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Fisheries Research Report No. 321

Houtman Abrolhos Islands Fish Habitat Protection Area: A Summary of Marine Resource Use and Ecological Attributes

Evans, S.N., Konzewitsch, N., & Bellchambers, L.M.

February 2022

Correct citation:

Evans, S.N., Konzewitsch, N., & Bellchambers, L.M. 2022. Houtman Abrolhos Islands Fish Habitat Protection Area: A Summary of Marine Resource Use and Ecological Attributes. Fisheries Research Report No. 321. Department of Primary Industries and Regional Development, Western Australia. 174pp.

Enquiries:

WA Fisheries and Marine Research Laboratories,
PO Box 20,
North Beach, WA 6920

Tel: +61 8 9203 0111
Email: library@dpird.wa.gov.au
Website: fish.wa.gov.au

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Department of Primary Industries and Regional Development
Gordon Stephenson House
140 William Street
PERTH WA 6000
Telephone: (08) 6551 4444
Website: dpird.wa.gov.au
ABN: 18 951 343 745

ISSN: 1035-4549 (Print) ISBN: 978-1-921258-97-8 (Print)

ISSN: 2202-5758 (Online) ISBN: 978-1-921258-98-5 (Online)

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List of Abbreviations

Abrolhos	Houtman Abrolhos Islands
AETOL	Aquatic Eco-Tourism Operators Licence
AIMWTMF	Abrolhos Islands and Mid-West Trawl Managed Fishery
AMF	Abalone Managed Fishery
ASA	Aquatic Science and Assessment
AWST	Australian Western Standard Time
BoM	Australian Bureau of Meteorology
BRUV	Baited Remote Underwater Video
CAES	Catch and Effort Statistics
CDR	Catch Disposal Records
CPUE	Catch Per Unit Effort
DoT	Department of Transport, Western Australia
DOV	Diver Operated Video
DPIRD	Department of Primary Industries and Regional Development
EG	Easter Group
EBFM	Ecosystem Based Fisheries Management
EPBC	Environment Protection and Biodiversity Conservation (Act)
ERA	Ecological Risk Assessment
ESD	Ecological Sustainable Development
ETP	Endangered, Threatened and Protected Species
FHPA	Fish Habitat Protection Area
FL	Fork Length
FRMA	Fish Resource Management Act
FRMR	Fisheries Resource Management Regulation
FTOL	Fishing Tour Operators Licence
GHRSST	Group for High Resolution Sea Surface Temperature
GVP	Gross Value of Production
HAINP	Houtman Abrolhos Island National Park
ITE	Individual Transferable Effort
ITQ	Individual Transferable Quota

LiDAR	Light Detection and Ranging
LPFR	Large Pelagic Finfish Resource
MAFMF	Marine Aquarium Fish Managed Fishery
MAFR	Marine Aquarium Fish Resource
MaxN	Relative Abundance Measure from BRUVS
MLL	Minimum Legal Length
MMF	Mackerel Managed Fishery
MSC	Marine Stewardship Council
MWADZ	Mid-West Aquaculture Development Zone
NI	North Island
OIMF	Octopus Interim Managed Fishery
PL/Y	Pot Lift Per Year
RFTOL	Restricted Fishing Tour Operators Licence
RLQMS	Rock Lobster Quota Management System
ROA	Reef Observation Area
SG	Southern (Pelsaert) Group
SSMF	Specimen Shell Managed Fishery
SST	Sea Surface Temperature
TACC	Total Allowable Commercial Catch
TL	Total Length
UTC	Coordinated Universal Time
VMS	Vessel Monitoring System
VMSLB	Vessel Monitoring System Logbook
VNS	Vessel Notification System
WA	Western Australia
WCDSIMF	West Coast Demersal Scalefish (Interim) Managed Fishery
WCDSR	West Coast Demersal Scalefish Resource
WCMZ	West Coast Management Zone
WCPSF	West Coast Purse Seine Fishery
WCRLMF	West Coast Rock Lobster Managed Fishery
WCSPSR	West Coast Small Pelagic Scalefish Resource
WG	Wallabi Group
WRL	Western Rock Lobster

