertebrate species. Areas of seagrass are typically interspersed amongst reef areas with no large meadows in the northern metropolitan region (Dept. of Environmental Protection 1996; Hutchins 1979 and 2001;Toohey 2007; Toohey et al. 2007; Tuya et al. 2008; Wernberg and Goldberg 2008).

In 1993, the major benthic habitats of the Perth metropolitan area coastal waters were mapped (Figure 13.6) with seven benthic habitat types identified:

- Silt
- Fine sand silt
- Bare sand with some sparse seagrass
- Coarse sand
- Seagrass meadow
- Subtidal reef – macroalgal dominated
- Intertidal reef platform – macroalgae (Department of Environmental Protection 1996)

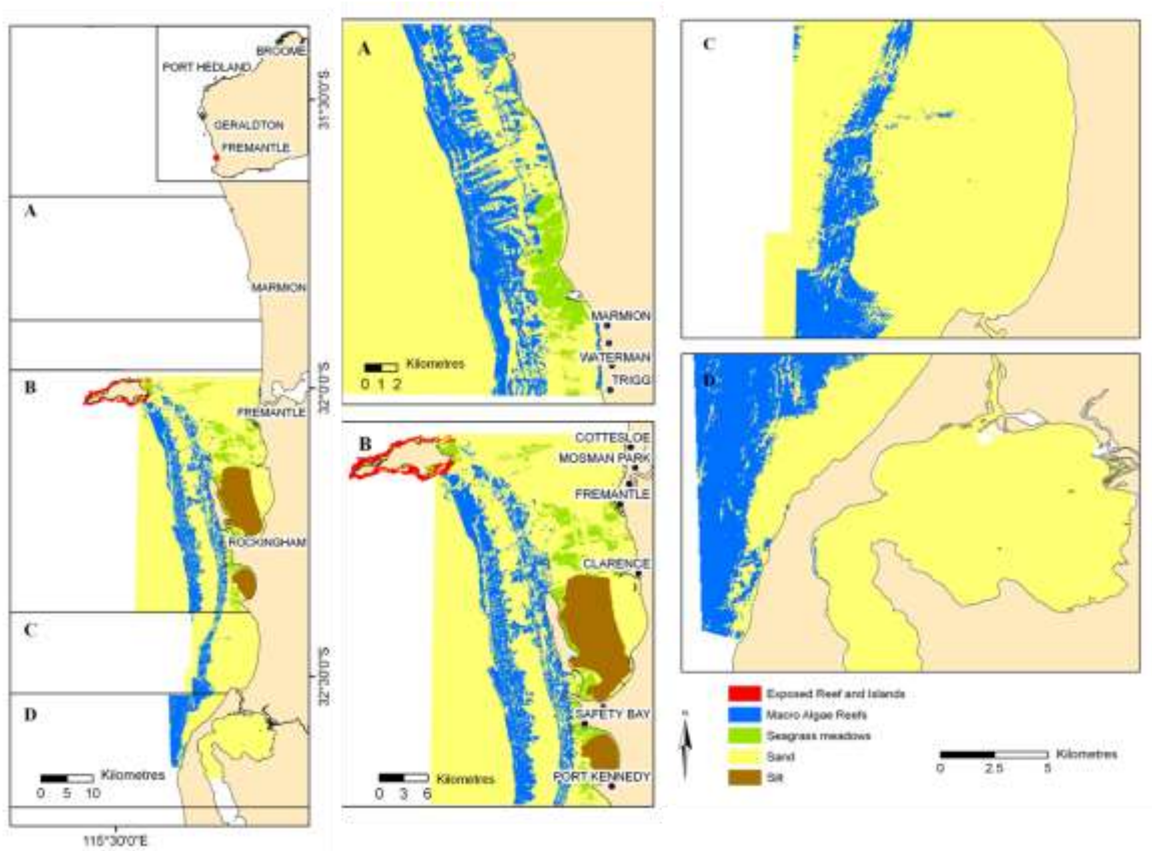

Figure 13.6. Major benthic habitats of the Perth metropolitan waters from Yanchep to Mandurah (Source: Dept. of Environmental Protection 1996)

13.3 Leeuwin-Naturaliste Ecosystem

The Leeuwin-Naturaliste Ecosystem (LNE) extends south from Perth (31° 60’ S) to Black Point (115° 57' 41" E), southeast of Augusta, on Australia’s south coast (Figure 13.1). The region is thought to have high species diversity and endemism, as it is a transition region between west and south coast communities (CoA 2008).

Continuing south from the CWCE, the shelf within the LNE is narrow and includes features such as limestone ridges, depressions defining an inshore lagoon, a relatively smooth inner shelf plain that meets the South Bank Ridge on the outer shelf and islands providing important habitat. The shelf progressively broadens to form the relatively sheltered waters of Geographe Bay before narrowing once again at Cape Mentelle (CoA 2008).

13.3.1 Habitat Descriptions and Mapping

13.3.1.1 Southern Perth Metropolitan Region

The Southern Perth Metropolitan Region stretches from Fremantle south to Mandurah and is the most northern section of the LNE. In addition to specific areas discussed below, an overview of the marine environment and benthic habitats found throughout the southern Perth metropolitan region (Yanchep to Mandurah) can be found in Section 13.2.1.3 above.

13.3.1.1.1 Cockburn Sound Region

Cockburn Sound is a protected marine region approx. 20 km south of Fremantle and is one of the most intensively used marine embayments in WA. It is sheltered to the west by Garden Island and bounded to the north and south by Parmelia Banks and Southern Flats, respectivley. Owen Anchorage is to the north of Cockburn Sound (Figure 13.7). The majority of the area has a sandy bottom, and marine flora includes seagrasses, seagrass epiphytes, reef algae and phytoplankton. Seagrass beds are composed of *Posidonia spp*. and *Halophila spp*.

There have been numerous physical alterations to the seabed in the Cockburn Sound and Owen Anchorage, including dredging of the Fremantle Ports shipping channels, construction of the Garden Island causeway and shells and resource dredging by Cockburn Cement Limited (Cambridge and McComb 1984, DAL 2000, DALSE 2003, D.A. Lorde and Associates Pty Ltd 2005, Kendrick et al. 2002). A large portion of the seabed in the area is covered in seagrass meadows, although a significant area of seagrasses have been lost due to dredging (Figure 13.8) (D.A. Lorde and Associates Pty Ltd 2005).

13.3.1.1.1.1 Garden Island and Carnac Islands Extensions

Garden Island extends off Cape Peron between Cockburn Sound and Shoalwater Bay. The western shore of the Island is exposed to moderate wave action and comprises long, sandy beaches between limestone headlands, although there are several semi-protected bays at the northern end. Wide, intertidal rock platforms are cut into the fronts of the headlands, and there are numerous shallow reefs and some rock islets close to shore (Wilson 1994). A causeway and bridge runs across Southern Flats linking Garden Island to the mainland and produces a 2 – 3 fold reduciton in the exchange of water occuring at the southern end of Cockburn Sound (DALSE 2003).

Carnac Island is located off the northern end of Garden Island and is almost completely surrounded by low limestone cliffs and intertidal rock platforms, with a beach on the eastern side. The intertidal flora and fauna at Carnac Island are species rich but lack the high proportion of tropical species present further north and offshore at Rottnest Island (Wilson 1994).

Offshore, west of Garden and Carnac Islands, there is a series of limestone ridges on the seabed, generally trending parallel to the coast. The ridges are deeply undercut and cavernous, with sandy gutters between them. The largest of these is Five Fathom Bank, approx. five kilometres offshore, which is one of the major structural features of the WCB (Wilson 1994).

Figure 13.7. Location of Owen Anchorage, Cockburn Sound and Garden Island (Source: Department of Environment 2005)

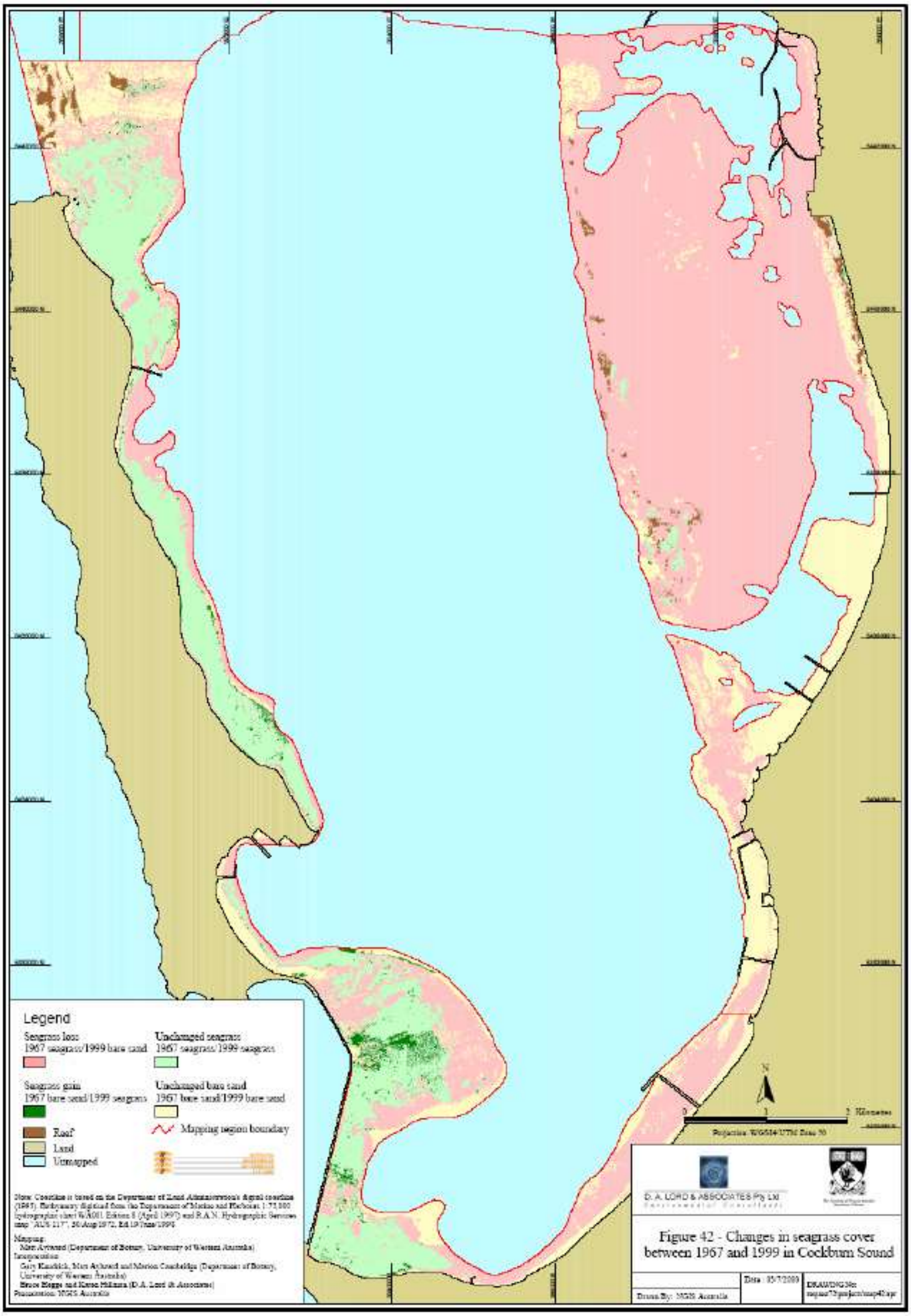

Figure 13.8. Changes in seagrass cover between 1967 and 1999 in Cockburn Sound (Source: D.A. Lorde and Associates Pty Ltd 2005)

13.3.1.1.1.2 Warnbro Sound

Warnbro Sound is south of Cockburn Sound and is included in the Shoalwater Islands Marine Park. The marine park covers approx. 6658 ha and is adjacent to the City of Rockingham, about 50 km south of Perth. Limestone ridges and reef platforms are found in the northern areas of the marine park, both along the coast and as a chain of islands and reefs, which protect the coast from south-westerly swell and waves. Underwater structures, including caves, archways, vertical channels, solution pipes, rocky slopes and platforms, are a result of chemical and mechanical weathering (DEC 2007).

The region is dominated by beach and rocky shore coastal habitats and includes six major marine benthic habitat types (Figure 13.9):

- Seagrass;
- Subtidal mobile sand;
- Bare reef (intertidal offshore);
- Subtidal high relief macroalgae;
- Subtidal low relief macroalgae; and
- Silt (DEC 2007).

Seagrass meadows consist mainly of *Posidonia* spp., *Amphibolis* spp., *Halophila ovalis* and *Heterozostera tasmanica* and support a diverse assemblage of fish and invertebrates. Soft-bottom areas are inhabited by fish and burrowing invertebrates, including molluscs and polychaete worms. Intertidal reef platforms are characterised by diverse algal communities that support large populations of animals, such as Roe's abalone, whelk, chiton and large turban shell (DEC 2007).

Subtidal reefs are dominated by large macrophytes, such as *Ecklonia radiata.* These areas are recognised as being one of the substantial contributors to primary production in the area and attract a range of fish and assemblages of sponges, gorgonians and other invertebrates, including western rock lobster (DEC 2007).

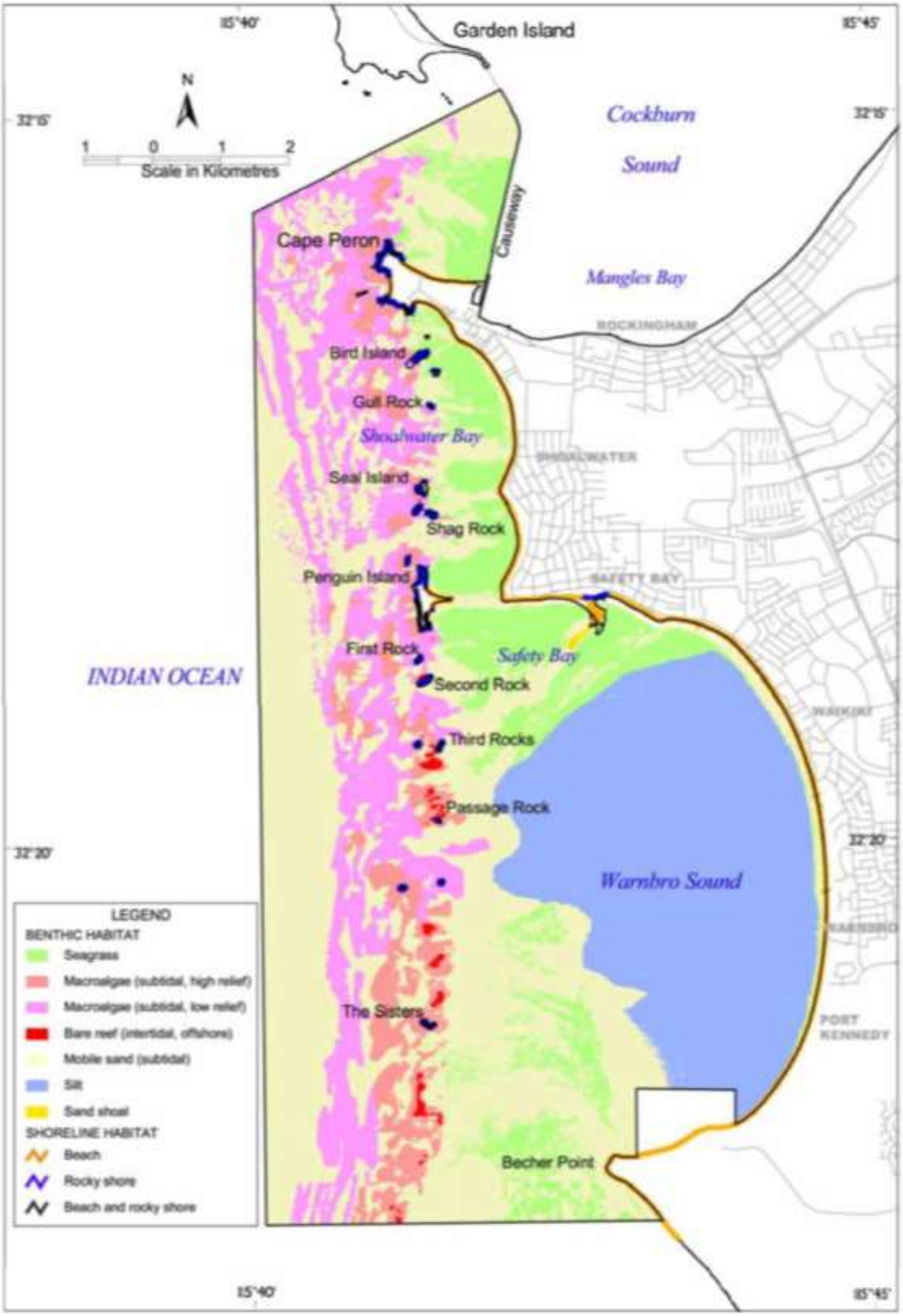

Figure 13.9. Major marine benthic and shoreline habitats within the Shoalwater Islands Marine Park (Source: DEC 2007)

13.3.1.3 Geographe Bay to Augusta

The area from Geographe Bay to Cape Leeuwin has two distinct coastal types, the low-profile, low-energy, sandy shores of Geographe Bay and the high-profile, high-energy, rocky shores of the Naturaliste-Leeuwin Ridge. There is one small estuary on the Leeuwin-Naturaliste coast at the mouth of Margaret River, with many other freshwater springs found elsewhere along the shore (Wilson 1994). This region (from Geographe Bay to Flinders Bay, near Augusta) has recently been designated as the Ngari Capes Marine Park (NCMP) in June 2012 (see Figure 13.10).

In summer, the cool West Australian Current flows northward along this shore and sweeps around into Geographe Bay; however, in late-summer and winter the Leeuwin Current flows southward off the coast, reaching as far south as Cape Leeuwin in some years (Wilson 1994).

13.3.1.3.1 Geographe Bay

The flora and fauna of Geographe Bay are generally temperate, although there is also a significant endemic West Coast element and some tropical species. Much of the seabed in the Bay is a sand plain, and the benthic communities of the inner part of the Bay are dominated by monospecific stands of the seagrass *Posidonia sinuosa* (approx. 70 % of the Bay), along with smaller areas of other seagrasses (Walker et al. 1987) (Figure 13.10). The seagrass meadows in Geographe Bay are one of the most extensive in the WCB and are known to occur to depths of at least 45 m (Wilson 1994). There is a rich epiphytic community of algae and invertebrates associated with the seagrass meadows, which is very distinctive and characteristic of southern WA (Wilson 1994).

In the Western part of Geographe Bay exist limestone ridges which provide hard substrate for macralgae and suspension feeding invertebrates, such as sponges and ascidians (Wilson 1994). Individual coral colonies are found on reef substrata in the western end of the Bay with fourteen species from seven genera have been identified in the area (Veron and Marsh 1988).

13.3.1.3.2 Leeuwin-Naturaliste Region

The region from Cape Naturaliste to Cape Leeuwin is a high energy zone with inter and subtidal reef platforms (Figure 13.10). Algae are the main primary producers in of intertidal reef systems with at least 26 species of macroalgae identified within the marine park (Osborne 2002). Some of the largest intertidal reefs occur at Yallingup, Cowaramup Bay, Margaret River, Gnarabup, Hamelin Island and Augusta (DEC 2013).

Shallow subtidal reefs (<10 m depth) are composed of either limestone or granite. In sheltered, low relief limestone areas, kelp species *Sargassum* spp. and *Ecklonia radiata* are dominant, while *Curdiea obesa*, *Pterocladia lucida* and *Callophyllus* spp. are dominant between the Capes (Harman et al. 2003). Low relief limestone habitat is associated with a wide range of invertebrates, such as ascidians, calcareous sponges and gastropods, while high relief areas are covered by a high diversity of fleshy macroalgae (e.g. *Ecklonia radiata*, *Sargassum dorycarpa*, etc.; Harman et al. 2003).

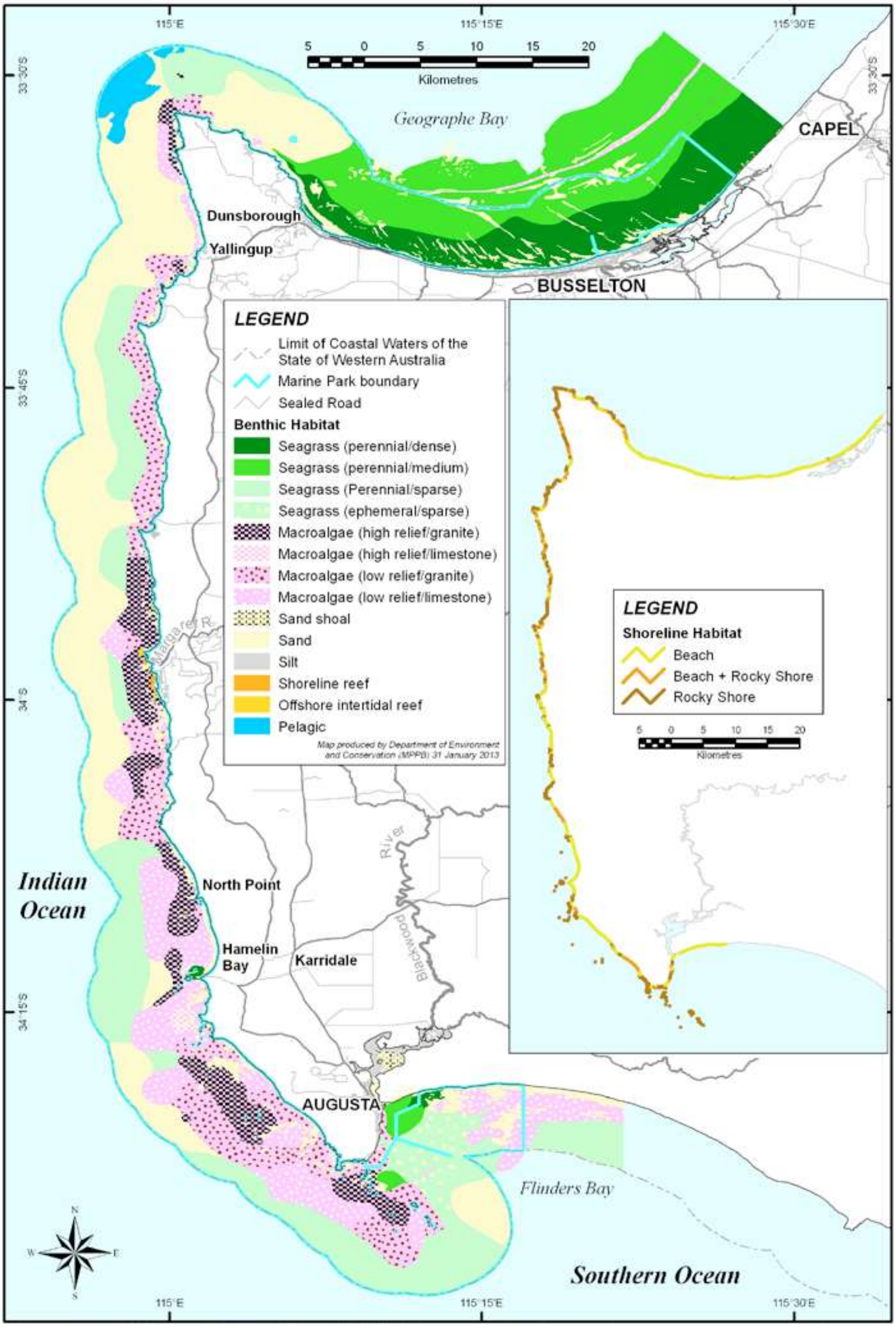

Figure 13.10. Major benthic and shoreline habitats within and adjacent to the Ngari Capes Marine Park (Source: DEC 2013)

Shallow, subtidal granite reefs are characterised by large buried boulders or fields of small boulders that may also incorporate small sand patches and are dominated by the algae *Platythalia angustifolia* (Harman et al. 2003). Low relief shallow granite reefs support a wide variety of invertebrates including ascidians, calcareous sponges and gastropods, while high relief granite reefs are dominated by crustose coralline algae, kelp and turf (DEC 2013).

Deep reef habitats are limestone and granite reefs, (> 10 m depth) with similar assemblages to shallow areas. The deeper waters between Cape Naturaliste and Cape Leeuwin are dominated by sparse, perennial seagrasses. These deep seagrass beds are exposed to heavy swells and are not found on any other coast in the world (Kirkman and Kuo 1990). South of Cape Naturaliste, seagrass beds occur within bays protected by offshore reefs or headlands. The clear waters near Cape Mentelle allow *T. pachyrhizum* to predominate, forming large, sparse beds at depths greater than 35 m. *Posidonia* spp. and *Amphibolis* spp. also occur in relatively deep waters (DEC 2013).

The southern boundary of the NCMP is in Flinders Bay, near Augusta (see Figure 13.10). Within Flinders Bay, seagrass communities are generally ephemeral and are sparsely distributed with smaller amounts of perennial seagrasses present. Corals are also found on the limestone patch reefs (DEC 2013).

13.3.1.3.3 Augusta

Augusta lies on the southern coast of WA, just east of Cape Leeuwin. The region from Augusta to Walpole is the wettest part of the State, with annual rainfall between 1000 and 1400 mm while evaporation is around 1100 mm. The coast is influenced by the flow of the Capes Current, which flows from east of Cape Leeuwin and extends northward to Rottnest Island. This current is fed by nutrient rich upwelling and is relatively cold with high chlorophyll content (WA Planning Commission 2003).

13.4 South Coast Ecosystem

The SCE extends from the WCB boundary at 115° 30’ E east to Israelite Bay, east of Esperance (123° 52’ E; Figure 13.1).

The lower south-west region of WA has a Mediterranean climate with mild to moderately hot dry summers with cool evenings. Mean minimum and maximum temperatures vary between 12 and 24° C in summer and 6 and 15° C in winter (Department of Environment [DoE] 2004a). Winters are typically cool and wet and are punctuated by periodic fronts bearing strong winds and rainfall. The high rainfall is reflected in the relatively high number of river systems and associated estuaries and inlets within this region (WA Planning Commission 2003). Prevailing winds along the south coast in summer are south-westerly to south-easterly, while southerlies prevail in winter (Sanderson et al. 2000).

The western SCE is largely influenced by the northward-flowing Capes Current. The Current is narrow (20 km wide) and transports relatively cold, nutrient-rich water. It replaces the Leeuwin Current in summer and can reach as far as Busselton in spring and summer onshore winds (WA Planning Commission 2003).

Unlike the lower west coast, which is protected by limestone reefs, there are few offshore islands or submerged features along the south coast (Sanderson et al. 2000). Additionally, as the continental shelf is narrow (ca. 25 – 30 km wide) along the south coast, the coast is exposed to the most extreme wave energy of the entire Australian coastline (Harris et al. 1991; Hemer 2006).

13.4.1 Habitat Descriptions and Mapping

13.4.1.1 Augusta to Walpole

The shore from Augusta to Point D'Entrecasteaux consists of a wide, curving beach more than 80 km long and trending NW-SE. The beach is almost continuous, interrupted only at Black Point where there is an outcropping of the Bunbury Basalt. The basalt here forms unusual rocky shores, including cliffs and boulder fields (Cockbain 1990).

13.4.1.2 Walpole to Albany

The region from Walpole to Albany has a rugged coastline characterised by a repeated pattern of long, arcuate sand beaches backed by dunes located between high, cliffed granite, doleritic or metasedimentary headlands. The most exposed parts of the headlands, facing south and south-west, are either cliffed or fronted by steep slopes, and are swept by swell surge. The south-eastern sides of the headlands, adjacent to the next wide bay and beach, are exposed to lesser wave action and tend to have granite or gneissic boulder fields along the shore (Wilson 1994).

The headland shores along this coast drop steeply to relatively deep water, meeting the sandy bottom at depths of 20 – 30 m. Vertical sublittoral rock walls are common, along with offshore granitic and gneissic reefs (Wilson 1994).

Estuaries along this coast include the Irwin, Parry and Wilson Inlets (Brearley 2005).

13.4.1.2.1 West Cape Howe

West Cape Howe is located between Denmark and Albany. It is the most southerly section of the WA coastline and includes the southern-most point at Torbay Head. The coastline in this region is dominated by granitic headlands, steep limestone cliffs and sandy beaches. It is a high energy environment, unprotected from the predominantly south-westerly Southern Ocean swells, although some more sheltered areas exist, e.g. at Dunsky Beach, which faces north-east and is shielded by Torbay Head (CALM 1995).

13.4.1.3 Albany Region

The Albany region borders the Southern Ocean from Wilson Inlet in the west to the Beaufort Inlet in the east. A number of rivers and creeks enter the ocean along this section of the coast, with commercial fishing in the estuaries of King George Sound, Princess Royal Harbour, Oyster Harbour, and Waychinicup Inlet.

Rainfall in the Albany region ranges from the wetter rainfall area in the west to the more arid area to the east. Most rain falls in winter, although infrequent summer cyclonic storms can also bring very high falls that can cause flooding (Brearly 2005).

Around the town of Albany, the large embayments of King George Sound, Princess Royal Harbour and Oyster Harbour create a safe haven in the rugged coastline, as further east the bays are more open and exposed (Brearly 2005).

East from Oyster Harbour, the rugged granite shore of Mount Martin and Mount Taylor alternate with sandy beaches. Further east, the granite cliffs of the Mount Manypeaks Range face south, broken by the rocky gorge of the Waychinicup Inlet. Beyond that, alternating headlands of gneiss and limestone line the coast from Hassell Beach east to Cape Richie (Brearly 2005).

Although the seafloor slopes gradually out to 20 m in Two Peoples Bay and off Hassell Beach, elsewhere there is a steep slope. The granitic shores of Cape Vancouver, Bald Island and the Manypeaks ridge drop off very steeply to 50 m within one or two kilometres of the shore. These areas are generally characterised by spectacular vertical rock walls in the sublittoral zone (Wilson 1994).

On open ocean shores, the rock slopes are densely vegetated with macroalgae down to depths of 15 – 20 m. Below that depth, macroalgae give way to a very dense community of attached, suspension-feeding invertebrates, including sponges, ascidians and coelenterates. Sublittoral vertical walls and undercuts where there is shade are also densely covered with a wall of sedentary invertebrates (Wilson 1994).

13.4.1.3.1 King George Sound

King George Sound (KGS) is a large bay that opens into the ocean on its eastern and south-eastern sides. While it is relatively protected compared to the open ocean, it is much more open and deeper than the adjacent Princess Royal and Oyster Harbours.

The seabed around Mistaken Island in KGS has been mapped by IRC Environment (2000) using aerial photography and multispectral imagery of the seabed, with habitats verified by field inspection using drop-down videos of different sites within the study area. The following categories were used to describe the key habitats and vegetation encountered in the area: seagrass on sand; algae on rock, sand or sandy pavement; and bare sand. The seagrass category was further divided into various species of larger seagrass, smaller seagrass or mixed larger and smaller seagrasses.

The broad habitat maps generated from the survey showed that seagrass composition and cover differed depending on location within the Sound. Along the south-western and southern sector in Frenchman's Bay, seagrasses appeared to be dominated by the perennial *Posidonia sinuosa* and smaller species, such as *Halophila* spp. and *Heterozostera tasmanica*. In contrast, seagrass beds in the north and north-east, along with those occurring in deeper waters and inshore of Michaelmas Island were predominantly species of the *Posidonia ostenfeldii* complex (IRC Environment 2000).

13.4.1.3.2 Mt Gardner and Two Peoples Bay

Two Peoples Bay faces due east between the granite headlands of Mount Gardner and Boulder Hill. The shoreline of Two Peoples Bay seems to have advanced from the surrounding hills, trapping swamps and Gardner and Angove Lakes behind low dunes. Two rivers flow towards the lakes and swamps, Goodna River and Angove River. Goodna River flows to Moates Lake, from which there is a small creek through dunes and swamps to Gardner Lake. The creek from Gardner Lake flows across the beach in most years, or the beach is cut to drain water from the swamps. Seawater and stranded seagrass debris wash back into the creek.

The gently sloping, relatively protected seabed of Two Peoples Bay has extensive seagrass meadows of *Posidonia* spp. and *Amphibolis* spp. The western side of the rocky spit at South Point at the southern end is relatively protected from swells and consists of a field of boulders and tide pools extending down into the sublittoral zone. This habitat is rich in macrophytes and invertebrates and has an assemblage of molluscs, crustaceans and echinoderms typical of South Coast rocky shores. Seagrass meadows begin at a depth of 2 – 3 m, beyond the limit of the boulders (Wilson 1994).

The deeper water region (> 10 m) off Mount Gardner has been mapped as part of the Marine Futures project (Radford et al. 2008, Figure 13.11). This region showed strong zonation related to depth and exposure to wave energy. Shallow sheltered areas were dominated by seagrass, which gives way to mixed macroalgae and invertebrates with increasing exposure and depth (Radford et al. 2008).

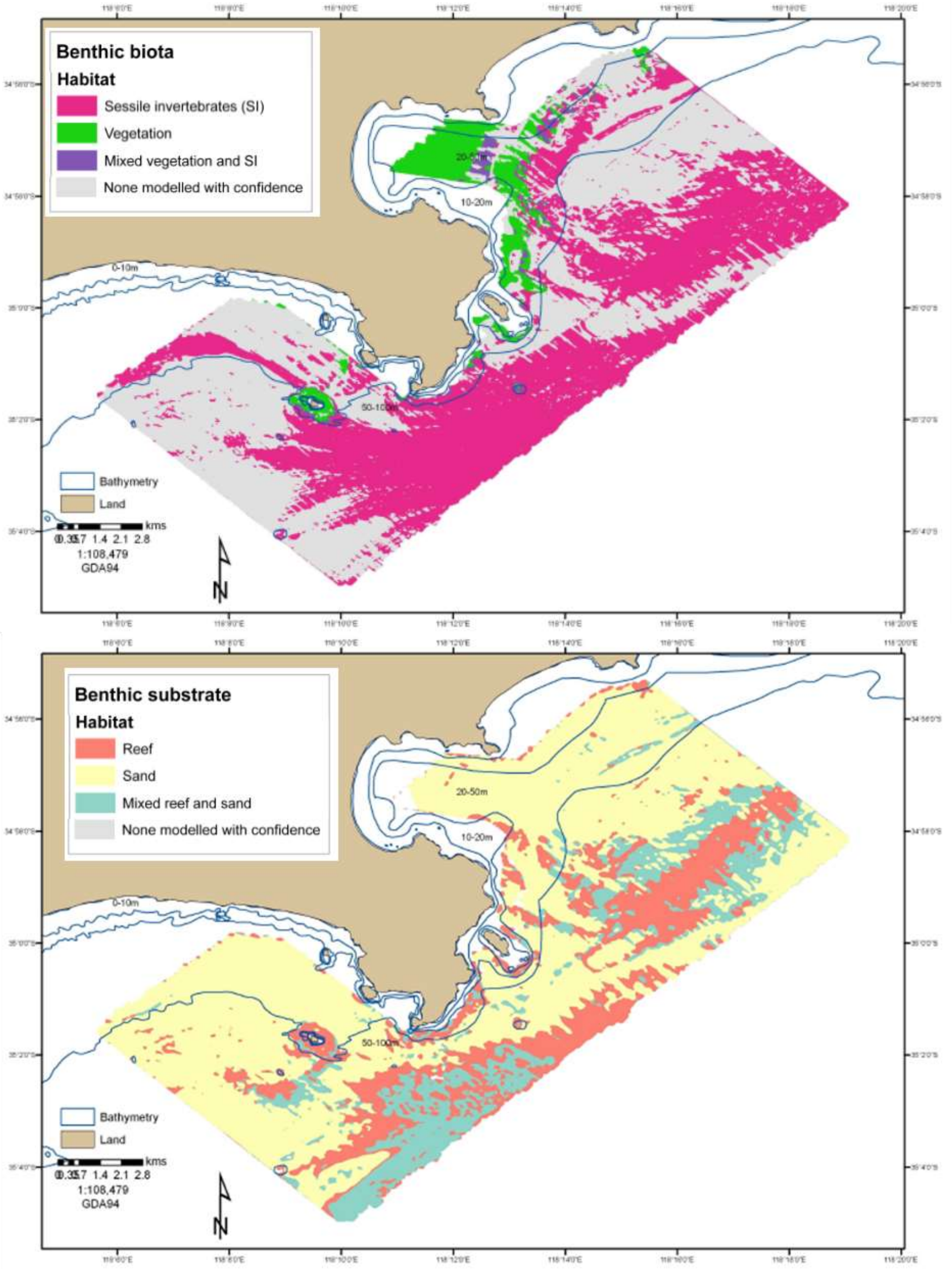

Figure 13.11. Habitat maps of deeper-water regions adjacent to Mount Gardner showing benthic biota (top) and substrate (bottom). (Source: Radford et al. 2008)

13.4.1.4 Bremer Bay to Esperance

There has been little marine habitat mapping between Bremer Bay to Esperance. Aerial photographs indicate there is extensive development of seagrass beds beyond the surf zone in Doubtful Island Bay (Wilson 1994), but no mapping has been undertaken in this area.

The deeper water region (> 10 m) off Point Ann was mapped as part of the Marine Futures project (Radford et al. 2008, Figure 13.12). This site showed pronounced depth zonation in biotic groups from shallow seagrass areas grading to mixed macroalgae and sessile invertebrates. Extensive rhodolith beds were found between 35 and 50 m depth, with deeper-water sessile invertebrate communities beyond 50 m depth (Radford et al. 2008).

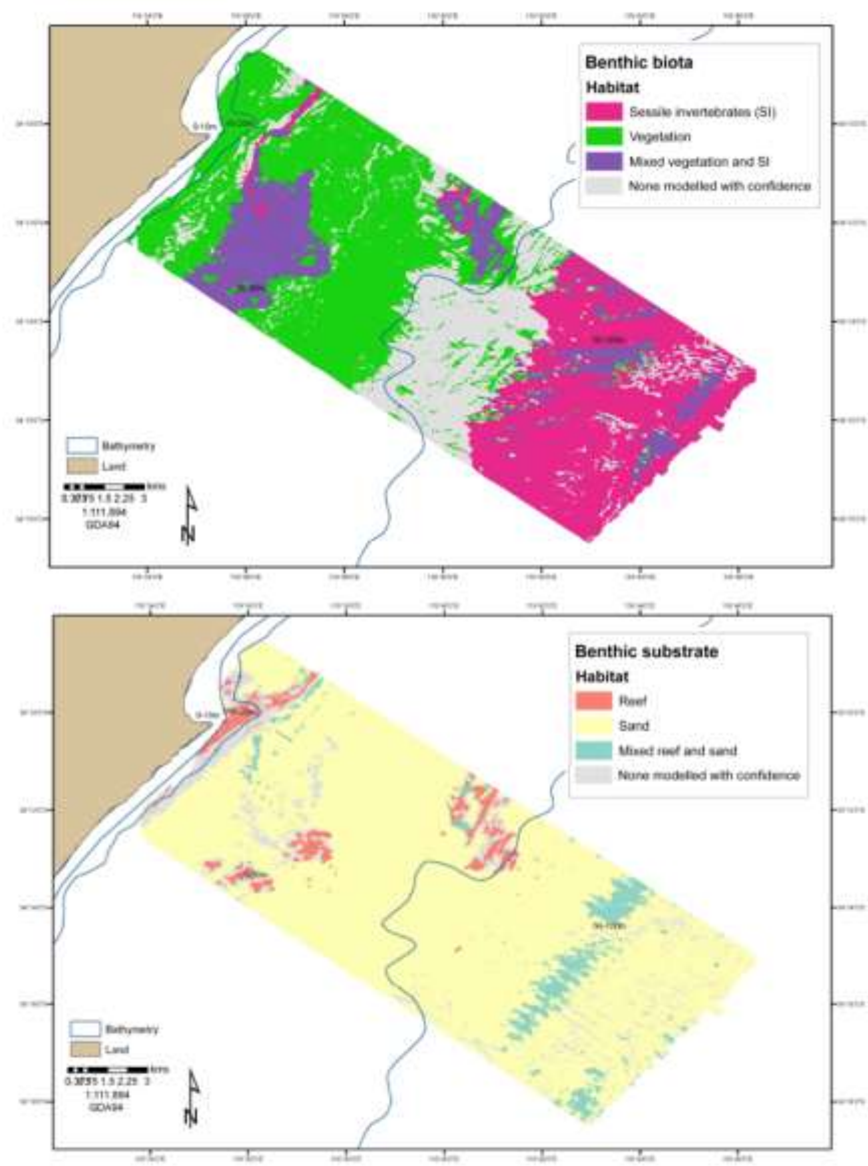

Figure 13.12. Habitat maps of deeper-water regions adjacent to Point Ann showing benthic biota (top) and substrate (bottom). (Source: Radford et al. 2008)

13.4.1.5 Recherche Region

The coastline from Esperance to Cape Arid is similar to that seen west of Esperance, with a series of shallow, south-facing bays between rocky headlands. However, the bays are smaller, the headlands are more numerous and the islands of Recherche Archipelago lie offshore.

The Recherche Archipelago is one of the major features of the SCE, stretching for a distance of more than 200 km and including many islands.

The coastline in the Recherche Archipelago region is characterised by arcuate sandy beaches located between rocky headlands (Wilson 1994). Exposed headlands, facing south and southwest, often have large cliffs or are fronted by steep slopes, which are swept by swell surge (Sanderson et al. 2000). These rocky shores fall steeply into the ocean until the reach the seafloor at depths of 20 – 30 m, where the substrate changes abruptly to sand. There are also numerous narrow limestone reefs paralleling the shore, which along with the open rocky shores, provide a variety of habitats (Kendrick et al. 2005).

Within the Recherche region, the continental shelf is as narrow as 50 km in some places (Li et al. 1999), widening to as much as 300 km as it approaches the Eucla Ecosystem boundary (James et al. 1994).

13.4.1.5.1 Recherche Archipelago

The Recherche Archipelago is a chain of approximately 105 islands and 1500 islets extending over 200 km of coastline (Lee and Bancroft 2001). The islands are scattered across the entire width of the continental shelf and resemble the granitic headlands of the mainland coast. However, on some islands, the granite-gneiss is capped by limestone resulting in a flatter topography where sea cliffs and shore platforms may be developed (e.g. Goose Island; Kendrick et al. 2005). The majority of the islands are inaccessible due to their steep dome-shaped sides; only two of the islands (i.e. Sandy Hook and Mondrain Islands) have beaches permitting landing from the sea (DoF 1999a).

Most of islands of the Recherche Archipelago are exposed to high or moderate wave action from all directions, and there are few safe anchorages or landings. The islands resemble the granite headlands of the coast in form and character, and their rocky promontories have smooth, steep sides that slope into the sea in the most exposed areas. More sheltered shores have boulders and tide pools (Wilson 1994).

The seafloor within the Archipelago averages about 40 m depth and most of the islands are within the 50 m bathymetric contour, although the outer islands rise from depths of 70 m or more. Typically, the rocky shores are steep-to with an abrupt change in substrate where the rock slopes meet the sandy seafloor. There are many vertical rock walls in the sublittoral zone (Wilson 1994).

The extensive area of granite reef (35 203 km^2 of reef habitat) and seagrass habitat of the Recherche Archipelago is noted for its high diversity of warm temperate species including 263 species of fish, 347 species of molluscs, 300 species of sponges and 242 species of macroalgae (CoA 2008).

The marine habitats in the region have been mapped and classified by several different organisations (DAL 1999 and 2001, DoF 1999, Kendrick et al. 2005). The most extensive mapping was undertaken by Kendrick et al. (2005) covering the Recherche Archipelago and Esperance Bay (Figure 13.13). Biological factors were classified in terms of observation of cover of dominant community and by the presence of a number of biological assemblages. Physical factors were classified in terms of depth, substrate and relief.

Five broad habitat classifications were identified in the Recherche Archipelago: high profile reef, low profile reef, sand, rhodoliths and seagrass. Overall, low profile reef represented 33.4 % of the area mapped; sand represented 28 %, seagrass represented 20.1 %, rhodoliths represented 13.7 % and high profile reefs represented 4.6 %; however, the percentages of each habitat varied across the regions.

Esperance Bay was dominated by seagrass (17.8 %), with coverage extending across the bay out to Cull Island and around towards Cape Le Grand. Seagrass was also found on the lee side of offshore islands group and in coastal embayments from Victoria Harbour to Alexander Bay. The area in the Duke of Orleans region was predominantly seagrass (53 %), and seagrass in the Cape Arid region was found mainly in Arid Bay and offshore north of Middle Island (Kendrick et al. 2005).

In general, most macroalgae were relatively rare, and macroalgal assemblages showed strong links with exposure, depth and island location. Where *Ecklonia* and *Scytothalia* were clearly dominant at exposed reefs, diversity was reduced compared to assemblages dominated by *Sargassum* and *Cystophora*. Of the six benthic invertebrate phyla examined, sponges and bryozoans were the dominant taxa (Kendrick et al. 2005).

Rhodolith beds were relatively widespread in the Esperance region (17 %), generally found in waters less than 45 m deep within Esperance Bay. Rhodoliths were also found further offshore in deeper water south of Remark Island and to some extent west of the Duke of Orleans region. Isolated rhodoliths were also observed in the Cape Arid region (Kendrick et al. 2005).

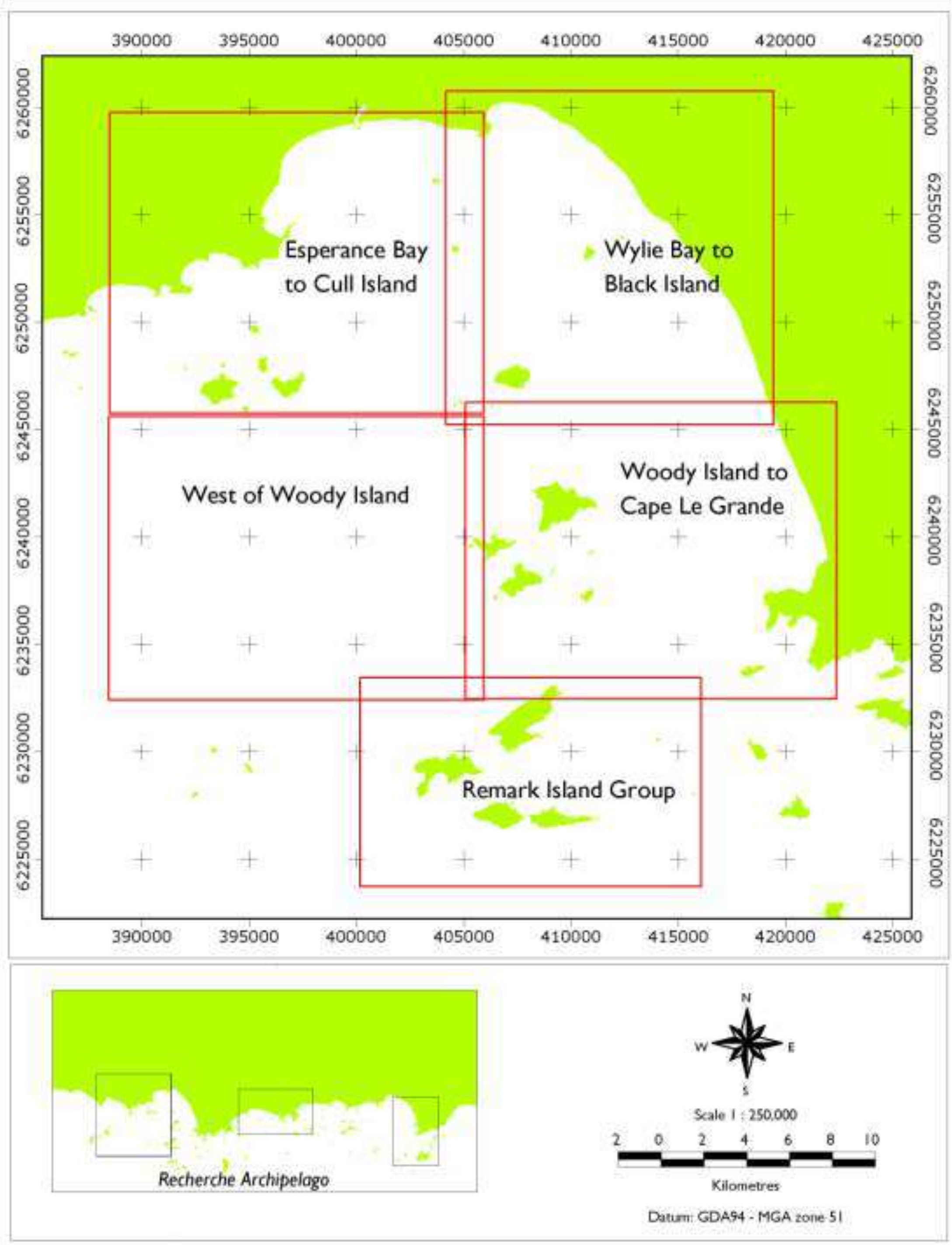

Figure 13.13. Location of mapping areas in the Esperance Region of the Recherche Archipelago and mapping locations at Duke of Orleans and Cape Arid regions (inset at bottom) (Source: Kendrick et al. 2005).

13.5 Eucla Ecosystem

The Eucla Ecosystem (EUC) stretches from Point Dempster (185 km east of Esperance) to Eucla, on the South Australian border (129° E; Figure 13.1).

The EUC includes a wide are of continental shelf. Ocean currents flowing through the region display marked seasonal patterns, particularly on the inner shelf. In summer, coastal winds generate west-bound coastal current along the inner shelf, leading to the formation of an anti-clockwise gyre in the Great Australian Bight (CoA 2008).

The coastline is exposed to the strong force of south-westerly swells and experiences very high wave energies. This ecosystem is particularly poor in nutrients, lacking some of the seasonal small upwelling events that distinguish the coast further east and receiving little inflow from the land (CoA 2008).

The continental shelf is wide and forms a large arcuate plain, with a maximum width of 300 km to the east of Eucla. The shelf is almost featureless, forming a gently sloping plain out to the shelf break at about 125 – 165 m depths (Edyvane 1998).