Executive Summary

The Houtman Abrolhos Islands (Abrolhos) is an archipelago of up to 210 small islands and associated reefs located approximately 65-90 km offshore from Geraldton, Western Australia (WA). The islands and waters of the Abrolhos are of significance for both land-based (e.g., seabird breeding, migratory shorebirds, carpet pythons, tammar wallabies and significant flora and vegetation) (DBCA, 2021) and marine based values (e.g., diverse and unique range of fish and marine aquatic species). The marine waters of the Abrolhos support the southernmost major coral reef system in the Indian Ocean and one of the highest latitude coral reef systems in the world. Along with its ecological significance, the Abrolhos also support substantial commercial fisheries (including ~20% of the annual West Coast Rock Lobster Managed Fishery), aquaculture and recreational activities. The marine state territorial waters of the Abrolhos (below high-water mark to three nautical miles) are managed by the Department of Primary Industries and Regional Development (DPIRD) as the Houtman Abrolhos Islands Fish Habitat Protection Area (Abrolhos FHPA). Effective management of the Abrolhos FHPAs unique marine aquatic resources and diverse commercial and recreational user groups requires specific, adaptive science and management plans to continue to support the sustainable use of this unique Western Australian marine environment.

The aim of this report is to provide a summary of the DPIRD data on aquatic resource use (e.g., aquaculture, commercial, recreational and charter fishing) and ecological attributes (e.g., coral reef health, environmental data, relative fish abundance, habitat mapping) specific to the Abrolhos FHPA. Summary data provided here aims to assist with informing the development of a new draft management plan for the Abrolhos FHPA (scheduled for release in 2022) and further guide the development of future science and monitoring plans. This report is divided into three main sections, commercial use, recreational use and ecological attributes. The commercial use section provides an overview of nine commercial fisheries as well as the fishing tour operator and aquaculture industries, specifically their relationship to the Abrolhos FHPA. The recreational visitation section provides an overview of recreational usage data available to DPIRD for visitation to the Abrolhos FHPA. The ecological attributes section summarises fishery independent DPIRD collected or collated data to assist with informing overall ecosystem health and ecological functions of the Abrolhos

FHPA. Where appropriate, recommendations are provided for further integration of science and management between the commercial and recreational activities, ecological attributes, and the Abrolhos FHPA. It is important to note that data summarised in this report for fisheries or industries and their specific association to the Abrolhos FHPA does not replace existing fishery or resource wide stock assessments nor provide detailed analysis of fisheries or species stock structure or status. Detailed information on biology, stock structure and status and management arrangements of species, fisheries, industries or broader aquatic resources should be sourced directly from the relevant fishery or industry's reported information, with guidance of where this can be found referred to within this report.

While this report provides a number of fishery or resource specific recommendations, where appropriate, the following strategic recommendations are provided by the Ecological Monitoring and Assessment Group of the Aquatic Science and Assessment (ASA) Branch of DPIRD to support the ongoing sustainable use and management of the Abrolhos FHPA across all user groups:

- Develop, implement and support a DPIRD science and monitoring plan, specific to the aquatic resources and ecosystems of the Abrolhos FHPA to further inform and support the management of this system's unique aquatic resources and diverse marine user groups
- Update Abrolhos FHPA Ecological Risk Assessment (ERA)
- Maintain and expand the reporting of commercial and recreational activities and associations within the Abrolhos FHPA
- Prioritise and support a habitat mapping and monitoring program (at an appropriate scale), particularly in the <30m depth zone of the Abrolhos FHPA, to support aquatic resources and ecosystem management
- Investigate management measures to further protect areas of ecological significance in the Abrolhos FHPA (e.g., sensitive habitats and fish spawning aggregations), especially in the <10m depth zone
- Investigate the effectiveness of management arrangements (e.g., ROAs) and potential expansion to ensure adequate representation across the entire Abrolhos FHPA
- Prioritise and support an Abrolhos FHPA specific recreational fishing survey