Geomorphology, sedimentology and hydrodynamics in the region interact to create ideal conditions for carbonate organisms, such as molluscs and bryozoans, to flourish without being smothered or buried. As a result, carbonate sediments derived from invertebrate skeletons and shells make up over 80 % of the shelf sediments. Within the wave abrasion zone (0 – 120 m depth), sediments are typically rippled and coarse-grained, forming a ‘shaved shelf’, where carbonate accumulation is less than the amount of active erosion resulting in a net loss of sediment from the shelf (CoA 2008).

During winter, water moved east through this ecosystem, fuelled by wind-driven coastal currents on the inner shelf and by the Leeuwin Current on the shelf break. During summer, the Leeuwin Current weakens to a point where it is largely absent, while coastal winds generate west-bound coastal currents along the inner shelf. Swells are predominantly from the south-west, although the concave shape of the coastline provides some protection to western parts of the Bight (CoA 2008).

13.5.1 Habitat Descriptions and Mapping

There has been no targeted habitat mapping along the EUC in WA; however, some information can be inferred from habitat information collected in the South Australian (SA) part of the IMCRA Eucla Bioregion.

The SA Eucla region is characterised by deep water (30 – 50 m deep). Most of the mapped subtidal habitats are bare sand stretches along the coast, with patches of reef. There is a relatively low diversity of algal species and only a few seagrass communities are found within the region (Baker 2004).

The SA section of the IMCRA Eucla bioregion is also part of the Great Australian Bight Marine Park (GABMP). The Great Australian Bight extends from Cape Pasley (near Esperance) to Cape Catastrophe at the entrance of Spencer Gulf in SA (ACIUCN 1986). The coastal nearshore marine habitats of the GABMP are mostly sand out to 2 – 3 km, interspersed with small narrow patches of low profile limestone reef (Edyvane and Baker 1996).

The benthic habitat of the GAB has been the subject of a few studies and surveys indicate benthic community assemblages are typical of warm to cool temperate waters and high swell wave conditions (South Australian Research and Development Institute (SARDI) 1994). On the rocky reefs within the GABMP, subtidal macroalgal communities are dominated by the kelp *Ecklonia radiata* and the fucoid *Scytothalia dorycarpa* (Edyvane 1998).

13.6 Marine Protected Areas

In WA waters (i.e. within 3 nm of the coastal baseline), biodiversity and fish habitats are protected through a network of marine protected areas gazetted under the FRMA and the CALM Act. Jurisdiction and management responsibility lies with two state government departments, the Department of Fisheries and the Department of Parks and Wildlife. In WA there are four types marine protected areas consistent with IUCN categories of I, II and III, these are:

- Fish Habitat Protection Areas (FRMA) at: Abrolhos Islands, Lancelin Island Lagoon, Cottesloe Reef and Kalbarri Blueholes
- Reef Observation Areas within the Abrolhos Islands Fish Habitat Protection Areas (FRMA) and Marmion Marine Park
- Area closures to fishing under Section 43 of the (FRMA) at: Yallingup Reef, Cowaramup Bay, the Busselton Underwater Observatory, Esperance Jetty and around the shipwrecks of the Saxon Ranger (Shoal Water Bay), Swan (Geographe Bay) Perth (Albany) and Sanko Harvest (Esperance)
- Marine parks, reserves and management areas (CALM Act) at: Jurien Bay, Marmion, Swan Estuary, Shoalwater Islands and Ngari Capes, Rottnest Island and Walpole-Nornalup Marine Park (in line with zoning outlined in the marine park management plans)

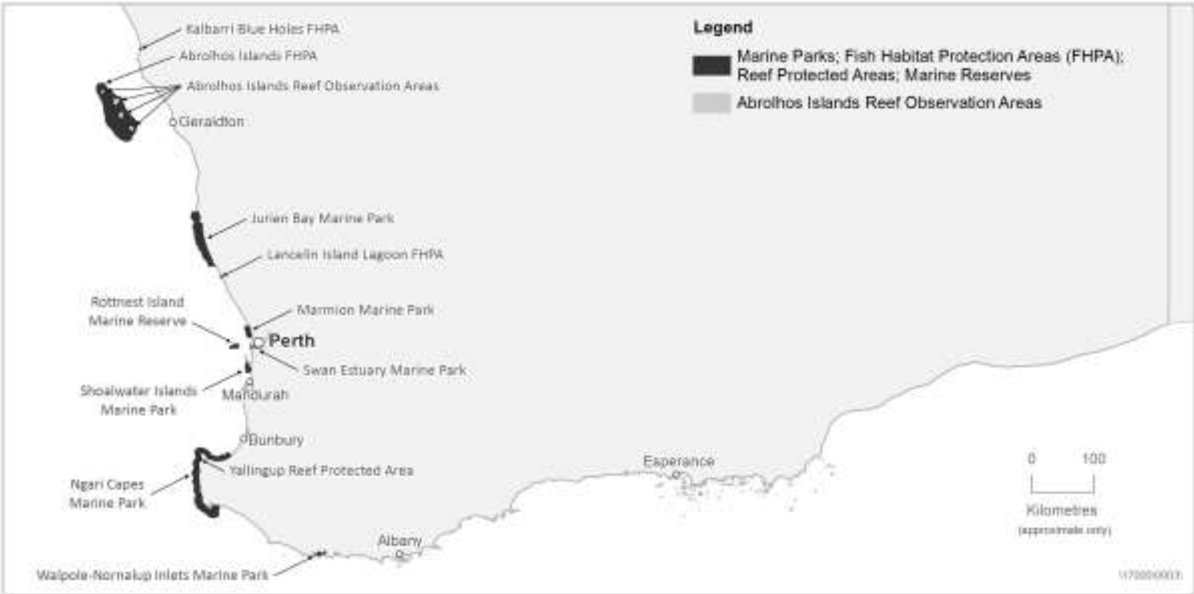

Figure 13.14. Current marine protected areas in the south west and south coasts of WA

13.6.1 Marine Park Zoning

The implementation of an appropriate zoning scheme is an important strategy for both the conservation of marine biodiversity and the management of human use in marine parks. Marine park zoning assists in separating conflicting uses and provides for specific activities such as for commercial and recreational activities, scientific study and nature appreciation. The zoning scheme also offers the opportunity to increase recognition and protection of culturally significant areas.

Section 13B of the CALM Act requires marine parks to be zoned as one or a combination of specific management zones (sanctuary, recreation, special purpose or general use zones), which are formally established as classified areas under Section 62 of the CALM Act. An overview of the zoning restrictions for marine parks in WA is provided below:

- Sanctuary zones: managed solely for nature conservation and low impact recreation and tourism. Passive recreational activities that do not compromise the ecological values are permitted but extractive activities are not;
- Special purpose zones: managed for a particular conservation purpose and / or priority use, such as protection of cultural heritage, seasonal events (e.g. whale breeding) or a particular type of activity, such as pearling. Uses that are not compatible with the specified conservation purpose are not permitted;
- Recreational zones: provide for conservation and compatible recreational activities. Commercial fishing, pearling, aquaculture and petroleum development is not permitted; and
- General use zones: activities (including commercial and recreational fishing) may be permitted where it is considered they do not compromise the cultural and ecological

values of the marine park. In some areas, proposals for activities must be assessed and approved by relevant agencies.

Commercial and recreational fishing for Greenlip, Brownlip and Roe's abalone is restricted from Sanctuary and Recreational zones, but is permitted within Special purpose and General use zones in some marine parks. Special Purpose Zones and their designated purposes differ between marine parks. Each marine park has a management plan which clearly articulates the boundaries of the different zones and the activities permitted within each: https://www.dpaw.wa.gov.au/management/marine/marine-parks-and-reserves/72-plans-and-policies.

13.7 Abalone Industry Impacts

Abalone live on hard surfaces, usually limestone reefs or granite boulders in waters <30 m deep. The hard surface provides a substrate for their large foot to secure and which with the external shell provides protection from predators. Abalone are sedentary and typically do not move large distances or across areas of open sediment (Geiger and Owen 2012).

Abalone fishing has the potential to physically impact on benthic habitats through the physical removal of abalone, from anchoring, through fishing equipment such as the catch bags or shark cages and from walking on reef platforms to access fishing areas.

Fishing effort for abalone is not evenly distributed across the state but tends to be concentrated in certain locations (Figures 3-4 to 3-6). Studies on Greenlip abalone in WA have found that they are not evenly distributed across hard limestone and granite rock areas, but instead form aggregations characterised by "bare habitat" which have a low abundance of macroalgae and/or macro invertebrates (Hart et al. 2013c). Intensive habitat surveys were undertaken as a part of an abalone restocking program to determine suitable locations and habitats for releasing juvenile abalone. A survey of 32 ha of reef identified that only around 2% of the benthic habitat was considered "bare habitat" suitable for Greenlip abalone with the remaining 98% a combination of sand, seagrass and unsuitable reef (Hart 2013c).

Roe's abalone are also not evenly distributed across hard reef surfaces. Research in the Perth metropolitan area at on reef platforms at Trigg, Watermen's and Cottesloe found abalone to be concentrated on areas of bare reef (Wells et al. 2007).

The FAO "International guidelines for the management of deep-sea fisheries in the high seas" defines Vulnerable Marine Ecosystems (VME) based on a series of characteristics (FAO 2009). The limestone reefs and granite boulders where abalone commercial and recreational fisheries operate do not have any of the VME criteria.

The impact of collecting Greenlip, Brownlip and Roes abalone is highly unlikely to cause serious or irreversible harm to the structure and function of commonly encountered and minor habitats for the following reasons:

- Abalone are typically restricted to depths <30m, divers are also restricted to shallower depths also to avoid decompression illness. Benthic habitats deeper than 30 m are typically not fished for abalone.

- The distribution of fishing effort for abalone is not even and there are large areas which are unfished.
- Within the areas which are fished, abalone habitat and distribution is highly restricted and forms only a small portion (<2%) of the total benthic habitat.
- Abalone divers collect abalone by prising the animals off the reef with a metal bar known as an “abalone iron”. The removal of abalone is done in a swift levering motion, mainly to break the suction of the foot from the rock with no impact on the substrate below.
- Abalone fishers typically do not anchor whilst fishing for Greenlip and Brownlip species on the south coast but instead collect whilst drift diving. Anchoring does occur whilst fishing for Roe’s with a stern sand anchor and a front wire anchor, which are typically set by divers to ensure the boat is secure and minimise impacts to habitat.
- There is a low number of licences and vessels in the AMF.
- Abalone fishers place their catch in a bag which rests on the bottom. As the bag becomes heavy the fishers inflate the attached lift bag so that it is easy to manoeuvre and divers do not have to drag the bag across the bottom.
- Divers can use shark cages and underwater scooters which are typically only slightly negatively buoyant and do not sit heavily on the bottom.
- On rare occasions divers walk on intertidal reef areas to access fishing areas. The habitats in intertidal zones are typically high energy zones and contain species capable of withstanding physical impacts. These areas are frequently exposed to natural disturbances such as storms.

13.7.1 Risk Assessment Outcomes

The 2015 ERA was undertaken based on the main habitats where the AMF currently operates. These habitat types occur in both the West Coast and South Coast Bioregions.

13.7.1.1 Rocky Reef

ERA Risk Assessment (2015): Impact of prising abalone from reef on rocky reef habitat in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

ERA Risk Assessment (2015): Impact of anchoring on rocky reef habitat in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

ERA Risk Assessment (2015): Impact of divers and diving equipment on rocky reef habitat in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

ERA Risk Assessment (2015): Impact of walking on intertidal reef areas on rocky reef habitat in SCB – C1, L1 = 1; NEGLIGIBLE

13.7.1.2 Seagrass

ERA Risk Assessment (2015): Impact of anchoring on seagrass habitat in Roe's fishery (WCB/SCB) – C1, L1 = 1; NEGLIGIBLE

13.7.1.3 Macroalgae

ERA Risk Assessment (2015): Impact of anchoring on macroalgae habitat in Roe's fishery (WCB/SCB) – C1, L1 = 1; NEGLIGIBLE

ERA Risk Assessment (2015): Impact of divers and diving equipment on macroalgae habitat in WCB/SCB – C1, L1 = 1; NEGLIGIBLE

13.7.1.4 Sponge beds/Coral gardens

ERA Risk Assessment (2015): Impact of anchoring on sponge bed habitat in Roe's (WCB– Garden Island) – C1, L1 = 1; NEGLIGIBLE

13.8 Management Strategy

A number of measures are used to minimise the impacts of fishing activities on habitats within south WA (Section 4). Habitats are primarily protected through spatial closures / zoning implemented and managed by the Department, DPaW and / or DotE. Different degrees of protection are afforded to areas in accordance with categories established by the International Union for the Conservation of Nature (IUCN). These categories range from sustainably-managed multiple use areas (Category IV) to complete no-take areas, where no extractive activity is permitted (Category I). Spatial closures are identified following a risk-based assessment of ecological parameters within a defined bioregion and can involve total or partial closures to fishing activity. Closures can be used alone but are often used in combination with other fisheries management tools (e.g. effort limitations, gear restrictions) to achieve specific objectives (Fletcher and Santoro 2015). Habitat protection measures within the west and south coast bioregions include:

- Spatial closure to trawl-based fisheries under the FRMA (IUCN Category IV); 44 % of total shelf area in WCB and 14% in the SCB);
- Total fishing closures (under section 43 of the FRMA[11])
- Fish Habitat Protection Areas (FHPA) Abrolhos Islands, Lancelin Island Lagoon, Cottesloe Reef and Kalbarri Blueholes
- Marine Parks, Reserves and Sanctuary Areas;

The government is also undertaking a Marine Bioregional Planning process within Commonwealth Waters between Kangaroo Island, South Australia and Shark Bay.

There is a specific strategy in place to manage the impacts of the AMF on benthic habitats, which utilises management measures under the FRMA, the FRMR and the Management Plan. As per the harvest strategy, the fishery has a long-term objective for habitats *to ensure the*

[11] http://www.slp.wa.gov.au/statutes/subsiduary.nsf/FisheriesO?OpenPage&Start=1&Count=30&Expand=2.2

effects of the AMF do not result in serious or irreversible harm to habitat structure and function. There are a number of measures in place to achieve this objective, including:

- Size limits and catch quotas on the number of abalone that can be collected annually;
- Spatial management via zoning;
- Limited entry;
- Statutory reporting of catch and the location of fishing activities.

The AMF has also established a number of initiatives to minimise and monitor impacts, including the implementation of an industry Code of Practice. The Code includes a number of initiatives to guide best environmental practices including minimising impacts to habitat whilst harvesting abalone and no disposal of rubbish whilst at sea.

Ongoing fishery performance against the long-term objective for habitats is measured and monitored annually via the Harvest Strategy. The fishery has a short-term (annual) objective for habitats that: '*fishery impacts are considered to generate an acceptable level of risk (i.e. moderate risk or lower) to habitats*' (DoF 2017). In the most recent risk assessment (2015), the fishery was considered to be a negligible risk to habitats. Compliance with management measures is monitored by field officers based in Metropolitan and regional areas, who patrol the entire fishing area (see Section 17.3).

13.9 Information and Monitoring

The nature and distribution of habitats within West Coast Bioregion and South Coast Bioregion have been described and mapped as part of a number of research projects and continues to be investigated as part of ongoing research conducted by the Department, other State and Commonwealth agencies and academic / research institutions (see Section 13.1).

The Department is involved in a number of current and future research projects within the Ngari Capes, Walpole-Nornalup Marine and Marmion Parks. Research on abalone densities is undertaken in the Watermans Reserve Marine Protected Area and the Cottesloe Fish Habitat Protection Area . These data are used to predict the abundance of legal size abalone and assess the effect of spawning stock and environmental conditions on the recruitment of abalone. Specific to the AMF the Department has undertaken research on ecological effects of stock enhancement for Greenlip abalone, which included detailed habitat studies (Hart et al. 2013a and b). In addition reef habitat is monitored as a of the fishery independent surveys conducted annually at multiple sites spanning the Greenlip/Brownlip and Roe's fisheries.

As a part of statutory reporting of catch and effort abalone fishers are require to report catches in 10 x 10 nM blocks and this information can be used to assess impacts of the AMF to habitats.

14 Ecosystem

14.1 Overview

From a global perspective, the South-west Marine Region is generally characterised by low levels of nutrients, and high species diversity with a high degree of endemism. The biological communities comprise species of temperate origin, which, in the north of the Region, mix with tropical and subtropical species. Broadly, these characteristics are caused by the influence of the Leeuwin Current, the low level of run-off from the land and the relatively stable recent geological history.

14.1.1 Oceanography and Ecological Drivers

There are a number of ocean currents in the Region, including the Leeuwin Current, the deeper subsurface Leeuwin Undercurrent on the west coast, the Flinders Current on the south coast, and the seasonal, coastal Capes and Cresswell Currents (Figure 14.1). The Leeuwin Current is the ‘signature current’ of the Region because of its extent and significant impact on the biological productivity of ecosystems and biodiversity. The Leeuwin Current is a shallow and narrow current (less than 300 m deep and 100 km wide) that transports warm, nutrient-depleted water from the tropics southward along the shelf break and outer parts of the shelf of the entire Region and south-east to Tasmania’s North-west Cape. Although the Leeuwin Current flows all year round, the strength of its flow shows a marked seasonal variation with the strongest flows occurring during winter. During summer, the Leeuwin Current weakens to the point that its inflow to the Great Australian Bight is largely absent (CoA 2008).

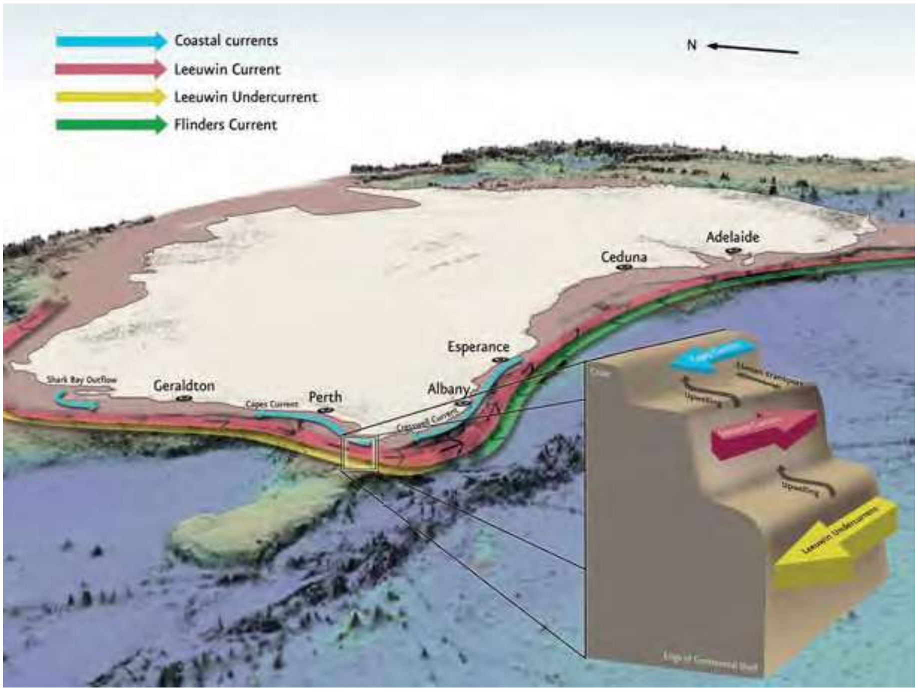

Figure 14.1. Schematic of major ocean currents flowing through the South-west Marine Region

The Leeuwin Current strongly affects the ecology of the Region in a number of ways. In nutrient poor waters, production hinges on the import of nutrients from deeper waters into surface waters through upwelling and meso-scale cyclonic eddies (50-200 km diameter eddies that spin clockwise and in some cases lift deeper water toward the surface). The Leeuwin Current suppresses predictable largescale upwellings on the west coast. As a result, the Leeuwin Current plays an important role in maintaining low levels of productivity on the west coast. Consequently, Australia's west coast is an area that can only support relatively small fisheries compared with all other areas with eastern boundary currents in the world, such as the Humboldt Current off Peru and the Benguela Current off Africa (CoA 2008).

In some areas the Leeuwin current interacts with seafloor features and other currents to generate relatively small, periodic upwellings that locally enhance nutrient levels. Such eddies are known to occur in predictable locations; off Shark Bay, the western edge of the Houtman Abrolhos Islands, south-west of Jurien Bay, the Perth Canyon, south-west of Cape Naturaliste and Cape Leeuwin, south of Albany, Esperance and Eyre Peninsula (Figure 14.2). The eddy systems are thought to have a profound effect on pelagic production, driving offshore production by transporting nutrients and entire pelagic communities offshore and also generating upwellings of deeper water that are higher in nutrients.

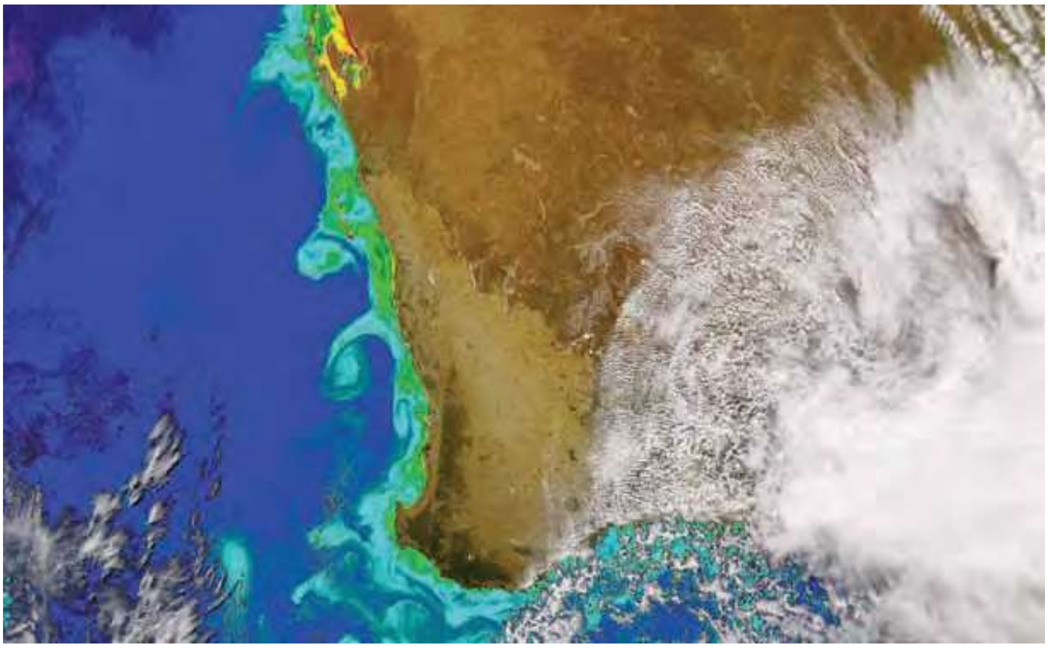

Figure 14.2. Ocean colour image showing the eddy structure of the Leeuwin Current off the west coast

The ecology is also greatly influenced by the lack of river discharge into the Region. The few significant rivers adjacent to the Region flow intermittently, and their overall discharge is low. Consequently, there is a limited amount of terrigenous (originating from the land) nutrient inputs. When combined with the suppression of large-scale upwelling, limited nutrient input from the land reinforces the Region's relatively nutrient-poor status compared with many other marine environments.

The low discharge of rivers and the generally low rate of biological productivity also results in low turbidity (suspended sediments), making the waters of the Region relatively clear. This means that light can penetrate to greater depths allowing a number of light-dependent species and associated communities to be found in waters deeper than those in which they live in other parts of Australia. For instance, macro-algae and seagrass are found at depths of up to 120 m in some parts of the Region (CoA 2008).

14.1.2 Biodiversity

The flora and fauna of the Region are a blend of tropical, subtropical and temperate species. Temperate species dominate the southern and eastern parts of the Region while tropical species become progressively more common in the north. The South-west Marine Region is known for its high species diversity and high numbers of endemic species (species that are found nowhere else in the world), and there are many more species yet to be discovered. Of the known species, more than 1000 species of macro-algae, between 17 and 22 species of seagrass, 600 species of fish, 110 species of echinoderm and 189 species of ascidians have been recorded in the Region. In the nearshore area of southern parts of the Region approximately 85 per cent of fish species, 95 per cent of molluscs and 90 per cent of echinoderms are thought to be endemic. By comparison, it has been estimated that only 13 per cent of fish, 10 per cent of molluscs and 13 per cent of echinoderms are endemic to tropical regions of Australia (CoA 2008).

High species richness in the region is attributed to the lack of mass extinction events associated with unfavourable environmental conditions – such as glaciation – over the recent geological past, and the moderating influence of the Leeuwin Current since the Eocene. High endemism is the product of long isolation of the marine flora and fauna as Australia has been separated from other land masses for the past 80 million years (CoA 2006).

14.1.3 Ecosystem Processes

The inshore lagoons and sheltered are thought to be important areas for benthic productivity (Figure 14.3) and recruitment for a range of marine species. These shallow water, sheltered environments are located between the shore and the inner shelf ridge and are characterised by extensive beds of macro-algae, interspersed with areas of seagrass which provide the primary source of benthic production inside the 50 m depth contour. Ground water enrichment may also supplement the supply of nutrients to inshore lagoon areas.

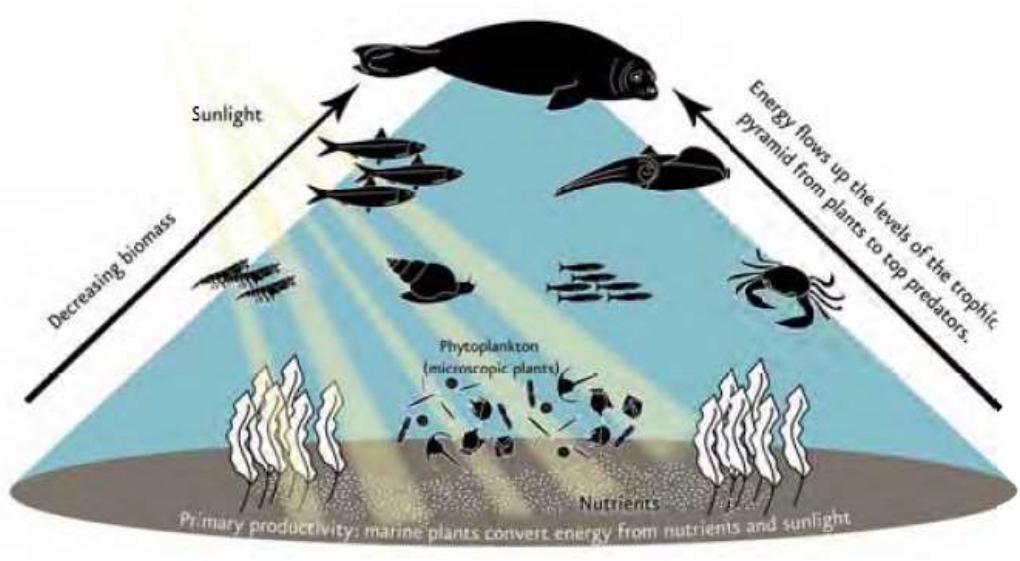

Figure 14.3. Simplified diagram of productivity in the marine environment

On the west coast the inshore lagoons provide important habitat for the breeding and nursery aggregations for a number of species, including the area's iconic species, such as western rock lobster, dhufish, pink snapper, breaksea cod, baldchin and blue gropers, and probably many other reef species. Western rock lobster, the dominant large benthic invertebrate on the west coast, is considered to be an important part of the food web of the inner shelf (Figure 14.5).

On the south coast the omnivorous reef predators, the Western Australian dhufish and smaller breaksea cod, disappear from the shallow shelf assemblage just to the east of Albany, and are replaced by mulloway, harlequin cod and 'nannygai' Bight redfish. Greenlip abalone can reach a significant biomass on shallow reefs (less than 40 m deep) as they do to the east along the entire southern Australian coast. Greenlip abalone are not seen on the coastal reefs of the west coast of the Australian continent. East of Albany, the dominant lobster species changes from the western rock lobster to the southern rock lobster (CoA 2008).

In areas of upwelling and along the south and west coasts small pelagic fish including herring, sardine, scaly mackerel, jack mackerel, yellow tail, blue mackerel, anchovy, blue sprat and sandy sprat are thought to be particularly important trophic links between plankton communities and larger fish-eating predators (Figure 14.4).

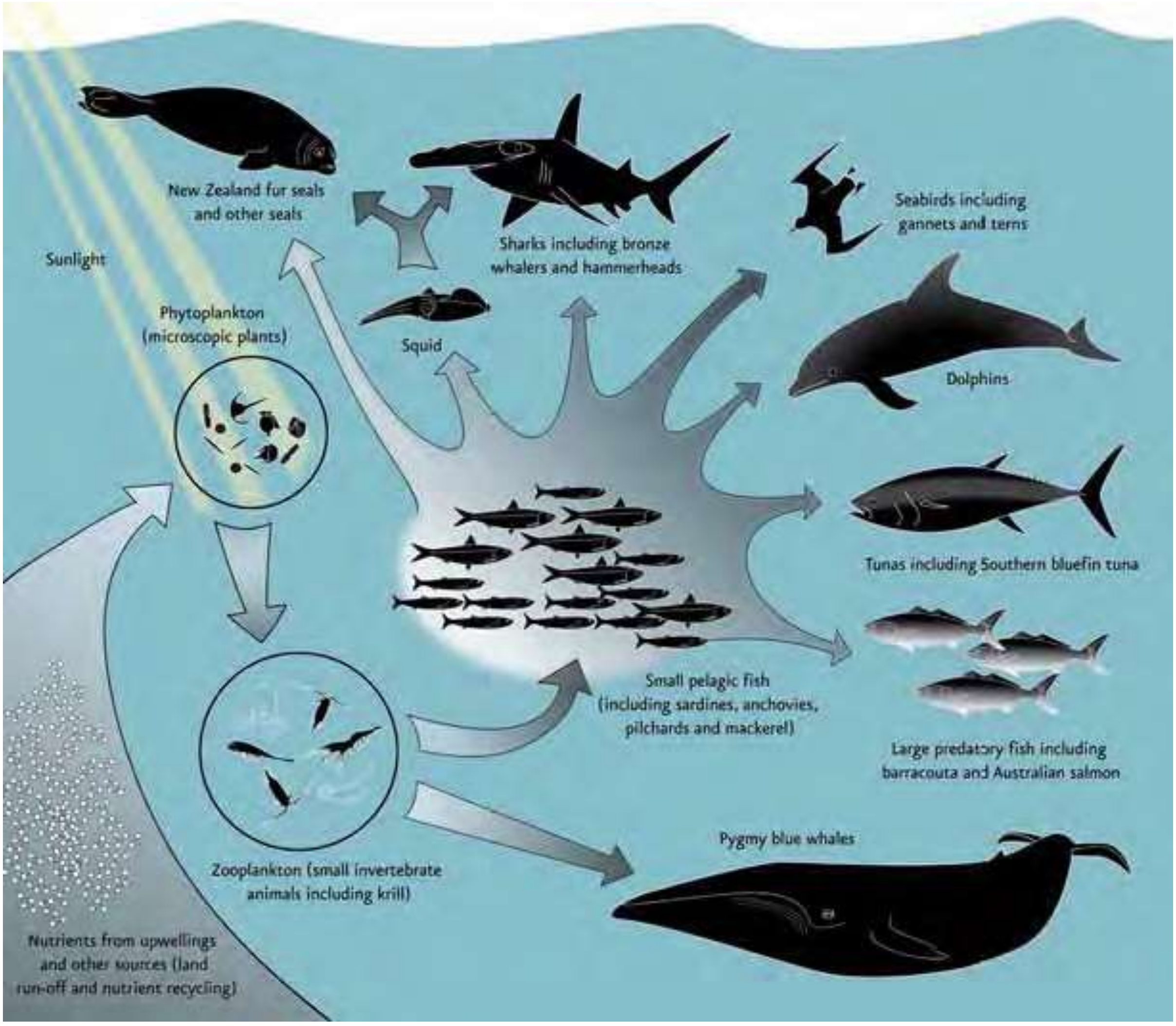

Figure 14.4. Simplified diagram of the predators and prey of small pelagic fish

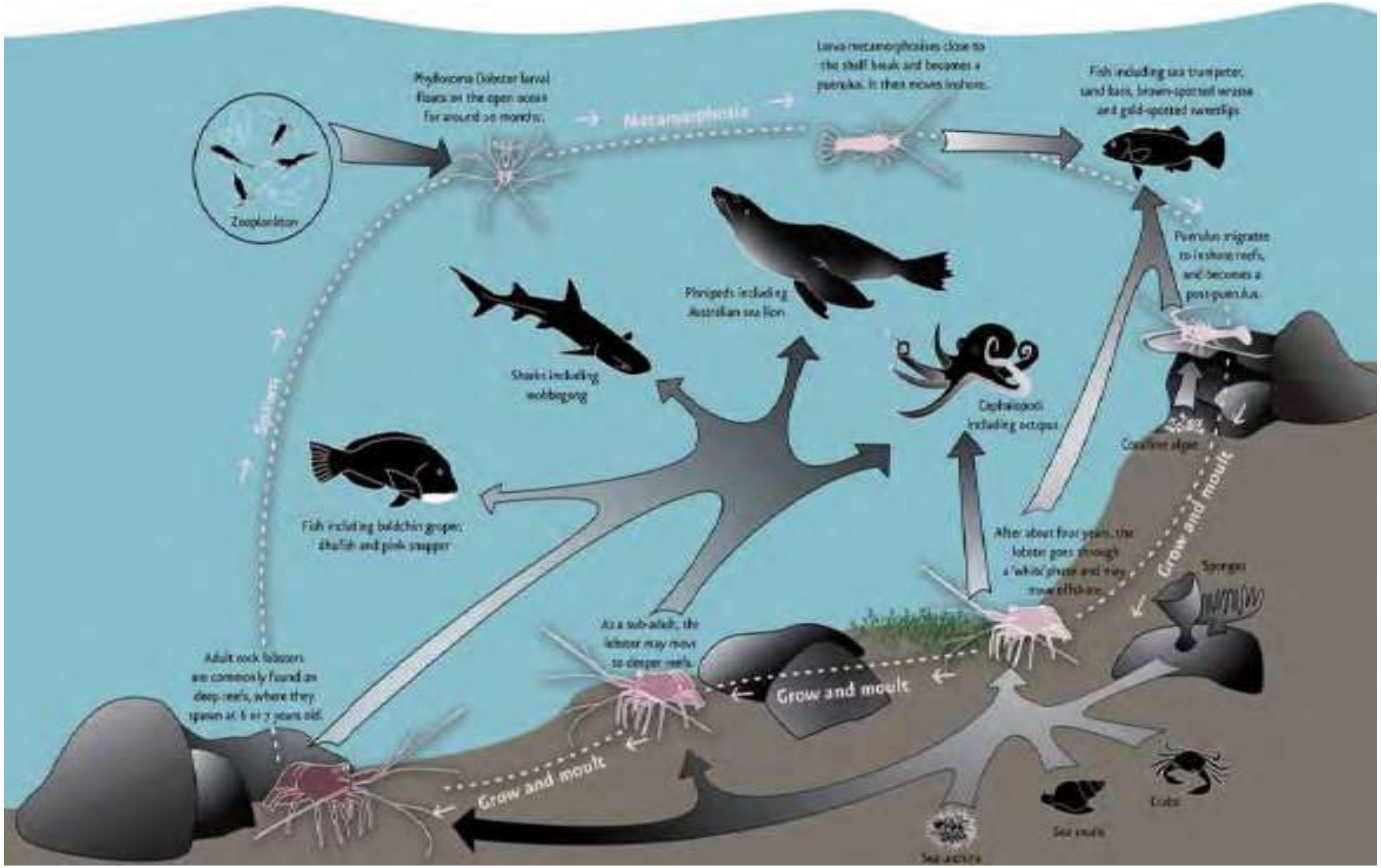

Figure 14.5. Simplified diagram of the life cycle of the western rock lobster including its main predators and prey

14.2 Abalone Industry Impacts

Abalone fishing is highly selective and physically benign, with the direct impacts of the fishing activity itself on other species likely to be of low importance ecologically. However, abalone fishing could have indirect effects on the ecosystem by changing competitive interactions with other benthic species and removal of a food source (Hamer et al. 2010). There have been several studies which have specifically examined the potential impacts of abalone fishing to the surrounding ecosystem, which are summarised the sections below.

14.2.1 Relevant research findings used in the abalone risk assessment

14.2.1.1 Effect of Roe's Abalone Fishing on Invertebrates in the Perth Metropolitan Area

In the Perth metropolitan area the potential effects of abalone fishing on benthic marine invertebrates was assessed by comparing invertebrate assemblages on reef platforms 20 years apart during which time several of the reefs had been closed to fishing (Wells and Keesing 1986, Wells et al. 1986, Wells et al. 2007). The initial study done in the 1980's, was instigated due to concerns about over-collection of the abalone *H. roei* on intertidal reef platforms in the Perth metropolitan area. The study involved intensive surveys on four reef habitats (inshore platform, *Sargassum* zone*, Ecklonia* zone and bare zone) with the diversity, density and biomass of molluscs and echinoderms assessed in each habitat. These surveys were undertaken on reef platforms at Cottesloe, Trigg and Waterman all which were popular locations for *H. roei* collection by commercial and recreational fishers.

Over the 20 year period several reefs were subsequently closed to fishing with varying levels of protection. The reef platforms at Trigg and Waterman were incorporated into the Marine Park in 1987. The study site at Trigg beach was gazetted as General Use, which permits commercial and recreational collection of abalone. The platform at Waterman's was gazetted as a Recreational Zone, which prohibits all types of abalone fishing. The Cottesloe reef was declared a Fish Habitat Protection Area (FHPA) in 2001, in which commercial fishing is prohibited, but recreational fishing for abalone is permitted in the season. In 2006 abalone collection from the Cottesloe FHPA was prohibited because of concerns for *H. roei* stocks in the area. Presently collection of abalone is prohibited south of the Cottesloe groyne (DoF 2010).

The 2007 assessment of the same reef platforms found that whilst there was considerable variation within and between transects and sites, the diversity, density and biomass of molluscs (with the exception of abalone) and echinoderms were similar to the ranges found in the 1980's. Abalone densities showed varying results. Densities of abalone at Waterman south decreased over the 20 year period, which may have been due to low compliance within the closed area. Abalone densities at Trigg (open to fishing) also declined since the 1980's although the proportion of legal sized abalone increased. Cottesloe was the only reef to show a large increase in abalone density from 8.2 to 11.2 m^2 in the 1980's to 26.8 m^2 in 2007 (Wells et al. 2007).

The study concluded that the populations of molluscs and echinoderms were consistent between the two studies. Whilst there were differences, the 2007 data were thought to be within the temporal and spatial ranges found during the 1980's. The authors concluded that the management strategies in place were effective in the protection of invertebrates as indicated by mollusc and echinoderms. They were also considered to be effective at protecting highly targeted abalone populations (Wells et al. 2007).

14.2.1.2 Studies on the Role of Blacklip Abalone in Ecosystems

The have been no specific studies which examine the ecological role of Greenlip and Brownlip abalone in WA. However, in Victoria, intensive research on the effects of commercial abalone fishing on the ecosystem has been undertaken for a closely related species, Blacklip abalone (*Haliotis rubra*).

In 2005 the Victorian Department of Fisheries commissioned a review of the ecosystem effects of Blacklip abalone fishing (Jenkins 2004). The review concluded that although the effects of abalone fishing appeared to be low compared to other fisheries such as trawling, there were little empirical data and the ecosystem effects were relatively unknown. In 2006 a study was instigated to assess the effect of abalone removal on benthic competitors and predators (Hamer et al. 2010). The results from this study are presented in Sections 14.2.1.2.1 and 14.2.1.2.2.

14.2.1.2.1 Impacts on Benthic Competitors

Abalone are considered relatively sedentary drift feeders, abalone are considered to primarily feed on drift algae and are thought to have minimal impact on macroalgal communities via grazing of live plants (Shepherd 1973; Strain and Johnson 2009). However, abalone may have an impact on benthic competitors through space exclusion.

The ecological role of Blacklip abalone with other epibenthic species was investigated using removal experiments at three widely separated locations along the Victorian coast. The experiments involved before and after assessments of the benthic communities associated with Blacklip abalone aggregations in two different treatments – fished and unfished. The unfished sites were protected from abalone fishing and served as controls, and the fished sites had all abalone removed, with some sites requiring numerous removals. Changes in epibenthic communities were assessed by analysing photographs of fixed sites. The experiments ran over two years between 2007 and 2009 (Hamer et al. 2010).

The experiments demonstrated that there was variation in the effects of abalone removal, which influenced by the physical aspects of the aggregation sites including pre-existing community composition, wave energy, kelp scouring, sedimentation rates, substrate characteristics/rock types, and orientation of rack surfaces. Overall the study found that unfished abalone aggregations were characterised by very stable, low diversity epibenthic communities, generally dominated by species of encrusting red algae. The fished sites, showed a shift in the benthic community structure towards more structurally complex and diverse algal and invertebrate species. The conclusion was that abalone play a role, albeit at a very local-scale (scale of aggregations), in limiting the overgrowth of encrusting red algae by other algae and invertebrate species (Hamer et al. 2010).

The role of abalone was also thought to be important for maintaining suitable sites for recruitment of juvenile abalone and areas of attachment for older individuals. Heavily fished reefs which can undergo shifts in community structure (within the aggregation site) to more diverse and three dimensional species assemblages may become unfavourable for abalone (Miner *et al.* 2006).

The authors of the study suggest that economics and profitability of a fishery may regulate the intensity of fishing and potential impacts to benthic communities. It was thought that for a well-managed fishery, before any major shifts in epibenthic community structure become noticeable at the reef scale, the commercial divers are likely to have already experienced low economic return and moved on to more profitable locations.

14.2.1.2.2 Impacts on Predatory Fish and Shark Species

Predatory fish which feed primarily or exclusively on abalone maybe affected by abalone fishing, but those which include abalone as part of a broad died including a range of prey items are likely to be less affected. The potential impacts of abalone fishing on predatory fish were studied by examining the diets of four common carnivorous reef fish species: banded morwong, bluethroat wrasse, sixspine leatherjacket and purple wrasse, together with small samples of other species such as bastard trumpeter and the Port Jackson shark. The diets were analysed for the number of prey eaten and the prey volume or weight. The number of prey eaten can provide information on the impact of the predator on pretty populations, whereas the volume or weight, can indicate the importance of prey items to the energy budget of predators, and has relevance to population dynamics of predators in terms of growth, reproduction and mortality. The dietary studies were undertaken at five locations across Victoria.

The study found that the diets of all the reef species included a broad range of prey types, with distinct differences amongst the diets of each species. Banded morwong and purple wrasse ate large numbers of small prey; small crustaceans in the case of morwong and small mussels in the case of wrasse. Bluethroat wrasse and sixspine leather jackets ate smaller numbers of a variety of larger prey. Abalone were not significant in the diets in terms of prey numbers but made a significant contribution to the dietary volume of blue throat wrasse at two sites, but not at other sites. Port Jackson sharks were found to eat a range of prey types, with gastropods, and fish featuring consistently. In terms of weight of prey eaten abalone were a very important component of the diet of Port Jackson sharks at two sites (50% of diet) but not recorded in the diet for sharks at other sites.

Overall, the study found that reef fish species and Port Jackson sharks tended to have a generalised diet. Although abalone were important for some species in some locations, this was not across all locations and it appeared that none of the species were highly dependent on abalone. The authors concluded that in a well-managed fishery, abalone fishing would be unlikely to have a significant impact on the populations of these predators (Hamer et al. 2010).

14.2.1.3 Interactions Between Sea Urchins and Abalone

Interactions between abalone and sea urchins are complex and differs substantially between different biogeographic regions and species (Tenger and Dayton 2012, Dayton et al. 1998). The relationship between urchins and abalone is also affected by factors such as overfishing and climate change, as described in the following sections.

14.2.1.3.1 Overfishing and Trophic Cascades

The removal of key predators from marine ecosystems can indirectly affect abalone abundance through trophic cascades. Throughout the world, overfishing of key predators has resulted in increased urchin abundances which overgraze kelp forests causing a shift in the community structure to crustose coralline-dominated "urchin barrens". The phenomenon of overfishing and trophic cascades has been observed in different parts of the world related to the removal a variety of different key predators including sea otters, spiny lobsters and snappers, cod, pollock and steephead (labrid fish) (Tenger and Dayton 2000). (Tenger and Dayton 2000). Increased urchin abundances have found to be negatively correlated with abalone densities which is attributed competition for food and preferred habitat (Strain and Johnson 2013).

14.2.1.3.2 Urchin Range Expansions

In Tasmania the urchin *Centropstephanus rodgersii* has undergone a range extension from NSW to the east coast of Tasmania. The range extension is attributed to poleward penetration of the East Australia Current linked to the effects of climate change (Ridgway 2007). Increased densities of the long spined urchin *C. rodgersii* has resulted in the creation of urchin barrens and large decreases in the black lipped abalone *Haliotis rubra* due to a lack of food and shelter (Strain and Johnson 2013). Declines in the abundance and productivity of abalone populations has had concomitant effects on the fishery (Strain et al. 2013a and b).

14.2.1.3.3 Competition Between Abalone and Urchins

Whilst sea urchins can have a detrimental effect on abalone when food is limited, the opposite may occur when food is abundant, with abalone outcompeting urchins for space (North and Pearse 1970). In California intensive fishing for abalone between the 1940's and 1960's resulted a collapse of the commercial abalone fishery. Sea urchin populations exploded a short time later which was thought to be related to reduced competition with abalone (North and Pearse 1970).

14.2.1.3.4 Relationship Between Juvenile Abalone and Sea Urchins

In some parts of the world a positive relationship has been found between sea urchins and abalone. In Japan, South Africa and California, urchin and abalone abundances are positively correlated for some species, which is attributed to juvenile abalone finding shelter and enhanced food supply beneath the spine canopy of adult urchins (Day and Branch 2000, Rogers-Bennett and Hearse 2001).

14.2.1.4 Risk Assessment Outcomes

The impact of fishing activities on the ecosystem has been assessed using a risk based approach (see Section 4.4). The results and justifications of the most recent risk assessment are provided below.

14.2.1.4.1 Trophic Interactions

14.2.1.4.1.1 Impact of discarding abalone gut on trophic structure

ERA Risk Assessment (2015): Impact on trophic interactions from discarding of abalone guts (provisioning) in: WCB/SCB – C1, L1 = 1; NEGLIGIBLE

In the Greenlip/Brownlip abalone fishery, the gut is usually discarded at sea after the abalone has been shucked. The discarding of the biological material to the environment provides a food source to other organisms. In the Roe's abalone fishery animals are discarded at a processing facility and are not considered an issue.

Approximately one-third (32.5%) of abalone by whole weight is the gut of the animal. Given this, it is estimated that approximately 65 tonnes of abalone gut is discarded in Western Australia each year.

This discarding of abalone gut is highly unlikely to cause serious or irreversible harm to the ecosystem structure and function due to:

- Fishing grounds are rotated and fishers tend not to visit the same area frequently each year.
- Greenlip and Brownlip abalone are shucked at sea, with one person shucking whilst the other is drift diving resulting in the gut being dispersed over a large area.
- Seabirds have demonstrated an aversion to abalone guts
- Roe's abalone are shucked on land.

14.2.1.4.1.2 Impact of abalone removal on community structure and function

ERA Risk Assessment (2015): Impact of abalone removal on community structure in: WCB/SCB – C1, L1 = 1; NEGLIGIBLE

ERA Risk Assessment (2015): Impact of removing abalone on trophic interactions in the ecosystem: WCB/SCB – C1, L1 = 1; NEGLIGIBLE

The removal of a species from the environment may alter the key elements of the local ecosystem including community structure and predator – prey interactions.

The commercial collection of abalone is highly unlikely to cause serious or irreversible harm to the ecosystem structure and function due to:

- A high proportion of the populations of Greenlip, Brownlip and Roes abalone are undersize and these individuals remain as a functioning component of the ecosystem.
- The habitat for Greenlip and Brownlip species is extremely restricted and forms less than 2% reef in WA (Hart 2013a).

- Throughout the state the key fishing areas are concentrated in a few key areas, with large parts of the ecosystem considered unsuitable and economically unviable for abalone fishing (Figure 3.6 to Figure 3.4).
- Fishing for Roe's abalone was found to have no significant effects on benthic invertebrates on reef platforms in the Perth Metropolitan area (Wells et al. 2007).
- The competitive relationship between abalone and urchins is highly asymmetrical with abalone having little or no effect on urchins (Strain and Johnson 2009, Strain et al. 2013a and b).
- Ecosystem studies on Blacklip abalone in Victoria have demonstrated that this species has a very restricted role in restricting the growth of macroalgae through space competition.
- In locations where there have been mass die offs of abalone whether due to heat waves (i.e. Kalbarri) or the AVG virus (i.e. Victoria) there has been no measureable changes to the community structure.
- Abalone are drift feeders and do not usually directly graze on macroalgae.
- Studies on trophic interactions for Blacklip abalone did not find that any of the common fish species or carnivorous sharks were dependent on abalone as a food source (Hamer et al. 2010).

14.2.1.4.1.3 Introduction of Diseases, Pests, Pathogens or Non-native Species

Risk Assessment: Impact of introducing diseases, pests, pathogens or non-native species from AMF vessels/equipment on the ecosystem in: WCB/SCB – C1, L1 = 1; NEGLIGIBLE

Marine pests and diseases can form a significant threat to WA ecosystem structure. Abalone vessels and divers move between different areas for fishing which have the potential to translocate marine pests and/or disease.

The AMF is highly unlikely to cause serious or irreversible harm to the ecosystem structure and function due from the introduction of diseases, pests and pathogens due to:

- Vessels fishing for abalone often are not stationary but instead drift or tow divers. Vessels are removed from the water and kept on land overnight, which is likely to kill an organisms attached to the hull.
- Very little interstate movement of boats and if boats do move from interstate boats are trailered with the bungs removed to ensure the boat drains dry. Generally there is at least 48 hours between boats moving between states which further reduces the opportunity to transfer pests and diseases.
- To date there have been no major disease or virus outbreaks in WA abalone stocks.
- Abalone fishers are highly vigilant and concerned about the introduction of pests and diseases to the marine environment. The Abalone Industry has established a Code of

Practice to minimise the risk of spreading disease which includes recommendations for daily wash down procedures for boats and dive gear, minimising fishing and movement between areas within the same day and avoiding disease affected areas. There is a list of recommended products for sterilizing boats.

- The Department maintains a passive surveillance program throughout WA, actively investigating any reports of abnormal mortalities, which are backed up by emergency response capability in the areas of both aquatic pests and diseases.
- A Departmental incident response manual has been developed, which details protocol associated with emergency biosecurity response. The Department is equipped with state-of-the-art diagnostic laboratories and capability. It participates in nationally-coordinated proficiency testing programs and is accredited to ISO17025 for both pest identification and pathogen identification.

14.3 Management Strategy

There is a strategy in place to manage the AMF impacts on the ecosystem, which utilises management measures under the FRMA, the FRMR and the Management Plan. As per the harvest strategy, the fishery has a long-term objective for the ecosystem *to ensure the effects of the abalone industry do not result in serious or irreversible harm to ecosystem structure and function*. There are a number of legislated measures in place to achieve this objective, including:

- Species restrictions limiting fishers to the take of Greenlip, Brownlip and Roe's abalone;
- Annual catch limits in the form a TAC for abalone;
- Limited Entry
- Size limits for each species;
- Spatial management via zoning and
- Statutory reporting of catch and the location of fishing activities.

The AMF has also established a number of initiatives to minimise and monitor impacts, including the implementation of an industry Code of Practice. The code includes a number of activities to guide best environmental practices including minimising impacts to habitat whilst harvesting abalone, no disposal of rubbish whilst at sea and biosecurity measures to minimise the potential for the introduction and spread pests, viruses and disease.

Ecosystem impacts from the removal of abalone from the wild are limited by the annual TAC and associated quota unit values, which minimises the potential for trophic impacts from the removal of abalone. Additionally, negative impacts on habitats and other species (including ETP species) are minimised by a number of spatial closures and specific strategies outlined in Section 4.

There is clear evidence that the strategy is being implemented successfully and is achieving its objective. Ongoing fishery performance against the long-term objective for habitats is measured and monitored annually via the harvest strategy. The fishery has a short-term (annual) objective for habitats that: '*fishery impacts are considered to generate an acceptable level of risk (i.e. moderate risk or lower) to ecosystem processes*' (DoF 2017). In the most recent risk assessment (2015), the fishery was considered to be a negligible risk to the trophic system of the northwest shelf. Additionally, there is clear evidence that the industry complies with the management measures in place based on compliance statistics (see Section 17.3).

14.4 Information and Monitoring

The impact of abalone removal on key ecosystem elements (i.e. trophic structure and function and community composition) has been investigated in both WA (Wells and Keesing 1986, Wells et al. 1986, Wells et al. 2007) as a part of the Roe's abalone fishery and in Victoria for Blacklip abalone (Hamer et al. 2010). These studies found abalone fishing to have either no discernible or highly localised effects on community structure and no detectable impacts on trophic function.

Overall, the number of licences is limited and the collection of abalone is controlled by the TACC. Fishers are required to report their catches to the Department daily via a *Catch and Disposal Record Book*. Catches and remaining quota are monitored by the Department's compliance staff based in Busselton.

15 Translocation

The sea ranch in Augusta, which uses artificial structures to grow out up to 2 million hatchery produced abalone (see Section 6.1 for a full description of the operation), has the potential to introduce pests or diseases to the environment potentially affecting wild abalone populations. This section examines the potential for the sea ranch operations to introduce pathogens to wild populations and the strategies in place to manage associated risks.

15.1 Abalone Industry Impacts

It is highly unlikely that the translocation of juvenile Greenlip abalone from the hatchery to the sea ranch will introduce pests, pathogens or non-native species to the surrounding ecosystem. To our knowledge, there have never been mortalities due to a disease outbreak in the WA wild populations, hatchery reared or sea ranch stock.

The minimisation of risk and management of disease is addressed through aquaculture licence conditions and Management and Environmental Monitoring Plans (which includes the Biosecurity Management Plan) as required under the FRMA 1994 (Section 15.2).

15.1.1 Risk Assessments

There have been four separate assessments of risk associated with disease in WA abalone.

15.1.1.1 Ecological Risk Assessment

The risk of abalone aquaculture and sea ranching on the spread of pests and diseases was accessed in an Ecological Risk Assessment undertaken in December 2015. The determination was a medium risk for both operations with the current DoF policy and industry protocols (Webster et al. 2017):

Risk Assessment: Impact of abalone aquaculture on the spread of pests and diseases on commercial fishery performance in WC/SC - C3, L3 = 9; MEDIUM

Risk Assessment: Impact of abalone ranching on the spread of pests and diseases on commercial fishery performance in SC - C3, L3 = 9; MEDIUM

15.1.1.2 Risk assessment - abalone stock enhancement and grow out (AVG virus)

In 2011 a risk assessment was undertaken to assess the likelihood of the AVG virus becoming established in a hatchery facility and infecting wild stock through the release of hatchery released juveniles into the oceanic waters. The likelihood of the outcome occurring was assessed as very low if the recommended hatchery management measures were applied to mitigate risk to an acceptable level (Jones and Fletcher 2012).

15.1.1.3 Risk assessment associated with abalone aquaculture and grow out (all diseases)

In 2014 a more comprehensive risk assessment was undertaken for abalone aquaculture facilities in WA including commercial abalone production (in land-based and open marine systems) and production for wild fishery restocking purposes (Dang et al. 2014). This risk assessment identified and assessed risk in relation to the following disease hazards: AVG;

Perkensus olseni; Vibrio spp.; Flavobacteria and Non-specific fungal infections. The 2014 risk assessment expanded the scope of Jones and Fletcher 2012 to include a broader range of research and commercial abalone aquaculture activities and also identified management measures in place to address identified risks.

Key overall risks identified in association with the proposal to develop abalone aquaculture in WA were identified as follows:

1. The spread of a significant pathogen or disease from an infected aquaculture facility leading to a significant impact on wild abalone stocks and associated fisheries as a result of; a) land based farming activities and b) translocation of a high number of farmed animals into the wild for sea-based aquaculture or restocking activities.
2. A pathogen is detected as a result of increased surveillance associated with abalone aquaculture resulting in a significant negative impact on the health status of Western Australian abalone and its associated domestic and export markets.

Critical pathways that could collectively lead to realization of these risks were identified (hazards) and reviewed systematically. Considering the biosecurity measures proposed by both the Department and the project proponent to address these hazards, the residual risk (after taking into consideration management intervention) of both identified overarching risks was assessed as Low for scenarios 1a and 2 and Medium for scenario 1b. This is assessed as providing an acceptable level of risk given adequate implementation and compliance with the proposed management measures (Dang et al. 2014).

15.1.1.4 Disease Risk Assessment for Abalone Stock Enhancement

In 2012 an independent risk assessment was commissioned by WAFIC to assess the impacts of a commercial scale stock enhancement project planned by the Department and Industry (Stevens 2012). Only one issue was scored as high risk - the inappropriate disposal of shells and waste material (viscera) into the marine environment. However, it was identified that this risk could be downgraded to negligible with appropriate control measures. For the wild stock fishery the control measure was that shells be shucked in the same locality as the point of harvest. For the sea ranch operations the control measure was a licence requirement that all abalone moved from site must be 'in-shell' until delivered to a licenced processing facility.

All other risks were rated as moderate or lower. Moderate risks related mostly to the introduction of the virus from water currents, fish and predators or humans. Control measures could only be applied to human activities for both wild harvest and aqua-cultural operations. After the application of control measures these risks were rated as low or negligible.

15.2 Management Strategy

There is a strategy in place to manage the translocation of abalone to the surrounding ecosystem, which utilises management measures under the *FRMA 1994*, the *FRMR 1995,* the Abalone Aquaculture Policy (DoF 2013), Policy on Restocking and Stock Enhancement in WA (DOF 2013) and the Translocation Policy (DoF 2012). Further legislated measures required include:

- Aquaculture licence (subject to conditions see Section 15.2.2);

- Management and Environmental Monitoring Plan (MEMP) which includes a biosecurity plan (see Section 15.2.1.3); and
- Aquaculture lease.

15.2.1 Abalone Aquaculture Policy

The Abalone Aquaculture Policy has several objectives:

- To establish management measures that will apply to the abalone aquaculture sector;
- To provide clear guidelines to applicants on key issues that will be considered in the assessment process; and,
- Provide for the development and growth of a sustainable abalone aquaculture industry in WA.

The specifications which are relevant to disease management and translocation onto the sea ranch facility are summarised in the following sections.

15.2.1.1 Spatial Separation and Location of Sites

The Policy specifies that to reduce the likelihood of disease spread, the distance between abalone farms, and between abalone farms and productive reef areas, should be five nautical miles, except in the case of a pre-existing authorisation.

Aquaculture gear in marine farms are required to be located on areas of sea bed with sandy or similar substrate and not be in contact with any natural reefs.

15.2.1.2 Aquaculture Feeds

To minimise the risk of disease transfer or outbreak arising from pathogens that may be present in commercial feeds, there is a requirement that feeds can only be sourced from manufacturers that comply with the requirements of specified quality standards and that have in place a defined quality and risk management system. Imported feeds must not be used unless approved by Biosecurity Australia and subject to a permit issued by the Australian Quarantine and Inspection Service. Feeds that contain abalone or abalone products and all unprocessed raw feeds are not allowed for the purpose of abalone aquaculture.

Note that sea ranch abalone rely on a natural supply of drift algae where as those in the land based hatchery are dependent on commercial feeds.

15.2.1.3 Biosecurity Plan

Each aquaculture licence is required to be accompanied by a MEMP, which includes provisions for biosecurity. Biosecurity plans are required to provide information and processes on matters that include:

- the assessment of biosecurity risks and protocols in relation to hatchery, nursery and grow-out areas (including quarantine); treatment of all incoming and discharge waters; and infrastructure, equipment and staff movements;
- disinfection and hygiene practices;

- stock monitoring and health assessment practices;
- methods and processes for the movement of hatchery-reared abalone to marine farms and their placement on the culture units;
- a requirement to immediately report unusual mortalities, noting that the biosecurity plan will specifically define “immediately” and “unusual mortalities”;
- record-keeping and reporting requirements; and
- emergency response plans.

No abalone may be moved from a hatchery except in accordance with a biosecurity plan approved by the Department.

15.2.1.4 Health Management and Certification

Before being transported from the hatchery, abalone are required to be held for a minimum period of two weeks in a quarantine facility designed to prevent any contact with other hatchery stocks. The quarantine facility is required to be supplied by sea water treated by ozonisation or filtered to a nominal five micrometres then treated using ultra-violet irradiation. For quarantine facilities holding broodstock, water discharged from the facility needs to be directed to an infiltration gallery and not directly into the sea. The following procedures apply for management and monitoring of abalone health:

- Sentinel abalone held in the two ponds receiving outflow from the farm must undergo disease testing as specified by the Department.
- Abalone stocked in marine-based grow-out farms must be visually inspected according to an agreed inspection schedule specified in the Biosecurity Plan; a record must be maintained of all inspection times.
- All unusual mortalities and the associated circumstances must be recorded and records maintained and made available to the Department upon request.

An independent audit of compliance with the biosecurity plan must be undertaken annually or as specified by the CEO and at the expense of the licence holder.

15.2.2 Aquaculture Licence Conditions

The conditions placed on both the hatchery and sea ranching aquaculture licences are legally binding and ensure that impacts to the ecosystem and the risk of translocation of pests or diseases are minimised. Most of the conditions are aligned with the Abalone Aquaculture Policy.

15.2.2.1 Hatchery Operations

The land based hatchery is carefully managed to minimise the risk of introducing pathogens from wild caught broodstock and the development of disease during the cultivation of abalone. These management strategies are detailed in the licence conditions and/or the MEMP with the relevant specifications summarised below.

The farm is divided into five physically separate facilities which minimises the risk of disease transfer. All facilities utilise ocean water governed by a system of uni-directional flow, such that there is no recirculation or reuse of water which minimises the risk of contamination between tanks. Waste water is passed through a settlement pond prior to flushing to the ocean to prevent escapees and minimise chances of disease entering the wild. There are two ponds on the farm. The farm consists of:

- Broodstock holding facility – in which wild caught broodstock are kept separate to minimise the risk of introducing disease. This facility has its own water supply and there is no discharge, with waste water directed to a sand infiltration gallery.
- Nursery facility– houses stock from settlement to juvenile stage.
- Weaning facility - which house abalone from 6 months to 1.5 years old.
- Growout facility which holds stock until abalone reach the marketable size.
- Quarantine holding facility – deep tank, where abalone are held for two weeks before being exported off site. Incoming seawater is treated with UV filtered to 0.5 microns.

All staff working in the hatchery are required to undergo a biosecurity induction. Staff undertake daily monitoring of broodstock, spat and juveniles, to check for unusual levels of mortalities and signs of disease. There are strict protocols for cleaning of tanks, pipes and equipment. Biosecurity protocols are outlined in the hatchery MEMP including incident and emergency response procedures should disease be detected in the facility.

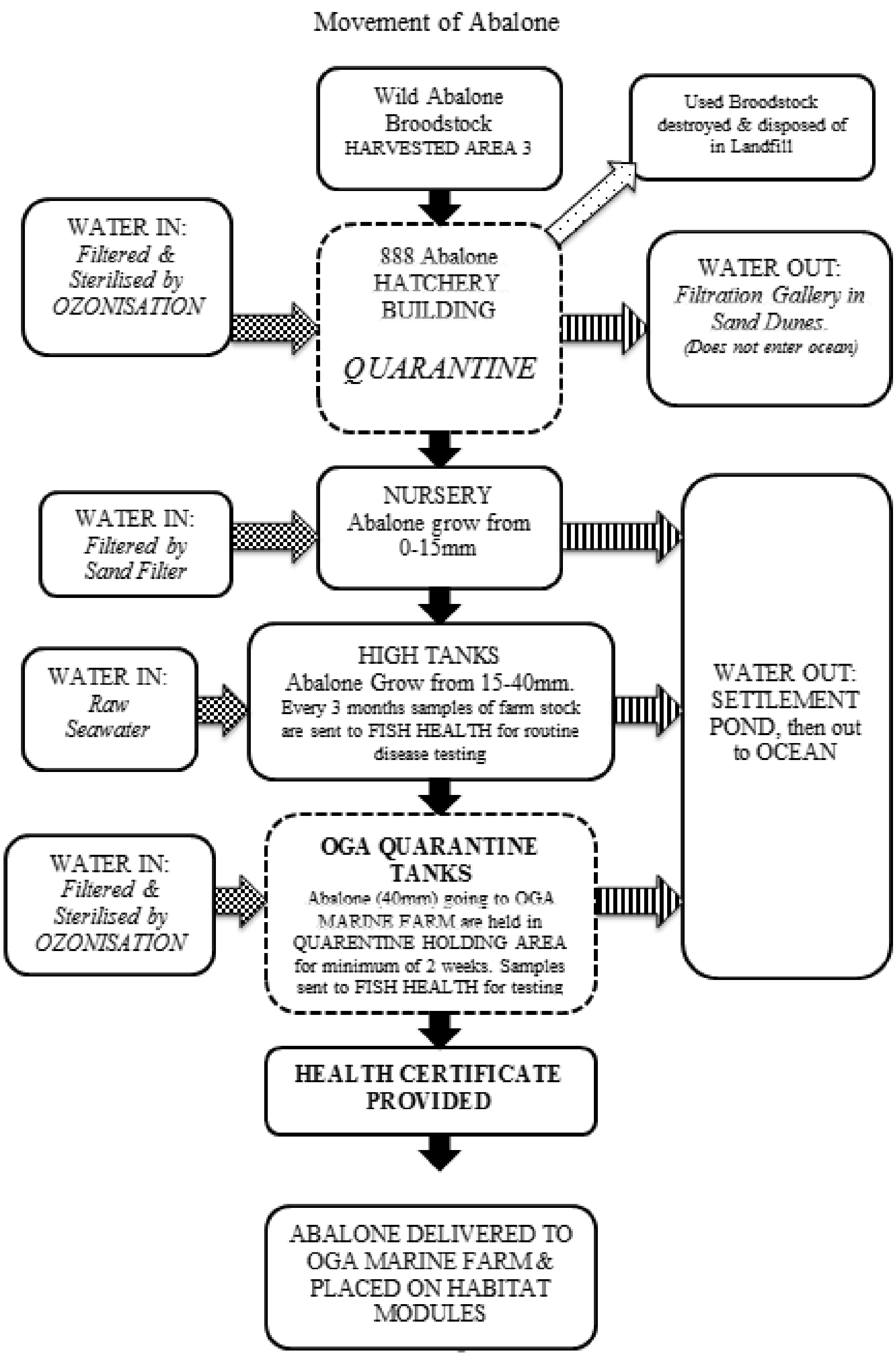

Figure 15.1. Biosecurity procedures involved with the movement of abalone (From 888 Abalone MEMP) (Note that the Department as modified the disease testing procedure See Section 15.2.2.1.1).

15.2.2.1.1 Disease testing

The Department's Fish Health Laboratory (FHL) has recently changed the testing regime for abalone translocated from hatcheries. In the past, prior to translocation each batch of abalone was stored for a minimum of two weeks in quarantine prior to testing by the FHL. This procedure has been identified as impracticable in terms of resources and costs for both the farmers and FHL. The aim of the new testing regime is to demonstrate disease freedom at the farm level to facilitate translocation within or between jurisdictions. The recommended surveillance protocol is based on:

- the Aquatic Animal Health Code from the World Organisation for Animal Health (OIE) (http://www.oie.int/en/international-standard-setting/aquatic-code/access-online/)
- the Nationally agreed "Abalone Health Accreditation Program"
- a risk assessment "An assessment of the hazards and risks posed associated with abalone aquaculture (*Haliotis* spp.) in Western Australia" (Dang et al. 2014, Section 15.1.1.3).

The testing regime has 2 components (which are currently in development)

1. An initial and single round of testing by histology (non-specific disease screen for clinical disease), and molecular testing of all cohorts in the existing farm stock to demonstrate disease freedom to 95% confidence. Molecular testing is undertaken using the polymerase chain reaction technique (PCR) which has been specifically developed for detecting the AVG virus.
2. Ongoing monitoring of two "sentinel populations" receiving outflow from the farm.
    - Populations checked daily for mortalities
    - For a 12 month period between March 2015 to March 2016, 30 animals (including the dead ones) from each pond were tested every six weeks (this was above the national guideline requiring six months of monitoring)
    - From March 2016 testing requirements were reduced to every three months, and from March 2017 testing will be every six months.
    - Providing test results continue to be negative, the farm status will be declared as disease free for AVG (OIE) in March 2017.

15.2.2.2 Sea ranch Operations

The sea ranch facility is carefully managed to minimise the risk of disease from juvenile abalone which are seeded onto the structures and during cultivation to marketable size. These management procedures are detailed in the licence conditions and/or the MEMP with the relevant specifications summarised below.

The sea ranch is located in Flinders Bay on an area of sand and seagrass away from reef areas where abalone grow naturally. The separation of the sea ranch facility from wild populations of abalone reduces the risk of disease translocation into natural populations.

To ensure the risk of translocation of pathogens or disease to the surrounding ecosystem is minimised the following management procedures are implemented as per the MEMP and/or licence conditions:

- All received stock must be accompanied by a health certificate.

- Prior to the release of stock from the transport vessel, stock are thoroughly examined for signs of disease.
- All equipment used to collect and transport stock, including dive equipment are required to be cleaned and disinfected.
- The number of artificial structures is limited to 5000 on the ranch.
- The stocking densities on the sea ranch are restricted to a biomass of three kilograms per square metre of artificial surface
- Abalone stocked in the ranch are inspected regularly, typically on at least a weekly basis, as per the licence conditions and a record maintained of all inspections
- On a quarterly basis random abalone from the ranch are selected and delivered to the Fish Health unit for routine disease testing (note this procedure is still being developed with the Department).
- Biosecurity protocols including incident and emergency response procedures of Risk Assessment Outcomes
- Sediment monitoring program.

15.2.3 Industry Initiatives

The AIAWA has developed a code of conduct for the Greenlip and Brownlip fishery and a code of conduct specific to Area 3 of the fishery (AIAWA 2015 a and b). The Code outlines environmental responsibilities of divers and sustainable fishing and operational practices, with particular emphasis on biosecurity.

The Aquaculture Council of WA (ACWA) has also developed an environmental code of practice for the sustainable management of WA's abalone aquaculture industry. The code covers facility operations and risk management, minimising environmental impacts during production, water quality and waste management (ACWA 2013).

15.2.4 Audits and Compliance

Both the hatchery and sea ranch aquaculture licences have a condition requiring annual independent audits of the facilities to ensure compliance with the licence and MEMP at the expense of the licence holder. An annual report on the MEMP is required to be submitted to the Department annually.

The Department undertakes planned inspections of the hatchery and sea ranch facilities every six months to ensure that all activities and documentation comply with the legislation, licence conditions, MEMP and biosecurity plan. Opportunistic inspections may also be undertaken at irregular intervals.

The movement of abalone from a hatchery to the farm must be accompanied with a consignment note which details the number, species and average size consigned. A duplicate copy of the consignment note must be forwarded to the local office of the Department within 24 hours of the consignment.

15.2.5 Independent assessments of risk

There have been four separate assessments of risk associated with translocation of disease from the hatchery to the sea ranch and surrounding ecosystem (Section 4.4). All assessments considered the risks to be acceptable providing proper control and management measures are in place (Jones and Fletcher 2012, Stevens 2012, Dang et al. 2015, Webster et al. 2017).

15.2.6 Contingency Plans and Responses in the Event of Disease Detection

There are legislated measures to control a suspected disease outbreak specified in the FRMR 1994 where by licensees are required to carry out actions at the Departments request. The Abalone Aquaculture Policy specifies that for a land based facility, no water from the facility must be discharged, quarantine measures must be put into place as directed by the Department and other measures enacted as specified in the biosecurity plan, the Aquatic Biosecurity Incident Management Protocol (DoF 2015) and in AQUAVETPLAN. The immediate shutdown of the water supply could also be considered. The Policy states that for a marine based facility, such as the sea ranch, total destocking of the affected farm may be required in response to a confirmed outbreak.

A formalised contingency plan in the case of an accidental introduction of diseases, pests, pathogens or non-native species due to translocation is specified in the MEMPs for both the land based hatchery and sea ranch operations.

15.2.6.1 Hatchery Operations

In the event of suspecting that abalone at a site are affected by disease or unusual levels of mortality the licence conditions specify that a licence holder must

- Notify an officer of the FHL of the Department
- Provide samples to the Principal Research Scientist fish health
- Within 24 hours provide a written report detailing the facts and circumstances or signs of disease.

The MEMP has a standard operating procedure for unexplained mortalities which details the following requirements:

- Record keeping
- Checklist for potential causes
- Sample collection and preparation for testing
- Sample collection for feed and water
- Transport details
- Destroying affected tanks
- Emergency harvest of affected stock

15.2.6.2 Sea Ranch Operations

In the event of suspecting that abalone at a site are affected by disease or unusual levels of mortality the licence conditions specify that a licence holder must:

- Notify an officer of the Fish Health Section of the Department
- Provide samples to the Principal Research Scientist fish health
- Within 24 hours provide a written report detailing the facts and circumstances or signs of disease.

The MEMP details the following:

- Contact Information – Departmental contacts, Website for reporting disease, Instructions for sample collection
- Standard operating protocols for unusual mortalities – recording information and collection of abalone and water samples
- Disinfection and cleaning procedures for boats and equipment.

15.2.6.3 Aquatic Biosecurity Incident Management Protocol

This aquatic incident management protocol sets out the processes to follow when a report of a marine pest or disease is received (DOF 2015).

The protocol sets out to notify key decision makers at the earliest stage for information sharing, but also notification of possible financial and staffing requirements.

This protocol is designed to:

- Enable the Department to respond to any biosecurity incident in a risk appropriate, consistent and effective manner; and
- Provide a range of responses to a range of situations, appropriate to the incident.
- Provide the basis for the provision and coordination of resource allocation.

This protocol is based on the Australasian Inter-Service Incident Management System (AIIMS) and clearly sets out the responsibilities of each role. Figure 15.2 outlines the biosecurity incident response initiation process.

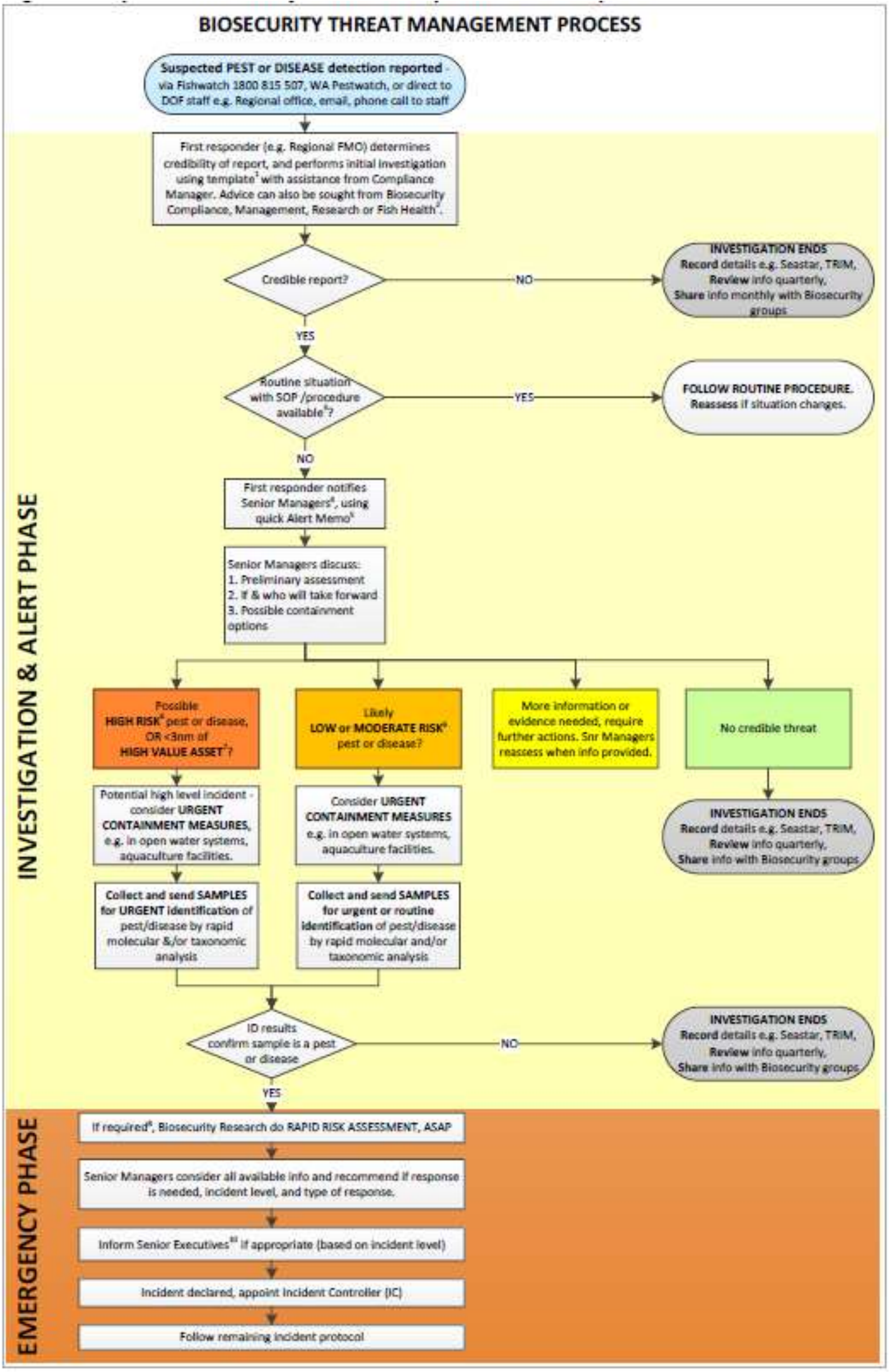

Figure 15.2 Aquatic Biosecurity Incident Response initiation process

15.2.6.4 Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN).

The Commonwealth Department of Agriculture and Water Resources has developed the Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN[12]) which are a series of manuals outlining Australia's approach to national disease preparedness. The manuals specify the proposed technical response and control strategies to be activated in a national aquatic animal disease emergency. The AQUAVETPLAN does not include information about disease prevention.

AQUAVET Plans are intended to complement, rather than replace, state or territory, industry, or farm operational emergency plans. Each State and Territory has operational responsibility for the surveillance, monitoring, control and eradication of aquatic animal diseases within its borders, whether the diseases are endemic or exotic. In an event of a disease outbreak the Department refers to the procedures outlined in each of the AQUAVETPLAN manuals. There are three types of AQUAVETPLAN manuals:

Disease Strategy Manuals - which have been individually developed for specific diseases. Currently there are two disease manuals for abalone:

- Abalone Viral Ganglioneuritis (AVG) manual
- Withering Syndrome of abalone manual

Operational Procedures Manuals

- Destruction manual - destruction of aquatic animals either farmed or wild populations
- Disposal manual - disposal of dead aquatic animals
- Decontamination manual - decontamination and disinfection methods following a disease incursion.

Management Manuals

- Control centres manual - provides a description of the procedures, management structures and roles to be implemented in the event of a suspected or actual aquatic animal disease emergency.
- Enterprise manual - This industry specific manual is designed to inform industry personnel of the necessary steps and factors involved in an emergency situation and to assist and to decision-makers to how to access information on industry practices.

15.3 Information and Monitoring

15.3.1 Information

The Department has undertaken extensive research on stock enhancement of Greenlip abalone examining long term growth and survival, population and ecological effects, bioeconomic evaluation and population genomics (Hart et al. 2016 and references within).

[12] http://www.agriculture.gov.au/animal/aquatic/aquavetplan

15.3.2 Monitoring

The licence conditions and MEMP's for the hatchery and sea ranch facilities have detailed requirements for monitoring and reporting.

15.3.2.1 Hatchery Operations

The hatchery MEMP specifies that daily water quality monitoring will be undertaken for temperature, flow and dissolved oxygen. Four times a year sampling is undertaken at the ocean intake and outflow pipes. A report on the monitoring results is submitted annually to the Department.

The hatchery licence conditions require abalone to be inspected on the farm for any sign of disease or unusually high levels of mortalities every three days. Licensees are required to keep detailed records of hatchery operations including mortalities and health certificates. Sentinel populations need to be regularly tested for disease (Section 15.2.2.1.1). All abalone being moved from a site are required to have a consignment note, which is approved by the CEO specifying the number or weight of abalone being moved.

The conditions also require an independent audit of the MEMP and licence conditions with a copy of the audit report sent to the CEO.

15.3.2.2 Sea Ranch Operations

The sea ranch licence holder is required to undertake a sediment quality monitoring program to detect potential changes in Total phosphorus, Total nitrogen and Total organic carbon and sediment redox twice annually (in February and August) with a written report provided to the CEO. The conditions also specify that abalone on the artificial structures are to be visually inspected for disease every two weeks. Dead or moribund abalone are required to be collected and if more than 30 are collected in a month, samples must be preserved and provided to the Fish Health Unit for testing. Prior to any movement from the site abalone must be accompanied by a consignment note approved by the CEO, stating the number of abalone being moved. The licence holder is required to keep records of:

- The number of grow out structures and movement of the structures
- The number and size of abalone moved onto or from each area of the site
- The number of abalone being kept each month at each area of the site
- The number of abalone harvested and removed from each area of the site
- The time, date and details of any inspections of abalone on the grow out structures
- All mortalities and all health certificates.

The MEMP for the sea ranch facility also requires an independent audit and an annual MEMP report provided to the CEO.

15.3.2.3 Wild Populations

Wild abalone populations are also closely monitored for pathogens and disease. Abalone divers are highly aware of the risk of disease to their industry and are vigilant for any abnormalities whilst harvesting. The AIAWA has developed a Code of Conduct to minimise biosecurity risks during the wild harvest of abalone and to date no disease outbreaks have occurred in natural populations.

The DOF undertakes annual monitoring of abalone for stock assessment purposes which includes assessment of populations for disease. The Departments Biosecurity section has an active surveillance program in the Fremantle Port for marine pests and diseases and a passive surveillance program throughout the state. There is also a passive surveillance program throughout WA, actively investigating any reports of abnormal mortalities, which are backed up by emergency response capability in the areas of both aquatic pests and diseases.

MSC Principle 3

MSC Principle 3 relates to the effective management of the fishery under assessment. Within this context, and where the unit of assessment (UoA) is not subject to international cooperation for management of the stock, the fishery must demonstrate that local and national laws and policies exist and incorporate institutional and operational frameworks to ensure responsible and sustainable resource use.

The established management system for fisheries in WA and for the AMF in particular, is based on the principles of good governance and the premise that responsibility for managing access to the common property resource is vested in the Government and its agencies. Together with supporting legislation, executive decisions are made on the best available information, formal consultation, communication and expertise based assessment processes.

The combination of having a large amount of relevant and accurate information on the biology and stock status of the Greenlip, Brownlip and Roe's abalone species, the sophisticated suite of management arrangements in place and the proactive management used in the Abalone Managed Fishery have resulted in the maintenance of abalone stocks and successful continuation of the fishery.

This section of the document provides the information on the AMF management system needed to score the fishery against the MSC's performance indicators under Principle 3 – Effective Management. Where appropriate, web links to supporting documents are also provided.

16 Governance and Policy

This section captures the broad, high-level context of the fishery management system within which the AMF operates. It includes:

- The legal and customary framework, including national environmental legislation, jurisdictional arrangements between the state of WA and the Commonwealth government and the system of governance in WA, including relevant fisheries legislation;
- Consultation processes and policies, as well as an articulation of the roles and responsibilities of people and organisations within the overarching fishery management system; and
- The long-term fishery management objectives.

16.1 Legal and/or Customary Framework

The management system exists within an appropriate and effective legal framework, which ensures that it: (1) is capable of delivering sustainability in the UoAs that are consistent with MSC Principles 1 and 2; (2) observes the legal rights created explicitly or established by custom of people dependent on fishing for food or livelihood; and (3) incorporates an appropriate dispute resolution framework.

16.1.1 Compatibility of Laws or Standards with Effective Management

16.1.1.1 National and State Legislative Framework

The Commonwealth Department of the Environment (DotE) is responsible for acting on international obligations on a national level by enacting policy and / or legislation to implement strategies to address those obligations. As such, all commercial fisheries in Australia are subject to national environmental legislation under the *Environment Protection and Biodiversity Conservation Act 1999* (EBPC Act), which is administered by the DotE. The EPBC Act provides a legal framework for the protection and management of nationally- and internationally-important flora, fauna, ecological communities and heritage places — defined in the EPBC Act as 'matters of national environmental significance'.

There are three different statutory entities responsible for the control and management of fisheries within Australian waters off the coast of WA: (1) the Commonwealth Australian Fisheries Management Authority (AFMA); (2) the WA State Fisheries Joint Authority; and (3) the WA Department of Fisheries (the Department).

The WA Government operates under the Westminster system, with the responsible Minister making executive management decisions. For fisheries in WA, the relevant executive decision maker is the Minister for Fisheries. The Minister for Fisheries has legislative power to turn knowledge and advice he is provided with into action, while the administration of these management arrangements is the responsibility of the Chief Executive Officer (CEO) (or Director General) of the Department, and the Department more generally.

The Minister / Department is responsible for the sustainable development and management of the State's aquatic resources, fisheries and aquaculture in accordance with its governing legislation. The Department is governed by the *Public Sector Management Act 1994* and is required to provide an *Annual Report*[13] to Parliament. This report includes a performance evaluation against a set of 'effectiveness' and 'efficiency' Key Performance Indicators (KPIs). The assessment against the effectiveness KPIs shows the extent to which the Department has achieved its goal of conserving and sustainably developing the State's aquatic resources, while the assessment against the efficiency KPIs measures the cost of resources used in the delivery of individual services.

In accordance with the *Offshore Constitutional Settlement 1995* (OCS), the Department's fisheries management responsibilities extend seaward beyond the three nautical mile limit of the State to the 200 nautical mile limit of the Australian Fishing Zone (AFZ). Additionally, the OCS sets out that the State will manage all trawling on the landward side of the 200 m isobath in the waters adjacent to WA and the Commonwealth will manage all deep-water trawling (seaward of the 200 m isobath). The OCS also provides for some fisheries in both State waters and the AFZ to be managed either jointly by the Commonwealth and State or solely by the Commonwealth (Brayford and Lyon 1995).

[13] The most recent annual report is available on the Department's website at: http://www.fish.wa.gov.au/About-Us/Publications/Pages/Annual-Report.aspx

Fisheries undertaken in waters adjacent to WA that are managed by the Commonwealth (AFMA) in accordance with Commonwealth legislation include a number of commercial fisheries (e.g. the Northern Prawn Fishery) and all recreational fishing in the waters of any Commonwealth marine park. Fisheries under joint Commonwealth-State jurisdiction are managed under the WA Fisheries Joint Authority (a body comprising State and Commonwealth ministers) in accordance with State legislation.

Except where specifically noted, fisheries involving the following species are managed by the WA Department of Fisheries in accordance with State law:

- All bony fish and sharks (except to the extent they are managed under a Joint Authority or by the Commonwealth);
- All aquatic invertebrates;
- All marine algae; and
- All seagrasses.

The Department provides management, licensing (where applicable), research, compliance and education services for commercial fisheries, recreational fisheries, customary fishing, pearling and aquaculture in all State waters (including marine parks) and the fish processing and charter boat industries. The Department's operations are guided by a *Strategic Plan 2016 - 2020*, which sets out explicit long-term objectives in three main areas: community and stakeholder benefits, sustainability and management excellence.

The fully integrated Department is structured around three key service delivery areas:

- **Aquatic Management:** provides management, policy development, licensing and legislation related to the State's commercial and recreational fisheries, pearling, aquaculture, fish processing, the charter boat industry, customary fishing and protection of aquatic ecosystems;
- **Compliance and Education:** provides state-wide fisheries compliance and community education, in accordance with the provisions of relevant legislation; and
- **Research and Monitoring:** provides timely, quality scientific knowledge and advice to support the conservation and sustainable use of the State's fish resources and aquatic systems.

The Department also provides a marine safety service on behalf of the Department of Transport.

Further information on the Department's structure, management, research, compliance and other activities is available in the *Annual Report*[14] and the annual *Status Reports of the Fisheries and Aquatic Resources of Western Australia: the state of the fisheries*[15].

[14] http://www.fish.wa.gov.au/About-Us/Publications/Pages/Annual-Report.aspx

[15] http://www.fish.wa.gov.au/About-Us/Publications/Pages/State-of-the-Fisheries-report.aspx

Commercial fishers must also comply with the requirements of the *Western Australian Marine Act 1982* and the *Wildlife Conservation Act 1950* (WA).

16.1.1.2 Relevant Legislation

Within WA, the Department assists the Minister in the administration of the following State acts and regulations[16]:

- *Fish Resources Management Act 1994* (FRMA);
- *Fish Resources Management Regulations 1995* (FRMR);
- *Pearling Act 1990*;
- *Pearling (General) Regulations 1991*;
- *Fisheries Adjustment Schemes Act 1987*;
- *Fishing and Related Industries Compensation (Marine Reserves) Act 1997*; and
- *Fishing Industry Promotion Training and Management Levy Act 1994*.

The FRMA is the primary instrument for fisheries management in WA and provides for the creation of subsidiary legislation, in the form of Regulations (i.e. FRMR), Orders, Management Plans, Ministerial Policy Guidelines and Policy Statements.

The FRMA deals with broad principles and the provision of head powers and high-level overarching matters, while the FRMR and other subsidiary legislation deals with the details needed to put these matters into practice. Parts 5 and 6 of the FRMA set out the general regulation of fisheries through the use of orders and regulations and the specific management of fisheries via the declaration or creation / amendment of fisheries management plans.

Fishery management plans in WA (such as the *Abalone Management Plan 1992*) set out the operational rules that control managed commercial fishing activities. Specifically, a fishery's management plan provides the power (pursuant to section 58 of the FRMA) to issue and restrict the number of authorisations and regulate other conditions and grounds related to fishing. There is also the power to set the capacity of a fishery under a management plan (under section 59).

In 2010, the (then) Minster for Fisheries directed the Department to review the existing legislation and scope the requirements for a new WA Act of Parliament to more explicitly reflect the Department's objective of ensuring the sustainable development and conservation of the state's aquatic resources into the future. As a result the Aquatic Resource Management Act (ARMA; currently before parliament as the *Aquatic Resource Management Bill 2015*[17]) was drafted and provides an innovative legislative and administrative framework for the future management of the State's fish and aquatic resources, based on the principles of Ecologically Sustainable Development and Ecosystem Based Fisheries Management.

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[16] Up-to-date versions of the legislation governing the Department and the Fisheries acts and regulations can be accessed via the Departmental website: http://www.fish.wa.gov.au/About-Us/Legislation/Pages/default.aspx

[17] The Bill can be viewed on the Parliamentary website http://www.parliament.wa.gov.au/parliament/bills.nsf/BillProgressPopup?openForm&ParentUNID=1D103914B411A4CF48257DF6001BBD6B

The ARMA is set to complete the Department's shift in focus from the management of individual commercial fisheries to the management of aquatic resources, placing sustainability at the fore of management considerations. It provides for transparent and well-defined allocations of the total allowable catch between the commercial and recreational sectors after setting aside the quantity of the resource required for sustainability and public benefit purposes such as fisheries research and customary fishing. It prescribes the development of Aquatic Resource Use Plans (ARUPs), setting out the sectoral rules for fishing the resource. Also included are enhanced powers to manage disease and other biosecurity risks in the aquatic environment. In most other respects the Bill contains similar provisions to those that already exist in the FRMA.

The new legislation will result in the repeal of the FRMA and the Pearling Act. However, transition provisions will ensure that management plans for managed fisheries continue in force and may be amended from time to time, until such time as the resource is declared and an Aquatic Resource Management Strategy (or ARMS) is made for that resource.

16.1.1.3 Management Framework

16.1.1.3.1 Key Policies

The legislative framework is supported by a range of high level policies. The Department has set out its fisheries and aquatic resource objectives in the *WA Government's Fisheries Policy Statement* (DoF 2012a)[18] which provides guidance on the Government's preferred approaches to key resource management challenges, including resource management, resource access and allocation, marine planning and governance and consultative structures. The Government has also recognised that more-detailed policies are needed for other key areas. These complimentary policies include:

- *Harvest Strategy Policy for the Aquatic Resources of Western Australia* (DoF 2015) This policy sets out the main requirements of an effective harvest strategy in WA, i.e. operational objectives, performance indicators, reference levels and harvest control rules. This policy is consistent with the *National Harvest Strategy Guidelines* (Sloan et al. 2014), but differs from the national guidelines by additionally covering sectoral allocation and the development of strategies for dealing with unacceptable risks to other ecological resources.
- *Aquatic Biodiversity Policy* (DoF In prep). This overarching policy describes the Department's role, responsibilities and jurisdiction in the management of the State's aquatic biodiversity. The policy focuses on five key asset areas (i.e. retained fish species, non-retained fish species, endangered, threatened and protected species, fish habitats and ecosystem processes) and seven key threats imposed upon these asset areas (i.e. habitat loss, invasive pests, unsustainable harvest, external drivers, lack of information, governance and cumulative impacts).

[18] http://www.fish.wa.gov.au/Documents/corporate_publications/wa_govt_fisheries_policy_statement.pdf

16.1.1.3.2 Ecologically Sustainable Development

In accordance with international treaties and initiatives, the Australian Government is committed to implementing the principles of Ecologically-Sustainable Development (ESD). ESD is a dynamic concept that seeks to integrate short- and long-term economic, social and environmental effects into the decision-making processes of government and industry. As per the *National Strategy for Ecologically Sustainable Development* (CoA 1992), ESD is defined as *"using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased"*. ESD is accepted as the foundation for natural resource management in Australia and is a major component of all fisheries legislation, at both Commonwealth and State levels.

The EPBC Act requires the Australian Government to assess the environmental performance of fisheries and promote ecologically-sustainable fisheries management (in line with the principles of ESD). For State-managed fisheries, an independent assessment[19] of a fishery in accordance with the EPBC Act is required for export approval (this is undertaken by the DotE through the Commonwealth Minister for the Environment). In order to meet these requirements, a comprehensive ESD reporting system has been developed for all Australian fisheries (Fletcher et al. 2002).

In any assessment using an ESD framework (e.g. export approval), all relevant environmental issues, social and economic outcomes and governance issues are addressed. In WA, these assessments are completed using a risk-based framework to examine the impacts of an individual fishery on retained species, bycatch (including protected species) and habitats, as well as any potential indirect impacts on the broader ecosystem. These assessments are independently-reviewed by the federal environmental agency against the *Guidelines for the Sustainable Management of Fisheries – V2* (*Guidelines*; CoA 2007), with their ongoing performance reported annually in the *Status Reports of the Fisheries and Aquatic Resources of Western Australia: the state of the fisheries* (e.g. Fletcher and Santoro 2015).

16.1.1.3.3 Ecosystem Based Fisheries Management

The Department has implemented Ecosystem Based Fisheries Management (EBFM) as the primary strategy to achieve the goal of ESD for fisheries in WA. EBFM deals with the aggregate management of all fisheries-related activities within an ecosystem or bioregion and takes into account the impacts of fishing on retained species, discarded species, protected species, habitats and the broader ecosystem — regarded as 'ecological assets' — and the social and economic impacts of aquatic resource use.

The EBFM framework used in WA was developed in 2010 in partnership with the Western Australian Marine Science Institution (WAMSI) and the Fisheries Research and Development Corporation (FRDC). The framework provides the operating policy / basis for implementing sustainable fisheries and ecosystem management in WA and is based on the

[19] Further information on fishery assessments against the EPBC Act is provided on the DotE website at: http://www.environment.gov.au/marine/fisheries

global standard for risk assessment and risk management (AS/NZS ISO 31000). The framework provides a step-by-step process (see Fletcher et al. 2010; Fletcher 2012) for identifying and ranking assets and risks to establish priorities, allowing the Department to focus on managing resources most at risk and of most value to the community. It also complements Integrated Fisheries Management (IFM), the Department's resource sharing process for ensuring fair access rights between the various sectors.

Within the EBFM framework, WA has been divided into six aquatic bioregions, with a high-level set of ecological resources / assets that are to be managed identified for each bioregion (see Fletcher and Santoro 2015 for more detail). The risks associated with each individual ecological asset are examined separately using formal qualitative risk assessment (consequence x likelihood) or more-simple problem assessment processes (as detailed in Fletcher 2005; Fletcher et al. 2011). All risk scoring considers both the current level of activities and management controls already in place.

The risk levels are then used as a key input in the Department's Risk Register, which combined with the assessment of the economic and social values and risk associated with these assets, is an integral part of the annual planning cycle (Figure 16.1) for assigning Departmental activity priorities (e.g. management, research, compliance, education, etc.).

The Department's Risk Register feeds into guidance documents for long-term Departmental activities, which are documented in Fish Plan and a five-year research plan (Figure 16.1). Fish Plan is the guiding document to assist the Department in achieving its desired agency-level outcomes, which are measured by the Department's key performance indicators and published in the Department's *Annual Report*[20] to Parliament. Fish Plan provides a planned, structured approach to the management of fishery resources, including a review of the management arrangements for fish stocks, assessment and monitoring of these stocks and compliance planning. Thus, Fish Plan includes two planning schedules; the first describes the key outcomes to be delivered at a resource / fishery level during the next five years (and potentially into the next five-year cycle). Within this schedule, fish resources considered to be at 'higher' risk are likely to receive higher priority than those where the risk is lower. The second schedule provides a description of the other key functions undertaken by the Department related to management of fishery resources. Many of these functions have an annual cycle, such as licensee and stakeholder liaison and fee setting, while others are addressed on an 'as needed' basis, such as marine park planning.

[20] http://www.fish.wa.gov.au/About-Us/Publications/Pages/Annual-Report.aspx

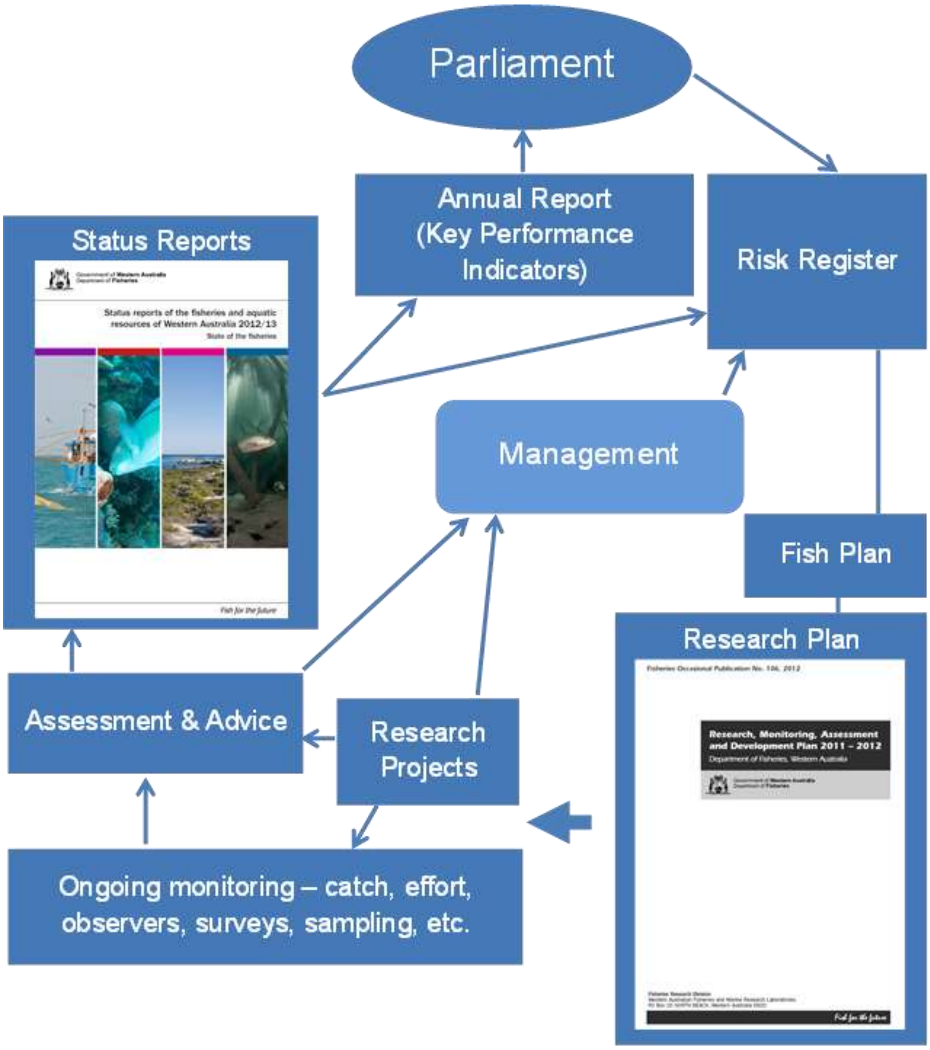

Figure 16.1 Outline of risk-based planning cycle used by the Department to determine annual priorities and activities.