1.0 Background

1.1 Houtman Abrolhos Islands

The Houtman Abrolhos Islands (Abrolhos) is an archipelago of up to 210 small islands (DBCA, 2021) and associated reefs located approximately 65-90 km offshore from Geraldton, Western Australia (WA) (nominally 28°43'S 113°37´E). The Abrolhos is divided into three main island groups, North Island / Wallabi Group, Easter Group and Pelsaert Group (Figure 1.1). North Island and the Wallabi Islands of the North Island / Wallabi Group are connected by a submerged reef platform (~20 m deep) and are separated from the Easter Group by the ~40 m deep Middle Channel, with Easter Group separated from Pelsaert Group by the ~40 m deep Zeewijk Channel (Wells, 1997) (Figure 1.1). The islands and waters of the Abrolhos are of significance for both land based (e.g., seabird breeding, migratory shorebirds, carpet pythons, tammar wallabies, and significant flora and vegetation) (DBCA, 2021) and marine based values (e.g., diverse and unique range of fish and marine aquatic species, significant commercial and recreational fisheries, aquaculture and marine tourism) (Webster et al., 2002).

Located in a convergence between northern tropical and southern temperate waters, the Abrolhos is heavily influenced by the poleward flowing Leeuwin Current which carries warm, low-nutrient tropical water southward from north-western Australia and maintains winter seawater temperatures at the Abrolhos between 20ºC to 22ºC (Pearce, 1997). The influence of the Leeuwin Current and its southern geographical location make the Abrolhos' marine environment the southernmost major coral reef system in the Indian Ocean and one of the highest latitude reef systems in the world (28º to 29º S, 113º35´ to 114º03´ E) (Webster et al., 2002; Lough, 2008; Abdo et al., 2012), whilst also supporting a diverse assemblage of temperate and tropical marine algae (Huisman, 1997; Phillips & Huisman, 2009). The reefs of the Abrolhos are extremely diverse, with 184 species of coral from 42 genera (Veron & Marsh, 1988; Wells, 1997) and 295 species of marine algae recorded (Huisman, 1997; Phillips & Huisman, 2009).

Of the marine algae recorded at the Abrolhos, 13.6% of species were endemic to the area, with a substantial mixture of temperate species (e.g., *Ecklonia radiata*) and tropical species (e.g., *Trichogloea requienii*) (Huisman, 1997; Phillips & Huisman, 2009). Similarly, the fish fauna of the Abrolhos is influenced by its unique ecosystem with a survey conducted by WA Museum reporting up to 389 species of which, 66% were tropical, 19% warm temperate and 13% subtropical (Hutchins, 1997). This work was supported by a subsequent survey which reported the observed fish species as 66% tropical, 21% warm temperate, and 13% subtropical (Watson & Harvey, 2009).