16.1.1.3.4 Catch Allocation and Integrated Fisheries Management

Historically, WA's fish resources have been shared on an implicit basis, with no explicit setting of catch shares within an overall total allowable catch (TAC) or corresponding total allowable effort (TAE). In more recent years, the Department has implemented an Integrated Fisheries Management (IFM) approach, taking into account the aggregate effects of all fishing sectors. This involves the use of a framework in which decisions on optimum resource use (i.e. allocation and re-allocation of fish resources) are determined and implemented within a total sustainable catch for each fishery or resource.

The IFM process generates explicit allocations and / or re-allocations to specific sectors using a formal and structured allocation process facilitated by an independent body – the Integrated Fisheries Advisory Allocation Committee (IFAAC). This process has already been completed for western rock lobster, metropolitan abalone fisheries (IFAAC 2009) and the West Coast Demersal Scalefish Fishery.

The IFM framework, including the need for explicit catch shares to strengthen access rights, will be further strengthened with the introduction of the ARMA. In essence, the IFM approach involves:

- Setting a total allowable harvest level of each resource that allows for an ecologically-sustainable level of fishing;
- Allocation of explicit proportional catch shares for use by the commercial and recreational sectors (after taking into account customary fishing);
- Continual monitoring of each sector's catch;
- Managing each sector within its allocated catch share; and
- Developing mechanisms to enable the reallocation of catch shares between sectors.

16.1.1.4 Memoranda of Understanding (MoUs)

Particularly in cases where cross jurisdictional issues arise and cooperation with other parties is required in order to meet management objectives, MoUs have been developed. For example, there is an MoU between the Commonwealth DotE and the Department which facilitates and formalises procedures for the reporting of protected species interactions in development.

16.1.1.5 Resourcing the Management Process

From July 2010, managed commercial fisheries have been subject to a new annual access fee model. The new access fee model aimed at improving flexibility for resourcing priority management needs and providing equity in how much licensees pay in access fees and greater certainty of funding and access rights. This involves managed commercial fisheries in WA paying an access fee equivalent to 5.75 % of the gross value of production (GVP) of the respective fishery. The costs of managing the AMF come each financial year from the State Government Consolidated Revenue and for research, from the Fisheries Research and Development Corporation (FRDC).

16.1.2 Resolution of Disputes

Disputes are informally dealt with or avoided through the educative role carried out by Fisheries and Marine Officers and other Departmental staff, and through ongoing communication and consultation with WAFIC and sectoral bodies (i.e. the Abalone Industry Association of Western Australia, AIAWA). Where necessary, there is a well-established formal mechanism for resolution of administrative and legal disputes in relation to fisheries through the WA State Administrative Tribunal (SAT) or WA court system. Dispute resolution for administrative decisions made under the FRMA is provided for in Part 14 of this Act through appeal to the SAT. Criminal offences are dealt with by the Magistrates Courts. Decisions of the SAT and the Courts are binding on the Department, and all SAT decisions must be carried out by the Department (under section 29(5) of the *State Administrative Tribunal Act 2004*).

While the SAT has settled disputes across a number of fisheries[21], there have been no appeals lodged for the AMF. Fishers are advised of the opportunity to lodge an appeal with the SAT following a decision made by the CEO of the Department.

All changes to existing or new fisheries legislation, including subsidiary legislation such as the *Abalone Management Plan 1992*, are potentially subject to review through the disallowance process of State Parliament. All subsidiary legislation is also reviewed by the Joint Standing Committee on Delegated Legislation, which may seek further advice on the reasons for the legislation and potentially move to disallow. In this way, there is Parliamentary and public scrutiny of all fisheries legislation.

16.1.3 Respect for Rights

Commonwealth legislation, the *Native Title Act 1993* (NT Act), provides the means by which the Australian legal system recognises the traditional rights and interests of Aboriginal and Torres Strait Islander people. This ensures access to fish and shellfish resources for people who depend on fishing for their food.

A 2013 Australian High Court decision related to the application of State fisheries law to native title holders fishing for abalone in their local area in South Australia concluded that the State fisheries legislation did not extinguish native title rights to fish and that the defence under section 211 of the NT Act was applicable.[22] It is likely that this decision also means that fisheries legislation in WA does not extinguish native title rights to fish where that right is exercised by an Aboriginal person for a traditional, non-commercial purpose.

A key aspect of the NT legislation is that proposed developments or activities (including fisheries where a registered claim or determination extends into State waters) that may affect native title are classed as 'future acts'. In 1999, the Department obtained a 'Report for Fisheries Western Australia' in respect to the interaction between fisheries / pearling legislation and the NT Act. The report advised that:

1. The very wide scope of what can be done under a fishery management plan means that fisheries / pearling do have the potential to affect native title. As a result, a new management plan would be considered a 'future act' for the purpose of the NT Act.
2. Because a new management plan would be covered by section 24 HA of the NT Act, it can be validly made without the need for any specific native title notification or comment procedure.
3. While specific notification is not required, it would, however, be prudent for comment to be sought from any native title parties likely to be affected by the new management plan under the provisions of the FRMA section 64(2).

[21] http://www.sat.justice.wa.gov.au/D/decisions_database.aspx?uid=8771-1201-5146-1913

[22] http://www.hcourt.gov.au/assets/publications/judgment-summaries/2013/hca47-2013-11-06.pdf

4. The granting of licences and permits under management plans will not be 'future acts' in their own right, and they can therefore be granted without the need for any native title procedure or notification requirement.

In accordance with point 3 above, the Department provides any native title party or parties with an opportunity to comment on the development of a proposed fishery.

The Native Title Tribunal facilitates the negotiation of indigenous land use agreements following a claim[23] or determination[24] and is required to keep registers of approved native title claims and determinations. There are a number of native title determinations and applications along the Western Australian coast that include marine waters that overlap with abalone fishing grounds although this does not impact native title rights. A map of all WA determinations and applications can be viewed from the National Native Title Tribunal website at http://www.nntt.gov.au/Maps/WA_NTDA_Schedule.pdf

16.1.4 Customary Fishing in WA

Customary fishing is legislated under the FRMA and means "*fishing by an Aboriginal person that – a) is in accordance with the Aboriginal customary law and tradition of the area being fished; and b) is for the purpose of satisfying personal, domestic, ceremonial, educational or non-commercial communal needs.*" The rights of Aboriginal persons to fish for a customary purpose are recognized under section 6 of the FRMA which provides that "*an Aboriginal person is not required to hold a recreational fishing licence to the extent that the person takes fish from any waters in accordance with continuing Aboriginal tradition if the fish are taken for the purposes of the person or his or her family and not for a commercial purpose*". Section 258 (1) (ba) of the FRMA provides the power to make regulations to manage customary fishing.

The Department released a *Customary Fishing Policy* position statement in 2009[25], which states that "*customary fishing applies, within a sustainable fisheries management framework, to persons:*

- *of Aboriginal descent;*
- *fishing in accordance with the traditional law or custom of the area being fished; and*
- *fishing for the purpose of satisfying personal, domestic, ceremonial, education or non-commercial communal needs*."

This policy statement explicitly states that "Customary fishing is to be articulated and clearly separated from other forms of fishing in fisheries legislation and policy to allow for the

[23] A registered native title claim is an application where a decision about native title is yet to be made.

[24] A determination of native title is a decision that native title does or does not exist in a particular area of land and/or waters (the determination area).

[25] http://www.fish.wa.gov.au/Documents/customary_fishing/customary_fishing_policy.pdf

development of appropriate management arrangements that reflect customary fishing access rights, practices and sustainability requirements."

Under the proposed ARMA, a quantity of each specified aquatic resource will be reserved for conservation and reproductive purposes, with a sustainable allowable harvest level set for use by the fishing sectors. The quantity 'reserved' includes an allowance for customary fishing and public benefit purposes, such as scientific research. Thus, a specific share does not have to be allocated to the customary sector, as that share is set aside prior to setting an allowable harvest level for the resource. In this way, customary fishing can continue in accordance with existing customary fishing arrangements. IFM also recognises the rights of customary fishers of Aboriginal descent who are fishing for cultural needs. The ARMA will further strengthen the statutory basis for customary fishing rights as part of an overall strengthening of the rights framework.

The Department has no record of the amount of abalone caught for customary purposes.

16.2 Consultation, Roles and Responsibilities

The WA Government's commitment to consultation and engagement in fisheries management is set out in the *Western Australian Government's Fisheries Policy Statement* of 2012. The management system of fisheries in WA has effective consultation processes with stakeholders who are clearly identified in the Department of Fisheries Annual Report and include commercial, recreational and customary fishers, pearling and aquaculture industries, charter fishing operators, fish processors, environmental groups, businesses and communities directly and indirectly dependent upon fishing, offshore industries and other state, national and international government agencies and tertiary institutions..

It should be noted that the Department recently broadened its stakeholder engagement process through a new Stakeholder Engagement Guideline (SEG), setting out the processes through which the Department will seek out relevant information from, and involvement by, stakeholders and interested parties on proposals relating to the management of WA's aquatic resources. The guideline has been signed off by the DG and is currently in the publication process. The guideline was an outcome of the Non-Fisher Stakeholder Engagement Project, which included a key stakeholder consultation phase during which more than 20 key stakeholders were interviewed. An early draft of the guideline was later sent for comment to all key stakeholders who had participated during the consultation phase. Comments were considered and a summary of submissions and the Department's response will be provided back to stakeholders once the guideline is published.

16.2.1 Roles and Responsibilities

The roles and responsibilities of organisations (e.g. Department of the Environment, Department of Fisheries, WAFIC) and individuals (e.g. Minister for Fisheries) who are involved in the management process are well understood with key powers explicitly defined in legislation (e.g. FRMA) or relevant policy statements and agreements.

16.2.1.1 Commonwealth Government

The roles and responsibilities of the Commonwealth Government with respect to ecological sustainability and conservation of marine resources, in relation to WA marine waters, are clearly set out in the Commonwealth EPBC Act. Further, the roles and responsibilities of the Commonwealth and the WA Government is clearly articulated in the OCS 1995 in relation to the management of fisheries outside the three nautical mile state-waters boundary.

16.2.1.2 Department of Fisheries

The roles and responsibilities of the State of WA in fisheries management is explicitly outlined in the FRMA, the OCS 1995 and the *Western Australian Government Fisheries Policy Statement (March 2012)*. For example, in the FRMA there is a division of power between the Minister for Fisheries and the statutory office of the Department's Chief Executive Officer (CEO). In broad terms, it is the Minister for Fisheries who establishes legal and policy framework for fisheries management (under Parts 5 and 6 of the FRMA) in line with consultation processes, while the Department's CEO (and staff) carries out the day-to-day administration of these frameworks.

The Department is structured around clearly defined divisions with specific roles relating to aquatic management, research and regional services (compliance and licensing). The roles and responsibilities of each of these areas is spelt out in the Department's Annual Report to Parliament[26].

Key Departmental personnel to whom the responsibilities of ensuring management, research and compliance outcomes (including proper prioritisation of departmental funding) for the abalone fishing industry include:

- Southern Bioregion Program Manager (Aquatic Management Division);
- Southern Bioregion Fisheries Management Officers (Aquatic Management Division);
- Supervising Scientist —Invertebrates (Research Division);
- Senior Research Scientist —Molluscs (Research Division);
- Compliance Manager South (Regional Services Division);
- Regional Manager South (Regional Services Division); and,
- Fisheries and Marine Officers in Esperance, Albany, Busselton, Bunbury, Mandurah and Perth (Regional Services Division).

The Minister / Department is responsible for advising licensees and WAFIC of Ministerial / Departmental decisions that are the subject of a consultation process. Responsibilities of the Department in formal consultation arrangements with WAFIC are that the Department —

- Provides annual funding to WAFIC equivalent to 0.5 % of WA commercial fishing gross value of product (based on a three-year average), plus a pro-rata amount

[26] http://www.fish.wa.gov.au/Documents/annual_reports/Annual%20Report%202014-15.pdf

equivalent to 10 % of water access fees paid by aquaculture and pearling operators. Payments to WAFIC are made by six-monthly instalments each year;

- Works with WAFIC in a manner consistent with WAFIC's role as the peak body representing commercial fishing interests in WA; and
- Engages with WAFIC, sector bodies and commercial fishing interests according to WAFIC's Operational Principles.

The Department is also responsible for ensuring the recreational fishing sector, through RFW, is formally consulted on proposed changes to recreational fisheries management and is advised of Ministerial / Departmental decisions that are the subject of a consultation process. The Department is responsible for providing RFW with a proportion of the income generated from annual recreational fishing licence fees to undertake its role as the peak body representing recreational fishing interests in WA.

16.2.1.3 Peak Sector Bodies

The WA Government formally recognises WAFIC and RFW as the key sources of coordinated industry advice for the commercial and recreational sectors, respectively.

16.2.1.3.1 Western Australian Fishing Industry Council

WAFIC[27] is the peak industry body representing professional fishing, pearling and aquaculture enterprises, as well as processors and exporters, in WA. It is an incorporated association that was created by industry more than 40 years ago to work in partnership with Government to set the directions for the management of commercial fisheries in WA. WAFIC aims to secure a sustainable industry that is confident of:

- Resource sustainability and security of access to a fair share of the resource;
- Cost-effective fisheries management;
- That its business can be operated in a safe, environmentally-responsible and profitable way; and
- That investment in industry research and development is valued and promoted.

WAFIC's responsibilities include coordinating Government funding (provided under a funding agreement) for industry representation and taking on a leadership role for matters that involve or impact on or across a number of fisheries or are of an industry-wide or generic nature. WAFIC also represents those commercial fishing sectors that do not have capability for self-representation.

WAFIC's responsibilities can be summarised as:

- Providing effective professional representation of commercial fishing interests and the commercial fishing sector to Government, industry, other relevant organisations

[27] More information about WAFIC is available on their website: www.wafic.org.au/

and the community. This includes engaging, facilitating and consulting, as necessary in order to meet this responsibility;

- Providing representation of commercial fishing interests on fisheries management and Ministerial committees, as required;
- Documenting priority issues for commercial fishing interests (by 30 March) each year to the Department;
- Providing feedback to the Department on proposed deliverables and budget priorities for expenditure of the Fisheries Research and Development account;
- Engaging with RFW and other appropriate parties with a view to identifying joint priorities and solutions to issues of shared concern;
- Engaging in promotion, education and awareness of key sustainability messages consistent with best practice fisheries management and objects of the FRMA; and
- Conducting agreed activities that are consistent with the FRMA as it relates to the provision of assistance to, or promotion of, the fishing industry (i.e. s238(5)(1) of the FRMA).

WAFIC's responsibilities for consultation services are clearly outlined in a Service Level Agreement (SLA) with the Department.

16.2.1.3.2 Recfishwest

Recfishwest (RFW[28]) is the peak body for the recreational sector and, in accordance with the Service Level Agreement between RFW and the Department, RFW has the responsibility to provide representation of recreational fishing interests in Western Australia and their key deliverables include:

- Provide recreational fishing representation, consultation and engagement;
- Provide peak body advice;
- Promote key sustainability messages; and,
- Project management.

RFW receives 15 % of the revenue raised from recreational fishing licence fees to provide the above deliverables.

16.2.1.4 Licensees / Sector Associations

Fishery licence holders have a responsibility to stay abreast of changes in fisheries legislation that relates to their activities. In order to fulfil this responsibility, the Department assists licence holders by explicitly reminding them in writing of where they can access the latest legislation. The following information can be found on every licence "*Fisheries legislation changes from time to time. To assist fishers, aquaculturists and members of the public to*

[28] More information about RFW is available on their website: www.recfishwest.org.au/

access fisheries legislation, the Chief Executive Officer has arranged for up to date fisheries legislation to be made available on the internet. Fisheries legislation may be viewed by logging on to the Department of fisheries website (www.fish.wa.gov.au) and clicking on the Legislation link on the top of the home page. The Chief Executive Officer recommends that the licence holders and persons acting on their behalf (e.g. employees), regularly access this legislation service and make themselves aware of the fisheries legislation that relates to their activities."

Licence holders operating in the AMF have a number of responsibilities including completion of CDRs to ensure that all of the relevant data and information is collected.

The Abalone Industry Association of WA (AIAWA) is the representative body for the abalone industry. The AIAWA is also the primary source of contact between the Department and Industry (although formal contact is via the Industry Consultation Unit at WAFIC, as established under the Service Level Agreement (SLA)). The AIAWA plays a major role in ensuring the sustainability of the industry through its commitment to the implementation of industry best practice through the Code of Conduct. The AIAWA also represents and supports its members across a range of issues including the provision of an abalone diver induction and instruction manual that is continually updated as new management arrangements are introduced. Industry assists the Department by providing samples of shells to the Research Division which provides important data to help understand fishing pressure and set quotas.

16.2.2 Consultation Processes

The WA Government's commitment to consultation with stakeholders is set out in the *WA Government's Fisheries Policy Statement*.

The Department's consultation processes have evolved substantially over time – necessitated by the progressive shift in fisheries management from 'open access' arrangements (focussed on target species), through the introduction of limited-entry for commercial fishing and the allocation of transferable fishing rights or units, to the current integrated, resource-based EBFM framework covering all sectors and the broader ecosystem.

The most recent changes were made following a review of consultation arrangements in 2009 and involved a move away from Management Advisory Committees (MACs), which had characterised consultation arrangements for key fisheries in WA for many years. MACs played an important role in informing the development and implementation of fishery management plans and in facilitating a 'co-management' approach between Government and industry. However, once the main management settings for most fisheries had been established, the consultation model was in need of review.

The major change that resulted from the review was that MACs were replaced with a framework (Figure 16.2) that established the Department of Fisheries as the principal source of Government management advice; WAFIC (commercial sector) and RFW (recreational sector) as the main sources of industry advice; and highly flexible, expertise-based and tasked working groups responsible for providing specific advice, as required, on the management of fish and aquatic resources, public policy and fisheries management issues.

The roles of WAFIC and RFW in providing consultation services, as requested, to both the Minister and the Department were formalised through a Service Level Agreement (SLA) with each peak body. High level strategic advice to the Minister and/or the Department is provided, as needed, by an independent committee, i.e. the Aquatic Advisory Committee (AAC).

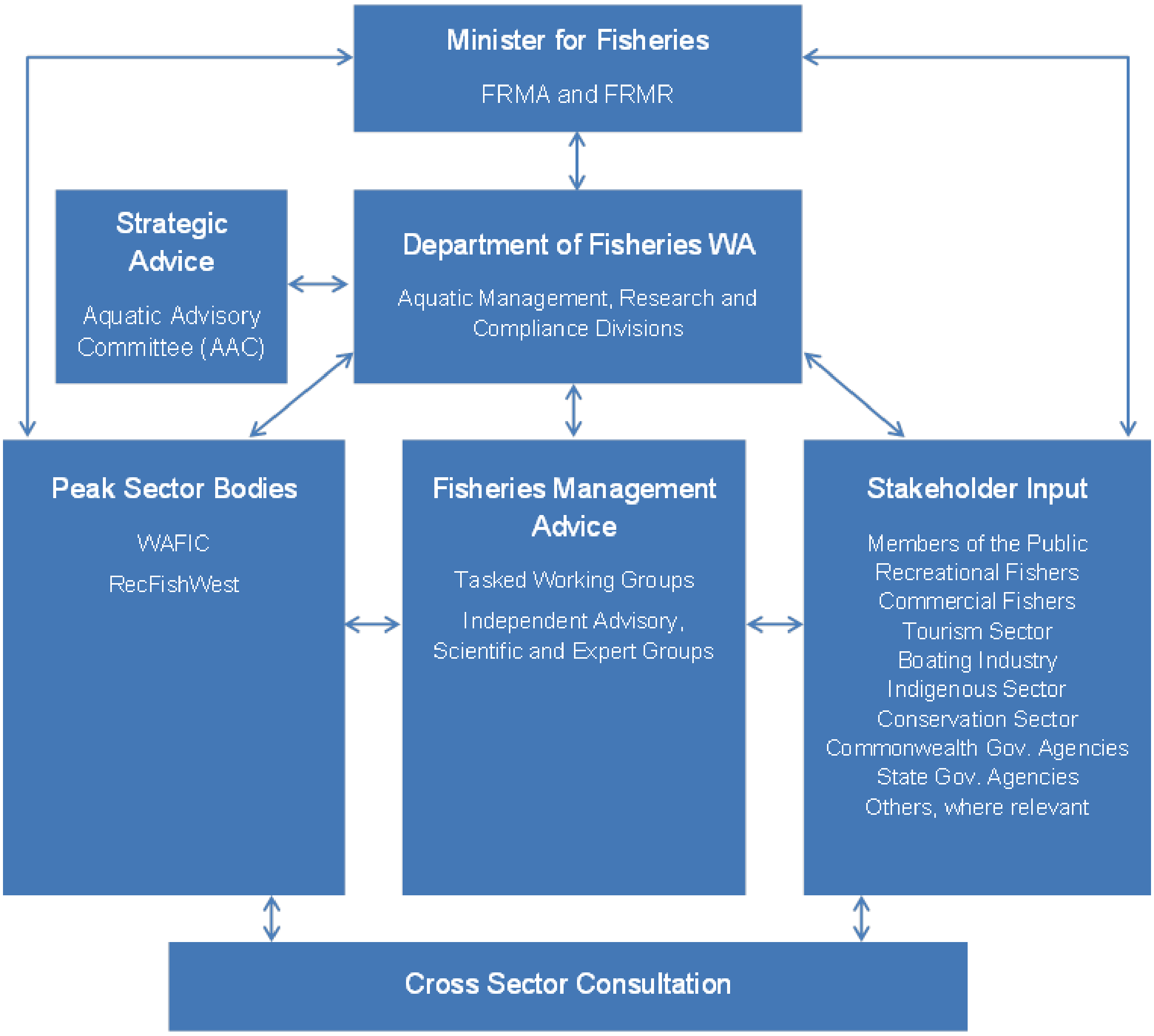

Figure 16.2 Broad fisheries management consultation framework in WA

The current framework ensures that decisions are made only after all available relevant information (including local knowledge) is sought out and considered. For example, the central position of WAFIC and RFW in the management framework ensures these peak bodies have direct input into the annual planning and priority-setting process used to determine management, compliance, research and other priorities for the Department. WAFIC and RFW have the responsibility of ensuring that local fishers (both commercial and recreational): (i) are actively encouraged to engage in these discussions and to provide relevant information; and (ii) are kept abreast of how this information has been used or not used.

The Department also receives local input through its regional officers who often closely work together, and share forums, with regional officers in other resource management departments (e.g. Department of Parks and Wildlife, Department of Water), statutory advisory committees (e.g. World Heritage Committee), Natural Resource Management (NRM) regional bodies and catchment councils. Other non-fisher stakeholders such as conservation sector NGOs, Traditional Owners, community groups etc., are often represented on the same regional forums as described above; are periodically represented on relevant tasked working groups set up by the Department; and/or are frequently provided with opportunities to be involved through key stakeholder and public consultation processes. Where input is provided, feedback on how this information was used or not used is typically provided in the form of publications such as Fisheries Management Papers (accessible to the public on the Department's website).

As part of the development process for the future management of the metropolitan Roe's abalone recreational fishery, for example, the Department published a Report of the Metropolitan Roe's Abalone Recreational Fishery Working Group (Fisheries Management Paper No. 243[29]) on its website. FMP 243 sought input from all interested parties and provided a feedback form in relation to a number of options for future management. The options in FMP 243 were based on the suggestions provided by licenced recreational abalone fishers, all of whom had been sent a research questionnaire beforehand. The survey results were presented in the FMP, ensuring a fair and transparent process.

16.2.3 Participation

The Department works closely with national, state and regional partners and other stakeholders in every aspect of its business and provides opportunities for involvement through a number of different processes.

16.2.3.1 Statutory Consultation under the EPBC Act

All fisheries in Australia that wish to export product for commercial purposes (such as the Abalone Managed Fishery) require assessment under the *Environmental Protection and Biodiversity Act 1999* (EPBC Act) to ensure compliance with obligations under CITES and the Biodiversity Convention. For species that are not declared 'exempt native specimens', export is only permitted if it is conducted in accordance with an approved Wildlife Trade Operation (WTO). Determination of whether a proposed WTO is an approved WTO by the Minister for the Environment (Commonwealth) is subject to a public consultation process and consideration of all issues raised and comments made during this process. Details of all public consultation periods are published on the Department of the Environment's website[30].

In cases where there is a very high degree of confidence in the sustainability of the fishery and compliance with international conventions, the specimens caught by the fishery may be included on the list of exempt native specimens (LENS), and be exempt from the export

[29] http://www.fish.wa.gov.au/Documents/management_papers/fmp243.pdf

[30] http://www.environment.gov.au/marine/fisheries/open-for-public-comment

regulations of the EPBC Act for a five or 10 year period. Abalone caught by the AMF are listed on the LENS.

16.2.3.2 Statutory Consultation under the FRMA

Under the requirements as set out in section 64 of the FRMA, any new fishery management plan can only be made after a public consultation period is affected and all comments on the draft plan are given due consideration. The Department uses a variety of processes to ensure coverage and engagement with stakeholders and the wider community during the consultation period, including:

- direct notification of a future stakeholder/public consultation process in writing;
- press releases;
- newspaper, radio and television interviews;
- dissemination of information via the Department's website;
- invitations for stakeholders to sit on tasked working groups or participate in scientific reviews / workshops, formal risk assessment processes and management reviews; and
- explicitly indicating what documents are open for public comment on the Department's website[31].

Amendments to an existing fishery management plan cannot be undertaken without addressing statutory consultation requirements pursuant to section 65 of the FRMA[32], with each fishery management plan explicitly identifying the key stakeholders for the fishery that the Minister must consult with prior to making and amendment. In the abalone fishery, this includes all licence holders of the Fishery (see clause 23B of the Management Plan). All comments are to be genuinely considered by the Minister prior to the final decision.

Management changes and fishing arrangements in the AMF are facilitated through a notice published in the Gazette or amendments to the management plan depending on the matter. The CEO is the final decision-maker in determining TACCs and approved fish processors, whereas the Minister is the final decision maker for amending legislation. The Department generally undertakes consultation work on the Minister's behalf, although statutory consultation with industry is presently conducted by WAFIC on behalf of the Department under an SLA.

For the implementation of other statutory fishing management tools under the FRMA, such as section 43 orders or section 7 exemptions, statutory provisions are silent as to procedural consultation requirements. Nevertheless, the Minister must have regard for common law principles to afford natural justice to the licence holder. The Department has a series of formal decision-making delegations for licensing decisions and exemptions from legislation.

[31] http://www.fish.wa.gov.au/About-Us/public-comment/Pages/default.aspx

[32] Note that section 65(4) of the FRMA provides for the Minister to amend a management plan without consultation if, in the Minister's opinion, the amendment is required urgently or is of a minor nature (but must provide advice following the amendment of the plan. This might include the need for amendments for emergency sustainability reasons.

Most Departmental decisions (excluding Ministerial decisions) are subject to review by the State Administrative Tribunal.

16.2.3.3 Consultation through Non-statutory Advisory Committees

Under sections 41 and 42 the FRMA, the Director General of the Department and/or the Minister may establish Advisory Committees. Two examples of committees established under section 42 are the Aquatic Advisory Committee and the Integrated Fisheries Allocation Advisory Committee (IFAAC). Both are non-representative expertise-based committees that provide independent advice to the Minister and/or the Department on high level strategic issues and aquatic resource allocation issues, respectively. Typically, findings of, or recommendations made by, these committees result in documents that are subsequently released for public consultation to provide opportunities for input by interested parties.

For example, one of the first matters referred to the Aquatic Advisory Committee for advice was the proposed framework for new legislation to replace the *Fish Resources Management Act 1994* and the *Pearling Act 1990*. Following advice from the Aquatic Advisory Committee, the discussion paper *A Sea Change for Aquatic Sustainability*[33] outlining the framework of a new Aquatic Resources Management Act was released for public comment in June 2010, specifically to provide opportunities for involvement of all interested parties at an early phase in the development of the new act.

Another example is the consultation process used by IFAAC to prepare its final report, containing advice and recommendations to the Minister, on future allocations for the Metropolitan Roe's abalone resource (IFAAC 2009). After investigating all allocation issues, IFAAC released a draft allocation report that was released for public comment (with a 5-month public consultation period) in August 2006. After reviewing all submissions and working through the key issues at an additional stakeholder workshop in March 2007 the report was finalised and presented to the Minister.

16.2.3.4 Consultation Arrangements with WAFIC and RFW

As the recognised peak bodies for commercial and recreational fishing in WA, and each acting in accordance with the relevant SLA with the Department, WAFIC and RFW are responsible for providing effective professional representation of commercial and recreational fishing views and interests on matters referred to it by the Minister or Department. In carrying out this function of consultation WAFIC and RFW are required to:

- Distribute proposed changes to management arrangements that include the Minister's / Department's reasoning for the proposal(s) and the information on which the proposal(s) is based to all licence holders in the relevant fishery or appropriate recreational fishing networks;
- Describe the method by which licence holders and interested parties (e.g. recreational fishers) may provide their views; this may be by way of inviting written responses, or it may involve additional processes, such as the establishment of appropriate forums

[33] http://www.fish.wa.gov.au/Documents/occasional_publications/fop079.pdf

in which licence holders and interested parties can discuss and deliberate on the merits of proposed changes prior to putting forward individual views as well as collective views, where appropriate;

- Ensure that licence holders and interested parties have a reasonable period in which to consider their position and respond;
- Ensure the decision maker is fully aware of the views being put forward, in order to ensure the decision maker gives proper and genuine consideration to the views being put forward (which may involve WAFIC and RFW consolidating these views into a summary report); and
- Engage and consult as necessary in order to meet its obligations outlined above. This includes providing documented evidence of consultation input in its submissions / responses to the Department (only relevant to RFW).

By way of these arrangements, the Department is providing opportunities for, and encouraging, all interested and affected fishing parties to be involved and is facilitating their effective involvement.

One example of the efficacy of this arrangement is the consultation process undertaken by RFW in relation to the proposed reform of state-wide recreational fishing rules in 2012 as outlined in Fisheries Management Paper 252[34]. RFW completed a consultation report (available on request) which summarized the process and outcomes for consideration by the Department. The consultation process included visiting regional locations such as Albany, Broome, Carnarvon, Denham, Derby, Esperance, Exmouth and Karratha, as well as holding information sessions at several metropolitan locations, allowing RFW to connect with anglers all over the state. RFW also conducted an online survey and produced a "Have your say" document to encourage involvement and seek input. A total of 996 submissions were received, including 850 via the online survey. A follow-up survey was coordinated by RFW in early 2014 to record how changes to fishing rules implemented in February 2013 have affected angler's experiences. RFW received 943 responses to this survey from a range of regions that closely resembles the distribution of Recreational Fishing from Boat Licence (RFBL) holders throughout the state. The results supported the changes made by the Department.

WAFIC and RFW also actively facilitate involvement of interested parties through a monthly newsletter to subscribers, keeping them up-to-date with new initiatives, research results and issues. News and other relevant information is also publically-available on their WAFIC and RFW websites (www.wafic.org.au and www.recfishwest.org.au, respectively).

For licensees there are additional opportunities for participation. The most important forum in this respect are fishery-specific annual management meetings (AMMs), co-hosted by the Department and WAFIC for fishery licensees to discuss research, management, compliance and other specific issues affecting the fishery (e.g. marine park planning). AMMs underpin the decision-making process at the fishery-specific level and are generally coordinated by

[34] http://www.fish.wa.gov.au/Documents/management_papers/fmp252.pdf

WAFIC (under the SLA) – with the location, timing and priority of the meeting determined by the WAFIC Industry Consultation Unit (ICU) in liaison with relevant Departmental resource managers. AMMs tend to be scheduled for a time prior to the start of a licencing year or at the end of a fishing year.

AMMs are widely recognised by the commercial licence holders as a mechanism for receiving the most up-to-date scientific advice on the status of the fishery, facilitating information exchange between stakeholders and decision-makers and for discussing new and ongoing management issues. The invaluable information licensees provide to the Department at these meetings is considered when making research, management and compliance decisions.

16.2.3.5 Non-fisher Stakeholder Participation/Consultation

The Department has regard for social and economic considerations in addition to ecological outcomes in its task of delivering sustainable management and development of WA's fisheries and aquatic resources and encourages involvement of interested parties. Generally speaking, substantial changes to aquatic resource policy are only made by the Minister after submissions by interested and affected parties have been invited and duly considered. The release of Fisheries Management Papers (FMPs; discussion papers) and draft Ministerial Policy Guidelines for public comment are the most common ways the Department encourages involvement by interested stakeholders on such proposals.

As part of the development of the ARMA, the Department published Fisheries Occasional Publication No. 79[35] on its website in 2010 to seek public comment on the framework of the new Act. Through this process, all interested parties were given the opportunity to participate in the development of the primary legislation for the management of Western Australia's aquatic biological resources at an early stage in the process. Following Cabinet approval of the resulting Bill for introduction to Parliament in 2013, a copy of the Bill was put on the Department's website. Several open submissions were received and responded to. Once the draft Bill is tabled in Parliament, it is again on the public record and members of the public/interest groups can seek review of the legislation through their elected representatives as part of the political process.

Another example of the Department's commitment to engage with all stakeholder groups on major strategic matters is the manner in which it designed Western Australia's trial of an Ecosystem Based Fisheries Management (EBFM) framework, applied to the West Coast Bioregion (WCB), which was undertaken with direct involvement by a broad range of fisher and non-fisher stakeholders (see Fletcher et al. 2010). All stakeholders attended a series of meetings over 12 months during which high-level community values and objectives were established for the WCB. Together, these provided a description of the key resources of the WCB and what the WA community wanted to achieve from the management of these resources. At this point, the various roles and responsibilities of the relevant agencies and stakeholders were documented, which involved formal consultation with many stakeholder groups and agreements with other government agencies where jurisdictional arrangements

[35] http://www.fish.wa.gov.au/Documents/occasional_publications/fop079.pdf

overlapped. Stakeholders then identified the ecological assets that needed to be managed and potential social and economic issues associated with activities affecting these ecological assets. More than 600 concerns and issues were identified through this process, each of which was then subjected to a risk assessment process to prioritise risks and determine which assets and issues needed direct management action from a whole-of-government perspective and what level of action should be undertaken. Through this process of prioritising assets and considering/ranking all raised issues, the EBFM framework could accommodate the expectations of all stakeholders in a realistic and useful manner.

For the development of other high level overarching key policies, the Department may seek more targeted expertise-based input. These may take the form of tasked working groups and / or independent advisory, scientific and expert groups. Tasked working groups and panels can be established by the DG or the Minister to provide independent, expert advice relating to a range of fisheries management matters. Working groups are highly flexible and work to specific terms of reference within a particular timeframe. They are usually provided with a specified task, such as addressing resource access (e.g. closures and compensation) and allocation (e.g. IFM) or reviewing research, management or Government policy.

For example, in the case of the *Harvest Strategy Policy and Operational Guidelines for the Aquatic Resources of Western Australia* (Fisheries Management Paper No. 271), a draft policy was sent for input to several key stakeholders, including the Australian Fisheries Management Authority and the Australian Fisheries Management Forum (who developed the National Fishery Harvest Strategy Guidelines) and, in addition, to WAFIC and RFW (who reviewed the draft policy twice). Verbal briefings were provided if requested. WAFIC also commissioned a consulting company to undertake a review of the draft policy, which supported the outcomes. A number of suggestions were incorporated into the final policy, which was accepted without further comment by WAFIC and RFW.

Cross-agency programs are another way in which the Department collaborates with key stakeholders in order to meet Government outcomes and priorities. For example, the Department collaborated with DPaW to develop and implement the 2014-15 marine park collaborative operational plans (COPs). Each COP details the joint annual services the departments will undertake in the areas for which they have joint responsibility such as marine park education and interpretation, patrol and enforcement, as well as research and monitoring. The Department provided fisheries compliance training to 10 DPaW staff as part of a cross-authorisation program providing more efficient fisheries and marine park enforcement and education.

With respect to fishery-specific consultation processes, the Department recently developed a new Stakeholder Engagement Guideline (SEG), which sets out the processes through which the Department will seek out relevant information from, and involvement by, stakeholders and interested parties. The guideline has been signed off by the DG and is currently in the publication process. In accordance with the guideline, the Department encourages stakeholder participation at various well-defined points, such as during the development of a fishery-specific environmental risk assessment (ERA) report and the development of an aquatic resource harvest strategy. Accordingly:

- an ERA workshop for the AMF was held in December 2015 for which a number of key stakeholders – including representatives from industry, the conservation sector, other Government Departments, Aboriginal/community groups and independent experts – were invited to attend; and
- the *Abalone Resource of Western Australia Draft Harvest Strategy 2016 – 2021* was sent for comment to key stakeholders and released for a 30 day public consultation period in June 2016.

This demonstrates the guideline is broadly supported within the Department and is successfully being implemented.

A collaboration between the Department, Oceanwatch and the South Coast Natural Resource Management Group, which saw the development and implementation of a Code of Practice for commercial abalone fishers on WA's south coast, also provided a fitting opportunity for interested parties to be involved.

Stakeholder briefings are another tool the Department uses to keep stakeholders informed and included. For example, the Department ran two major stakeholder briefings on the WA Government's $14.5 million initiative to provide every WA commercial fishery the opportunity to be independently certified by the MSC's international gold standard for sustainable fisheries in March 2014 and October 2015 (see Appendix E). Invitations to the event were sent to a range of stakeholders including research organisations (Universities, AIMS, CSIRO), Government Departments (DPaW, Tourism, WA Museum, Agriculture, Development Commissions, Local Government), Retailers (Supermarkets, Seafood suppliers), NGOs (Conservational Council, Australian Marine Conservation Society, Wilderness Society, WWF), Education organisations (TAFE, Science Teachers Association, Perth Zoo, Scitech, AQWA) and other representative bodies (RFW, PPA, WAFIC). The event was well attended and well received.

It is also worth noting that all stakeholders have the opportunity to play a role in the management process of fisheries through direct contact with the Department, contact with the relevant sector Association (e.g. Abalone Industry Association of WA) or, in the case of compliance issues, by reporting any illegal fishing to FISHWATCH.

The Department aims to keep the general public informed through transparent management processes, a wealth of information on its website and the publication of two e-newsletters. "Catch!"[36] is the recreational fishing e-newsletter that is sent to over 77,000 subscribers every two months. Among other things, it highlights research results and encourages community participation with programs such as the "Send Us Your Skeleton" campaign. The "Freshwater Guardian"[37] quarterly e-newsletter delivers information on the work and

[36] http://createsend.com/t/y-688A52EA8E6CA32F

[37] http://createsend.com/t/y-8C23D6A42FAD0F84

research being conducted in WA's unique freshwater ecosystems. The Department also provides face to face opportunities for interested people to learn about the fishing industry through its roving Fisheries and Marine Officers and Community and Education Officers, front counter staff and displays at district and regional offices, stands at the various festivals (e.g. Fremantle Seafood Festival, Mandurah Crab Fest) and shows (e.g. Mandurah Boat Show).

16.3 Long-Term Objectives

The fisheries management legislation and policy in WA has clear long-term objectives to guide decision-making that are consistent with MSC Principles and Criteria and incorporate the precautionary approach. These objectives are explicit in fisheries legislation and are required by management policy.

Sections 3 and 4a of the FRMA set out the overarching long-term sustainability strategy for fisheries and the aquatic environment in WA. As set out in section 3, the objects of the FRMA are to:

"(a) to develop and manage fisheries and aquaculture in a sustainable way and (b) to share and conserve the State's fish and other aquatic resources and their habitats for the benefit of present and future generations."

The FRMA outlines the following means to achieve these objectives, including:

- *"Conserving fish and protecting their environment;*
- *Ensuring that the impact of fishing and aquaculture on aquatic fauna and their habitats is ecologically-sustainable and that the use of all aquatic resources is carried out in a sustainable manner;*
- *Enabling the management of fishing, aquaculture, tourism that is reliant on fishing, aquatic eco-tourism and associated non-extractive activities that are reliant of fish and the aquatic environment;*
- *Fostering the sustainable development of commercial and recreational fishing and aquaculture, including the establishment and management of aquaculture facilities for community or commercial purposes;*
- *Achieving the optimum economic, social and other benefits from the use of the fish resources;*
- *Enabling the allocation of fish resources between users of those resources, their reallocation between users from time to time and the management of users in relation to their respective allocations;*
- *Providing for the control of foreign interests in fishing, aquaculture and associated industries; and*
- *Enabling the management of fish habitat protection areas and the Abrolhos Islands reserve."*

Additionally, section 4a of the FRMA outlines the use of the precautionary principle in fisheries management:

"*In the performance or exercise of a function or power under this Act, lack of full scientific certainty must not be used as a reason for postponing cost-effective measures to ensure the sustainability of fish stocks or the aquatic environment.*"

The ARMA more-explicitly incorporates broader ESD and biodiversity conservation goals, with objects to:

"(a) ensure the ecological sustainability of the State's aquatic resources and aquatic ecosystems for the benefit of present and future generations; and (b) to ensure that the State's aquatic resources are managed, developed and used having regard to the economic, social and other benefits that the aquatic resources may provide."

In order to effectively deal with community expectations for aquatic resource management, these legislative objectives will be translated into clearly-defined operational arrangements and procedures for each resource / fishery in the form of a fishery- or resource-specific harvest strategies. The harvest strategies will be used to implement adaptive and precautionary approaches to fisheries management and includes the identification of harvesting approaches, the establishment of precautionary reference points and harvest decision and control rules that describe how fishing exploitation should be adjusted as a function of stock size and other relevant factors (DoF,2015).

The FRMA is also supported by a number of strategic (e.g. Strategic Plan 2016-2020) and public policy documents (e.g. Fisheries Policy Statement 2012) which further define Western Australia's commitment to management principles consistent with MSC principles 1 and 2 (e.g. ESD and EBFM). The Department's *Strategic Plan 2016 - 2020*[38] sets out clear and explicit long term objectives which include-

- Community and stakeholder benefits: Working together to provide value to, and to be valued by, the community and our stakeholders.
- Sustainability: Sustainably managing WA's aquatic resources and fisheries through a risk-based, dynamic and adaptive approach; and supporting resilient aquatic resources and ecosystems by being responsive to changing conditions and management needs.
- Management excellence: Striving for excellence through strong accountability and governance systems, and effective and efficient practices across all areas of the Department.

[38] http://www.fish.wa.gov.au/Documents/corporate_publications/strategic_plan_2016-2020.pdf

17 Fishery-Specific Management System

This section focuses on the management system directly applied to the AMF and includes:

- Fishery-specific management objectives;
- The decision-making processes used in the Fishery;
- The compliance and enforcement system and its implementation; and
- The system of monitoring and evaluating the performance of the management system in meeting the Fishery's objectives.

Fisheries legislation forms the main component of the control system for commercial fisheries in WA and the AMF is primarily managed under the *Abalone Management Plan 1992*[39]. The control measures in place in the AMF, including licence requirements (limited entry), species and spatial restrictions, size limits, and the quota system are summarised in the abalone harvest strategy.

17.1 Fishery-Specific Management Objectives

The long term ecological objectives of the AMF, which are consistent with the overarching objective of the FRMA, are clearly defined in the abalone harvest strategy (DoF 2017) as:

1) To maintain spawning stock biomass of each target species (i.e. Roe's, Greenlip and Brownlip abalone) at a level where the main factor affecting recruitment is the environment;
2) To ensure fishing impacts do not result in serious or irreversible harm to bycatch species populations;
3) To ensure fishing impacts do not result in serious or irreversible harm to endangered, threatened and protected (ETP) species populations;
4) To ensure the effects of fishing do not result in serious or irreversible harm to habitat structure and function; and
5) To ensure the effects of fishing do not result in serious or irreversible harm to ecological processes.

The harvest strategy has been developed in line with the Department's *Harvest Strategy Policy* and translates the ecological objectives into short-term operational objectives with measureable performance indicators to enable monitoring of the fishery's performance against the objectives. The harvest control rules articulate pre-defined, specific management actions designed to maintain each resource at target levels and achieve the management objectives for the fishery.

[39] http://www.slp.wa.gov.au/statutes/subsiduary.nsf/0/ABC550C1B146589348257E050001EF63/$file/34+abalone+management+plan+++10.03.15.pdf

One of the long-term objectives of the FRMA is to achieve the optimum economic, social and other benefits from the use of fish resources for both direct stakeholders (e.g. the commercial fishing industry, recreational fishers, customary fishers, conservation sector) and indirect stakeholders (e.g. the tourism sector, fishing tackle suppliers, restaurants and retail sector, consumers and the wider WA community). In line with the principles of ESD, the abalone harvest strategy also includes economic and social objectives, relating to the provision of opportunities to ensure (1) commercial fishers can maintain / enhance their livelihood and (2) that all fishers can maximise cultural, recreational and / or lifestyle benefits of fishing. The economic and social objectives for the commercial and recreational abalone fishery do not currently have explicit performance measures within the harvest strategy. Rather, it is through formal consultation processes that regulatory impedi ments to maintaining or enhancing economic return, and maximising social benefits of fishing, are discussed. Where possible, and in due consideration of ecological sustainability, fisheries management arrangements can be adjusted or reformed to help meet these objective. Once suitable and measurable indicators for monitoring performance against the economic and social objectives have been identified, these will be included in future revisions of this harvest strategy.

17.2 Decision-Making Processes

There are established decision-making processes in the AMF that result in measures and strategies to achieve the objectives listed above. These processes and the decision making framework, roles and responsibilities are explicit in legislation (e.g. *FRMA, Abalone Management Plan 1992*) and policy documents (e.g. Fisheries Policy Statement) and are publically available.

There are two main processes for making decisions about the implementation of management measures and strategies in the AMF:

- Annual decision-making processes that may result in measures to meet the short-term fishery objectives (driven by the annual quota limit control rules contained in the abalone harvest strategy); and
- Longer-term decision-making processes that result in new measures and / or strategies to achieve the long-term fishery objectives (i.e. changes to the management system such as an amendment to the *Abalone Management Plan 1992*). These decisions are generally taken by the CEO or Minister, after consultation with commercial and recreational fishers. However, the FRMA provides for decisions to be taken without such consultation where there is an urgent need for action. Consultation in this case may then be retrospective.

Decision-making processes can also be triggered following the identification of new or potential issues as part of an ecological risk assessment (generally reviewed every 3 – 5 years), results of research, management or compliance projects or investigations, monitoring or assessment outcomes (including those assessed as part of the harvest strategy) and / or expert workshops and peer review of aspects of research and management.

Once an issue has been identified, mitigation measures are developed and implemented in consultation with industry. Alternatively, if appropriate, additional research may be undertaken, with research results used to inform management action. A recent example was the decision to completely close Area 8 of the Roe's abalone fishery following the mass mortality event associated with the marine heatwave in 2010/11.

17.2.1 Annual Processes

Monitoring and research results are presented to the AIAWA in briefings conducted by Departmental research staff during the season. These briefings provide the AIAWA with information such as current state of the stocks, abalone meat condition, etc. which is fed back to industry meetings whereby co-management can occur.

The annual TACC for the Abalone Managed Fishery is determined by the Director General (DG) of the Department through a consultative process that occurs at the end of the abalone fishing season from November to March each year (Figure 17.1). Based on results from the annual assessments of Roe's, Greenlip and Brownlip abalone, preliminary advice on the recommended SHLs (for each species in their relevant management areas), and an industry consultation form, are developed by Departmental research staff and sent to abalone licence holders, the AIAWA and WAFIC for consultation. Following the receipt of the this preliminary advice, AIAWA holds an industry meeting to discuss the research summary and determine the industries view on the recommended SHLs for the coming season. Following this industry meeting, AIAWA advises the Department in writing of their recommended SHLs and any additional feedback as required. The Department's SHL recommendations are considered by the AIAWA and abalone industry more broadly at the AMM, along with co-management arrangements such as voluntary size limits and any fish-down arrangements.

Final recommendations on the sustainable harvest level (SHL) (from the Department's research division), along with the AMM and AIAWA positions on the recommendations, are then provided to the DG of the Department for consideration and a final determination. Once the final determination is made, the DG notifies AIAWA in writing through publication of a Notice of Determination[40], and licence renewals and season arrangements for the following year commence.

[40] http://www.slp.wa.gov.au/statutes/subsiduary.nsf/Fisheriesexec?openpage

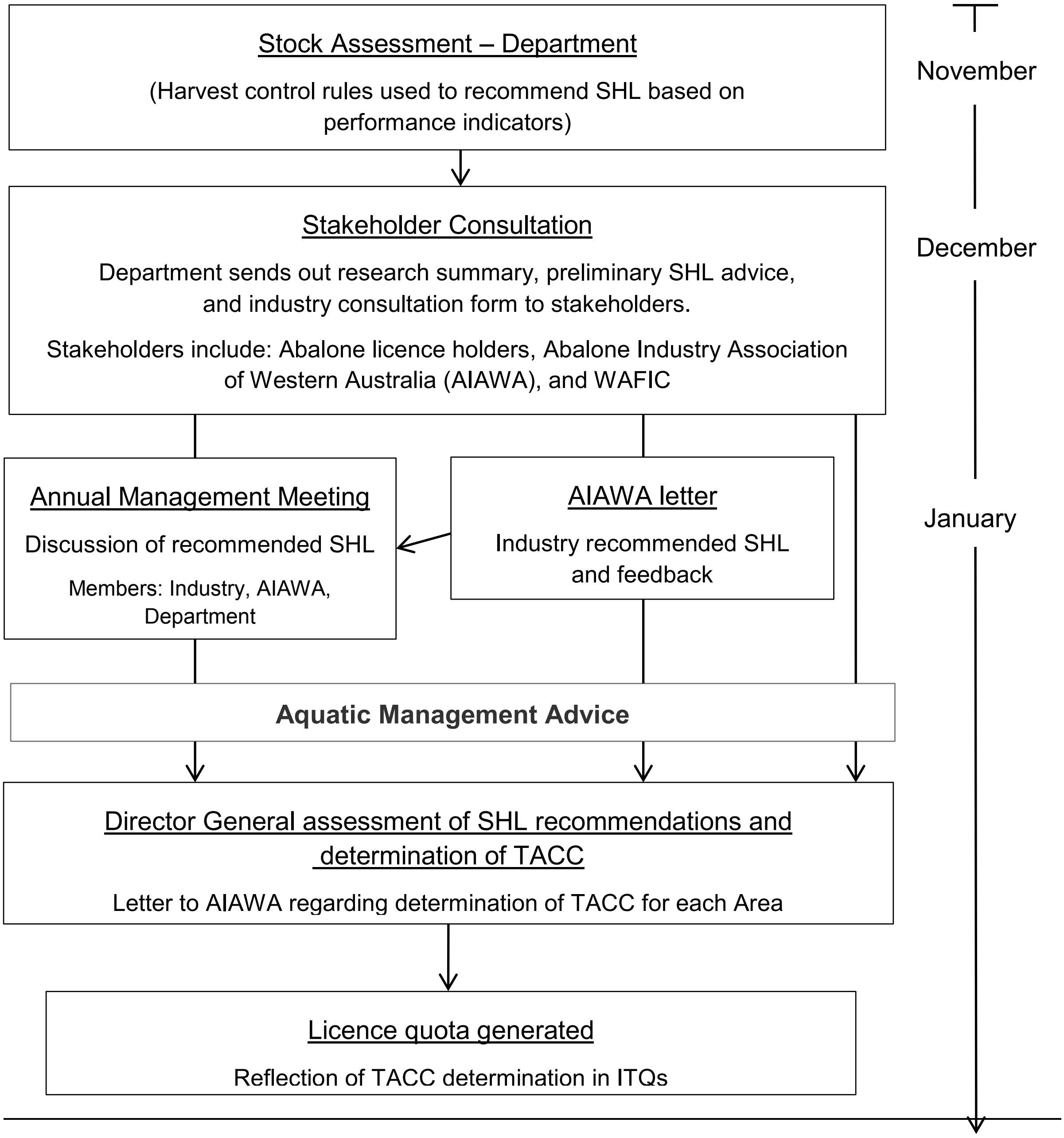

Figure 17.1. Annual TACC setting process for the commercial Abalone Managed Fishery

17.2.1.1 Harvest Strategy

The *Abalone of Western Australia Harvest Strategy 2016 – 2021* guides management responses in the event that a short-term objective is not met. The harvest control rules and management actions are commensurate with the breach of Reference Levels. The harvest strategy ensures that if catch rates (the performance indicator) fall below the Threshold the TAC will be reduced and set at 70% of the long term level. If the catch rate is equal to or less that the Limit Reference Levels, the TAC will be reduced to 0-50 % of the long term level depending on the severity of the breach. In addition, if the impacts of fishing on bycatch species, ETPs, habitats or ecosystems are no longer at an acceptable level, research and management staff will undertake a review of the reasons. This review includes an investigation of any changes that may have taken place in the fishery (e.g. fishing grounds, seasonality, etc.), environmental factors, such as variations in weather or water temperature, or other external factors, such as changes in any market forces that influence fishing effort (e.g. fuel prices, demand, etc.). This review is often undertaken in conjunction with the licence holders, as they provide many of the details needed during the review process (e.g. changes in effort).

The outcomes from the previous season's assessment against the defined reference levels (including any additional reviews undertaken as described above) are provided to industry by the Department both prior to and at the Annual Management Meeting. It is at this stage that any issues arising from the annual evaluation of the fishery's performance are discussed. Where sustainability is considered to be at risk, changes to the management arrangements are discussed with the licensees, agreed upon and proposed changes for the following fishing season are submitted to the CEO for assessment and determination.

17.2.1.2 Annual Management Meetings

The Annual Management Meeting (AMM) is typically held in January or early February each year prior to the setting of the TACC. Participants include Department staff, the AIAWA, WAFIC, licence holders and divers. Research, management and compliance reports are provided at the meeting. The primary objectives of the meeting are to discuss and agree on the management arrangements for the fishery for the following season including:

- The TACC;
- Size limits;
- Abalone research and assessment results;
- Evaluation of the fisheries performance; and
- Changes to management arrangements.

17.2.2 Long-term Processes

There is also an established decision-making process in place to ensure the long-term management objectives are met. This process is triggered primarily as a result of analysing longer-term patterns or trends in the annual fishery performance. Variations in the operating environment caused by other factors (e.g. environmental conditions, market forces, fishing behaviour, conflicts with other user groups, marine planning, etc.) can also trigger an investigation and discussion that may lead to more-permanent changes (i.e. lasting more than one season) in the management system.

Longer-term changes are often implemented in legislation. The decision-making process that respond to issues that results in changing legislation involves a high level of consultation with industry and other stakeholders through a number of mechanisms, including:

- Directly in writing;
- At licensee meetings;

- At internal workshops, e.g. harvest strategy development, compliance risk assessments;
- Through the establishment of a tasked working group; and/or
- As part of external / expert workshops (e.g. ecological risk assessments).

These forums are used to work through options for addressing emerging issues and provide the opportunity for decision-makers to consider all interested stakeholder advice. Comments provided during this process also allow managers to take into account the broader implications for management.

Following this consultation process, any new proposed management measures or strategies that require changes to legislation are provided to the statutory decision maker (usually the DG or the Minister) by the relevant Departmental staff (Aquatic Management).

A Scientific Advisory Group (SAG) was formed in 2015 to facilitate communication on scientific research and development to the wider industry and to provide and review scientific advice in relation to research and development and stock assessment in the abalone fisheries. The SAG consists of industry and research and management staff from the Department. Three formal meetings were held in 2015. The SAG also prepared two research and development funding applications. Research results inform management of changes to the system often in the longer term.

17.2.3 Responsiveness of Processes

The governance system in place allows for a timely response in instances where management changes need to be applied to alleviate unacceptable risks to stocks. One example of highly responsive management action in the AMF was the closure of Area 8 for the commercial take of Roe's abalone following a marine heatwave in 2010/11 which resulted in a mass mortality event. Area 8 remains closed and will be closely monitored for the recovery of stocks.

For the recreational fishery, the bag limit for Roe's abalone was reduced from 20 to 15 in 2014 to help protect stocks following a decline from environmental factors[41]. The Department's Annual Report highlights other examples of "taking action now to ensure fish for the future".

The performance of the fishery continues to be tracked annually against the harvest strategy control rules, with pre-agreed decision rules requiring action if threshold and limit reference points are met. Periodic changes to TACs (e.g. Area 3 Greenlip abalone) result.

Decision making responses such as those noted above are subject to various transparency requirements which are met through media releases, publications of reports and papers on the Department's website, written advice to licence holders, identified in the Annual Report and through public access to legislation.

[41] http://www.fish.wa.gov.au/About-Us/Media-releases/Pages/Catches-for-metro-abalone-season-will-be-closely-monitored.aspx

Section 43 of the FRMA also provides the power for immediate action by allowing the Minister for Fisheries to prohibit fishing activities (i.e. close an area to fishing) should information come to hand that purports to an unacceptable risk. Should immediate action be required, section 65(4) of the FRMA provides for the Minister to amend a management plan without consultation if, in the Minister's opinion, the amendment is required urgently.

17.2.4 Use of Precautionary Approach

The precautionary approach underlies decision making processes for all fisheries in the State (see Section 4 of the FRMA) and is an important consideration in the Department's EBFM framework and risk assessment process. EBFM is the operating basis for implementing sustainable fisheries and ecosystem management by identifying ecological assets in a hierarchical manner the risks associated with them. Thus, the levels of knowledge needed for each of the issues only need to be appropriate to the risk and the level of precaution adopted by management. The ecological risks associated with each of WA's fisheries are annually assessed and reported within the Status Reports on the Fisheries and Aquatic Resources of Western Australia (Fletcher and Santaro 2015). In addition to the annual internal risk assessments undertaken by the Department, external risk assessments involving stakeholders such as fishers, AIAWA, and other government departments are undertaken to ensure that there are no unacceptable threats to the environment from fishery. The last AMF risk assessment was held in December 2015.

The control rules in place under the abalone harvest strategy incorporate a precautionary approach to the decision-making process by requiring a review of the fishing activities and management arrangements when a threshold reference level is met (i.e. prior to reaching the limit level). The use of a threshold level provides for an inherent 'early warning system', with any potential issues recognised, investigated and potentially addressed early. The frequency of evaluation (annually) allows for management action to alleviate adverse impacts before a limit level is reached and long-term sustainability may be compromised.

For example, during the 2012/13 TACC setting process for the area 2 Greenlip fishery, the performance indicator breached the threshold reference level. Consequently, the decision rule concluded that the TACC should be set at the long term sustainable level of 30.0 t. Following industry consultation on stock status, and examination of the outcomes of a new harvest control rule (incorporating egg conservation targets achieved through fishing mortality indicators), a precautionary approach was adopted for area 2 and the TACC was maintained at 28.8 tonnes.

Another example of the precautionary approach in the AMF is that the commercial industry has its own self-imposed size limits for the Greenlip and Brownlip, which can vary from 153 mm to 145 mm and can change between areas whenever industry sees the need. The legal minimum length is 140 mm shell length.

17.2.5 Accountability and Transparency

The Department provides a comprehensive range of formal reports to stakeholders on annual fishery performance, including information on fishery outcomes, management, relevant findings and recommendations from research, monitoring, evaluation and review activities. This information is published and publically available on the Department's website and includes:

- The *Annual Status Reports of the Fisheries and Aquatic Resources of Western Australia: the state of the fisheries* (e.g. Fletcher and Santoro 2015).
- The Department's *Annual Report* to Parliament.
- The *Research, Monitoring, Assessment and Development Plan 2015 – 2020* Fisheries Occasional Publication No. 122, Department of Fisheries 2015.
- Fisheries Management Papers (FMP), Fisheries Research Reports (FRR), Fisheries Occasional Papers (FOP) and peer-reviewed scientific journal articles. For example, recent publications relevant to the AMF includes:
    - The *Abalone Resource Harvest Strategy 2016 – 2021.*
    - Fisheries Research Report No 269. Bioeconomic evaluation of commercial-scale stock enhancement in abalone (Hart and Strain (eds), 2016)
    - Fisheries Management Paper No. 204. Integrated Fisheries Management Report – Abalone Resource. (DoF, 2005).
    - Fisheries Management Paper No. 226. Integrated Fisheries Management Allocation Report – Roe's Abalone Resource, Perth Metropolitan Region. (DoF, 2009).
    - Fisheries Management Paper No. 243. Future management of the metropolitan recreational Roe's abalone fishery. (DoF 2010).
    - Fisheries Research Report No 227. Assessment of the risks associated with the release of abalone sourced from abalone hatcheries for enhancement or marine grow-out in the open ocean areas of WA. (Jones and Fletcher, 2012).
    - Fisheries Occasional Publication No 32. Allocation of the Western Australian Abalone Resource between user groups. (DoF, 2005).
    - Fisheries Research Report No 185. Performance indicators, biological reference points and decisions rules for Western Australian abalone fisheries (*Haliotis sp*): (1) Standardised catch per unit effort. (Hart et al. 2009).
    - Fisheries Research Report No. 170. Biomass and commercial catch estimates for abalone stocks in areas proposed as sanctuary zones for the Capes Marine Park. (Hesp, A et al 2008).
    - Fisheries Research Report No. 241. Biology History and assessment of Western Australian abalone fisheries. (DoF, 2013).

- Hart, A.M., Strain, L., Fabris, F., Brown, J., Davidson, M. (2013). Stock enhancement of Greenlip abalone: (1): Long-term growth and mortality. *Reviews in Fisheries Sci*ence 21: 299-309.
- Hart, A.M., Fabris, F., Murphy, D., Brown, J., Strain, M., Davidson, M., (2013). Stock enhancement of Greenlip abalone: (2): Population and ecological effects. *Reviews in Fisheries Science* 21: 310-320.
- Hart, A.M., Strain, L.W.S., Hesp, A. (2013). Stock enhancement of Greenlip abalone: (3): Bioeconomic evaluation. *Reviews in Fisheries Sci*ence 21: 354-374.
- Mayfield, S., Mundy, C., Gorfine, H., Hart, A.M., Worthington, D. (2012). Fifty years of sustained production from the Australian abalone fisheries. *Reviews in Fisheries Sci*ence 24: 220-250.

Fishery-specific legislation, including the FRMA, FRMR and Government Gazettes are publically available on the State Law Publishers Website[42]. The implementation of any new statutory arrangements is formally communicated to the licence holders in writing.

The Department is required to maintain a public register of authorisations (pursuant to section 125 of the FRMA) for all fisheries that is available for public inspection, subject to payment of the prescribed fee. The register contains the names and business address of the holder, any security interest in the authorisation, entitlement, black marks and other details as prescribed.

The management system is able to respond to findings and recommendations emerging from research, monitoring, evaluation and scientific publications. An example of a formal report with decisions on recommendations for the allocation of the Roe's abalone resource can be found on the website[43].

The harvest strategy outlines the decision rule framework for annual quota setting in the fishery based on research and monitoring of standardised CPUE data. Licensees are provided with information on the catch history, research results and recommendations for the following season prior to the formal TACC determination decision. The harvest strategy is published on the Department's website.

17.2.6 Approach to Disputes

The Department proactively avoids legal disputes through the involvement of stakeholders in management decisions and the educative role played by FMOs in the field. These processes allow for impacts of proposed management changes to be considered and for the resolution of conflicts. The IFM process for allocation of the Roe's abalone resource[44] is an example of a transparent process that contained multiple consultation opportunities including a stakeholder workshop. Additionally, the collaboration and regular communication between the

[42] State Law Publisher website https://www.slp.wa.gov.au/index.html

[43] http://www.fish.wa.gov.au/Documents/minister_determinations/determination-roe-abalone-resource.pdf

[44] http://www.fish.wa.gov.au/Documents/management_papers/fmp226.pdf

Department and the AIAWA has resulted in a mutual and in-depth understanding of industry operations and the fishery management system. The AMM is the key forum for discussion of management matters in the AMF where licence holders actively participate in discussions including the TACC settings.

Should a dispute arise, there are well-established mechanisms for administrative and legal appeals of decisions, as prescribed under part 14 of the FRMA. These mechanisms have been used and tested across several fisheries, although there have been no SAT decisions made relating to the AMF. Any SAT decisions are binding on the Department and judicial decisions are responded to promptly.

17.3 Compliance and Enforcement

In order to optimally utilise compliance resources, enforcement effort is designed to maximise the potential for fishers to voluntarily comply with legislation, while at the same time provide a reasonable threat of detection, successful prosecution and significant penalties for those who do not comply. This is achieved through a range of strategies, including effective monitoring and surveillance, appropriately trained staff, suitable deterrents in the forms of fines and administrative penalties and targeted education campaigns.

The Department's Regional Services Division (RSD) delivers the Department's compliance and education services, with the support of the Communications and Education Branch. There is nearly 200 RSD staff across the State, spread throughout regional and district offices. Regional operational areas are supported by the Regional Services Branch's Perth-based Central Support Services and Strategic Policy sections.

For compliance purposes, the AMF is considered part of the West and South Coast Bioregion and the majority of compliance services are delivered by Fisheries and Marine Officers (FMOs), based at the Busselton, Albany and Esperance offices, from the Bunbury office if required and district patrol vessels. Abalone fishing north of the Busselton jetty is the responsibility of the wider metropolitan regional staff located in Mandurah, Fremantle and Hillarys. The south coast bioregion compliance manager is required to attend the AMM, provide a compliance update and answer any questions from industry.

During 2013/14, the South Coast Bioregion FMOs delivered a total of 2,562 hours and in the West Coast Bioregion a total of 21,917 hours of compliance and community education services in the field (Fletcher and Santoro, 2015). A continuing emphasis was placed on employing risk- and intelligence-based approaches to compliance planning and prioritisation.

FMOs undertake regular land, air and sea patrols using a compliance delivery model supported by a risk assessment process and associated operational planning framework. Compliance activities in the AMF include land patrols, sea patrols, landing inspections, covert surveillance and operations, factory inspections, wholesale / retail checks, aerial surveillance and intelligence gathering. FMOs are well equipped with resources including all terrain vehicles, small patrol vessels and surveillance equipment. They also provide a wide variety of educational and extension services through formal and informal media to commercial fishers, fishing related operations (wholesale / retail / processors), other resource management agencies and community members (Fletcher and Santoro, 2014).

The Department also delivers at-sea marine safety compliance services on behalf of the Department of Transport (DoT) in the Metropolitan Region extending from Mandurah to Lancelin (excluding the Swan and Canning Rivers). Outside of this area, marine safety is unfunded, and inspections are carried out in combination with fisheries compliance inspections. Marine park education and compliance functions are also undertaken in the Ngari Capes Marine Park (South West), Shoalwater and Marmion Marine Parks (Metropolitan) and Jurien Bay Marine Park (Midwest). These functions are primarily related to the integrity of management arrangements for the different zoning within the marine parks (Fletcher and Santoro 2015).

17.3.1.1 Implementation of Monitoring, Control and Surveillance Systems

Monitoring, control and surveillance (MCS) mechanisms ensure a fishery's management measures are enforced and complied with. The MCS system for the AMF is administered by the Department's RSD through the Abalone Operational Compliance Plan.

17.3.1.2 Compliance Risk Assessments

The Department conducts compliance risk assessments every 1 – 2 years in major fisheries (e.g. the AMF) or those perceived to be at high risk and every 3 – 5 years in minor fisheries. The risk assessment process feeds into an Operational Compliance Plan[45] (OCP), which provides the formal framework for the delivery of specific compliance services that remove or mitigate those identified risks.

The compliance risk assessment process identifies modes of offending, compliance countermeasures and risks. The process relies on a weight-of-evidence approach, considering information available from specialist units, trends and issues identified by local staff and Departmental priorities set through Fish Plan. The risk assessment process can be triggered by a change in management arrangements (including the subsequent introduction of new legislation) in a fishery / resource. For example, a compliance risk assessment for the commercial abalone fishery was conducted in 2015 to review the existing risk assessment in light of the fishery moving to extended fishing trips. Identification of any new major issues that would require RSD managers to assess their compliance program also include (but not limited to):

- A sectoral complaint;
- Ministerial or Parliamentary enquiry;
- Management framework issues;
- Public complaint or sustained media interest;
- Market changes;

[45] By their nature, finished OCPs contain sensitive information and are only made available to authorised compliance personnel.

- Intelligence; and/or
- Upward trend in non-compliance.

There are broadly three levels of compliance risk assessment and associated planning and monitoring undertaken by the RSD. The AMF undergoes a Level 2 compliance risk assessment, planning and monitoring, with a review and update of compliance assessment and associated compliance strategies, manuals and procedures. Risk assessments are usually undertaken by the relevant Compliance Manager, in consultation with the Regional Manager, Regional FMOs and Fisheries Management Officers, Supervising FMOs and often broader departmental staff, with a focus on the introduction of major or important changes affecting compliance delivery, which may include changes arising from technology, fishing practices, community attitudes, environmental factors or policy re-alignment.

17.3.1.2.1 Operational Compliance Plan

The Abalone OCP provides a formal process for staff to carry out defined compliance activities in order to monitor, inspect and regulate the compliance risks in the AMF, and in turn confirm they are at an acceptable and manageable level. The Abalone OCP is reviewed following each compliance risk assessment. In addition, annual reviews of the OCP allows the plan to be modified to take into account changes in technology, fishing practices, community attitudes and evolving factors.

Following a formal review of the OCP and associated compliance strategies, compliance activities are prioritized in accordance with risk, budget and resourcing considerations.

Annual planning meetings are held with regular specific planning of day-to-day targeted and non-targeted patrols linked to the OCP based on resources and competing priorities.

17.3.1.2.2 Resourcing Compliance Operations

RSD staff co-ordinate the allocation and prioritisation of existing resources across all programs in the region based on risk assessments and related OCPs for each program. Compliance planning meetings are held regularly to ensure staffing requirements are adequate for scheduled compliance activities.

Available compliance resources are allocated based on the risk assessment outcomes and the contacts and compliance statistics which are captured, reported on and reviewed at the end of each year. The allocated resources and compliance strategies (i.e. monitoring, surveillance and education activities) are outlined in the OCP, which specifies planned hours and staff allocated to key compliance tasks and duties. This planning and delivery process allows for more-targeted, effective and relevant compliance service in terms of both cost and activities.

There is also flexibility within the region to allocate additional resources to respond to changes, such as the need for a planned tactical operation in response to new intelligence. This may be achieved by redirecting existing resources or seeking additional resources from other areas or units. Similarly, changing priorities and resourcing on a local level can involve reducing planned delivery of compliance services to ensure resources are directed to where they are most needed.

17.3.1.2.2.1 Key Compliance Personnel

The Regional Office of the Department relevant to the AMF is located in Albany, and staff located at this office and surrounding district offices provide the primary on-ground compliance and education delivery for the fishery. Key compliance and enforcement personnel located in the region and their responsibilities include:

1. Compliance Manager
    - Overall responsibility for the OCP, including creating the plan, reviewing it and ensuring its outcomes are delivered;
    - Responsible for providing sufficient and appropriate resources to achieve the operational compliance plans outcomes;
    - Ensuring that FMO safety is considered at all times and the Region's occupational health and safety requirements are met;
    - Monitoring the progress of the OCP during its execution;
    - Consulting with all key stakeholders when reviewing the OCP; and
    - Reporting outcomes.
2. Supervising FMO
    - Field responsibility for the OCP, including reporting any deficiencies in the execution of the plan and reporting the outcomes as they are delivered or achieved;
    - Supervision of staff performance in relation to the OCP;
    - Ensuring that FMO safety is considered at all times and the district's occupational health and safety requirements are met;
    - Provide briefings and de-briefings as required;
    - Ensuring all equipment required to execute the OCPs is serviced, operational and available; and
    - Liaising with staff from other agencies operating in a joint servicing arrangement.
3. FMOs
    - Day-to-day responsibility for the execution of the OCP in their interaction with users of the Fishery;
    - Ensuring that FMO safety is considered at all times and that individual occupational health and safety requirements are met;
    - Reporting any deficiencies and outcomes in a timely and accurate manner; and

- Complying with the, *Prosecution Policy Guidelines*[46], the Department's *Code of Conduct* and promoting the vision and mission statement of the Department and its joint-servicing partners. .

FMOs are formally appointed pursuant to the FRMA, which clearly sets out their powers to enforce fisheries legislation, enter and search premises, obtain information and inspect catches. FMOs are highly trained; they must have a thorough knowledge of the legislation they are responsible for enforcing and follow a strict protocol for undertaking their duties in accordance with the FRMA and in recording information relating to the number and type of contacts, offences detected and sanctions applied.

In addition to regional compliance staff, there are a number of units within the Department that support the delivery of compliance outcomes, including:

1. Patrol Boat Business Unit
   - Provides large oceangoing patrol vessels for State-wide offshore compliance operations and education activities.
2. Vessel Monitoring System[47] Unit
   - Operates the Department's vessel monitoring system (VMS) to help manage the State's commercial fisheries.
3. Serious Offences Unit
   - Undertakes covert operations and deals with connections to organised crime;
   - Conducts major investigations and initiates proactive intelligence-driven operations;
   - Targets any serious and organised criminal activity within the fishing sector;
   - Provides specialist investigative training; and
   - Provides technical assistance in relation to covert surveillance.
4. Fisheries Intelligence Unit
   - Responsible for providing intelligence reports to support strategic, operational and tactical needs of compliance programs; and
   - Collects and analyses compliance data.
5. Compliance Statistics Unit
   - Develop monitoring and sampling programmes to support compliance delivery;
   - Collects and analyses compliance data to identify trends; and

[46] The *Prosecution Guidelines* is a confidential guide used by FMOs that provides a tiered framework for dealing with fishery offences, thus it is not a publically-available document.

[47] Note VMS is not required to be used for AMF vessels

- Provides compliance statistics to help target enforcement activities.

6. Prosecutions Unit
    - Manage the electronic system used to issue warnings or commence prosecution processes when offences are detected; and
    - Custodians of information relating to detected offences which can be used for official reporting purposes.
7. Strategic Policy Section of the Regional Services Branch
    - Develops and implements strategic compliance policy and standards;
    - Provides compliance risk assessments for fisheries;
    - Provides review and implementation of fisheries management and compliance legislation;
    - Oversees collection and analysis of compliance data;
    - Oversees compliance research projects;
    - Develops occupational health and safety standards for FMOs; and
    - Provides recruitment and training of new and existing FMOs.

17.3.1.3 Formal Monitoring, Control and Surveillance Systems

There are four focal areas for monitoring, control and surveillance in the AMF:

1. Monitoring of quota through auditing CDRs;
2. Landing inspections and CDR checks;
3. Factory, wholesale and retail inspections; and
4. Black market.

17.3.1.3.1 Wildstock quota management

The long term sustainability of wildstock abalone is primarily managed through the annual setting of the TAC of the resource and the associated annual allocation of commercial quota. Abalone divers are required to provide daily catch and disposal records (CDRs) containing information on the number and weight of abalone and the date, location, details of persons harvesting the abalone and the approved fish processor/consignee. These CDRs form the basis of the compliance program and also assists with research and management of the fishery.

Quota compliance is primarily conducted by inspecting the CDRs at the point of landing and at approved processor facilities to ensure the weights are correct. The CDR form is in triplicate to ensure checks and balances are in place during transportation and at the processors facility. Exceeding entitlement and failure to complete the CDRs correctly are offences that could result in prosecution. Penalties are commensurate with the amount of abalone over quota.

17.3.1.3.2 Marine Park Compliance

There are several marine parks, marine reserves and other fishing closures within the boundaries of the AMF including Jurien Bay, Marmion, Rottnest Island, Shoalwater Islands, Ngari Capes, Lancelin FHPA, Cottesloe FHPA and many wreck or reef observations areas. Fishing for abalone is completely prohibited, restricted or allowed in all or parts of each of these marine reserves. Regular marine patrols are undertaken to ensure that abalone fishing is not occurring in prohibited or restricted areas. There are currently several dedicated vessels and staff for marine patrols of the marine parks both within the Department and DPaW.

17.3.1.3.3 Daily Patrol Contact Form

Surveillance and compliance activities undertaken during air, sea and land based patrols are recorded and reported by FMOs using a daily patrol contact (DPC) form (Appendix F). The purpose of these forms is to record and classify contacts and time spent in the field for each FMO. These forms provide managers with information about:

- The number of field contacts made, which provides a context for the number of offences detected and reported. This includes random contacts and offences from random inspections;
- The number of targeted[48] contacts made, which provides information on the effectiveness of the intelligence gathering capacity at identifying 'targets';
- The number of face-to-face contacts outside of a compliance context (referred to as 'A/L/E' contacts) made, which provides information on the educative effort of FMOs in a fishery; and
- Other routine information that can be used to help managers' report on where and which fisheries FMOs have undertaken patrols. This information is also used in patrol planning and risk assessments and ensures accountability of the compliance program.

A 'contact' occurs when an FMOs has a chance of detecting illegal activity being undertaken by a fisher and includes personal contact (face-to-face), covert activities (e.g. deliberate, intensive surveillance) and unattended gear checks (contact statistics available in Table 17.1).

Table 17.1. Total contacts for the Commercial Abalone Fisheries for 2010 – 2014

Year	2010	2011	2012	2013	2014
Greenlip/Brownlip fishery	119	91	103	130	77
Roe's fishery	45	30	17	34	16
Total	164	121	120	164	93

The DPC form also includes a section to record details of individual commercial vessel inspections / checks. These inspections may involve:

[48] A targeted contact is one that is initiated because available information indicates that an offence may have been committed or may be more likely to have been committed.

- Inspection of quota;
- Inspection of abalone size;
- Inspection of licences; and
- Inspection of Vessels.

The Department has also implemented an initiative called Fishwatch[49], whereby the community can report instances of suspected illegal fishing. The Fishwatch phone line provides a confidential quick and easy way to report any suspicious activity to Departmental compliance staff.

17.3.2 Applying Sanctions

There is an explicit and statutory sanction framework that is applied should a person contravene legislation relevant to the AMF. Sanctions to deal with non-compliance are listed in the FRMA and FRMR and can be severe. These sanctions consist of:

- Significant monetary penalties;
- Licence cancellations or suspensions; and,
- Confiscation of gear and catch.

Breaches in fishery rules may occur for a variety of reasons, and FMOs undertake every opportunity to provide education, awareness and advice to fishers; however, all offences detected in the fishery are considered to be of significant concern and are addressed by FMOs via the prosecution process outlined in the Department's *Prosecution Guidelines* and rules set out in the FRMA and FRMR. When an FMO detects a breach of the FRMA, the officer determines if the matter is prosecutable (according to the Department's *Prosecution Guidelines*) and where it is, a prosecution brief is prepared by the FMO and submitted to their supervisor. Based on the *Prosecution Guidelines*, there are four tiers of enforcement measures applied by FMOs when an offence is detected in the fishery including:

- Infringement warnings: These are written warnings issued for minor fisher offences. They do not incur a fine, but are a written record of a minor offence that may be referred to by Fishery Officers in the future. A certain number of infringement warnings for similar offences in a designated period may result in an infringement notice;
- Infringement notices: These are written notifications to pay a monetary penalty for an observed offence. Fishers issued infringement notices may choose to defend the matter in court; however, most fishers choose to pay the fine. The Department may initiate a prosecution brief for habitual offenders;
- Letters of warning: A letter of warning (LOW) is a formal record of a commercial offence where a prosecution may be unduly harsh under the circumstances. A LOW

[49] http://www.fish.wa.gov.au/About-Us/Contact-Us/Pages/Fish-watch.aspx

may be issued where an offence may have been committed but detected outside of the 45-day period where an infringement can be issued. There may not be a public interest in prosecution, but this still formally records the detected offence. A LOW formally advises the offender of their actions and seeks future 'voluntary' compliance.; and

- Prosecutions: These are offences of serious nature (prescribed in the FRMA) that immediately proceed to formal, legal prosecution. Such matters often incur hefty fines or can even result in incarceration, and matters brought before the court are often vigorously defended (especially by commercial fishers).

FMOs have the autonomy to issue an infringement warning after detecting some 'minor' offences that have resulted from a lack of understanding of the rules or an error of judgment, while infringement notices are used to apply a modified penalty and are usually used in cases where the offence does not warrant prosecution action that is likely to end up in court. Modified penalties are prescribed in Schedule 12 of the FRMR and can only be applied to particular sections of the FRMA (including contravening a provision of a Management Plan) and the FRMR[50]. A copy of the infringement notice is provided in Schedule 14 of the FRMR. If there is a dispute over an infringement notice, the offender can request the matter be heard in court.

More serious offences against the legislation will require the Department to seek to prosecute. The Department's Prosecution Advisory Panel (PAP) reviews recommendations made by the RSD in respect to alleged offending against the FRMA and considers whether such decisions are in the 'public interest'. This process ensures fairness, consistency and equity in the prosecution decision-making process. The PAP consists of three panel members (representing legal and executive services and the compliance and aquatic management branches) who meet on a monthly basis or as necessary. The PAP operates on a majority basis, with the prosecution process continuing where the majority of the PAP agrees with the recommendation to prosecute. If the majority of the PAP disagrees with the recommendation to prosecute, the matter is referred to the Chief Executive Officer (CEO) of the Department, who will then make a determination on the matter. Should prosecution action be undertaken, the outcomes are generally released to the public via media releases and recorded on the Department's website[51].

Penalties for illegal activity in WA fisheries are commensurate with the value of the illegal fish involved and the type of illegal activity. This can result in large monetary penalties for certain types of activities, with large penalties considered necessary in order to create a deterrent effect for high-value species, such as western rock lobster or abalone. Additional penalty provisions that apply should there be a prosecution are provided in the FRMA under sections 222 (mandatory additional penalties based on value of fish), 223 (court ordered

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[50] http://www.slp.wa.gov.au/legislation/statutes.nsf/main_mrtitle_1458_homepage.html

[51] Example of media release: http://www.fish.wa.gov.au/About-Us/Media-releases/Pages/Court-fines-hit-hard-for-out-of-season-lobster-fishing.aspx

cancellations or suspensions of authorisations), 225 (prohibition on offender activities) and 218 (forfeiture of catch, gear, etc.).

A successful prosecution for a serious offence in a commercial fishery may result in a 'black mark' against the fisher or the commercial licence (as per section 224 of the FRMA). If an authorisation holder or a person action on behalf of the holder accumulates three black marks within a 10-year period, the authorisation is suspended for one year. Additionally, under section 143, the CEO has the administrative power to cancel, suspend or not renew an authorisation in certain circumstances, which can be used even if cancellations through the court are unsuccessful. These powers have been used to deal with serious offending in other fisheries.

All fisheries offences in WA are recorded in a dedicated Departmental offences system, which also manages the workflow associated with infringements and prosecutions. In order to link this information with patrol data, FMOs include information about the fishery, DPC area, type of patrol and whether the offence resulted from a targeted inspection in all offence paperwork.

17.3.2.1 (b) Sanctions in the AMF

Non-compliance in the AMF in the last ten years has been dealt with using the sanctions described above. LOWs are not often used in the AMF and none were issued in the last 10 years. During this period, the number of prosecution briefs has reduced and no offences were detected in 20011/12 and 2013/14 (Table 17.2) which demonstrates that the sanctions provide an effective deterrence.

Table 17.2. Summary of detected offences in the AMF from 2005/06 – 2014/15

Year	Infringement Warnings	Infringement Notices	Prosecution Briefs
2005/06			2
2006/07			5
2007/08			8
2008/09		1	4
2009/10			4
2010/11	3	1	10
2011/12			0
2012/13	1	1	6
2013/14		2	0
2014/15			4

Some of the offences above were committed by the same offender. Most of the offences that resulted in a prosecution brief related to contravention of clause 17A of the *Abalone Management Plan 1992*. This clause relates to fishing in excess of the unit value. However, clause 17B of the Plan prescribes the administrative penalty system whereby it is a defence, in respect of contravening clause 17A, for the person charged to prove that: a) the amount of abalone by which the entitlement conferred by the licence was exceeded is not more than

20 kilograms meat weight or 60 kilogram whole weight; and b) not more than 28 days after being notified by the Department of having exceeded entitlement the licence holder paid to the Fisheries Research and Development Fund a monetary sum derived by multiplying the number of kilograms by which the entitlement was exceeded by the prescribed value (per unit of weight) for that species of abalone as set out in Schedule 9 of the regulations. For example, during 2010/11, 7 of the 10 prosecution briefs were for over quota and all monies owing under clause 17B were paid.

Penalties that can apply to a breach of the *Abalone Management Plan 1992* are a maximum $25,000 fine plus a mandatory additional penalty of 10 times the value of the abalone that are associated with the breach. In addition, the MFL can be given a black mark that can affect the value of the licence.

17.3.3 Level of Compliance

In evaluating compliance in a specific fishery, the Department uses a weight-of-evidence approach, which considers:

- Ongoing evidence of a sustainable fishery, i.e. whether ecological objectives continue to be met;
- Assessment of the risk posed by the fishery to target species and ecosystem components under the current management regime;
- Annual outputs arising from formal MCS systems —
    - Number of offences and successful prosecutions (dependent on whether compliance is undertaken in a random or targeted manner);
- Number of reports of illegal activity logged by Fishwatch and from intelligence gathered by FMOs that is entered into the "Seastar" database;
- General level of industry support / buy-in around fishing rules; and
- Level of compliance education and communications during key stakeholder engagement (at least annually).

Using this weight-of-evidence approach, there is a high degree of confidence that abalone fishers comply with the management system in place, including providing information of importance to the effective management of the fishery. Every year, abalone fishers provide the Department's research team with a quantity of shells to assist with understanding fishing pressure on the stock.

CDRs are an integral tool in the management of the abalone fishery and the correct use and information recorded on the CDR is vital. Compliance with this requirement is very important as the information is used to verify catches and monitor individual and total quotas to ensure the fishery remains sustainable. Industry compliance with CDRs is very high and harsh penalties apply if not completed correctly. Quota or entitlement is monitored by staff at the Busselton District Office.

The AIAWA, through distribution of the Code of Practice, actively encourages fishers to comply with the management system by informing them of their obligations to ensure a sustainable fishery. The Code of Practice for the abalone industry explicitly sets out its purpose as:

1. establishing a voluntary set of standards or behaviour for responsible commercial fishing of the resource;
2. demonstrating our commitment to ensuring these fisheries are, and continue to be, managed in a sustainable way and to reduce the risk of a bio-security threat to the fish stock; and
3. providing a valuable source of information to those wanting to know more about the abalone fishery within WA.

17.3.4 Systematic Non-Compliance

There is no evidence of systematic non-compliance within the AMF.

17.4 Monitoring and Management Performance Evaluation

The Department has a number of processes in place for monitoring and evaluating the performance of the AMF management system against its objectives. An annual review of the fishery's performance is undertaken by Departmental research, management and compliance staff, with outcomes used to assess the extent to which the fishery's management system has met both the long- and short-term objectives.

17.4.1 Evaluation Coverage

Performance against the short-term (annual) objectives is measured using the performance indicators, reference levels and management control rules that are explicitly identified in the abalone harvest strategy. Where the fishery has failed to meet the short-term objective (i.e. is at or below the threshold reference level for a particular component), a review of the fishery operations, including the management system is triggered. In the case that the review indicates that the management system is not achieving the desired objective, appropriate management action will be undertaken to reduce fishing impacts to an acceptable level.

The annual fishery performance outcomes are provided to licence holders at the AMM. The Department is also required to report to Parliament on the stock assessment outcomes for all target species, with this information provided in the Department's *Annual Report.* The fishery performance outcomes for target and retained non-target species, bycatch, ETP species, habitats and ecosystems is evaluated annually and made publically available in the *Status Report of the Fisheries and Aquatic Resources of Western Australia: the state of the fisheries* (SRFAR; e.g. Fletcher and Santoro 2015).

The effectiveness of the compliance regime is evaluated through periodic risk assessments, revision of OCPs and monitoring and analysis of compliance statistics and trends.

17.4.2 Review of the Management System

17.4.2.1 Internal Review

17.4.2.1.1 FishPlan

FishPlan is the guiding document that outlines the review schedule for the 5 year planning schedule and the next planning cycle. It includes a timeframe for review of compliance activities and management. Scientific reviews for some resources may also be identified in FishPlan. This process is established by the Department to provide formal independent or Departmental level reviews of specific research projects or monitoring and assessment programs/outputs to ensure continued relevance and/or focus on continuous improvement and best practice. FishPlan undergoes an annual review that involves input from WAFIC and RFW.

17.4.2.1.2 State of the Fisheries

Overall performance is reviewed and reported on annually in the SRFAR. The EBFM risk assessment process is also reviewed annually, reported on in SRFAR and informs the decisions and priorities of management. There are numerous internal validation processes that are undertaken to ensure all of the catch and effort data that is compiled for the SRFAR is presented accurately. Routine validation within the database checks for errors and inconsistencies within the data.

17.4.2.1.3 Management Plan

Whilst there is no in built review period specified in the management plan, amendments are made on a regular basis. The latest amendments to the plan were completed in March 2015, February 2013 and September 2011. Licence holders are reminded (as a footnote on their licences and through the AIAWA Code of Conduct) to regularly check the legislation for updates.

17.4.2.1.4 Annual Management Meetings

The fishery and stocks are reviewed annually both prior and during the AMM, with quota decisions made each February. A mid-season research update is carried out during August to September. The AMM is a process of review with stakeholders to discuss current and future research programs, management arrangements for the coming season, compliance and other issues such as marine parks, MSC certification and Fisheye reporting.

17.4.2.1.5 Risk Assessments and Research

Risk assessments are undertaken periodically (every 3 – 5 years) to reassess any current or new issues that may arise in the fishery; however, a risk assessment can also be triggered if there are significant changes identified in fishery operations or management activities or controls. Each new risk assessment will inform a major review of the management system, including FishPlan, Research activities and compliance requirements. The most recent abalone risk assessment was undertaken in December 2015 and participants included internal and external stakeholders.

In 2012, the Department released Fisheries Research Report 227 *Assessment of the risks associated with the release of abalone sourced from Abalone Hatcheries for enhancement or marine grow-out in the open ocean areas of WA* (Jones and Fletcher 2012). The report outlined an assessment of the risks posed by AVG virus occurring in juveniles sourced from hatcheries in WA and translocated to the open ocean in southern Western Australia either for stock enhancement (reseeding) or for marine grow-out (sea-ranching) purposes using standard risk assessment methodology with the outputs having been independently reviewed.

The abalone research program is reviewed annually with subsequent advice provided to management. The last comprehensive review of the current stock assessment in Western Australian abalone fisheries that included a summary of the biology, demography, research and management was published in 2013 (Hart et al. 2013a).

17.4.2.1.6 Review of Harvest Strategy

The *abalone harvest strategy* requires annual evaluation of performance of the fishery against specified performance indicators across ecological and socio-economic aspects of the fishery. During the harvest strategy development it was subject to extensive internal (within the Department's management and research divisions) and external (WAAIA) review in 2016, as part of the preparation for MSC full assessment. While the next formal review of the harvest strategy is scheduled to occur in 2021, the appropriateness of the current performance indicators, reference levels and control rules may be further refined and updated in the interim (in consultation with the licence holders) as additional information becomes available (e.g. new research results, updated risk assessments, expert advice, etc.).

17.4.2.1.7 Compliance Review

The Abalone OCP is reviewed following each compliance risk assessment (every 1 to 2 years). The last compliance risk assessment was conducted in May 2015 and the OCP was reviewed and updated in September 2015 based on these outcomes. In addition, annual reviews of the OCP allows the plan to be modified to take into account changes in technology, fishing practices, community attitudes and evolving factors. The effectiveness of the compliance regime is also evaluated through monitoring and analysis of compliance statistics.

A significant evaluation project of the compliance program in all Western Australian fisheries was undertaken by Green and McKinlay (2009).

17.4.2.2 External Review

17.4.2.2.1 Export Approval under the EBPC Act

The Western Australian commercial abalone fisheries were first assessed by the Commonwealth DoE to meet the requirements outlined in the *Guidelines for the Ecologically Sustainable Management of Fisheries* and under parts 13 and 13A of the EPBC Act in 2002 and subsequently granted an exemption to export product. Product derived from abalone fisheries is listed on the List of Exempt Native Specimens (LENS). The LENS is a list of native specimens that are exempt from export prohibitions.

The commercial abalone fisheries were reassessed in October 2009 and June 2014 and were again provided with an exemption from export controls valid for five years each time. In 2015, the Commonwealth Minister for the Environment extended the maximum timeframe for EPBC Act approvals from five years to ten years for commercial fisheries assessed as posing low environmental risk. The AMF has had their export approval extended until May 2025.

17.4.2.2.2 Peer Review

In recent years the Department has had a schedule for peer review of research and assessments for fisheries, employing a mix of internal and external (e.g. universities, CSIRO, inter-state fisheries departments) fisheries experts. The abalone fishery assessment was peer reviewed in 2010 by Professor Neil Loneragan (Murdoch University) and Dr Steve Mayfield (SARDI) and a copy of that review can be obtained upon request. Among other things, this external review looked at the stock assessment methodology, harvest strategy framework, research programs and the standard operating procedures for data collection and analyses.

Following this review, the Department published a comprehensive review of the management system for the abalone fisheries in Western Australia in Research Report No. 241: *Biology, History and Assessment of Western Australian Abalone Fisheries* (Hart et al. 2013a).

17.4.2.2.3 External Government Audit

The compliance system was the subject of a specific external review by the Western Australian Auditor General. This Public Sector Performance Report[52] on compliance in Western Australia's commercial and recreational fisheries was submitted to Parliament in June 2009.

[52] Department of the Auditor General website https://audit.wa.gov.au/wp-content/uploads/2013/05/report2009_07.pdf

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19 Appendix A

Summary of key management changes in the WA abalone fishery 1964 to current

Year	Effort Controls									Catch Controls								Details
	Open access	Closures	Spatial management	Licence limitation	Size limits	Catch Monitoring	Limited entry	Bag limits	Recreational	TACC/IQs	Quota monitoring	Nominated operators	ITQs (transferable)	Spatial TACC	Performance indicators	TACC decision rules	IFM	
1964																		Fishing begins in the Perth metropolitan Roe's abalone fishery. The fishery was open access.
1971																		Licence limitation introduced. 36 non-transferable commercial licenses, reduced to 25 by 1975. Rolling closures begin in Perth fishery on approx. a 3 year rotation between North, Central, and South areas. System continues till 1982. Size limits (60 mm) introduced in Roe's abalone fishery.
1972																		Minimum size limit (100 mm) introduced for Greenlip and Brownlip fishery, corresponding to size at maturity.
1975																		Formal spatial management introduced. Three zones created. Zone 1 (6 divers) and Zone 2 (8 divers) for the Greenlip and Brownlip fishery. Zone 3 (12 divers) for the Roe's abalone fishery. Size limits for Greenlip and Brownlip fisheries changed to minimum weight of 113 g. Monthly catch and effort monitoring (CAES) introduced at the spatial scale of 1 degree (60 x 60 nautical miles). Flinders Bay (Zone 2) Greenlip fishery closed for 2 years.
1976																		Limited entry (owner operated, non-transferable licenses) first introduced in Zone 2.
1978																		Daily bag limit (100 kg) introduced for Perth commercial fishery. Remains in place till 1999 when the 36 tonne spatial TACC introduced. Flinders Bay (Zone 2) Greenlip fishery closed for 18 months
1980																		Size limits in Perth Roe's abalone fishery increased from 60 to 70 mm. Recreational fishery in Perth limited to a seasonal opening from mid-October to mid-December. Flinders Bay (Zone 2) Greenlip fishery closed for 2 years.
1985																		Total Allowable Catch (TACC) introduced to Zone 1. TACC initially allocated as non-transferable IQ (Individual Quota). Size limit in Greenlip and Brownlip fishery increased.
1986																		TAC introduced to Zone 2. Flinders Bay (Zone 2) Greenlip fishery closed for 2 years. Spatially delimited size limits introduced to Zone 2. Daily catch (quota) and effort monitoring introduced, initially in Zone 2.
1988																		State-wide TACC introduced for Zone 3 (Roe's abalone). Recreational fishing further restricted in Perth fishery. Only permitted on weekends and public holidays between 6 and 10 am.