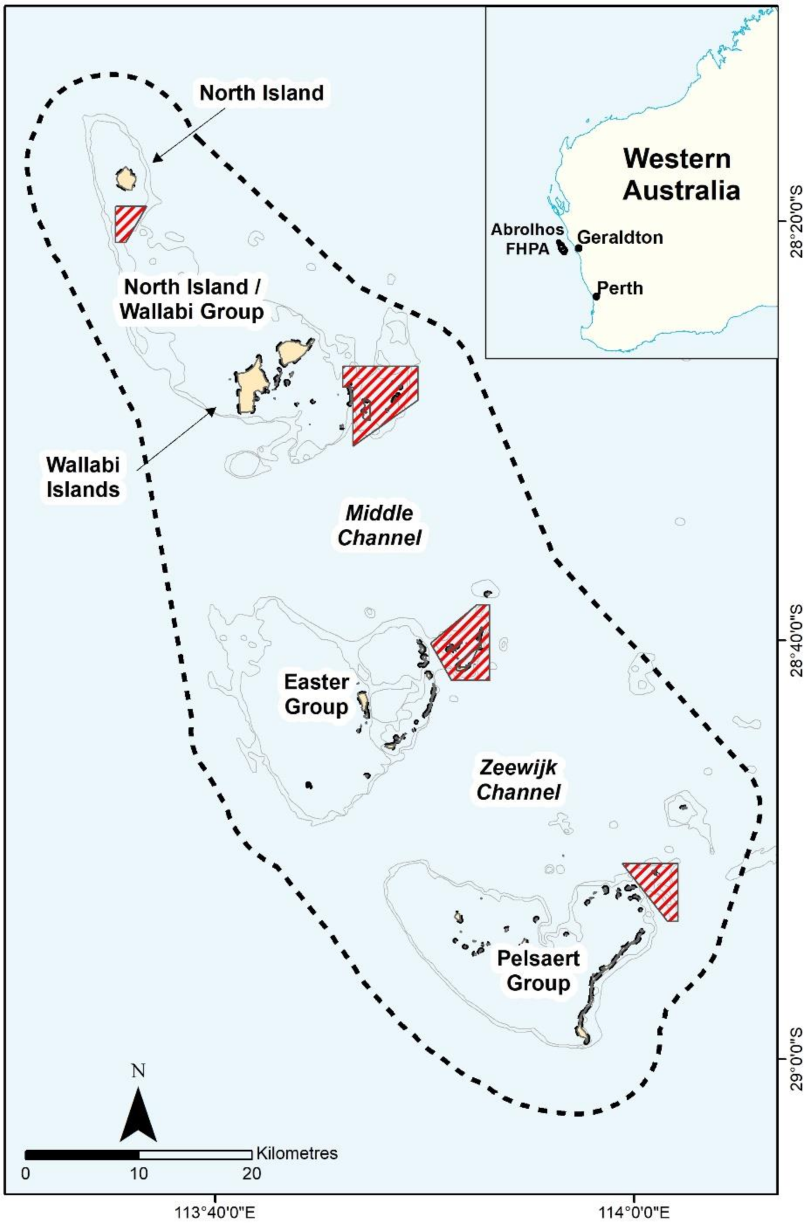

Figure 1.1. Map of the Houtman Abrolhos Islands showing the Fish Habitat Protection Area (black dashed) and Reef Observation Areas (red hatched). Grey isobaths indicate 10-20m depth range.

Although rich in natural values, maritime history (Edwards, 1989; Green, 2020), early industrial development (e.g., guano mining) and ongoing commercial fishing (e.g., western rock lobster) (Stanbury, 1993; Bertelsen, 2009), to date significant permanent tourism-based development or infrastructure (either land-based or marine) has not occurred at the Abrolhos. This is likely a result of its remote offshore location, prevailing heavy wave action from the southwest and persistent, strong, southerly winds (in excess of 32km/h for 44% of the time) (Webster et al., 2002). However, with changes and developments in the commercial fishing, fishing tour industries, aquaculture and improved access to the Abrolhos with the increase in availability of suitable recreational vessels and digital weather forecasting, the need to quantify and manage current and future users is imperative. This should be undertaken within an adaptive and responsive management framework, such as the existing management framework for the Houtman Abrolhos Islands Fish Habitat Protection Area.

1.2 State Land and Water Management Arrangements

The islands of the Abrolhos have been protected as a Class A reserve (Reserve 20253) for over 100 years, first declared in 1898 for the conservation of nature (Abbott, 2006). Until 2019 management was solely under the care and control of the WA Minister for Fisheries (DBCA, 2021). In 2019, coinciding with the 400-year anniversary of Dutch navigator Frederick de Houtman’s sighting of the Abrolhos, the stewardship of the majority of the islands shifted to the Minister of the Environment with the creation of the Houtman Abrolhos Islands National Park (DBCA, 2021). The Houtman Abrolhos Island National Park (HAINP) extends to the landward side of the high-water mark and includes the uninhabited areas of five of the occupied islands (North Island, West Wallabi Island, Big Rat Island, Leo Island and Newman Island) (DBCA, 2021). The remaining inhabited land and occupied islands, which have commercial fishing or aquaculture operational infrastructure (in addition to the intertidal zone), remain under the control of the Minister for Fisheries as a Class A reserve (Reserve 20253) for the “conservation of flora and fauna, tourism and for purposes associated with the fishing and aquaculture industries” (DBCA, 2021). Reserve 20253 also includes all intertidal land between the high- and low-water marks. The marine state territorial waters of the Abrolhos (below high-water mark to three nautical miles) continues to be managed by the Department of Primary Industries and Regional Development (DPIRD) as the

Houtman Abrolhos Islands Fish Habitat Protection Area (Abrolhos FHPA) (Figure 1.1), with other Local (e.g., City of Geraldton), State (e.g., DBCA, WA Museum and Department of Transport) and Commonwealth (e.g., Australian Maritime Safety Authority) agencies having specific legislative responsibilities for the HAINP, Abrolhos Reserve and Abrolhos FHPA.