Year	Effort Controls									Catch Controls								Details
	Open access	Closures	Spatial management	Licence limitation	Size limits	Catch Monitoring	Limited entry	Bag limits	Recreational	TACC/IQs	Quota monitoring	Nominated operators	ITQs (transferable)	Spatial TACC	Performance indicators	TACC decision rules	IFM	
1991 to 1996																		Experimental closures and rotational fishing undertaken by industry in Zone 2 Greenlip fishery (Augusta region) to test effectiveness of reef-based management
1992																		Nominated operators (i.e. lease divers) permitted in the fishery. Represents first step away from non-transferability. Daily access hours reduced from 4 to 2 hours on permitted fishing days in Perth recreational fishery.
1993																		IQs introduced in the Roe's abalone fishery to reduce issues stemming from the competitive TACC. Minimum legal size changed from a meat weight (g) to shell length (mm) in all fisheries because of compliance concerns.
1995																		Permitted fishing days in Perth metro fishery reduced to 6 days in total during November / December creating a 9 hour annual fishery.
1999																		TACC unitised, quota made transferable (ITQs), and fishery divided into 8 new spatial units (Area 1 to Area 8) each with its own TACC. See Figure 19.1 below for a comparison of "old" and "new" spatial areas.
2005																		Formal performance indicators introduced to monitor stock status and assist in TACC setting process.
2006																		Permitted fishing hours in Perth metro fishery reduced to 1 hour per day resulting in a 6 hour annual fishery.
2008																		TACC decision rules introduced. Integrated Fisheries Management (IFM), which determines sectoral catch allocations, introduced for the Perth Roe's abalone fishery. Recreational fishery now has total allowable recreational catch (TARC).
2010																		Permitted fishing hours in Perth metro fishery reduced to 5 days in total during November/December
2011																		Permitted fishing days in Perth metro fishery changed from 5 consecutive weeks in Nov/Dec to a Summer season starting on the first Sunday of each month from November through March.
2011																		Area 8 commercial fishery and Northern zone recreational fishery closed due to catastrophic mortality from a marine heatwave event
2014/15																		Perth metro fishery subject to in-season monitoring, and reduction in recreational bag limits and commercial catch quota, as a consequence of increased mortality, and lowered growth and recruitment subsequent to the 2011 marine heatwave event

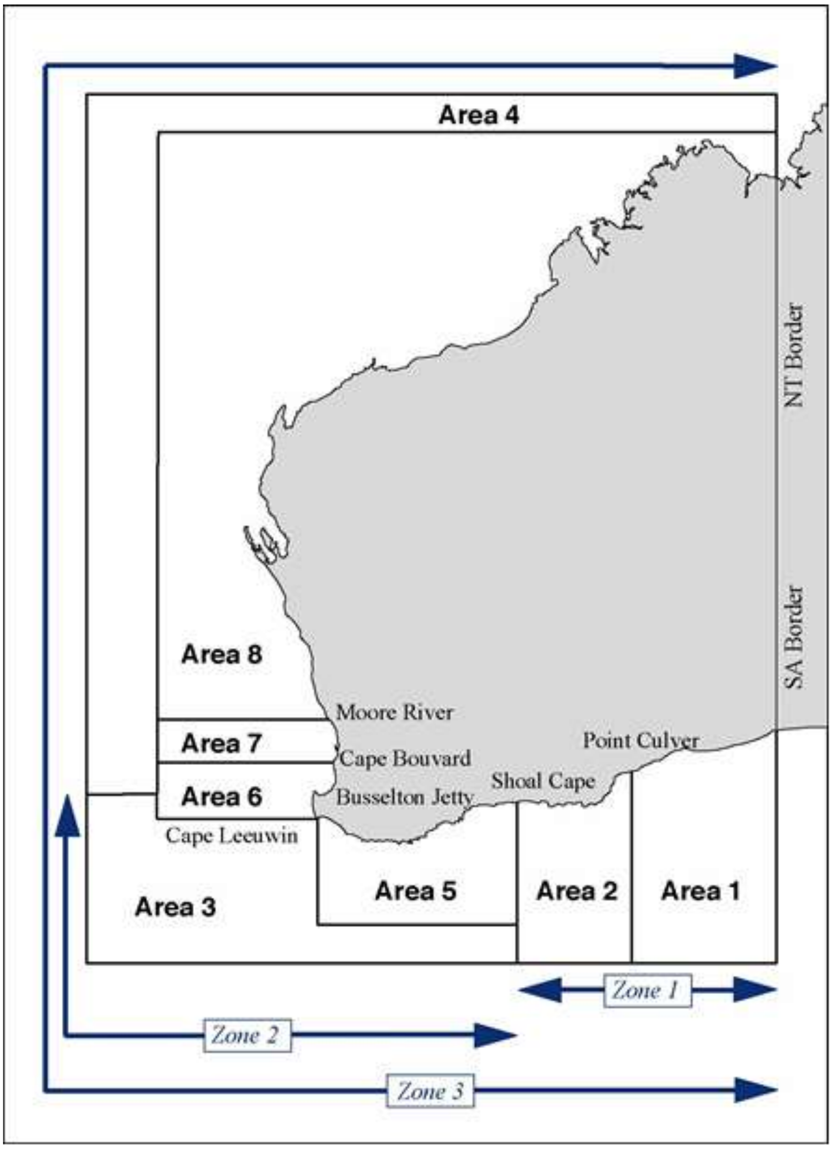

Figure 19.1. Map comparing old zonal arrangements (1975-1998; Zone 1, 2 and 3) and new management areas (1999-2012+) of the commercial abalone fishery in WA

20 Appendix B

Examples of Managed Fishery, Fishing Boat and Commercial Fishing Licences

Government of **Western Australia**
Department of **Fisheries**

Western Australia
Fish Resources Management Act 1994

Head Office
3rd Floor, The Atrium,
168 - 170 St Georges Terrace, Perth WA 6000;
Locked Bag 39, Cloisters Square WA 6850
Telephone (08) 9482 7333
Facsimile (08) 9482 7390
customerservice@fish.wa.gov.au
www.fish.wa.gov.au
ABN: 55 689 794 771

Licence No: [redacted]
Fee: [redacted]

Abalone Managed Fishery Licence

Name and Business Address of Licence Holder(s)

[redacted]

is authorised to use the licensed fishing boat(s) specified below and up to the extent of the entitlement specified below to engage in fishing during the term of this licence for Abalone in the Abalone Managed Fishery.

Name of Boat: [redacted]
Registration Number: [redacted]
Length: 5.88 metres

Name and Address of Nominated Diver(s):

[redacted]
Commercial Fishing Licence Number: CFL[redacted]

[redacted]
Commercial Fishing Licence Number: CFL[redacted]

Permanent Entitlement:

Brownlip Abalone Area 3 Units: 50
Brownlip Abalone Area 3 Unit Value: 6.25
Brownlip Abalone Area 3 Kilograms (Meat Weight) of entitlement: 312.5000

Brownlip Abalone Area 4 Units: 0
Brownlip Abalone Area 4 Unit Value: 0.00
Brownlip Abalone Area 4 Kilograms (Meat Weight) of entitlement: 0.0000

Greenlip Abalone Area 3 Units: 500
Greenlip Abalone Area 3 Unit Value: 4.44
Greenlip Abalone Area 3 Kilograms (Meat Weight) of entitlement: 2220.0000

Greenlip Abalone Area 4 Units: 0
Greenlip Abalone Area 4 Unit Value: 0.00
Greenlip Abalone Area 4 Kilograms (Meat Weight) of entitlement: 0.0000

Receipt details: **AB1877** **19/03/2015** **RCT0002507698** **Cheque** **$4,347.11** **DRB**

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Government of **Western Australia**
Department of **Fisheries**

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www.fish.wa.gov.au
ABN: 55 689 794 771

Western Australia
Fish Resources Management Act 1994

Licence No: **AB1877**

Current Entitlement: *

Brownlip Abalone Area 3 Units: 50
Brownlip Abalone Area 3 Unit Value: 6.25
Brownlip Abalone Area 3 Kilograms (Meat Weight) of entitlement: 312.5000

Brownlip Abalone Area 4 Units: 0
Brownlip Abalone Area 4 Unit Value: 0.00
Brownlip Abalone Area 4 Kilograms (Meat Weight) of entitlement: 0.0000

Greenlip Abalone Area 3 Units: 500
Greenlip Abalone Area 3 Unit Value: 4.44
Greenlip Abalone Area 3 Kilograms (Meat Weight) of entitlement: 2220.0000

Greenlip Abalone Area 4 Units: 0
Greenlip Abalone Area 4 Unit Value: 0.00
Greenlip Abalone Area 4 Kilograms (Meat Weight) of entitlement: 0.0000

---

* - Current entitlement is permanent entitlement +/- temporary transfers

Conditions:

The holder of this licence or any persons acting on that person's behalf, must hold a commercial fishing licence granted under the Fish Resources Management Regulations 1995.

NO ADDITIONAL CONDITIONS

Term of Authorisation: Wednesday 01 April 2015 to Thursday 31 March 2016
File No: L1320/13

Chief Executive Officer

This licence must be produced to a Fisheries Officer on demand.
WARNING: This licence will have no effect until the imprint of the cash register or other authority is hereon.

Renewal Application - 19/03/2015

ALL FISHING ACTIVITIES MAY BE SUBJECT TO OPTICAL SURVEILLANCE BY FISHERIES OFFICERS USING BINOCULARS, TELESCOPES AND NIGHT VISION EQUIPMENT

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Department of **Fisheries**

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www.fish.wa.gov.au
ABN: 55 689 794 771

Western Australia
Fish Resources Management Act 1994

Licence No: **AB1877**

Attention
Fisheries legislation changes from time to time. To assist fishers, aquaculturists and members of the public to access fisheries legislation, the Chief Executive Officer has arranged for up to date fisheries legislation to be made available on the internet. Fisheries legislation may be viewed by logging on to the Department of Fisheries website (www.fish.wa.gov.au) and clicking on the Legislation link on the top of the home page. The Chief Executive Officer recommends that the licence holders and persons acting on their behalf (eg. employees), regularly access this legislation service and make themselves aware of the fisheries legislation that relates to their activities.

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www.fish.wa.gov.au
ABN: 55 689 794 771

Western Australia
Fish Resources Management Act 1994

Licence No: **FBL[redacted]**
Fee: [redacted]

FISHING BOAT LICENCE

Name and Business Address of Licence Holder(s)

[redacted]

Name of Boat: [redacted]
Registration Number: [redacted]
Length: 5.88 metres

The holder of this licence, or a person having day to day control of the boat named on this licence, is authorised to use the boat for commercial fishing in accordance with the Fish Resources Management Act 1994 and applicable subsidiary legislation and subject to the following condition (if any).

Condition No: 282

The boat in respect of which this licence is in force must only be used for fishing by a person who is fishing for Abalone under the authority of Abalone Managed Fishery Licence No's 1877 & 1892 .

Condition No: 283

The boat in respect of which this licence is in force must not be used to fish for, transport, store or bring onto land any fish other than abalone.

NO ADDITIONAL CONDITIONS

Term of Authorisation: Thursday 01 January 2015 to Thursday 31 December 2015
File No: 617/99

Chief Executive Officer

A copy of this licence must be held on board the boat named in this licence.
This licence must be produced to a Fisheries Officer on demand.
WARNING: This licence will have no effect until the imprint of the cash register or other authority is hereon.

Application – 19/02/2015

ALL FISHING ACTIVITIES MAY BE SUBJECT TO OPTICAL SURVEILLANCE BY FISHERIES OFFICERS USING BINOCULARS, TELESCOPES AND NIGHT VISION EQUIPMENT

Attention

Fisheries legislation changes from time to time. To assist fishers, aquaculturists and members of the public to access fisheries legislation, the Chief Executive Officer has arranged for up to date fisheries legislation to be made available on the internet. Fisheries legislation may be viewed by logging on to the Department of Fisheries website (www.fish.wa.gov.au) and clicking on the Legislation link on the top of the home page. The Chief Executive Officer recommends that the licence holders and persons acting on their

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www.fish.wa.gov.au
ABN: 55 689 794 771

Western Australia
Fish Resources Management Regulations 1995

Licence No: **CFL**[redacted]
Fee: [redacted]

COMMERCIAL FISHING LICENCE

Name and Address of Licensee

[redacted]

The holder of this licence is authorised to engage in commercial fishing in accordance with the Fish Resources Management Act 1994 and applicable subsidiary legislation and subject to the following conditions (if any).

NO ADDITIONAL CONDITIONS

Term of Authorisation: Wednesday 11 March 2015 to Thursday 10 March 2016
File No:

Chief Executive Officer

This licence must be produced to a Fisheries Officer on demand.
WARNING: This licence will have no effect until the imprint of the cash register or other authority is hereon.

Renewal Application – 20/02/2015

ALL FISHING ACTIVITIES MAY BE SUBJECT TO OPTICAL SURVEILLANCE BY FISHERIES OFFICERS USING BINOCULARS, TELESCOPES AND NIGHT VISION EQUIPMENT

Attention
Fisheries legislation changes from time to time. To assist fishers, aquaculturists and members of the public to access fisheries legislation, the Chief Executive Officer has arranged for up to date fisheries legislation to be made available on the internet. Fisheries legislation may be viewed by logging on to the Department of Fisheries website (www.fish.wa.gov.au) and clicking on the Legislation link on the top of the home page. The Chief Executive Officer recommends that the licence holders and persons acting on their behalf (eg. employees), regularly access this legislation service and make themselves aware of the fisheries legislation that relates to their activities.

Receipt details:	**CFL99687**	**20/02/2015**	**RCT0002507541**	**Cheque**	**$87.00**	**PNC**

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21 Appendix C

In addition to annual monitoring of the primary performance indicator used to inform the harvest strategy for abalone in WA (i.e. the three-year moving average of standardised commercial catch rates for each species in their relevant management areas), the status of Roe's, Greenlip and Brownlip abalone stocks is determined using a weight-of-evidence approach that considers a range of other available data and information. Summaries of additional information for the three species are provided below.

21.1 Roe's Abalone Research Summary

Additional data available for Roe's abalone in Area 7 of the commercial AMF and the recreational West Coast fishery include population length frequencies and fishery-independent survey estimates of density of harvestable animals. These data have been used to estimate growth, fishing mortality, and provide estimates of population biomass.

21.1.1 Growth Analysis

Estimation of growth is important for abalone stock assessments that involve estimating total mortality when using length-converted catch curves. Growth in abalone is highly variable and does not follow clear patterns described by traditional growth equations such as the von Bertalanffy curve. A range of alternative growth curves has been used to describe abalone growth, such as the Gompertz model (Troynikov et al. 1998; Bardos 2005; Hart et al. 2013b), the Gaussian probability density function (Rogers-Bennett et al. 2007; Hart et al. 2013c) and an inverse logistic equation (Haddon et al. 2007; Helionidotis et al. 2011).

The growth of Roe's abalone was previously modelled on the basis of the von Bertalanffy growth model, which assumes that there is a linear pattern of change in growth rate with respect to initial length. The von Bertalanffy growth model used to estimate the expected change in length of an individual between initial capture and recapture, $\Delta\hat{L}$, from mark-recapture data is

$$\Delta\hat{L} = (L_{\infty} - L_t)(1 - e^{-k\Delta t}) \qquad 1$$

where L_{∞} is the average maximum length of individuals in the population, k is the growth coefficient, L_t is the length of the individual at the time of initial capture and Δt is the period of time between capture and recapture (e.g. Haddon 2011). The fit of this growth model to tag-increment data for Roe's abalone has more recently been compared with several alternative models, including an inverse logistic model (Haddon et al. 2007), a "double logistic" model, and the Gaussian probability density function (Rogers-Bennett et al. 2007). Applying the inverse logistic model, $\Delta\hat{L}$ is estimated as

$$\Delta\hat{L} = a\left\{1/\left[1 + e^{\ln(19)(L_t - L_{50})/(L_{95} - L_{50})}\right]\right\} \qquad 2$$

where a is the estimated maximum length increment attained by individuals at any initial length, L_{50} is the initial length midway between the largest and smallest growth increment on the descending limb of the curve, and L_{95} is the initial length at which 95% of the difference between the largest and smallest growth increment on the descending limb of the curve is reached.

Applying the double-logistic curve, $\Delta\hat{L}$ is estimated as

$$\Delta\hat{L} = a\left\{1/\left[1+e^{-\ln(19)\left(L_t-L_{50_1}\right)/\left(L_{95_1}-L_{50_1}\right)}\right]\right\}\left\{1/\left[1+e^{\ln(19)\left(L_t-L_{50_2}\right)/\left(L_{95_2}-L_{50_2}\right)}\right]\right\} \qquad 3$$

where a is the estimated maximum length increment attained by individuals at any initial length, L_{50_1} is the initial length midway between the smallest and maximum growth increment on the ascending limb of the curve, L_{95_1} is the initial length at which 95% of the difference between the smallest growth increment and maximum growth increment on the ascending limb of the curve is reached, L_{50_2} is the initial length midway between the largest and smallest growth increment on the descending limb of the curve, and L_{95_2} is the initial length at which 95% of the difference between the largest and smallest growth increment on the descending limb of the curve is reached. This growth curve incorporates the (non-seasonal) "inverse logistic" curve described by Haddon et al. (2007), but also contains an ascending logistic curve to describe the growth of the smallest individuals.

Using the Gaussian probability density function (PDF), $\Delta\hat{L}$ is estimated as

$$\Delta\hat{L} = Ae^{-(L_t-u)^2/2\sigma^2} \qquad 4$$

where A is the maximum growth (mm, year^{-1}), u is the size at maximum growth (mm) and σ is the standard deviation of the distribution of maximum growth *vs* size (Rogers-Bennett et al. 2007). Growth models were fitted to mark-recapture data for Roe's abalone near Perth (Area 7 of the AMF and West Coast recreational). Growth curves were fitted separately to abalone sampled from the reef platform (fished by recreational fishers) and the subtidal habitat (fished by commercial operators). It was hypothesised that estimated size-at-age of Roe's abalone in the platform habitat would typically be less than of those in the subtidal habitat reflecting, in the platform habitat, higher densities, shallower waters, greater exposure of individuals in this habitat to waves and to terrestrial temperature fluctuations. As the "times at liberty" of Roe's abalone were highly variable (generally ranging from ~100 days to ~400 days, and occasionally up to ~750 days), it was important to account for these differences when fitting growth models to tagging data.

Analyses considered that the initial length of each individual was recorded at time zero, L_{t_0}. An estimate of the length increment for the j^{th} individual at the final time, i.e. when individuals are re-measured, $t_{F,j}$, was obtained by solving the "initial value problem" using a numerical 4th order Runga-Kutta integration. Applying the inverse logistic model, for example, denoting $L_{t_{0,j}}$ as the initial length for the j^{th} individual, dl/dt_j, the change in length with respect to the time at liberty for the j^{th} individual may be described as

$$dl / dt_j = a\left\{1 / \left[1 + e^{\ln(19)(L_t - L_{50})/(L_{95} - L_{50})}\right]\right\} + L_{t_{0,j}} \qquad 5$$

The length increment for the j^{th} individual attained over its time at liberty, i.e. $L_{t_{F,j}} - L_{t_{0,j}}$, can thus be calculated as

$$L_{t_{F,j}} - L_{t_{0,j}} = \int_{t_{0,j}}^{t_{F,j}} a\left\{1 / \left[1 + e^{\ln(19)(L_t - L_{50})/(L_{95} - L_{50})}\right]\right\} \qquad 6$$

All of the growth models were fitted in AD Model Builder by maximising λ_{gc}, the negative log-likelihood associated with the predicted length increments of animals at the end of their times at liberty, calculated as

$$\lambda_{gc} = -\frac{n}{2}(\ln(2\pi + 2\ln(\hat{\sigma}) + 1) \qquad 7$$

where n is the number of animals for which measurements were taken of their initial and final length lengths, $\ln$ is the natural logarithm and $\hat{\sigma}$ is the standard deviation associated with the deviations between the observed and predicted final lengths.

The statistical fits of the various growth models were assessed by comparing the values of Akaike's Information Criterion, AIC. The model with the lowest AIC value, *i.e.* $AIC_{\min}$, was the one considered to provide the best statistical fit to the data. AIC was calculated as

$$AIC = -2LL + 2K \qquad 8$$

where K is the total number of growth parameters in the respective growth model (including the variance) (Burnham and Anderson 2002).

For both the platform reef and subtidal reef habitat, the model with the lowest value for the negative log-likelihood and AIC was the inverse logistic model (Table 21.1). This model is therefore used in subsequent analyses for this species.

Plots showing the fit of the inverse logistic model to the available growth increment data for Roe's abalone and associated diagnostic plots in the Perth metropolitan area are provided for the platform reef habitat in Figure 21.1, and for the subtidal reef habitat in Figure 21.2. As indicated in (a) and (b) in each of these figures, the relationships between the growth increments, and final lengths for Roe's abalone in the platform and subtidal habitats, with respect to initial length, are not "smooth," reflecting the effect, on the estimated final lengths, of differences in time at liberty. The inverse logistic growth model provided a relatively good fit to the length increment data in each habitat, as indicated by the lack of structural deviations of the residuals between the observed and estimated final shell lengths with respect to initial length, or time at liberty (Figure 21.1c, d and Figure 21.2c, d).

On the basis of the fitted growth models, Roe's abalone in the subtidal habitat are on average slightly larger than those on the reef platform at corresponding ages. For example, by 3, 5 and 10 years of age, animals in the subtidal habitat are expected to have attained a shell length of ~66, 76 and 85 m, respectively, compared with 61, 73 and 82 mm, for the reef platform habitat (cf. Figure 21.1e, f and Figure 21.2e, f).

Table 21.1. Values of estimated parameters derived by fitting the Inverse logistic model, Double logistic model, Gaussian PDF and von Bertalanffy growth model, to tag-recapture data for Roe's abalone in WA. Stdev refers to standard deviation, NLL refers to negative log-likelihood, and AIC refers to Akaike's Information Criterion statistic. The growth curves were fitted to 363 observations for the platform reef habitat, and 333 observations for the subtidal reef habitat.

Inverse logistic model			**Double logistic model**			**Gaussian PDF**			**von Bertalanffy model**		
Parameter	Estimate	stdev	Parameter	Estimate	stdev	Paramete	Estimate	stdev	Paramete	Estimate	stdev
Platform reef habitat (recreational fishery)											
a	0.068	0.005	a	0.11	0.007	A	0.095	0.011	L_∞ (mm)	83.92	2.52
L_{50} (mm)	59.15	2.07	$L_{50,1}$ (mm)	$6.9\text{x}10^{-8}$	0.001	u (mm)	25.13	1.76	k (year^{-1})	0.385	0.037
L_{95} (mm)	79.33	2.82	$L_{95,1}$ (mm)	131.5	0.00001	σ (mm)	22.2	1.85			
			$L_{50,2}$ (mm)	50.09	2.75						
			$L_{95,2}$ (mm)	77.97	2.54						
NLL	403.79		404.87			404.89			410.96		
AIC	813.58		815.74			815.78			827.92		
Subtidal reef habitat (commercial fishery)											
a	0.069	0.005	a	0.11	0.007	A	0.105	0.015	L_∞ (mm)	85.64	2.87
L_{50} (mm)	61.85	2.09	$L_{50,1}$ (mm)	$72\text{x}10^{-8}$	0.001	u (mm)	27.05	1.67	k (year^{-1})	0.382	0.04
L_{95} (mm)	79.64	2.87	$L_{95,1}$ (mm)	131.9	0.00001	σ (mm)	21.54	1.84			
			$L_{50,2}$ (mm)	53.91	2.83						
			$L_{95,2}$ (mm)	78.41	2.62						
NLL	372.5		373.07			373.61			380.69		
AIC	751		752.14			753.22			767.38		

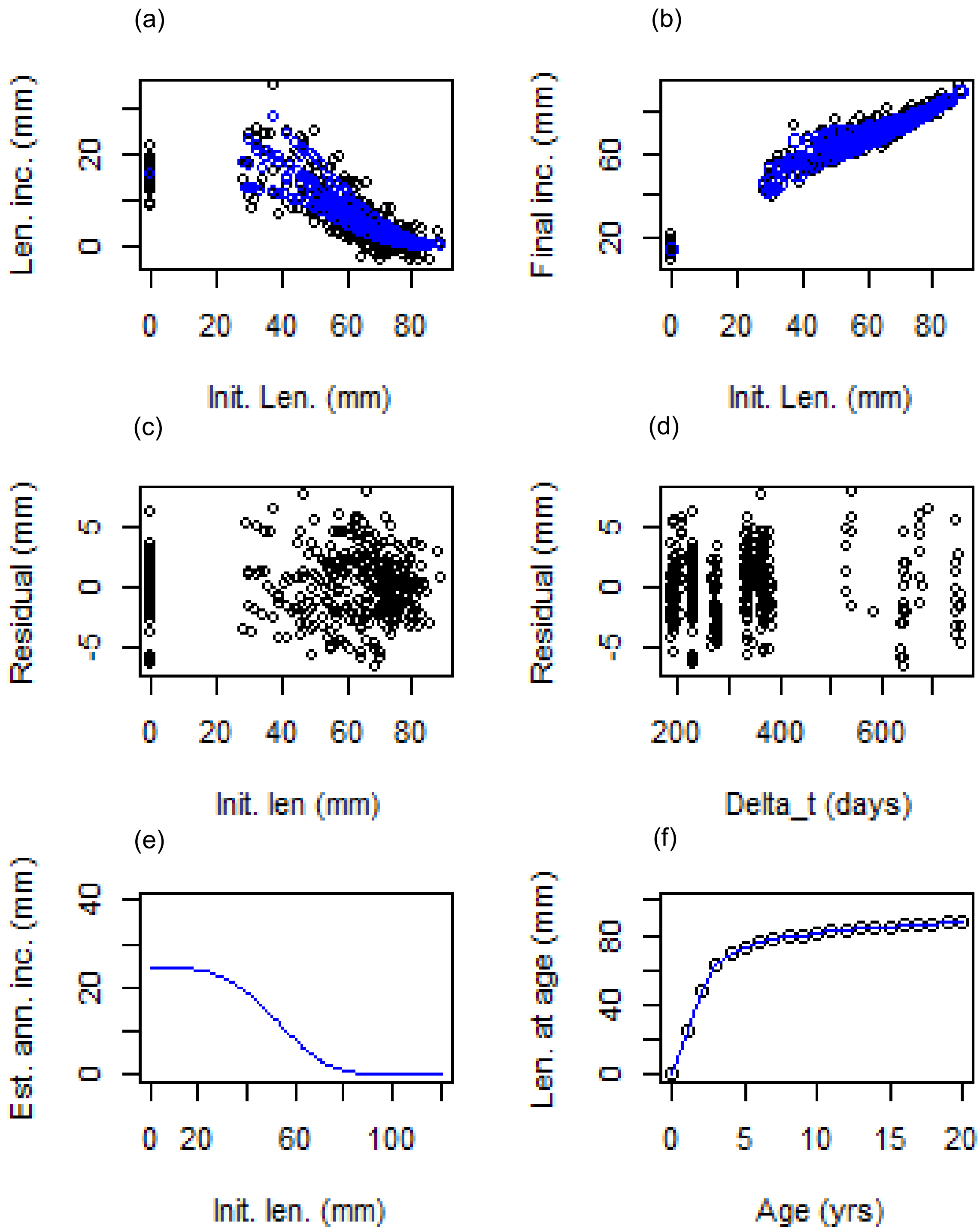


Figure 21.1. Plots associated with the fitting of an inverse logistic model to tag increment data for Roe's abalone from the recreational fishery (platform habitat). (a) Observed (black circles) and expected (blue circles) growth increments and (b) final lengths for abalone with respect to their initial sizes and taking into account their varying times at liberty. (c) Residuals between the observed and expected annual growth increments with respect to initial length and (d) time at liberty (days). (e) Estimated average annual growth increment as a function of initial length and (f) expected lengths at each integer age, based on the relationship described in (e).

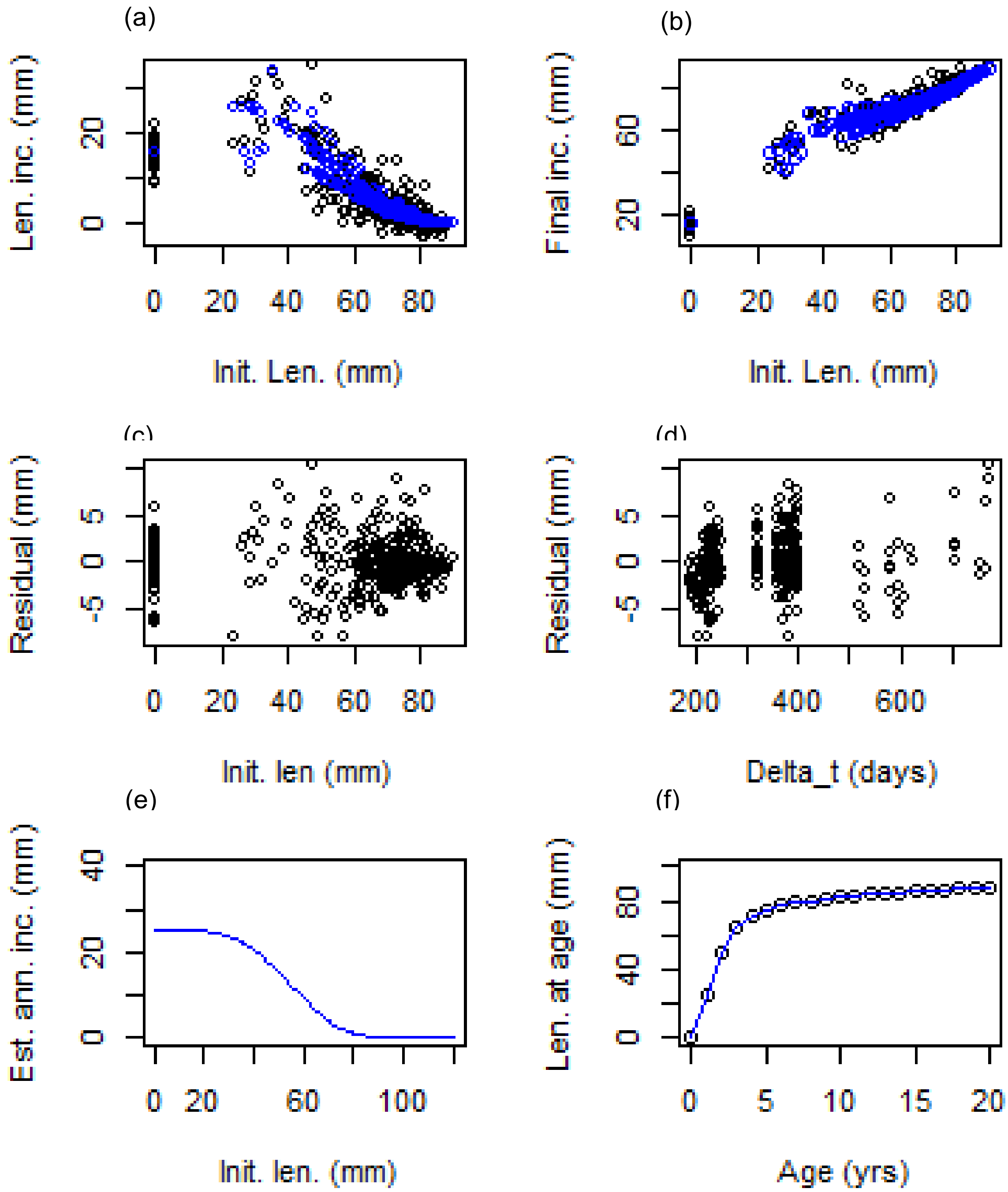


Figure 21.2. Plots associated with the fitting of an inverse logistic model to tag increment data for Roe's abalone from the commercial fishery (subtidal habitat). (a) Observed (black circles) and expected (blue circles) growth increments and (b) final lengths for abalone with respect to their initial sizes, taking into account their varying times at liberty. (c) Residuals between the observed and expected annual growth increments with respect to initial length and (d) time at liberty (days). (e) Estimated average annual growth increment as a function of initial length and (f) expected lengths at each integer age, based on the relationship described in (e).

21.1.2 Mortality Estimation

The mortality estimates for Roe's abalone provided in this report are the only available estimates for this species in WA. The approach involves estimating, based on the growth curve, the time taken for abalone to grow from one length class to the next (denoted below as Δt), and estimating the relative frequencies of abalone in successive length classes, based on a value of total mortality and a selectivity pattern.

On the basis of the fitted growth curve, an estimate of the expected duration between the mid-point of length class l and $l+1$ may be obtained by determining the value of Δt that would result in this change of length. For a given initial length L and time interval, the expected length at the end of that time interval, t, may be estimated by solving the "initial value problem" using numerical integration (see Section 21.1.1). The value of t at which the expected length at that time $\hat{L}_t$ has grown to a specified length may be determined using an iterative approach, e.g. using Newton's algorithm. Considering, for the j^{th} fish, the value of length at time t as a function, i.e.

$$L_{t,j} = f(t, L_{t_0,j}) \qquad 9$$

where the value of t at which $L_{t,j} = L_{F,j}$ may be estimated as the root of the equation, i.e.

$$L_F - f(t, L_{t_0,j}) = 0 \qquad 10$$

Selectivity for Roe's abalone was assumed to be "knife-edge", at the minimum specified shell length. The minimum specified shell length was 61 mm for the unfished and recreationally fished areas, and 70 mm in commercially fished areas. In fitting the catch curve, S_l, the length-based selectivity of abalone to fishing in length class l, is set to zero, if the shell length is less than the minimum legal shell length, or else set to 1. F_l, the fishing mortality in length class l, is thus

$$F_l = S_l F \qquad 11$$

N_l, the expected number of survivors per recruit in length class l may be calculated as

$$N_l = N_{l-1}\exp(-Z_l \Delta t) \qquad 12$$

where Δt represents the time taken for animals to grow from the mid-point of length class $l-1$ to that of l, and where Z_l is the sum of F_l and natural mortality, M. Applying the Baranov catch equation, the expected catch per recruit in length class l may be calculated as

$$C_l = \frac{F_l}{Z_l}(1-\exp(-Z_l \Delta t) N_l \qquad 13$$

The negative multinomial log-likelihood associated with the catch curve, λ_{cc}, is

$$\lambda_{cc} = n\sum_{l} p_l \ln\hat{p}_l \qquad 14$$

where n is the sample size of the commercial length composition, and p_l and $\hat{p}_l$ are the observed and expected proportions of abalone in length class l. To account for uncertainty in estimating growth when fitting catch curves, the growth and catch curve models were fitted simultaneously. The overall log-likelihood, λ, was thus calculated as

$$\lambda = \lambda_{gc} + \lambda_{cc} \qquad 15$$

The log-likelihoods associated with the growth curves and catch curves, which were within the same order of magnitude, were given equal weighting within the overall objective function. Preliminary sensitivity analyses, applying alternative weightings for the components of the overall objective function (e.g. reducing the weighting of the likelihood associated with length composition data, λ_{cc}, by a factor of 10), showed that mortality estimates were similar across a wide range of alternative weightings.

As is evident in the "catch curve" plots, this model provided relatively good fits to the annual length-frequency data in each year between 2006 and 2016, obtained during fishery-independent surveys for Roe's abalone in the reef platform and subtidal habitats of the Perth metropolitan region, including both fished areas (Figure 21.3 and Figure 21.4) and unfished areas (Figure 21.5).

21.1.2.1 Fished Areas

The frequencies of Roe's abalone in the platform habitat in each year between 2006 and 2016 typically declined progressively in each length class, from the first length class of 60-62 mm (Figure 21.3). This is consistent with the view that this species becomes fully selected at ~60 mm, the length corresponding to the minimum legal length for this species (i.e. for the Perth recreational fishery which takes this species on the reef platform habitat). The fact that there has been substantial compliance monitoring over the very short recreational fishing season for Roe's abalone (currently 5 hours in total) suggests that it is highly unlikely that substantial numbers of this species are taken below 60 mm, i.e. knife-edge selectivity at this length is a reasonable assumption for assessment of the recreational fishery.

The length-frequency distributions demonstrate that the relative abundances of larger individuals (>75 mm) in the platform habitat declined progressively between 2006 and 2014, before increasing, conspicuously, in 2015 and 2016 (Figure 21.3). This trend is consistent with the estimates of total mortality having increased substantially from 0.87 year^{-1} in 2006 to 1.95 year^{-1} in 2014, before declining in 2015 and 2016 to 1.27 year^{-1} (Table 21.2). Note that the estimates of "mortality" for the platform reef habitat could represent a combination of the effects of mortality and movement of animals from the platform habitat to the subtidal habitat, if such movement occurs. However, the substantial increase in mortality does provide strong evidence of an increase in mortality between 2006 and 2013, and a decrease in mortality particularly in 2016 (assuming a constant rate of movement from the platform to subtidal habitat). The substantial decrease in mortality of Roe's on the platform habitat from 1.95 $year^{-1}$ to 1.27 $year^{-1}$ between 2014 and 2016 coincided with marked reductions in recreational catch of this species in that habitat (from 49 t in 2009 to ~20 t in the past few years), following strong management measures aimed at reducing fishing mortality in that habitat (Table 21.2, Figure 21.3 and Figure 21.4).

For the subtidal habitat, the relative abundances of larger individuals (>75 mm) remained fairly stable between 2006 and 2010, before declining between 2011 and 2014, then showing a slight recovery in 2015 and 2016 (Figure 21.4). As with the platform reef habitat, the trends in length frequencies are consistent with the estimates of mortality, i.e. remaining stable in the earlier period before increasing up until 2014 then decreasing slightly in the last two years (Table 21.2). As with Roe's abalone in the platform habitat, the apparent decline in mortality in the subtidal habitat coincided with management measures introduced to reduce exploitation in the subtidal habitat (by commercial fishing). However, the recent mortality in the subtidal habitat appears to have declined to a lesser extent than is evident for the platform habitat, which probably reflects the lesser reductions in commercial catch (in the subtidal habitat) compared with the amount of recreational catch reduction (in the platform habitat). The different trends in mortality (and size structure) of Roe's abalone in recent years provide some suggestion that, following initial settlement, the amount of movement from the platform to subtidal habitat may not be as marked as previously hypothesised.

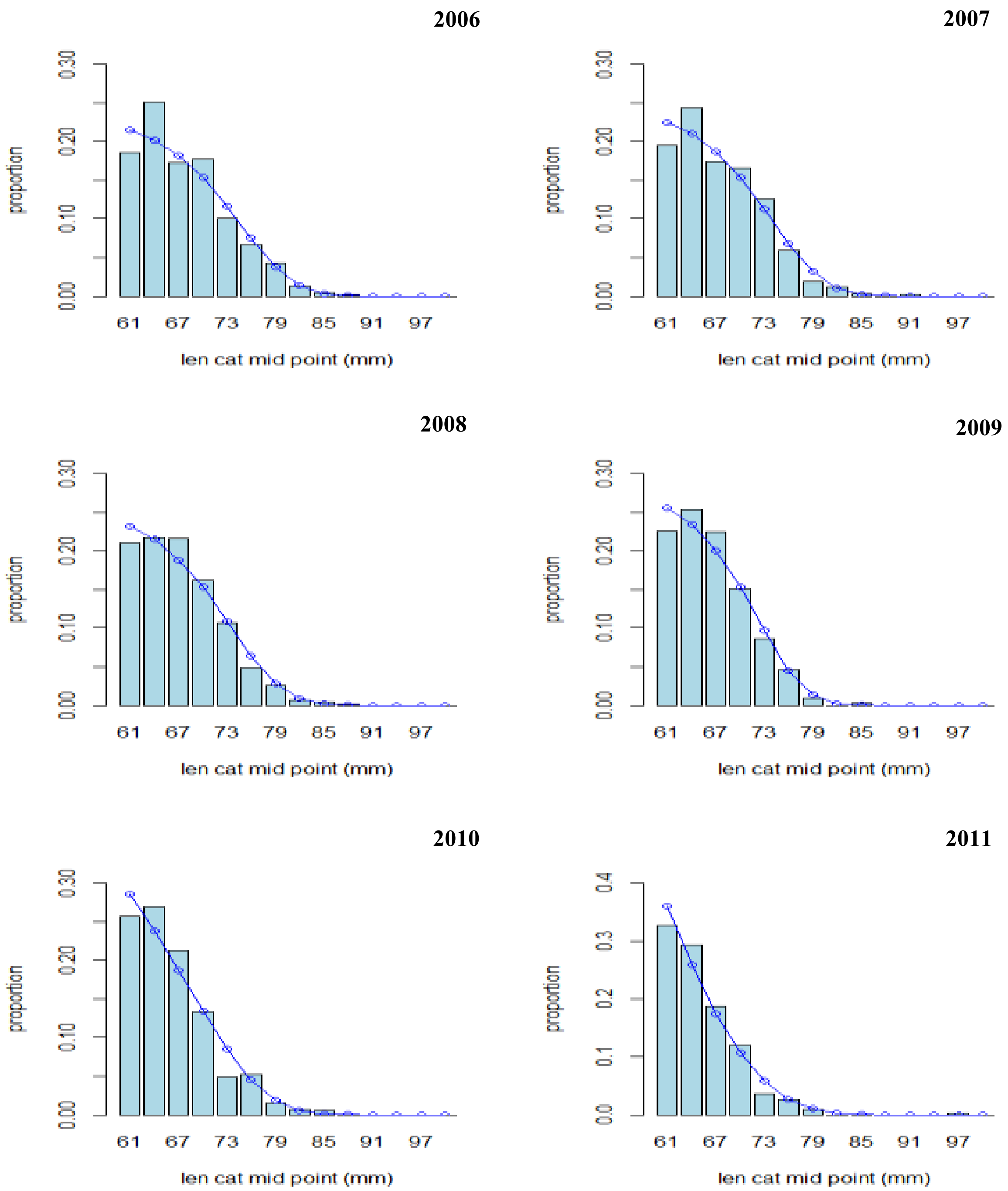


Figure 21.3. Catch curves (blue lines) fitted to length frequency data collected by fishery-independent surveys of Roe's abalone on the reef platform habitat (West Coast recreational fishery). Note the change of the scale in 2011 (x – axis).

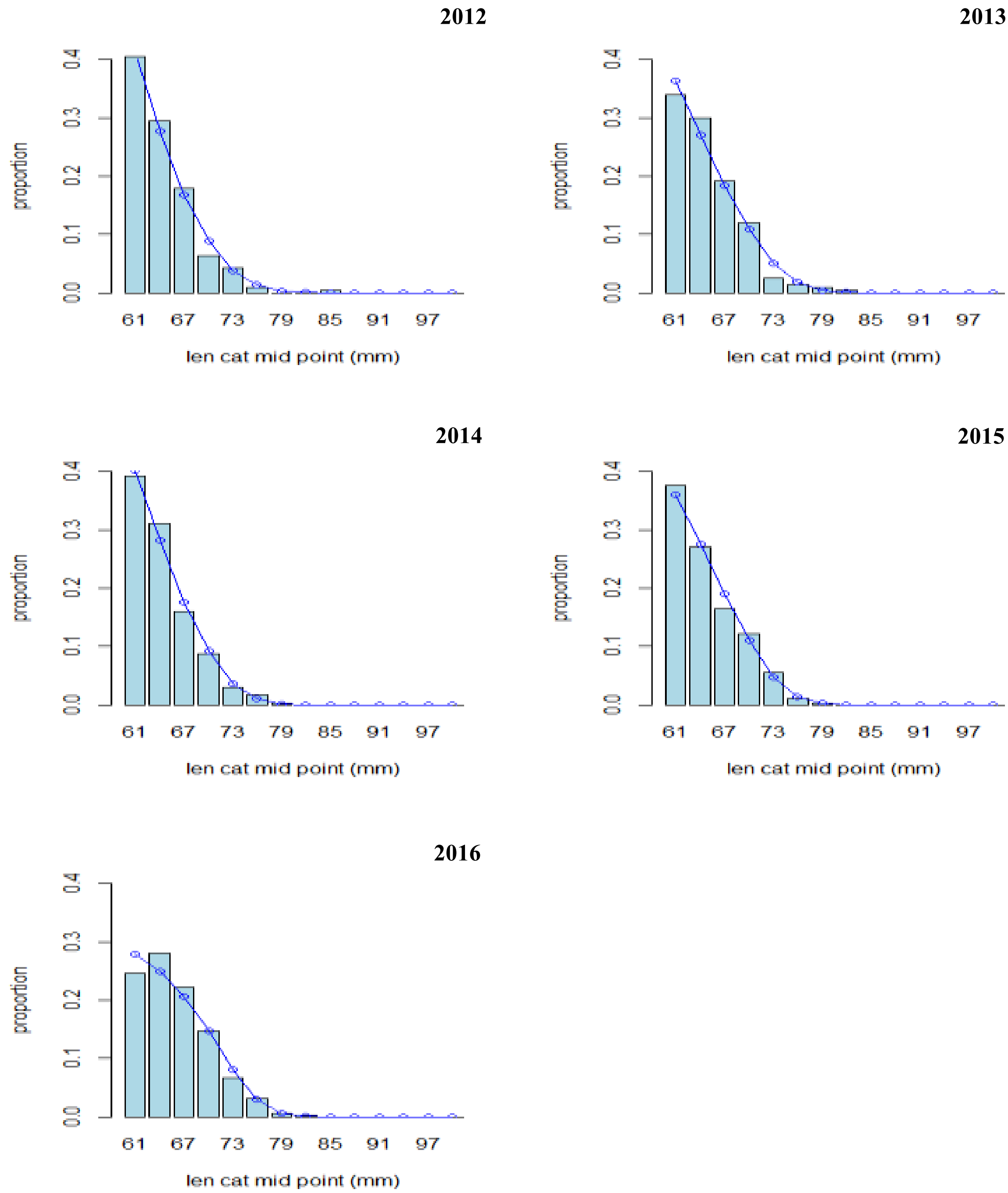


Figure 21.3. Continued

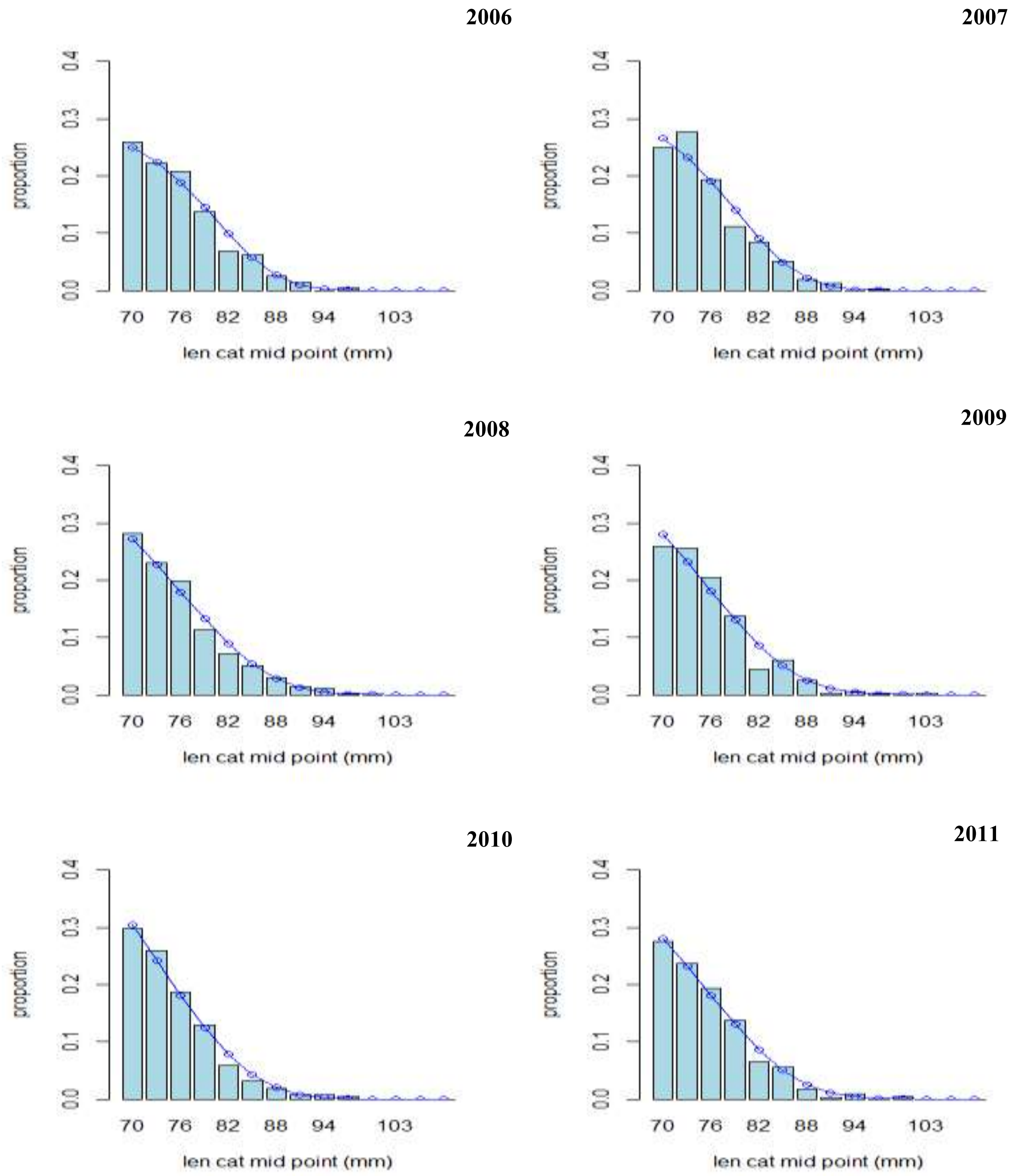


Figure 21.4. Catch curves (blue lines) fitted to length frequency data collected by fishery-independent surveys of Roe’s abalone on the subtidal reef habitat (Area 7 commercial fishery).

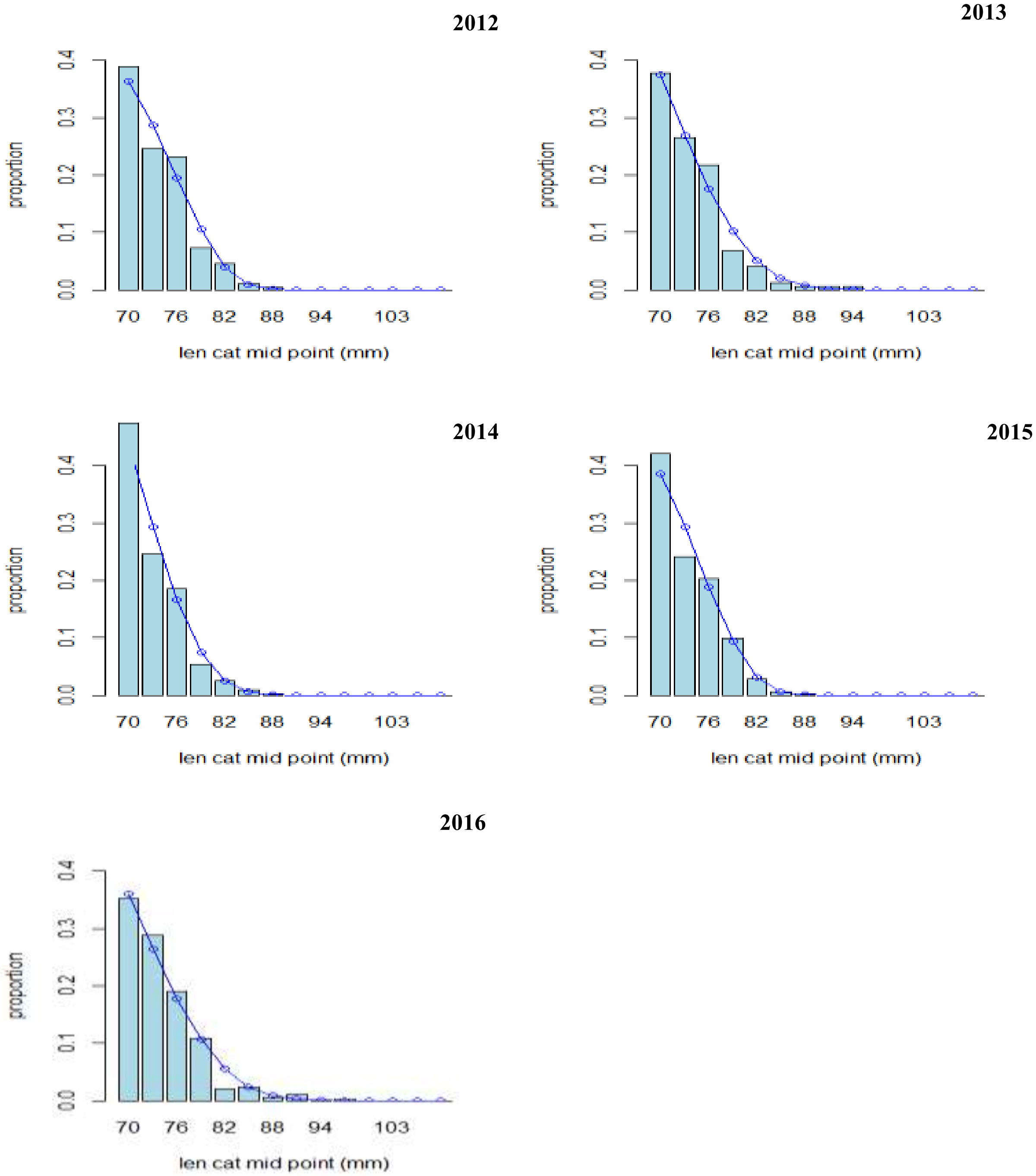


Figure 21.4. Continued.