Fish Habitat Protection Areas are established under the Fish Resource Management Act 1994 (FRMA 1994) for 'the conservation of fish, fish breeding areas and associated aquatic ecosystems' and are a popular place for tourism and recreational activities (DoF, 2012a). The Abrolhos FHPA was designated as a Fish Habitat Protection Area in 1999 and covers an area of ~2,494 km^2 (Figure 1.1). It includes specific regulations such as:

- temporal (seasonal) closures (e.g., closed season for baldchin groper, *Choerodon rubescens*, between the 1st of November and 31st of January)
- spatial closures (e.g., Reef Observation Areas (ROAs) ~64.3km^2 or 2.6% of Abrolhos FHPA)
- recreational fishing specific bag and possession limits (for more information see: https://www.fish.wa.gov.au/Documents/recreational_fishing/rec_fishing_guide/recreational_fishing_guide.pdf)

The Abrolhos FHPA has significant economic and social value for commercial and recreational fishing, aquaculture and tourism. As stated in the Abrolhos FHPA Order, the Abrolhos FHPA is set aside as a protection order, in section 115(2) of the FRMA (1994), for:

- the conservation and protection of fish breeding areas, fish fossils or the aquatic ecosystem; or
- the culture and propagation of fish and experimental purposes related to that culture and propagation; or
- the management of fish and activities relating to the appreciation or observation of fish

For over 20 years, the Abrolhos FHPA has been managed under an adaptive legislative framework for the protection and sustainable management of this unique marine environment in conjunction with significant and valuable stakeholders (e.g., commercial and recreational fishing, aquaculture and fishing tour operators). In 2022, DPIRD will release a new Houtman Abrolhos Islands Fish Habitat Protection Area Draft Management Plan. This report aims to support the Abrolhos FHPA Draft Management Plan (2022) by providing a summary of existing data sources that are collected or collated by DPIRD on anthropogenic associations (e.g., commercial fishing, recreational fishing, aquaculture and visitation) and ecological attributes (e.g., coral reef health, environmental data, relative fish abundance, habitat mapping) within the Abrolhos FHPA. The report also reviews the existing data and associated trends to provide strategic recommendations for future monitoring and assessment to support the sustainable use and management of this unique Western Australian aquatic resource. In addition to providing strategic recommendations, where appropriate, the report also provides recommendations at a fishery or resource level to assist with addressing management outcomes.

2.0 Commercial Use

The Abrolhos FHPA Draft Management Plan (2022) supports commercial fishing activities within the Abrolhos FHPA under the management objective that fishing activities are managed consistent with an ecosystem-based approach, maintaining the ecological and cultural heritage values of the Abrolhos. This section summarises data collected by DPIRD, from both fishery dependent and independent sources for nine managed, interim or developing commercial fisheries, the fishing tour industry and aquaculture activities within the Abrolhos FHPA.

However, data summarised in this report for fisheries and their specific association to the Abrolhos FHPA does not replace existing fishery wide stock assessments nor provide detailed analysis of fisheries or species stock structure or status. Detailed information on biology, stock structure and status and management arrangements of species, fisheries, industries, or broader aquatic resources should be sourced directly from the relevant fishery or industry's reported information, with guidance of where this can be found referred to in this report.

Unless otherwise stated, data collation, data manipulation, analysis, and figures were performed in R (R Core Team, 2021) or Microsoft Excel, and spatial analysis and mapping undertaken using ArcGIS® software by ESRI or R (R Core Team, 2021).