Table 21.2. Estimates of total mortality of Roe's abalone from fished areas derived by fitting a length-converted catch curve to length-frequency data collected during annual fishery-independent surveys in the Perth metropolitan region.

Year	Platform reef habitat (Recreational fishery)			Subtidal reef habitat (Commercial fishery)		
	Z ($year^{-1}$)	SE	n	Z ($year^{-1}$)	SE	n
2006	0.87	0.09	655	0.65	0.10	278
2007	0.91	0.10	745	0.69	0.10	332
2008	0.95	0.10	730	0.74	0.10	501
2009	1.11	0.13	647	0.75	0.11	468
2010	1.18	0.13	588	0.83	0.12	440
2011	1.46	0.16	465	0.75	0.11	413
2012	1.87	0.20	420	0.99	0.16	285
2013	1.64	0.18	537	1.08	0.15	336
2014	1.95	0.22	476	1.29	0.19	312
2015	1.78	0.21	481	1.08	0.17	356
2016	1.27	0.15	561	1.02	0.15	306

21.1.2.2 Unfished Areas

Total mortality of Roe's abalone in the unfished Watermans Reserve was estimated at 0.38 $year^{-1}$ (± 0.06) and 0.83 $year^{-1}$ (± 0.1) in subtidal and platform habitats, respectively (Table 21.3). Length frequency distributions for Roe's abalone differed markedly between the two habitats with the proportions of individuals in the larger length categories being substantially greater in the subtidal habitat (Figure 21.5).

This marked difference, despite the minimal difference in growth of abalone between these two habitats (see Section 21.1.1) may, in part, reflect a higher rate of natural mortality of Roe's abalone in the platform habitat. A higher natural mortality in the platform habitat might be expected given the increased wave exposure, less stable water temperatures and, in some areas, periodic sand inundation, of this habitat compared with the subtidal habitat.

It is also possible that the differences in length frequency distributions may reflect, in part, a movement of individuals from the platform habitat to the subtidal habitat. If so, the catch curve estimate of the platform habitat would reflect a combination of both mortality and movement. It thus follows that the catch curve estimate of natural mortality of Roe's abalone in the platform habitat may represent an overestimate. Likewise, if substantial movement of individuals from the platform to subtidal habitat occurs, the lower estimate of natural mortality of 0.38 $year^{-1}$, for this species in the subtidal habitat, potentially represents an underestimate. In terms of stock assessment, a lower value of natural mortality implies lower productivity, and thus greater susceptibility of the population to fishing pressure. M values of 0.3-0.43 $year^{-1}$ (i.e. around the subtidal M estimate) have been chosen for further analyses (see Section 21.1.4), as lower values of M lead to more conservative estimates of stock status (and thus more precautionary management).

The value of 0.38 year^{-1} for natural mortality produced by the catch curve analysis implies that individuals of this species rarely live to more than about 10 years, and that populations of Roe's abalone are more productive than those of Brownlip and Greenlip abalone, which occur in colder, deeper waters (i.e. more stable environments) and grow to a much larger size.

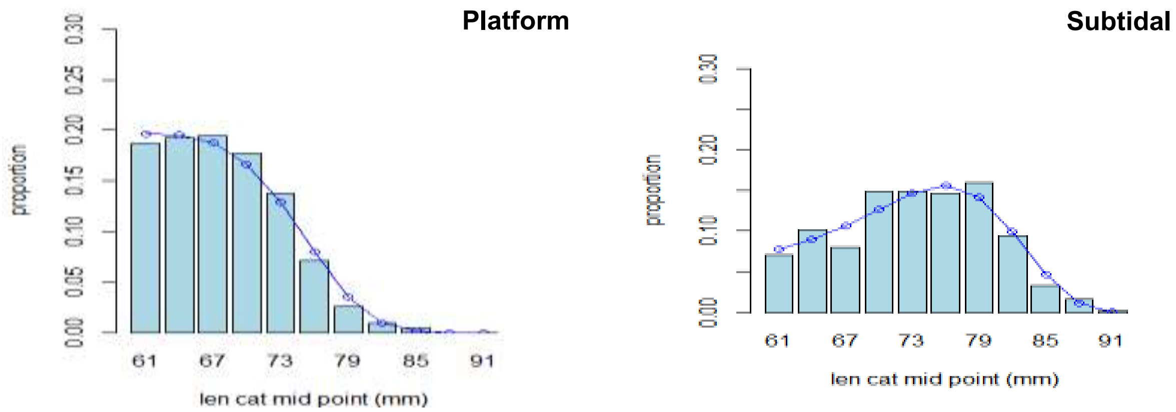


Figure 21.5. Catch curves (blue lines) fitted to length frequency data collected during fishery-independent, in-water surveys of the platform reef habitat of Watermans Reserve (no take area). Data pooled from 2007-2009.

Table 21.3. Estimates of total (natural) mortality of Roe's abalone from an unfished area (Watermans Reserve) derived by fitting a length-converted catch curve to length-frequency data for collected during annual fishery-independent surveys in the Perth metropolitan region. The value for the subtidal reef habitat (M = 0.38) is used in subsequent analyses as an estimate for natural mortality.

Year	Mortality, year^{-1} (±1stdev)	*n*
Platform reef habitat		
Pooled data (2006-09)	0.83 (0.1)	659
Subtidal reef habitat		
Pooled data (2006-09)	0.38 (0.06)	552

21.1.3 Density Trends

Fishery-independent survey data for Roe's abalone in platform and subtidal habitats in the Perth metropolitan area are used for monitoring annual trends in density of harvest-sized individuals. Comparisons of data between fished and unfished areas provide valuable information on environmental effects on densities that may be simultaneously occurring with fishing.

The fishery-independent density data for Roe's abalone are analysed using GLM models. For routine monitoring, density is analysed for different size-class groupings that correspond to approximate year classes prior to recruitment, plus recruited (harvest-sized) animals (see Table 21.4). Estimates of density are derived using a three-factor (*Year*, *Location* and *Habitat*) ANOVA model (using S_Plus). A logarithmic transformation of the raw data is undertaken to take into account the skewed distribution associated with density data. The least squares mean of the factor *Year* is used to produce an annual index of density, standardised by location and habitat.

Table 21.4. Size and age classes used in the analysis of Roe's abalone survey densities. Age classes are derived from growth curve of Hancock (2004)

Size class	Age-class (approximate)	Description
3 – 16 mm	0+ years	New recruits (~6-9 months) at time of the surveys in January/February
17 – 32 mm	1+	Age 1 year old (size-frequency analysis usually distinguishes between Age 1 and Age 0 classes)
33 - 50 mm	2+	Approximately 2 years of age, about 2 years prior to recruitment into the Recruits size-class
51 - 60 mm	3+	Approximately 3 years of age, about 1 years prior to recruitment into the recreational fishery, which targets 60 mm+
61 - 70 mm	4+	Approximately 4 years of age, corresponding to recruitment into the recreational fishery
≥71 mm	Recruits	Approximately 5+ years of age – animals begin recruiting into the commercially exploited population at size 71 – 75 mm.

21.1.3.1 Fished Areas

Trends in density of fished stocks of Roe's abalone varied among size-classes (Figure 21.6). The densities of abalone in the smaller size classes ≤ 50 mm have declined substantially since 2011 (Figure 21.6a-c), indicating a period of the lowest recruitment since surveys began in 1997. In contrast, the densities of the larger size classes of abalone that have recruited into the fishery (i.e. 61-70 and > 70 mm, noting that the minimum legal sizes of Roe's abalone for recreational and commercial fishers in the Perth metropolitan area are 60 and 70 mm, respectively) have only declined slightly (Figure 21.6e, f). The limited recruitment in recent years thus appears largely environmentally-driven and is not a result of low spawning stock levels. This is further supported by comparing the abalone densities in fished and unfished areas, which shows a similar declining trend in densities of smaller individuals, independent of fishing pressure (see Section 21.1.3.2).

Further analysis of density declines in the larger abalone reveals a difference between the recreationally fished (platform habitat) and commercially fished (subtidal habitat) areas (Figure 21.7). Density declines have largely occurred on the platform habitat, however, data from 2015 and 2016 shows an increase in platform densities for the first time since 2007 (Figure 21.7).

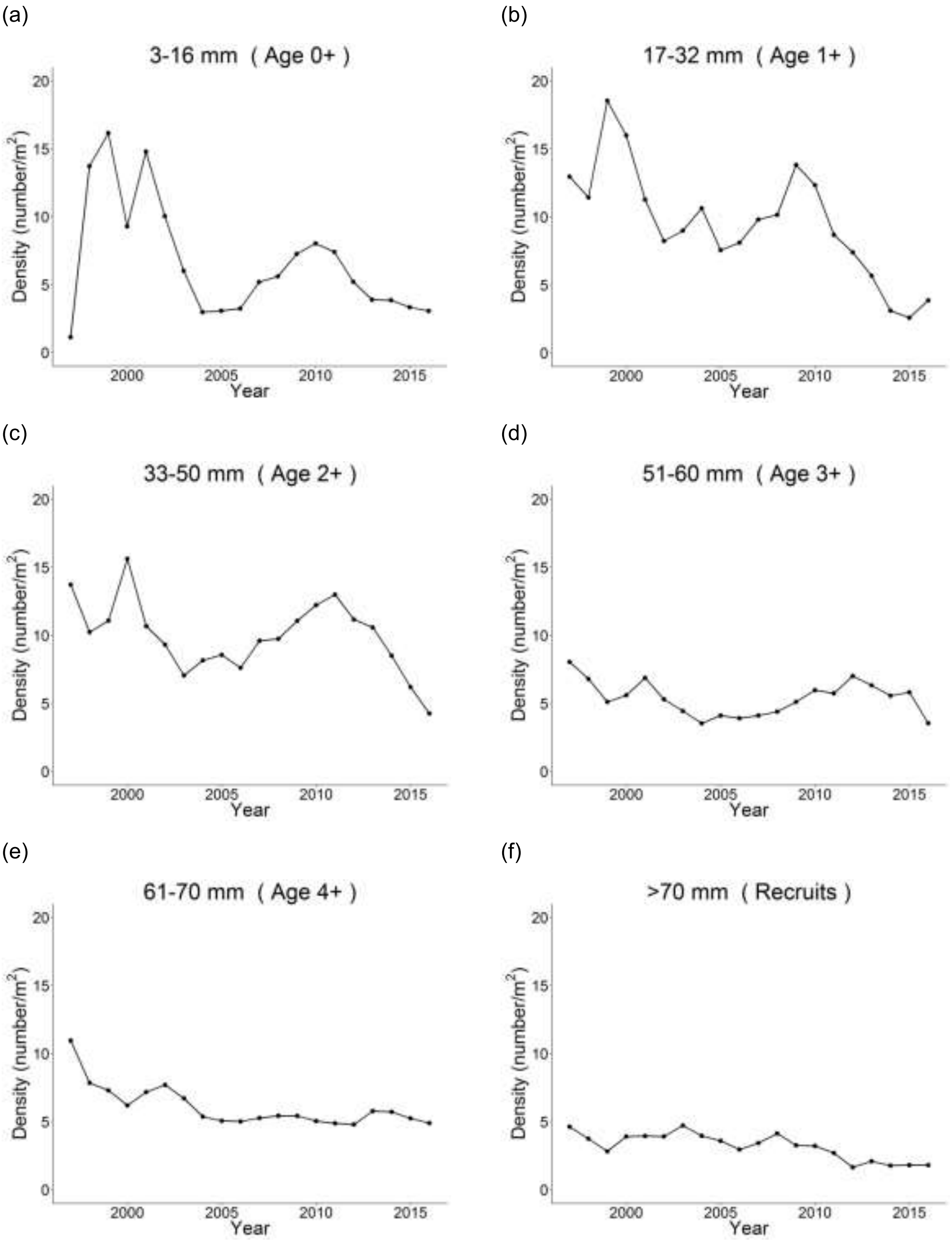


Figure 21.6. Trends in the density (number of individuals per m^2) of different size classes (a-f) of Roe's abalone in the Perth metropolitan area, based on data collected in fishery-independent surveys. Approximate age groups have been assigned to each of the different size classes, based on a deterministic (von Bertalanffy) growth curve

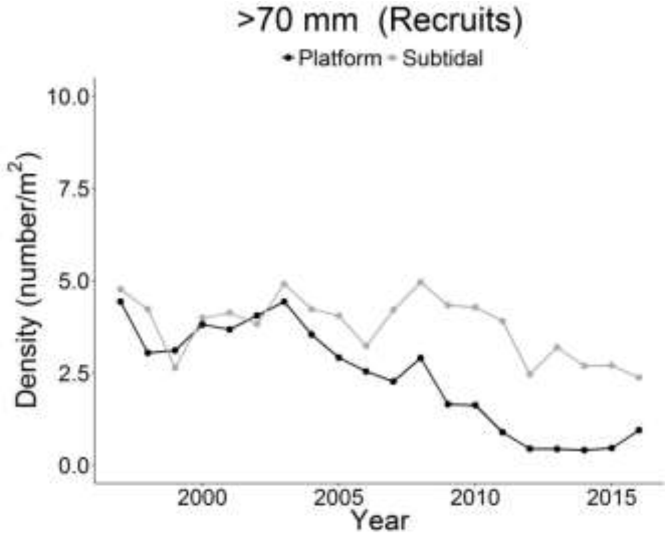


Figure 21.7. Trends in the density (number of individuals per m^2) of fully-recruited Roe's abalone in recreationally (platform) and commercially (subtidal) fished habitats of the Perth metropolitan area, based on data collected in fishery-independent surveys.

21.1.3.2 Unfished Areas

Between 1997 and 2015, total density of Roe's abalone in fished areas was, on average, about 68% of unfished densities in Watermans Reserve (Figure 21.8a). In comparison, there was no significant difference in mean density of Age 1 + animals between fished and unfished areas during this time (Figure 21.8b). The densities of Age 1 + Roe's abalone in the two areas were highly correlated (r = 0.78; Figure 21.8b), confirming that environment is the main driver of recruitment levels in this fishery. The four worst years of recruitment (2013-2016) were the same for both fished and unfished stocks. The environmental effect is hypothesized to be the marine heatwave of 2011/12, which decimated the Roe's abalone stock several hundred kilometres to the north of Perth, in Kalbarri (Area 8 of the AMF), at the northernmost limit of the distribution of this species in WA (Caputi et al. 2014).

A clear pattern emerges when examining the % of the population that is comprised of large (>71 mm) abalone. There is a declining trend between 2004 and 2012 in both fished and unfished stocks, however, the rate of decline increases sharply between 2010 and 2012 (Figure 21.9). Large animals in the Watermans unfished area declined from a high of 39% in 2004 to 7% in 2012. A similar decline occurred in fished stocks but it was not as severe. Recovery of this size class is now occurring in both fished and unfished areas.

(a) (b)

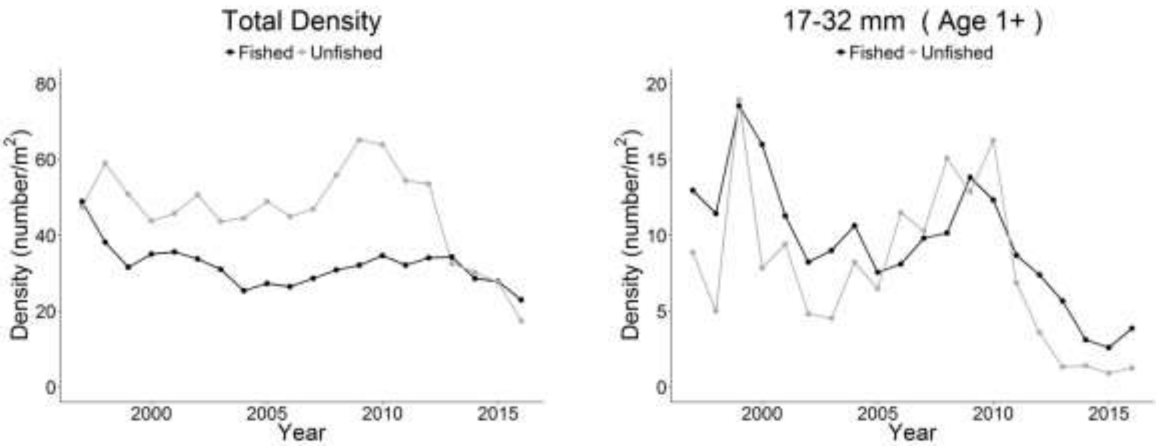


Figure 21.8. Trends in the (a) total density (number of individuals per m^2) and (b) density of Age 1+ individuals (i.e. 17-32 mm) of Roe's abalone in the Perth metropolitan area, based on data collected in fishery-independent surveys of fished (black) and unfished (grey) areas

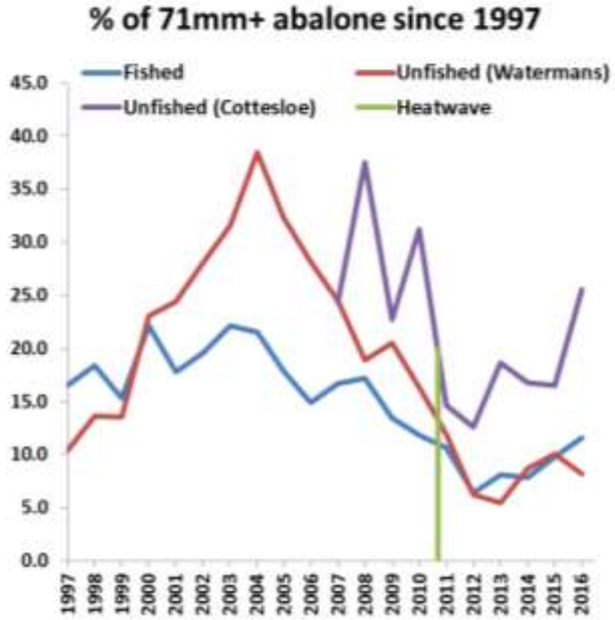


Figure 21.9. A comparison between the % of large (71 mm+) Roe's abalone in fished and unfished areas of Area 7 (Perth metropolitan region)) between 1997 and 2016

21.1.4 Biomass Estimation

Two methods have been applied to estimate biomass of Roe's abalone; a model that estimates spawning biomass from density data and the total fished area of the commercial (Area 7) and recreational (West Coast) fishery (as adapted from Hart et al. 2013c), and a biomass dynamics model.

Firstly, the total spawning biomass of Roe's abalone in the Perth metropolitan area was estimated from annual fishery-independent density data, mortality estimates from catch curve analyses, and estimates of the total fished areas in the platform and subtidal habitats using an approach modified from Hart et al. (2013c). Estimates of biomass were produced separately for the two habitats. Total spawning stock biomass, SSb_f, may be calculated as

$$SSb_f = SSb(H_f) \qquad 16$$

where SSb is the spawning biomass per unit area, as estimated from independent surveys, and H_f is the habitat area fished, calculated as

$$H_f = N_a / D_a \qquad 17$$

In the above equation, N_a is the numbers of harvest-sized abalone in the population at the time of the survey and D_a is an estimate for the mean density of harvest-sized abalone at the time of the survey. D_a was calculated as the back-transformed average of $\log_e(x+1)$ transformed values for abalone densities at n = 384 survey quadrats for the platform habitat and n = 260 survey quadrats for the subtidal habitat. To account for uncertainty, 1000 values of D_a were calculated by randomly resampling, with replacement, the density values recorded at each site. The value of N_a was determined as:

$$N_a = N_b(e^{-Z_F t}) \qquad 18$$

where N_b is the number of animals in the population before fishing, Z_F is the level of total mortality to which the stock is subjected during the fishing season, and t, is the period from the start of the commercial fishing season to the time of the survey. Z_F is calculated as $F_F + M$, where M is instantaneous rate of natural mortality and F_F is the fishing mortality applied during the fishing season, calculated as the annual value of Z, estimated from the catch curve analysis, divided by t.

N_b is unknown but can be solved numerically by minimising the sum of squared deviations between the numbers of animals in the observed catch *vs* the expected catch, C_e. Using the Baranov catch equation, C_e is estimated as

$$C_e = \frac{F_F}{Z_F}\left[1 - e^{-Z_F t}\right] N_b \qquad 19$$

A resampling analysis was undertaken to produce 1000 estimates of SSb_f in each habitat, in each case using a different estimate for D_a, SSb, Z and M. Uncertainty in M was considered by generating 1000 estimates for this parameter from an assumed normal distribution, with a mean of 0.43 year^{-1} (as estimated by catch curve analysis applied to data for Roe's abalone from the subtidal habitat in an unfished area), using a standard deviation of 0.02. The analysis was also repeated assuming a more conservative value for M of 0.3 year^{-1}. It must be noted here that the most recent estimates of M for this species are provided in Table 21.3 (catch curve analysis) and Section 5.1.3.7 (field experiment). The range between the upper (0.43) and lower (0.3) estimates of M investigated in this analysis encompasses the catch curve (M = 0.38) and field experiment (M = 0.32) estimates of M.

For each scenario, estimates of biomass on the platform and in the subtidal habitat were produced based on an estimate for total mortality for 2006-2009 (i.e. by fitting the catch curve model to pooled data for these four years). Random values were generated based on the estimate for the standard error produced by the catch curve analysis. The inverse transform method was used to resample the harvest and spawning biomass per unit area data from 2006-2009. The data were pooled across these years to increase the precision of biomass estimates, noting that the estimates of biomass per unit area did not differ significantly over this period in either habitat.

The estimated spawning biomass, when applying the catch curve estimate of M of 0.43 year^{-1}, was substantially less for the platform habitat (87 t; 95%CL 51-172 t) than for the subtidal habitat (174 t; 95% CL 85-759 t). The distributions for spawning biomass estimates are, however, relatively broad (Figure 21.10). This was also reflected in the smaller estimate for the area of the platform habitat (44,109 m^2; 95%CL 26,751-88,181 m^2) than for the subtidal habitat (90,139 m^2; 95%CL 44,242-383,120 m^2). The estimates of spawning biomass derived from the conservative more scenario (i.e. M = 0.3 year^{-1}) were less for both the platform habitat (66 t; 95%CL 42-120 t) and the subtidal habitat (117 t; 95%CL 67-276 t) (Figure 21.10).

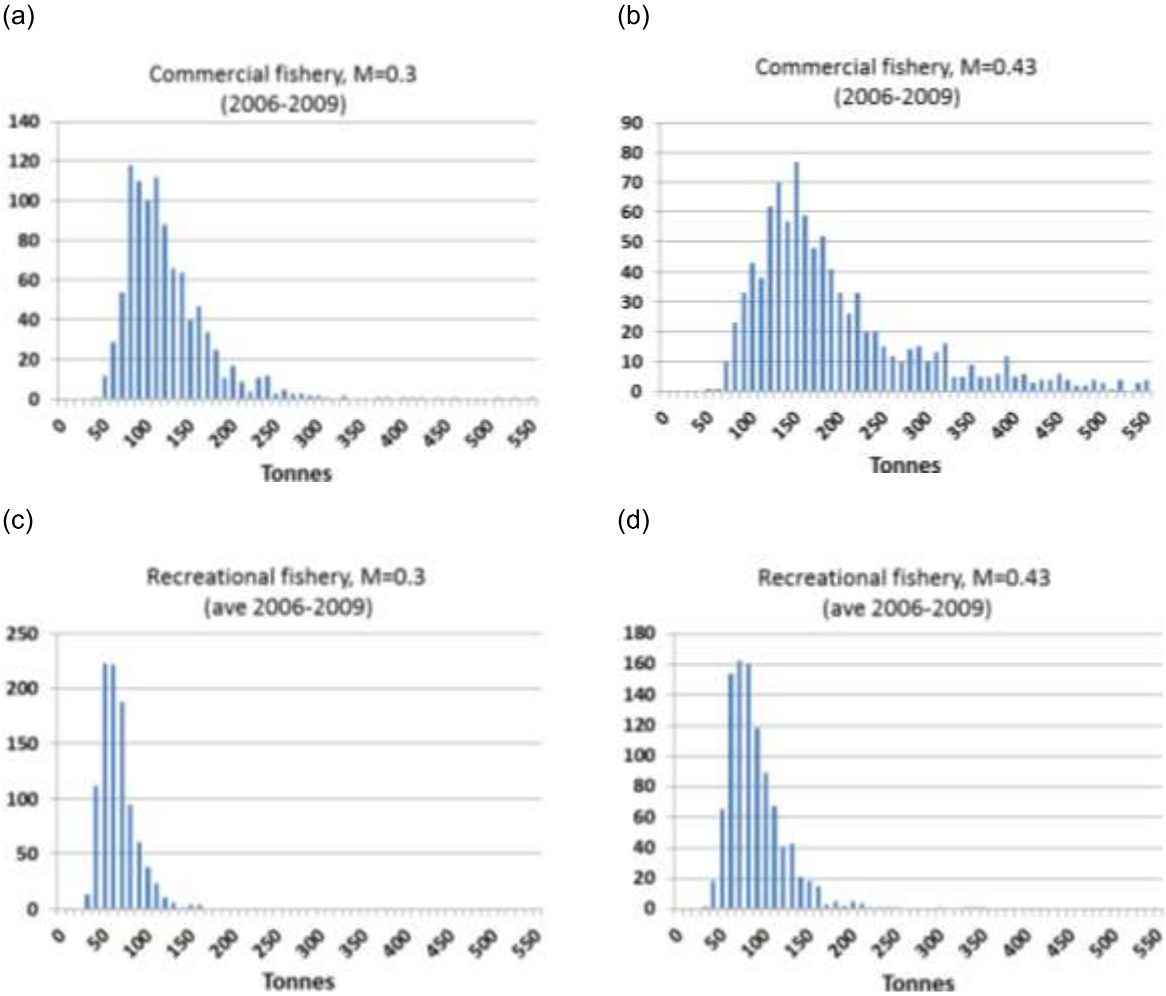


Figure 21.10. Probability based estimates of spawning biomass (t) of Roe's abalone in the Area 7 commercial fishery (a, b) and West Coast recreational fishery (c, d), based on two natural mortality scenarios: M = 0.3 (a, c), and M = 0.43 (b, d). Estimates from n = 1000 bootstrap runs for the 2007 fishing year.

21.1.4.1 Biomass Dynamics Model

A preliminary attempt was made to obtain an alternative estimate of MSY for Roe's abalone in the Perth metropolitan fishery. A standard Schaefer biomass dynamics model was used to estimate the level of biomass of this species in the overall fishery, and in the important fishery areas, relative to estimated unfished levels in those areas.

As described by Hilborn and Walters (1992) and Haddon (2011), the model relates the catch taken by the fishery to changes in the catch rate to estimate the carrying capacity (K) and the intrinsic rate of increase (r) from which the current level of biomass, relative to the unfished level can be estimated, together with MSY. The model used was the discrete form of Schafer model (Hilborn and Walters 1992):

$$B_t = B_{t-1} + rB_{t-1}\left(1 - \frac{B_{t-1}}{K}\right) - C_{t-1} \qquad 20$$

where B_t is the biomass of the stock at time t, B_{t-1} is the biomass of the stock at time t-1, r is the intrinsic rate of population growth, k is the carrying capacity, and C_{t-1} is the yearly catch at time t-1.

The parameters of the model (r, K, q and the virgin biomass B_0) were estimated by minimising the negative log likelihood (in AD Model Builder), calculated based on the squared deviations between the natural logarithms between the observed and expected catch rates (i.e. abundance indices from fishery-independent surveys). To account for the fact that the stock had been fished prior to the beginning of the time series, the estimated biomass in the first year of the time series was multiplied by either 0.7 or 0.8 (i.e. indicating that the stock in the first year was already depleted by either 30 or 20%). Values less than 0.7 were also considered, but the analysis became unstable. The catches represented the combined recreational and commercial catch. Estimates of maximum sustainable yield were calculated as

$$MSY = (rK)/4. \qquad 21$$

To provide estimates of the distributions for the parameters and estimates of MSY, the model was fitted employing MCMC (using 100,000 iterations with a thinning interval of 20). (Note, further work is required to confirm if convergence was likely to have been achieved).

As is demonstrated by the distributions for the parameter estimates, the values for K and r are unrealistic, indicating that there was insufficient contrast in the data to provide reliable estimates of these parameters. However, the estimates for MSY were more realistic (~50-55 t, or slightly less if an initial depletion of 0.2 is assumed), being of a similar level to that provided by the reference point analyses (Figure 21.11). As MSY is based on the ratio of K and r, even if these parameters are highly confounded and not well estimated, the estimates of MSY may still be realistic. However, given the inability to estimate the other parameters of the model, this analysis must be treated with a high degree of caution.

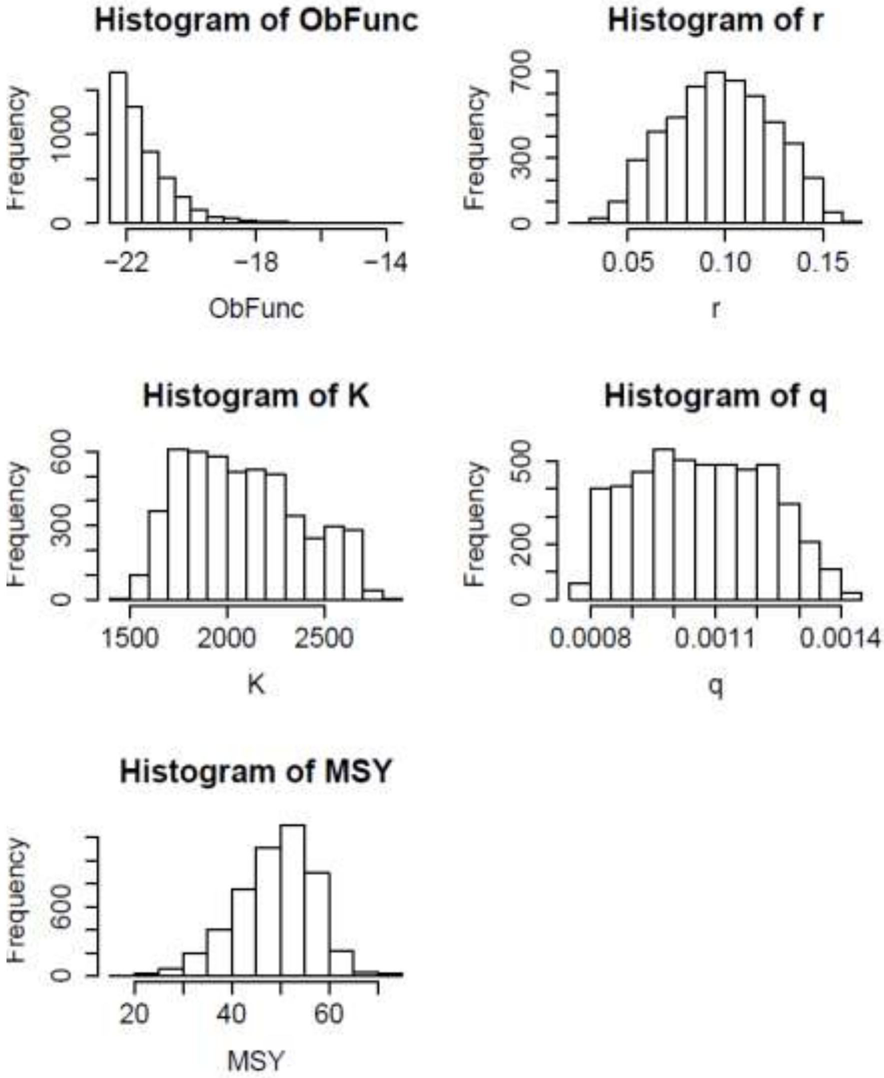


Figure 21.11. Distributions of parameters estimated by the biomass dynamics model applied to data for Roe's abalone in the Perth metropolitan area, and associated values of the objective function and estimates of Maximum Sustainable Yield (MSY)

21.2 Greenlip & Brownlip Abalone Research Summary

21.2.1 Growth Analysis

Growth of Greenlip and Brownlip abalone was analysed using the same methods as those described in detail for Roe's abalone, in Section 21.1.1.

21.2.1.1 Greenlip Abalone

When fitted to all data for sites in Areas 2 and 3 combined, the model with the minimum value for the negative log-likelihood was the double logistic model. This was only marginally lower than the negative log-likelihood for the Gaussian PDF curve and thus these two models essentially fit equally well to the data (Table 21.1). These two models provided substantially better fits than the von Bertalanffy growth model (Table 21.1). On the basis of the AIC statistic, the double logistic model was considered as the most appropriate growth model for Greenlip abalone.

As indicated in (a) and (b) of Figure 21.12, the relationship between the growth increments, and also final lengths of Greenlip abalone, with respect to initial length, are not "smooth". For example, the observed growth increments of individuals initially measured at around 40-60 mm were much less than for individuals just below and above this range. This, to a major extent, reflected the relatively shorter times at liberty of individuals of 40-60 mm (~200 days) compared with that for most other individuals (generally ~1 year). The fit of the double logistic growth model to the length increment data is relatively good (see residual plots in Figure 21.12c, d).

On the basis of the fitted growth model, on average, Greenlip abalone of initial lengths of 50, 100 and 150 mm, respectively, are estimated to grow by 42, 28 and 6.5 mm in a year. By 2, 5 and 10 years of age, on average, individuals are expected to have attained lengths of about 44, 136 and 167 mm. The same plots produced when fitting the Gaussian probability density function to the data for Greenlip are almost identical (figure not included).

21.2.1.2 Brownlip Abalone

Similar to Greenlip abalone, the double logistic model and Gaussian probability density function both provided substantially better fits to the Brownlip abalone data than the von Bertalanffy model (Table 21.1). Although the fits provided by the former two models were similar, the negative log-likelihood for the double logistic model was the lower of the two, while the AIC for the Gaussian PDF was slightly lower than for the double logistic curve (Table 21.1), thereby indicating that the Gaussian PDF was a slightly better choice of model given the data.

As with Greenlip abalone the times at liberty of Brownlip abalone were variable. As such, the relationships between the growth increments and final lengths, and initial length were not smooth (Figure 21.13a, b), although the residual plots indicated that the model provided a good fit to the data (Figure 21.13c, d). On the basis of the fitted growth model, on average, Brownlip abalone of initial lengths of 50, 100 and 150 mm are estimated to grow by 32, 19 and 6 mm in a year, respectively. By 2, 5 and 10 years of age, on average, individuals are expected to have attained about 55, 131 and 162 mm.

Table 21.5. Values of estimated parameters derived by fitting the Double logistic model, Gaussian probability density function and von Bertalanffy growth model to tag-recapture data for Greenlip and Brownlip abalone in Western Australia. Stdev refers to standard deviation, NLL refers to negative log-likelihood, and AIC refers to Akaike's Information Criterion statistic. The growth curves were fitted to 956 observations for Greenlip abalone and 628 observations for Brownlip abalone.

Double logistic model			**Gaussian PDF**			**von Bertalanffy model**		
Parameter	Estimate	stdev	Parameters	Estimate	stdev	Parameter	Estimate	stdev
Greenlip abalone								
a	0.124	0.025	A	0.124	0.006	L_∞ (mm)	206.07	15.84
$L_{50,1}$ (mm)	17.6	9.5	u (mm)	69.18	1.68	K (year^{-1})	0.189	0.03
$L_{95,1}$ (mm)	63.9	35.4	σ (mm)	42.29	1.6			
$L_{50,2}$ (mm)	123.5	8.2						
$L_{95,2}$ (mm)	164.6	6.7						
NLL	1171.41			1172.28			1210.03	
AIC	2332.82			2338.56			2416.06	
Brownlip abalone								
a	0.113	0.009	A	0.094	0.013	L_∞ (mm)	198.05	10.23
$L_{50,1}$ (mm)	46.48	25.15	u (mm)	55.33	5.38	K (year^{-1})	0.15	0.09
$L_{95,1}$ (mm)	121.31	92.20	σ (mm)	53.17	5.54			
$L_{50,2}$ (mm)	121.91	12.09						
$L_{95,2}$ (mm)	171.84	7.00						
NLL	743.93			745.46			749.85	
AIC	1497.86			1496.93			1503.7	

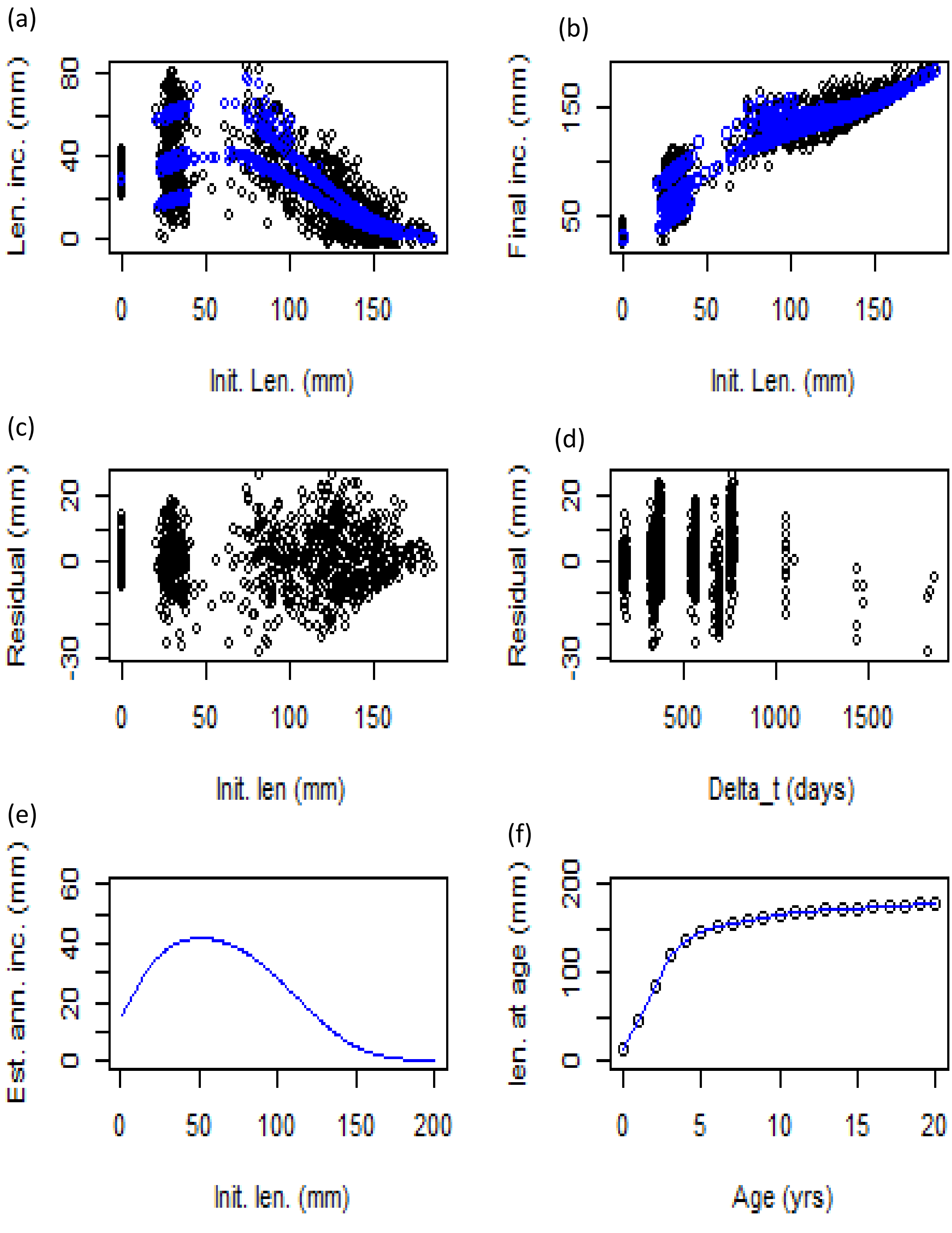


Figure 21.12. Plots associated with the fitting of a double logistic model to tag increment data for Greenlip abalone. (a) Observed (black circles) and expected (blue circles) growth increments; (b) Final lengths after one year, for abalone with respect to their initial sizes and taking into account their varying times at liberty; (c) Residuals between the observed and expected annual growth increments with respect to initial length and (d) time at liberty (days); (e) Estimated average annual growth increment as a function of initial length; and (f) Expected lengths at each integer age, based on the relationship described in (e).

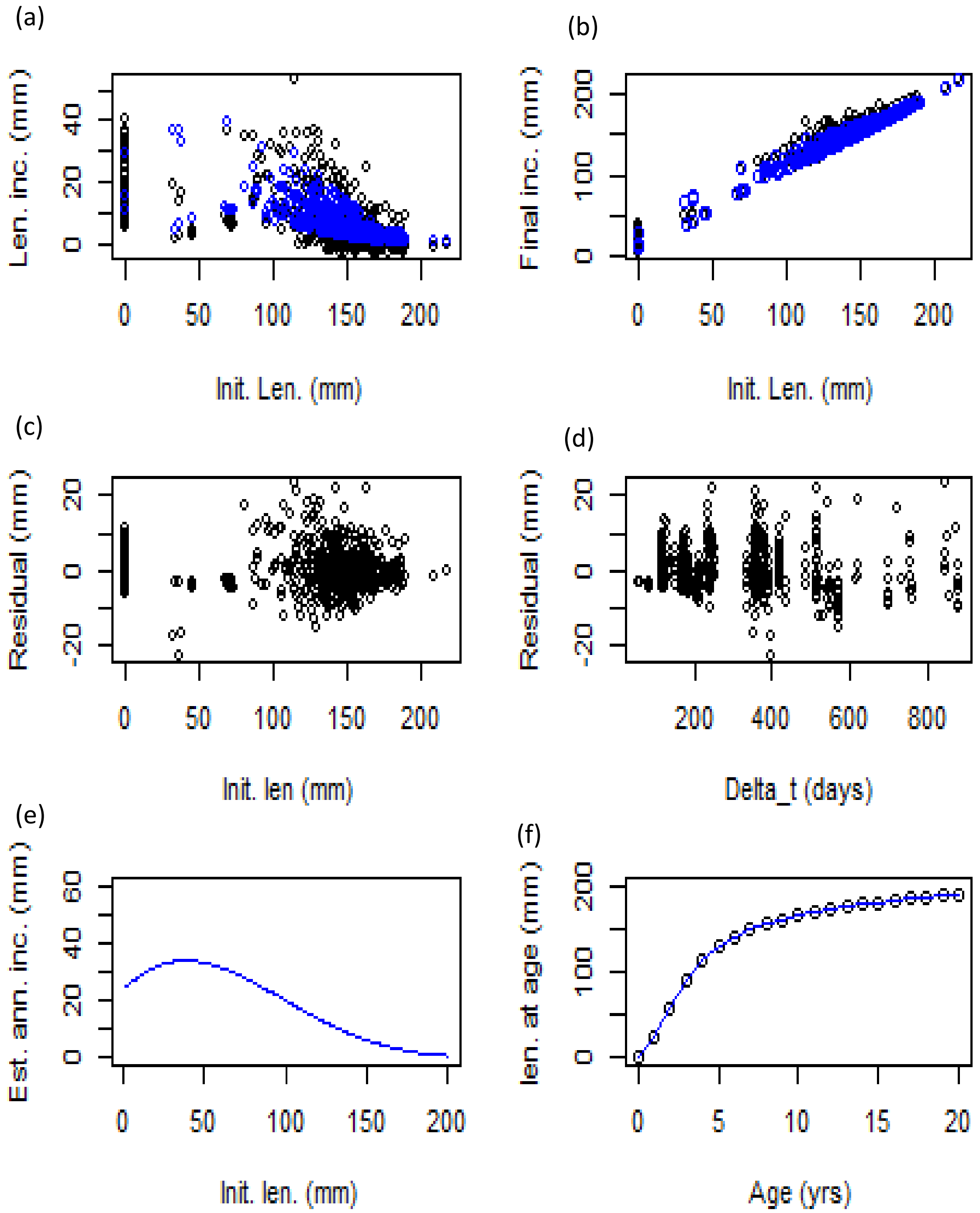


Figure 21.13. Plots associated with the fitting of a Gaussian model to tag increment data for Brownlip abalone. (a) Observed (black circles) and expected (blue circles) growth increments; (b) Final lengths after one year, for abalone with respect to their initial sizes and taking into account their varying times at liberty; (c) Residuals between the observed and expected annual growth increments with respect to initial length and (d) time at liberty (days); (e) Estimated average annual growth increment as a function of initial length; and (f) Expected lengths at each integer age, based on the relationship described in (e).

21.2.2 Mortality Estimation

Estimates of total mortality for Greenlip and Brownlip abalone were derived using the same model as described for Roe's abalone (Section 21.1.2).

Preliminary catch curve analyses for Greenlip abalone also involved comparisons between the results obtained by this catch curve with those obtained from the length-converted catch curve described by Pauly (1984). This latter catch curve, which is fitted to the descending limb of length frequency distributions calculated from annual catch samples taken by commercial fishers, is

$$\ln\left[N_l\left(dl_l / dt_l\right)\right] = -Zt + b \qquad 22$$

where Z is total mortality, N_l is the number of abalone in length class l and dl_l / dt_l is the growth rate (cm year^{-1}) in that length class at age t, estimated from the growth model (Hart et al. 2013b). Although the point estimates of Z derived from the two catch curve models were similar, the precision of those derived from Pauly's (1984) method was very poor (results not shown), and thus the method of Pauly (1984) was not used in the final assessment.

The catch curve model adopted for assessment, based on the Baranov catch equation, and which for both Greenlip and Brownlip abalone employed a logistic function to describe the pattern of selectivity with shell length, tended to provide good fits to the commercial catch data in each year between 2004 and 2015 for which data was available (Greenlip - Figure 21.14; Brownlip - Figure 21.15.

21.2.2.1 Greenlip Abalone

The estimates of total mortality for Greenlip abalone in all sub-areas apart from Augusta, calculated for each year between 2004-2015 where data was available, ranged from 0.46 and 0.67 year^{-1} (Table 21.6). The estimated lengths at which 50% and 95% of Greenlip abalone became selected into the fishery were very similar in each year, i.e. 144-148 mm and 148-155 mm, respectively.

The Augusta sub-area was separated from the rest of the fishery due to industry's management of size limits, with higher minimum sizes fished over the years (>150 mm) and an upper size limit (<165 mm) imposed in 2014 and 2015. When applying the new catch curve model, growth was modelled on Augusta tag-recapture data only (n = 762) using the same methodology as for the rest of the Greenlip fishery (Section 21.2.1). The model with the minimum value for the negative log-likelihood was the double logistic model and the plots produced were very similar to those when fitting the double logistic model to the data for the Greenlip fishery minus the Augusta sub-area (table and figure not included). The estimates of total mortality for Greenlip abalone in the Augusta sub-area only, calculated for each year between 2004-2012 where data were available, ranged from 0.43 and 0.75 year^{-1} (Table 21.7). The estimated lengths at which 50% and 95% of Greenlip abalone become selected into the Augusta sub-area fishery were very similar in each year, i.e. 150-159 mm and 154-165 mm, respectively. These estimated lengths for both 50% and 95% of Greenlip abalone becoming selected were 6-11 mm higher than for the Greenlip fishery minus the Augusta sub-area.

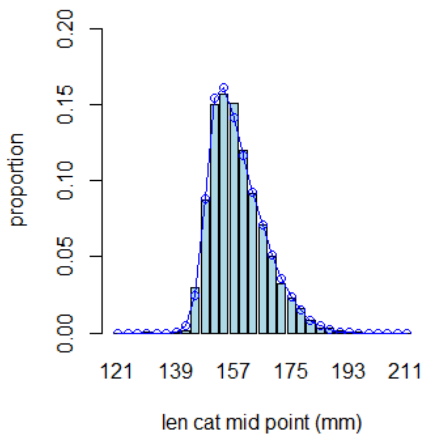
Table 21.6. Estimates of total mortality and selectivity parameters derived by fitting a catch curve assuming a multinomial likelihood to commercial length-frequency data for Greenlip abalone in all sub-areas apart from Augusta. Note that growth curves were fitted simultaneously to tag-recapture data whilst fitting each catch curve to annual commercial length-frequency data.

Year	Z, year^{-1} (±1stdev)	L_{50}, mm (±1stdev)	L_{95}, mm (±1stdev)	NLL	*n*
2004	0.67 (0.08)	148.5 (0.3)	153.7 (0.6)	7381.18	2616
2005	0.66 (0.09)	146.6 (0.3)	152.3 (0.6)	7271.47	2527
2007	0.56 (0.07)	144.8 (0.3)	148.6 (0.7)	5477.71	1836
2008	0.52 (0.08)	145.9 (0.5)	151.1 (1.1)	4637.85	1423
2009	0.60 (0.09)	145.9 (0.5)	150.6 (1.1)	4447.64	1420
2010	0.61 (0.13)	148.0 (1.0)	155.1 (2.0)	2285.68	463
2011	0.46 (0.09)	144.7 (0.8)	150.0 (1.6)	2253.38	440
2014	0.58 (0.08)	144.8 (0.4)	150.8 (0.7)	7504.73	2600
2015	0.54 (0.08)	143.9 (0.4)	150.6 (0.9)	11209.5	4182

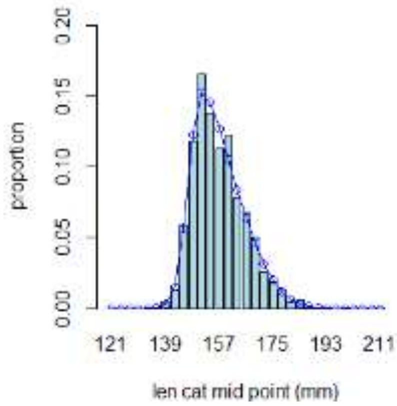
Table 21.7. Estimates of total mortality and selectivity parameters derived by fitting a catch curve assuming a multinomial likelihood to commercial length-frequency data for Greenlip abalone in the Augusta sub-area only. Note that growth curves were fitted simultaneously to tag-recapture data whilst fitting each catch curve to annual commercial length-frequency data.