2.1 West Coast Rock Lobster Managed Fishery

2.1.1 *Fishery Description*

The West Coast Rock Lobster Managed Fishery (WCRLMF) is a pot fishery that targets the western rock lobster (WRL), *Panulirus cygnus* (George 1962). The WCRLMF is Australia's most valuable single species wild capture fishery and spans the temperate waters of the WA coast from the North West Cape to Cape Leeuwin, across coastal nearshore waters to the edge of the continental shelf (Figure 2.1.1) (de Lestang et al., 2016). Records of commercial WRL fishing in WA date back to the late 1890's with the fishery expanding rapidly in the 1940's through to the late 1950's when the annual catch was over 8000 tonnes (Bertelsen, 2009; de Lestang et al., 2012). Traditionally, the majority of catch and effort for the WCRLMF is from the mid-west coast of WA, between Kalbarri and Mandurah, which includes the Abrolhos FHPA (Bellchambers et al., 2017).

In March 1963, the WCRLMF was declared as a limited entry fishery, with a limit on the number of pots. The WCRLMF was divided into three management zones with two different seasons (A zone = 3.5 months, B and C zones = 7.5 months) and managed through an Individual Transferable Effort (ITE) system (Figure 2.1.1B) (de Lestang et al., 2016). In 2000, the WCRLMF became the first fishery in the world to achieve Marine Stewardship Council (MSC) certification for its sustainable fishing practices (Bellchambers et al., 2017) and has maintained this certification, entering its fifth recertification in 2021. In 2010, the WCRLMF began to transition to an Individual Transferable Quota (ITQ) fishery and progressed towards year-round fishing. The three fishing zones (A, B and C) were maintained and were allocated a Total Allowable Commercial Catch (TACC) of 18, 32 and 50 percent (%) respectively (de Lestang et al., 2021; de Lestang et al., 2016). The introduction of ITQ with a total allowable catch of 5,500 t (~50% of the historical landings) resulted in a ~80% reduction of effort compared to pre-2000 levels across the entire WCRLMF, despite an increase in allowable fishing days to the full 12 months per year (de Lestang et al., 2016).