Year	Z, year^{-1} (±1stdev)	L_{50}, mm (±1stdev)	L_{95}, mm (±1stdev)	NLL	*n*
2004	0.65 (0.12)	155.3 (0.7)	163.1 (1.2)	2823.0	777
2005	0.55 (0.08)	152.1 (0.3)	156.1 (0.7)	4442.35	1511
2006	0.43 (0.08)	149.9 (0.5)	154.1 (1.1)	2126.66	495
2007	0.68 (0.09)	152.4 (0.3)	156.9 (0.7)	3853.67	1214
2008	0.43 (0.09)	154.7 (0.9)	162.3 (1.9)	2913.49	800
2009	0.43 (0.06)	153.9 (0.2)	154.9 ()	4237.72	1405
2010	0.46 (0.08)	157.6 (0.4)	162.6 (0.9)	4517.64	1562
2011	0.75 (0.14)	158.9 (0.4)	162.8 (0.8)	2605.6	775
2012	0.46 (0.09)	156.9 (0.9)	164.8 (1.7)	2672.55	707

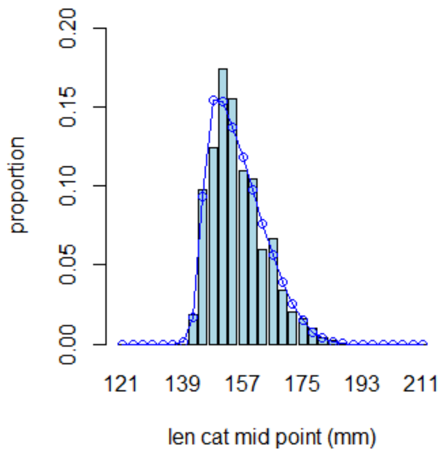
2004



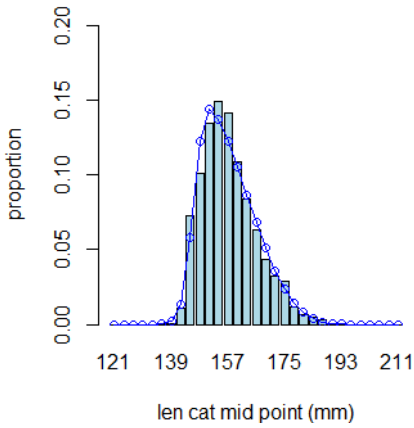
2005



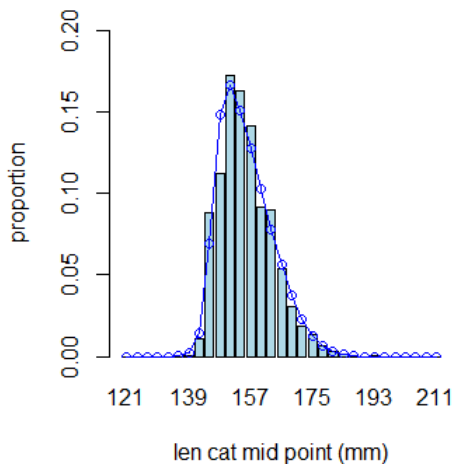
2007



2008



2009



2010

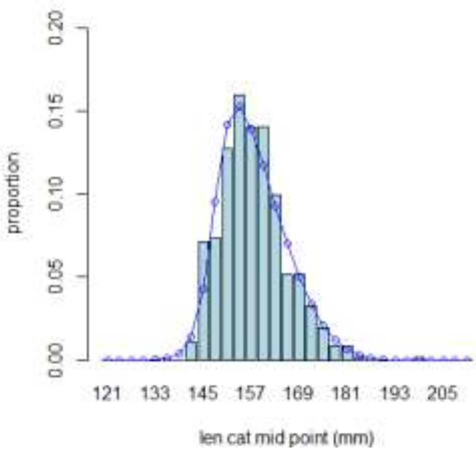
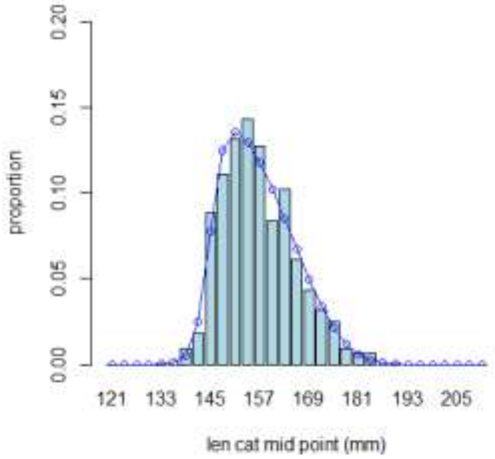
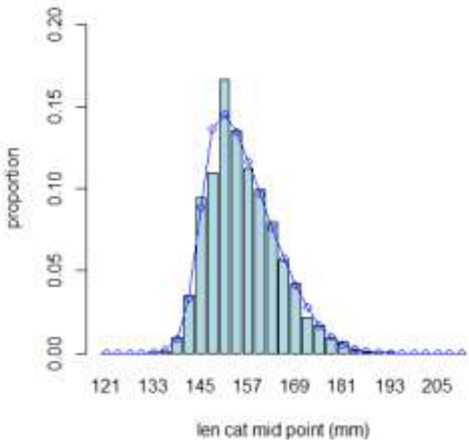


Figure 21.14. Catch curve model (blue lines) fit to commercial length-frequency data for Greenlip abalone in all sub-areas other than Augusta collected between 2004 and 2015. Note that growth curves were fitted simultaneously to tag-recapture data (n = 956) whilst fitting each catch curve to annual commercial length-frequency data.

2011



2014



2015

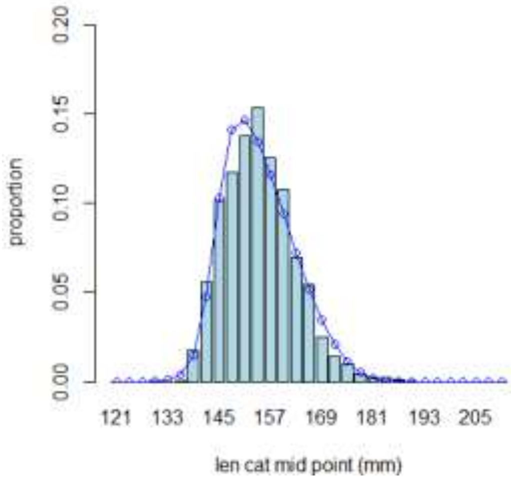


Figure 21.14. Continued.

21.2.2.2 Brownlip Abalone

Estimates of total mortality for Brownlip abalone were consistently less than those for Greenlip abalone, ranging from 0.18 to 0.26 year^{-1} (Table 21.8). Brownlip abalone are typically fished at a larger size than Greenlip, which is reflected in larger values for the estimates of L_{50} of 150-158 mm for Brownlip compared with 140-148 for Greenlip abalone (Table 21.8). However, in the Augusta sub-area only, Greenlip abalone typically start to be fished at a similar size (L_{50}) to Brownlip abalone.

Table 21.8. Estimates of total mortality and selectivity parameters derived by fitting a catch curve assuming a multinomial likelihood to commercial length-frequency data for Brownlip abalone. Note that growth curves were fitted simultaneously to tag-recapture data whilst fitting each catch curve to annual commercial length-frequency data.

Year	Z, $year^{-1}$ (±1stdev)	L_{50}, mm (±1stdev)	L_{95}, mm (±1stdev)	NLL	*n*
2004 – 2006	0.26 (0.04)	158.2 (1.0)	170.7 (1.9)	5777.42	1733
2007 – 2009	0.20 (0.03)	154.9 (0.9)	165.6 (1.9)	7089.14	2166
2010 – 2012	0.18 (0.03)	153.3 (1.6)	164.2 (3.2)	3096.92	814
2013 – 2015	0.26 (0.04)	150.2 (0.7)	160.9 (1.5)	8856.48	2781

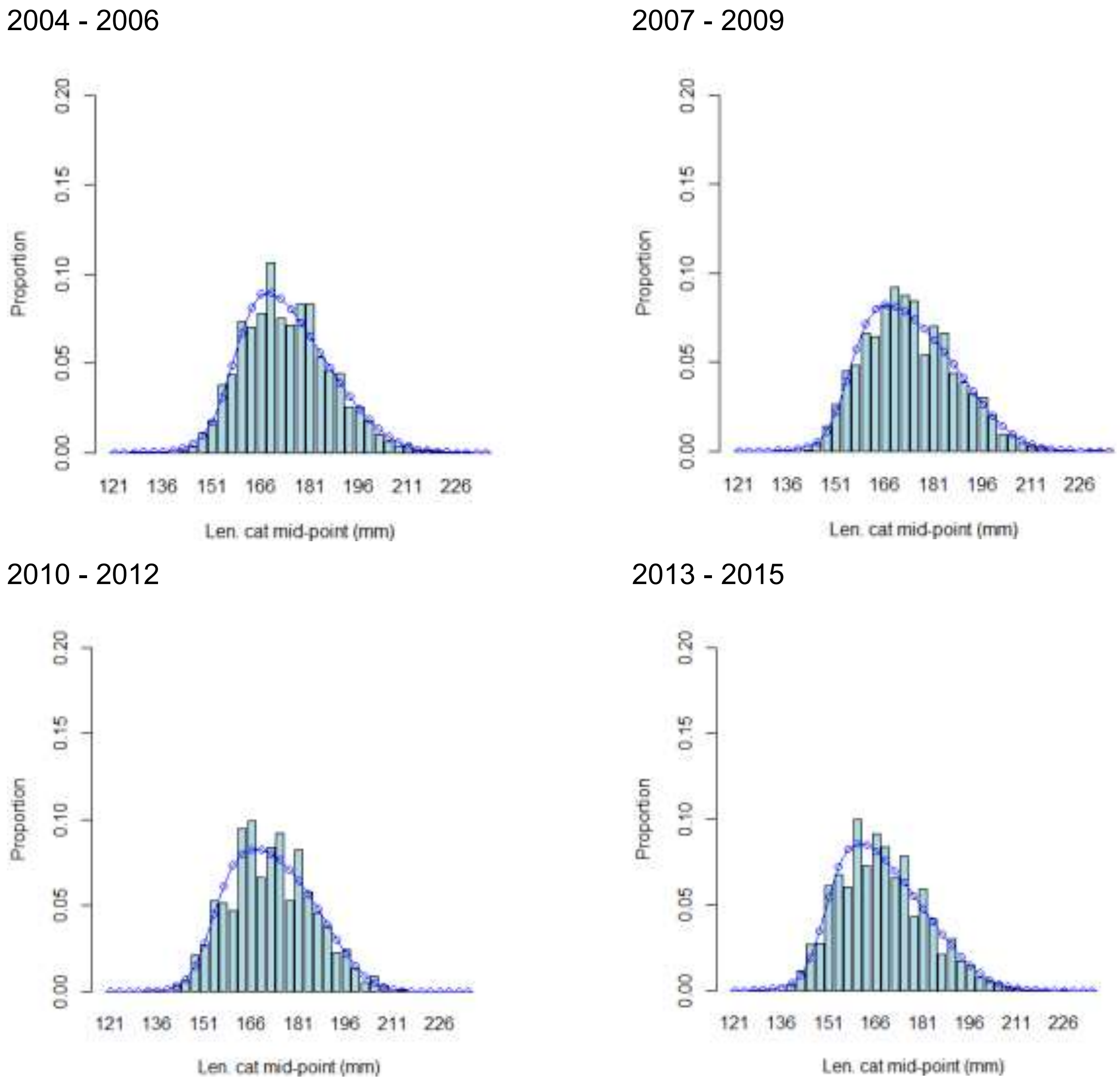


Figure 21.15. Catch curve model (blue lines) fit to commercial length-frequency data for Brownlip abalone collected between 2004 and 2015. Note that growth curves were fitted simultaneously to tag-recapture data (*n* = 628) whilst fitting each catch curve to commercial length-frequency data.

21.2.3 Density Trends

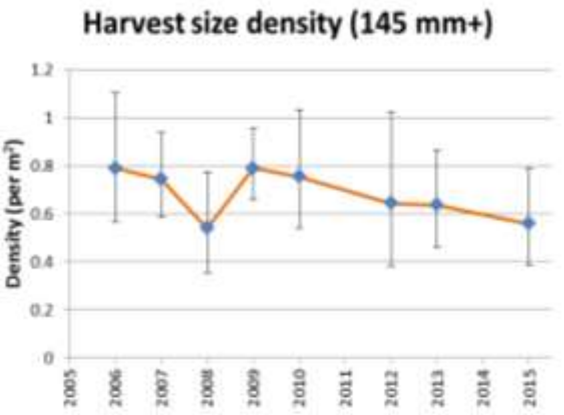
Estimates of density (Figure 21.16b) are derived using a 3-factor (*Year*, *Site*, *Diver*) GLM model. A logarithmic transformation of raw data is undertaken to take into account the skewed distribution associated with density data. The least squares mean of the factor *Year* is used to produce an annual index of density, standardised by sub area and diver.

In the current assessment, which looked at the fishery as a whole and covered the 2006 to 2015 period, the GLM model examined the effect of *Year* on juvenile (< 80 mm length) and harvest-sized density (≥ 145 mm).

Annual estimates of mean density of harvest-sized Greenlip abalone ranged between 0.8 and 0.6 per m^2 during 2006 to 2015 (Figure 21.16a) and estimates of juvenile density varied between 0.3 and 0.7 per m^2 over the same time period (Figure 21.16b).

Estimates of juvenile density from the period from 2012 to 2016 were lower than the previous time periods, indicating a period of lower recruitment. It is hypothesised that, as with Roe's abalone, this is an environmentally driven response to warming waters. In contrast the harvest sized density has remained relatively stable, however it would be expected that the period of low juvenile recruitment would be entering the fishery over the current and next few seasons, as is showing up in the catch rates.

(a) (b)



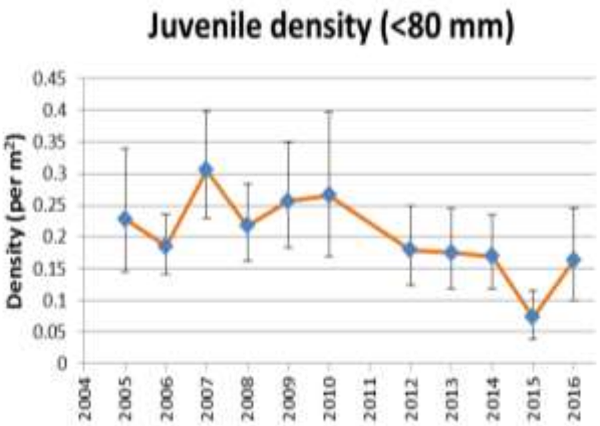


Figure 21.16. Estimates of density (number of individuals per m^2) of harvest-sized Greenlip abalone in WA from fishery-independent data. (a) trend over time between 2006 and 2015, and (b) differences between the major fishing sub-areas.

21.2.4 Biomass Estimation

21.2.4.1 Greenlip Abalone

Total spawning biomass of Greenlip abalone has been estimated from the annual fishery-independent estimates of spawning biomass per unit area and an estimate of the total fished area, using the same approach as that described in Section 21.1.4 for Roe's abalone.

Under the first scenario (M = 0.2 year^{-1}), total spawning biomass of Greenlip abalone was estimated as 641 ± 91 t (standard deviation, SD) meat weight for the period 2007 to 2012

(Figure 21.10a). In comparison, the average commercial catch of Greenlip abalone over this time period was 60 ± 2.3 t (SD), or about 9% of the spawning biomass. Under the second scenario (M = 0.15 year^{-1}), total biomass of the Greenlip abalone fishery was estimated as 536 ± 68 t (SD) meat weight for the period 2007 to 2012 (Figure 21.10b). In this case, the average commercial catch over that period (60 t) represented 11% of the estimated spawning biomass.

Using the median spawning biomass estimates, scenario 1 represents an exploitation rate of F = 0.45 M (where M =0.2), and scenario 2 represents an exploitation rate F = 0.73M for (where M = 0.15). These levels of exploitation are well within commonly used F-based reference levels.

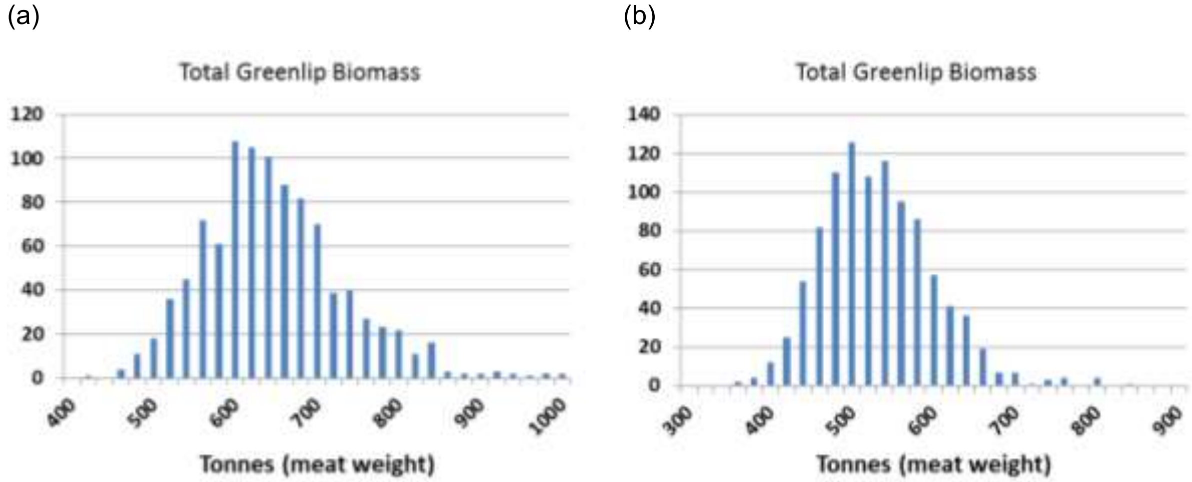


Figure 21.17. Probability-based estimates of biomass (tonnes meat weight) of Greenlip abalone assuming a value for natural mortality (M) of 0.2 (a) and 0.15 (b). Estimates from n = 1000 bootstrap runs.

21.2.4.2 Brownlip Abalone

A preliminary length-structured, single sex model has been developed for Brownlip abalone (implemented in AD Model Builder) which is fitted to a time series of commercial catches and length composition data (e.g. Figure 21.18). This model is being developed as part of an FRDC funded study, which is now close to completion. The final report resulting from that study, which will contain a full description of the model and results, is currently being drafted (Strain et al. in prep.).

The following is a very brief overview of the model and preliminary results. Growth of Brownlip abalone is based on the same model as described above for catch curve analysis (i.e. the Gaussian PDF, fitted to growth increment data, from tag-recapture studies). Given an estimate of the variance associated with the observed annual growth increments, the “growth increment model” is used to derive a length transition matrix for describing the probabilities of individuals, at each annual time step, growing from a given length class into any other possible length class (Figure 21.19). The integrated model, which is conditioned on catch, tracks the abundances of abalone belonging to each length classes throughout the history of the fishery and provides estimates of annual total biomass, spawning biomass, vulnerable biomass and fishing mortality, as well as several other parameters including, the level of recruitment at the beginning of data time series for the fishery (i.e. 1984), and (logistic) selectivity parameters describing the vulnerability of abalone to being caught at different lengths. The model also employs a Beverton and Holt stock-recruitment relationship to estimate the levels of recruitment in each year, given the estimated size of the spawning stock. The "base" model, for which results are reported here, assumes a value of 0.15 $year^{-1}$ for natural mortality, and a value of 0.6 for the steepness parameter of the stock-recruitment relationship.

Between 1998 and 2016, the catch of Brownlip abalone has fluctuated between ~ 5 and 15 t. After 2000, the catches remained relatively stable at ~13-16 t, until 2015, in which year the catch declined to below 10 t (Figure 21.18). Note that in the model, fishing mortality is estimated by matching the catches estimated by the model to the observed catches (employing Newton's algorithm), and thus the estimated and observed catches match exactly.

There is limited signal in the observed commercial catch rate data, i.e. with the catches rates (in log space) remaining steady between 1999 and 2010, declining to a conspicuously lower level in 2011 and remaining steady until 2015 (Figure 21.18). The estimated catch rates (i.e. by the model) are similar to the observed catch rates up to 2004. Between 2005 and 2008, the expected catch rates are lower than the observed catch rates, and after 2011, the expected catch rates are always greater than the observed catch rates. In some years, the (approximate) 95% confidence limits associated with the catch rates estimated by the model do not overlap those for the observed catch rates (estimated in an external GLM catch rate standardisation model).

The model provided very good visual fits to the length composition data derived from random sampling of commercial catches (Figure 21.19). As also indicated by the catch curve analyses, the selectivity patterns estimated by the model varied considerably between periods, with the selectivity curves for earlier years (2004-2010) laying well to the right of those in later years (2011-2014) (Figure 21.20). The reduction in mean size at which abalone become selected into the fishery, as estimated by the model (and evident in the size composition data), is consistent with the expectation, from the model, of an increasing trend in annual catch rates in later years. That is, by lowering the size at first capture, fishers would be expected to have access a greater proportion of the available stock. This could result in an increase in catch rate, or maintenance of a steady catch rate, in a situation where the abundance of larger individuals in the population is in decline. This is supported by the preliminary modelling results, which indicate that the exploitable (or vulnerable) biomass, which decreased progressively between 1988 and 2010, started to increase in 2011, coincident with the reduction in minimum harvest size (Figure 21.21a). In contrast, the estimated exploitable biomass of Brownlip abalone above a constant size of 165 mm (the minimum size above which, in the earlier years fishers, would retain this species in their catch) continued to decreased throughout the full time series (Figure 21.21a). That is, there is strong evidence that the abundance of larger individuals in the population is currently in decline.

The estimated spawning biomass of Brownlip abalone has declined by about 30% between 1988 and 2015, i.e. over the period of time for which data is available for modelling (from ~ 140 t to 99 t; Figure 21.21b). Noting that some commercial fishing did occur from the mid-1970s, catches during that time were almost certainly lower than those in 1988 to 2015 due to their lower value compared to Greenlip abalone (which was the primary target species). Although the biomass of Brownlip abalone was not at the unfished level in 1988, it would not have been markedly lower than that level. Thus, the model results provide no indication that the female spawning biomass of Brownlip abalone has declined to unacceptable levels.

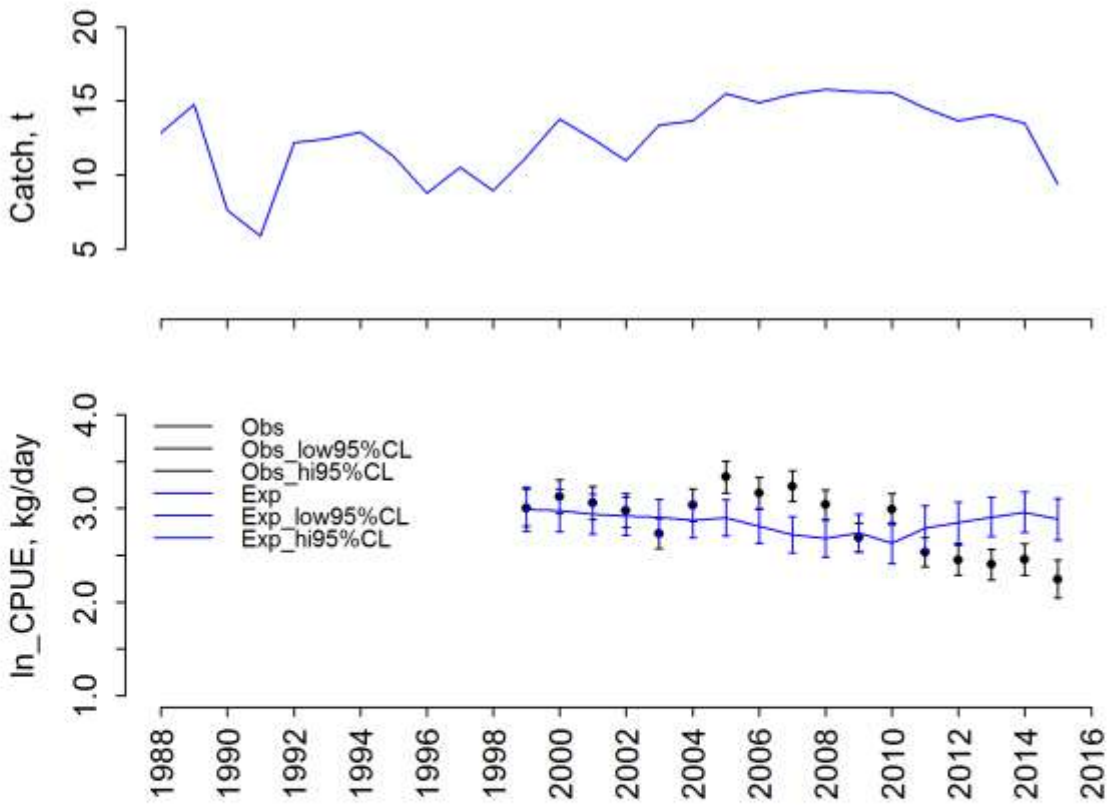


Figure 21.18. Commercial catches (tonnes, whole weight) (top) and commercial catch rates (kg/day) (bottom) for Brownlip abalone. Black points and blue lines represent observed and estimated values, respectively. Note that the estimated catches completely overlay the observed catches, because in the model, annual fishing mortalities are estimated as the values at which the estimated catches match the observed catches (top plot).

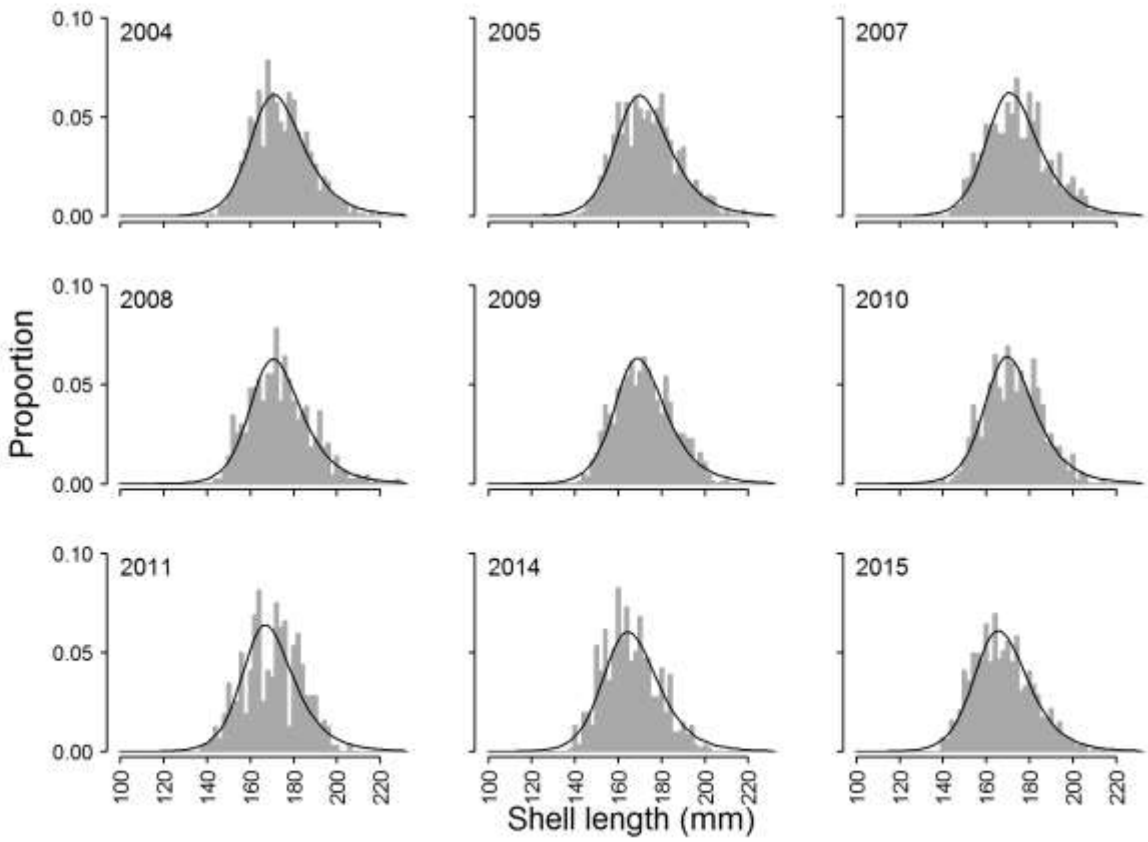


Figure 21.19. Fits of the model (black lines) to length composition data for Brownlip abalone derived from random sampling of commercial catches (grey bars).

a)

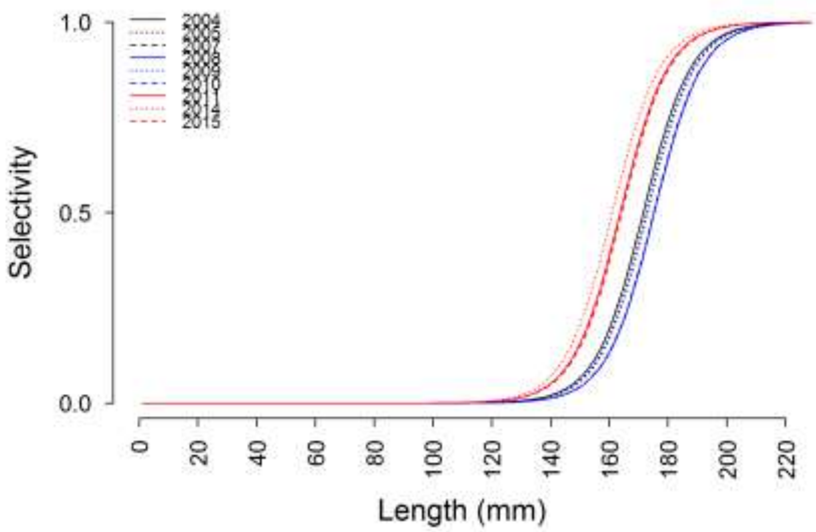
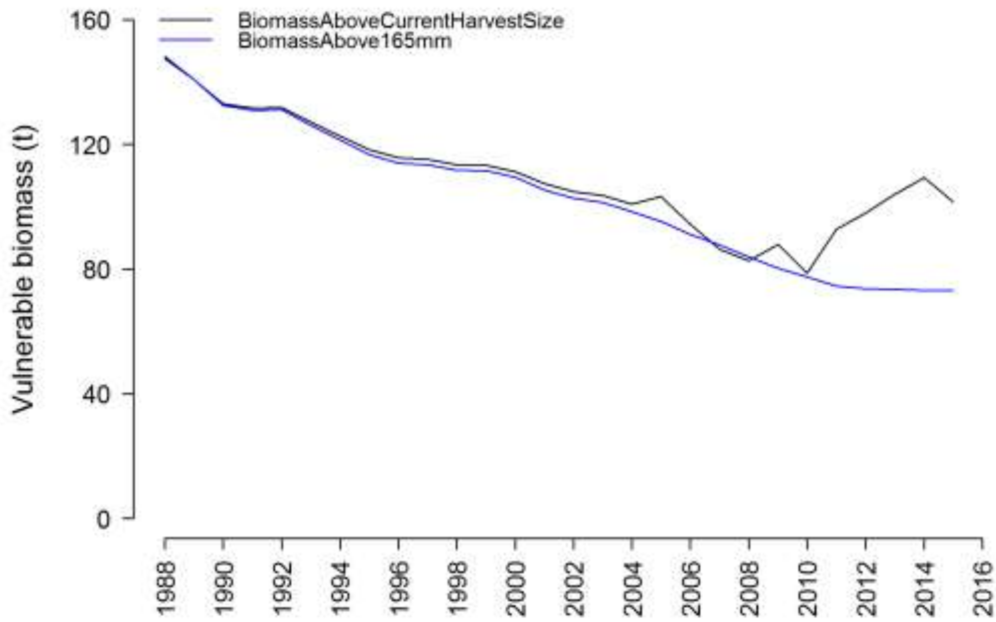


Figure 21.20. Estimated selectivity curves for Brownlip abalone between 2004 and 2015.

a)



b)

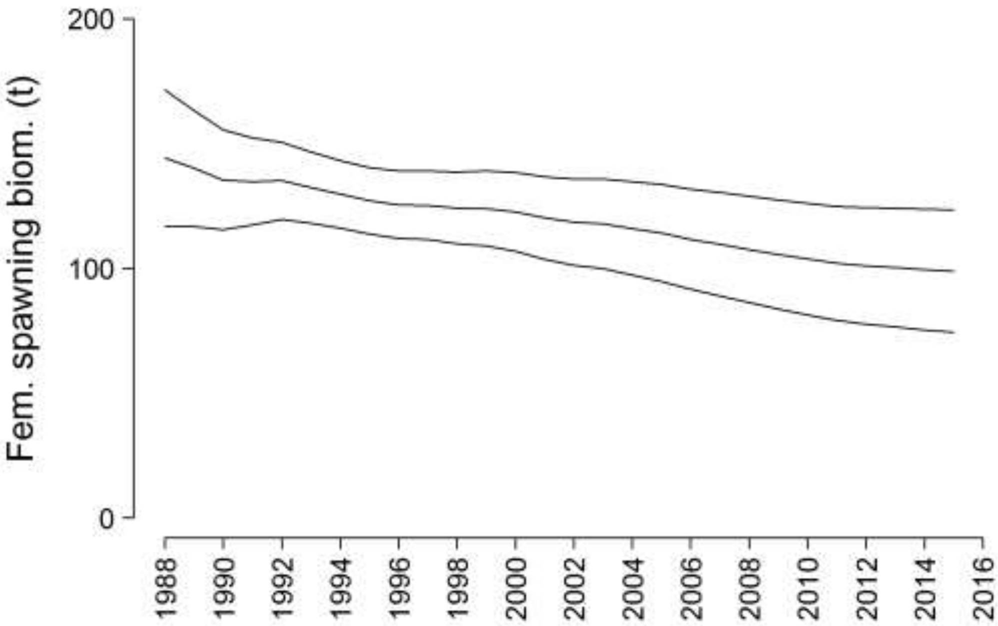


Figure 21.21. Annual estimates of a) biomass above harvest size and above 165 mm in each year, and of female spawning biomass between 1988 and 2015.

21.3 Productivity Susceptibility Analysis (PSA)

Productivity Susceptibility Analysis (PSA) is a semi-quantitative risk analysis originally developed for use in Marine Stewardship Council (MSC) assessments to score data-deficient stocks, i.e. where it is not possible to determine status relative to reference points from available information (Hobday et al. 2011; MSC 2014). The PSA approach is based on the assumption that the risk to a species depends on two characteristics: (1) the extent of the impact due to the fishing activity, which will be determined by the susceptibility to the fishing activities (Susceptibility) and (2) the productivity of the species (Productivity), which will determine the capacity of the stock to recover if the population is depleted.

Productivity is determined by the species life history traits i.e. growth and maturity characteristics, trophic level and fecundity (MSC 2014). Susceptibility is calculated using the overlap of the fishing area compared with the species range (geographical spread and depth/habitat overlap), the potential of the fishing gear to retain the species (i.e. selectivity) and the likelihood of post capture survival. For invertebrate species, there are six productivity categories and four susceptibility categories. The scores for productivity are combined with susceptibility scores to produce a risk score. PSA scores are divided into low risk (i.e. <60), medium risk (i.e. 60-80) and high risk (i.e. >80).

The PSA is limited in its usefulness for providing stock status advice because of the simplicity and prescriptiveness of the approach, which means that risk scores are very sensitive to input data and there is no ability to consider management measures implemented in fisheries to reduce the risk to a stock (Bellchambers et al. in prep.). Consequently, the PSA has been undertaken for Greenlip, Brownlip and Roe's abalone to produce a measure of the vulnerability of the stocks to fishing, which is then used together with other available information in the overall weight-of-evidence approach to assessing stock status.

Based on the productivity and susceptibility attributes of Greenlip, Brownlip and Roe's abalone (see Table 21.9), noting that susceptibility was scored the same for the commercial and recreational fishing sectors and thus only one score is presented for each species, PSA scores of 2.33 were obtained for each of the species (Table 21.10). This translates into a MSC score of 91, i.e. low risk. The main driver in this low overall score is the low selectivity scores, which are a result of fishers targeting individuals that are larger than the size at which these species mature.

Table 21.9. Productivity and Susceptibility attributes and associated explanations for Greenlip, Brownlip and Roe's abalone

Species/Group	Productivity						Susceptibility				References
	Average age at maturity	Average max age	Fecundity	Reproductive strategy (BS - broadcast spawner DEL - demersal egg layer LB - live bearer)	Trophic level	Density dependence	Availability (Areal overlap)	Encounterability (Vertical overlap)	Selectivity	Post-capture mortality	
Greenlip abalone	3 yrs	13 yrs	2 million	BS	Algal drift feeders	High	>30%	High	Low	High	Hart et al. (2013a) McAvaney et al. (2004)
Brownlip abalone	3 yrs	10-25 yrs	>20,000	BS	Algal drift feeders	High	>30%	High	Low	High	Hart et al. (2013a) Wells and Mulvay (1992)
Roe's abalone	2.5 yrs	10 yrs	Up to 8.6 million per year	BS	Algal drift feeders	High	>30%	High	Low	High	Hart et al. (2013a) Wells and Keesing (1989)

Table 21.10. Productivity Susceptibility Analysis (PSA) scores for Greenlip, Brownlip and Roe's abalone, with the overall risk ratings and MSC scoring guidepost.

				Productivity							Susceptibility								
Category	**Scientific name**	**Common name**	**Gear type**	**Average age at maturity**	**Average max age**	**Fecundity**	**Reproductive strategy**	**Trophic level**	**Density dependence**	**Total Productivity**	**Availability**	**Encounterability**	**Selectivity**	**Post-capture mortality**	**Total Susceptibility**	**PSA Score**	**MSC Score**	**Risk Category Name**	**MSC scoring guidepost**
Target	*Haliotis laevigata*	Greenlip abalone	Hand collection	1	2	1	1	1	3	1.50	3	3	1	3	1.65	2.33	91	Low	>80
Target	*Haliotis conicopora*	Brownlip abalone	Hand collection	1	2	1	1	1	3	1.50	3	3	1	3	1.65	2.33	91	Low	>80
Target	*Haliotis roei*	Roe's abalone	Hand collection	1	2	1	1	1	3	1.50	3	3	1	3	1.65	2.33	91	Low	>80

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22 Appendix D

Daily Catch Disposal Record log sheets for fishers in the Abalone Managed Fishery

CDR No:

Allocation of Roes Abalone

DAILY CATCH AND DISPOSAL RECORD

FISH RESOURCES MANAGEMENT ACT 1994
Abalone Management Plan 1992 (clause 20)

PART B (Consignee to Complete)

Processor to weigh immediately on receival

DETAILS OF CONSIGNMENT RECEIVED

Date received: / /

Time received: : am/pm

containers received:

Receipt number issued to fisherman:

RECEIVED	Weight (kg)	
	Whole	Shucked
ROEI		

CONSIGNMENT WEIGHED

Date: / /

Time: : am/pm

PERSON AUTHORISED TO RECEIVE CONSIGNMENT

I certify the information above is complete and accurate

Print Name (clearly):

Signature:

Stamp of Approved Receiver:

Within 24 hours, approved receiver to forward this page to:
Department of Fisheries
PO Box 671
BUSSELTON WA 6280

ORIGINAL COPY - This copy to accompany consignment to approved receiver.

Government of **Western Australia**
Department of **Fisheries**

PART A (Nominated Operator to Complete all shaded areas)

Area (1,2,5,6,7,8 only):

Place of landing:

Date of landing:

Time of landing (am/pm):

containers transported from landing:

Nominated courier:

Nomination receipt:

Fish processor:

containers transported or delivered to processor:

DETAILS OF ABALONE TAKEN

For Consignment ☐ Not for Consignment (own use) ☐ (Tick One)

	Whole	Shucked
ROEI		

Address where abalone retained:

Other CDRs relating to this consignment:

RESEARCH INFORMATION

Name of place fished:

Grid reference:

Block name or code:

Protected species (Y) (N):

If yes, species:

NAME/S OF NOMINATED DIVER/S WHO TOOK ABALONE

Name: CFL:

Dive Time (min) Roei:

Name: CFL:

Dive Time (min) Roei:

AQIS DECLARATION OF COMPLIANCE

Reg. Est. No.:	Name & address of Occupier	Reg. Est. No. of receiving establishment:

Transportation

Temperature required during transportation: Keep chilled at between -1°C & +5°C

Declaration of Compliance

I hereby Declare that:
The conditions and restrictions specified in orders 40 to 50 of the Export Control (Fish & Fish Products) Orders 2005; and the importing country requirements identified in the Approved Arrangement; that apply to and in relation to the fish and fish products prepared by the establishment are complied with and there is a sound basis for making this declaration; and that all the information provided is true and complete. Product as described on Catch and Disposal Record is acceptable to all countries where the requirements of the Export Control (Fish & Fish Products) Orders 2005 are accepted without additional requirements or change.

NOMINATED OPERATOR

I certify the information contained here is true and correct.

Print Name (clearly):	Signature	MFL:

CDR No:

Allocation of Greenlip/Brownlip Abalone

DAILY CATCH AND DISPOSAL RECORD

FISH RESOURCES MANAGEMENT ACT 1994

Abalone Management Plan 1992 (clause 20)

PART B (Consignee to Complete)

Processor to weigh immediately on receival

DETAILS OF CONSIGNMENT RECEIVED

Date received: / /

Time received: : am/pm

containers received:

Receipt number issued to fisherman:

RECEIVED	Weight (kg)		
	Whole	Shucked	# animals
GREENLIP			
BROWNLIP			

CONSIGNMENT WEIGHED

Date: / /

Time: : am/pm

PERSON AUTHORISED TO RECEIVE CONSIGNMENT

I certify the information above is complete and accurate

Print Name (clearly):

Signature:

Stamp of Approved Receiver:

Within 24 hours, approved receiver to forward this page to:

Department of Fisheries
PO Box 671
BUSSELTON WA 6280

ORIGINAL COPY - This copy to accompany consignment to approved receiver.

Government of **Western Australia**
Department of **Fisheries**

PART A (Nominated Operator to Complete all shaded areas)

Area (1,2,3 only):

Place of landing:

Date of landing:

Time of landing (am/pm):

containers transported from landing:

Nominated courier:

Nomination receipt:

Fish processor:

containers transported or delivered to processor:

DETAILS OF ABALONE TAKEN

For Consignment ☐ Not for Consignment (own use) ☐ (Tick One)

	Whole	Shucked	# animals
GREENLIP			
BROWNLIP			

Address where abalone retained:

Other CDRs relating to this consignment:

RESEARCH INFORMATION

Name of place fished:

Grid reference:

Block name or code:

Protected species (Y) (N):

If yes, species:

NAME/S OF NOMINATED DIVER/S WHO TOOK ABALONE

Name:		CFL:
Dive Time (min)	Greenlip:	Brownlip:
Name:		CFL:
Dive Time (min)	Greenlip:	Brownlip:

AQIS DECLARATION OF COMPLIANCE

Reg. Est. No.:	Name & address of Occupier	Reg. Est. No. of receiving establishment:

Transportation

Temperature required during transportation: Keep chilled at between -1°C & +5°C

Declaration of Compliance

I hereby Declare that:
The conditions and restrictions specified in orders 40 to 50 of the Export Control (Fish & Fish Products) Orders 2005; and the importing country requirements identified in the Approved Arrangement; that apply to and in relation to the fish and fish products prepared by the establishment are complied with and there is a sound basis for making this declaration; and that all the information provided is true and complete. Product as described on Catch and Disposal Record is acceptable to all countries where the requirements of the Export Control (Fish & Fish Products) Orders 2005 are accepted without additional requirements or change.

NOMINATED OPERATOR

I certify the information contained here is true and correct.

Print Name (clearly):	Signature	MFL:

23 Appendix E

Invitation to a Stakeholder briefing regarding the MSC initiative

Department of Fisheries

WAFIC

Western Australian Fishing Industry Council Inc.

CERTIFIED SUSTAINABLE SEAFOOD MSC www.msc.org

The WA Fishing Industry Council, the peak industry body representing commercial fishing, pearling and aquaculture, invites you to a Stakeholder's briefing on the WA Government's $14.5million initiative to provide every WA commercial fishery the opportunity to be independently certified by the Marine Stewardship Council's (MCS) international gold standard for sustainable fisheries.

Date: Friday March 14, 2014
Time: 9am – 10.30am
Venue: WA Fisheries and Marine Research Laboratories, 39 Northside Drive, Hillarys
RSVP: Monday March 10, 2014 to Jo-Ann Ledger jle88720@bigpond.net.au

The purpose of the briefing is to:

- Outline objectives and progress of the initiative
- Introduce you to the Marine Stewardship Council
- Inspire future partnership opportunities in research, education, tourism, hospitality and NGOs.

Agenda:

» **The fast facts on the MSC plan for WA**
Mr Arno Verboon, Chair, WA Fishing Industry Council

» **MSC's mission**
Dr Keith Sainsbury Vice Chair, MSC Board of Trustees

» **How the plan is rolling out**
Ms Heather Brayford: Deputy Director General, Department of Fisheries

» **MSC communication partnerships**
Ms Charlotte Connell – Communication Manager Australia and New Zealand

» **The new partnership: The MSC eco-label, the fisherman, the scientist, the conservationist, the retailer, the chef and the seafood consumer.**
Mr Guy Leyland – MSC Industry Project Leader, WA Fishing Industry Council

» **Questions**

Background information follows

Supported by

FRDC

BACKGROUND

DR KEITH SAINSBURY

Dr Keith Sainsbury joined the London based MSC Board of Trustees in 2002 and was appointed Vice Chair in April 2005.

Keith has conducted research on the assessment, ecology, exploitation and conservation of marine resources and ecosystems for over 25 years. Most recently he has focused on multiple-use planning and management of marine ecosystems. He is Professor of Marine System Science at the University of Tasmania, a Commissioner on the Australian Fishery Management Authority, and a strategic advisor to the CSIRO Wealth from Oceans program. Chair of the MSC Technical Advisory Board from 2001 to May 2007.

THE MSC

www.msc.org

The MSC mission is to use our eco-label and fishery certification program to:

1. Contribute to the health of the world's oceans by recognising and rewarding sustainable fishing practices;
2. Influence the choice people make when buying seafood; and
3. Working with our partners to transform the seafood market to a sustainable basis.

The MSC sets two standards:

1. Standard for sustainability fishing
2. Standard for seafood traceability (chain of custody)

The MSC sustainable fishing standard has 3 overarching principles that every fishery must prove that it meets:

PRINCIPLE 1: SUSTAINABLE FISH STOCKS

The fishing activity must be at a level, which is sustainable for the fish population. Any certified fishery must operate so that fishing can continue indefinitely and is not overexploiting the resources.

PRINCIPLE 2: MINIMISING ENVIRONMENTAL IMPACT

Fishing operations should be managed to maintain the structure, productivity, function and diversity of the ecosystem on which the fishery depends.

PRINCIPLE 3: EFFECTIVE MANAGEMENT

The fishery must meet all local, national and international laws and must have a management system in place to respond to changing circumstances and maintain sustainability.

WHY IS THE MSC CHAIN OF CUSTODY STANDARD NEEDED?

To ensure fish sold with the MSC eco-label comes from a certified sustainable fishery

Traceability is a hot topic in the seafood industry. Mislabelling is a recognised problem and the complex international supply chain for most seafood products makes it difficult to find high quality information about the fish source. Ideally, labels on seafood products should provide verifiable information about the species, the source fishery and sustainability information.

Once a fishery has been certified, all companies in the supply chain that wish to handle or sell an MSC certified product not in consumer-ready packaging, must have MSC Chain of Custody certification. This way every link is checked to make sure the MSC label is only displayed on seafood from a MSC certified sustainable fishery.

FAST MSC FACTS

- Almost 11% of the world's total allowable catch is engaged in the MSC program.
- MSC sets a standard for sustainable fishing and seafood traceability. Third-party independent bodies assess the fisheries.
- Every McDonald's Fillet-O-Fish burger sold in America is now MSC certified.
- Almost all of the McDonald outlets in Europe are involved in the MSC program.
- Germany now sells more than 5,000 MSC certified products in its supermarkets.
- Coles and Woolworths have both made commitments to source MSC certified seafood.
- MSC is an international non-profit organisation based in London.

24 Appendix F

Daily Patrol Commercial Contacts Form

Government of Western Australia
Department of Fisheries

FMO Daily Patrol Commercial Contacts Form

District: ______________ Date: ___/___/___ Reporting FMO: ____________________ Covert Initially: Y / N Page ___ of ___

Commercial Information							Quota Information								TPF		Outcomes	
												Containers						
INSP TIME (24h)	*LFB # or Lic #*	Licence Checks	Gear Checks	Amount Of Gear	Boat Search	Bag Checks	Initial Insp Loc Code	Nr Containers Insp	CDR / Consignment #	Scale Verification	Independent Weight Checks	Weight Checks	Security Checks	Weighing Location	TPF Check	#TPF	Compliant?	Comments
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Return to: Anita Ward CSU | PO Box 20 North Beach, WA 6920
Modified:16-Sep-14

L = Landing Areas | D = Depot | R = Receiver
T = Transit | P = Processor | O = Other