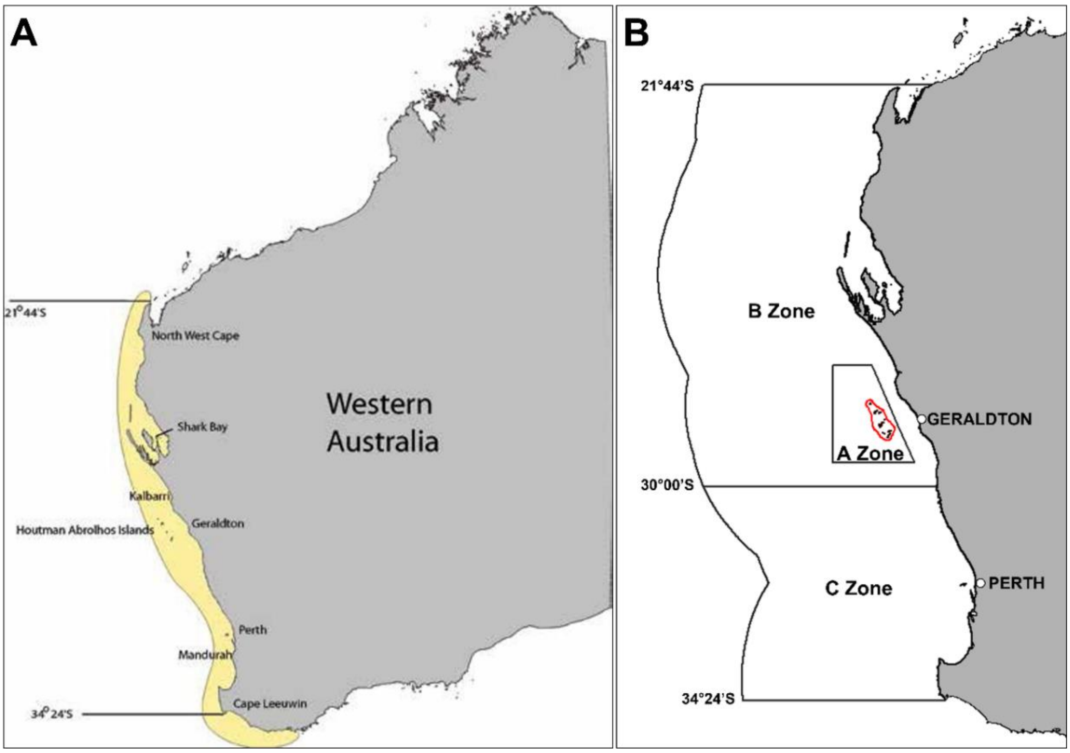

Figure 2.1.1. (A) Distribution (yellow shading) of the western rock lobster, *Panulirus cygnus*, and (B) the management zones of the WCRLMF (A, B and C Zones) with the boundary of the Abrolhos FHPA indicated in red.

The WCRLMF has a harvest strategy (DoF, 2014) which supports the decision-making process of the fishery, consistent with the principles of Ecologically Sustainable Development (ESD) and Ecosystem Based Fisheries Management (EBFM) (Fletcher, 2002; Fletcher et al., 2012). For further descriptions of this and other WCRLMF legislation, regulations (e.g., gear size, temporal and spatial closures) and history, as well as biological and ecological characteristics of WRL see:

- DoF. (2014). West Coast Rock Lobster Harvest Strategy and Control Rules 2014-2019. Fisheries Management Paper No. 264. Department of Fisheries, Western Australia. 899.
- de Lestang, S., Caputi, N. & How, J. (2016). Resource Assessment Report: Western Rock Lobster Resource of Western Australia. Western Australian Marine Stewardship Council Report Series No. 9. Department of Fisheries, Western Australia.
- Bellchambers, L., Mantel, P., Chandrapavan, A., Pember, M. & Evans, S. (2012). Western Rock Lobster Ecology – The State of Knowledge Marine Stewardship Council Principle 2: Maintenance of Ecosystem. Fisheries Research Report No. 236. Department of Fisheries, Western Australia. 128p.

2.1.2 *WCRLMF and the Abrolhos FHPA*

The shallow water zones, associated channels, and fringing reefs of the Abrolhos have been fished for WRL since the 1890's (Bertelsen, 2009), as part of a limited entry fishery since 1963 (de Lestang et al., 2016), within an FHPA since designation in 1999 (Abrolhos Island Fish Habitat Protection Order 1999, FRMA) and as an MSC certified fishery since 2000 (SCS Inc., 2000). The Abrolhos FHPA accounts for ~9.4 % (~2494 km^2) of the spatial area of the WCRLMF A zone (~26,550 km^2) and ~0.4% of the entire WCRLMF (~605,065 km^2). The WCRLMF has had year-round access to the entire Abrolhos FHPA since 2013. Although a small spatial component of the WCRLMF, the Abrolhos FHPA is important not only for the high proportional contribution of WCRLMF catch and effort, but also as a significant source of breeding stock and egg production that contributes to the ongoing sustainability of the fishery (Webster et al., 2002; Bellchambers et al., 2012).

In 2019, the WCRLMF had an economic gross value product (GVP) of A$417 million and a TACC of 6397 tonnes (de Lestang et al., 2021). With 18% allocation of the

TACC in 2019, this equates to a catch of ~1152 tonnes and a GVP of ~A$75 million for the WCRLMF A Zone, which encompasses the entire Abrolhos FHPA.

2.1.3 *Fishery Dependent Catch and Effort Association to the Abrolhos FHPA*

2.1.3.1 *Methodology*

Historically, the WCRLMF catch and effort has been reported using Catch and Effort Statistics (CAES) from compulsory monthly fisher returns recorded in 60 nautical mile blocks. Prior to 1989, CAES data for the WCRLMF A Zone (Abrolhos Islands Area) was reported in a unique polygon of ~7740 nm^2, CAES block 97000 (Figure 2.1.2 A) and then as one of five transects (97011-97015) within CAES block 97000 until the fishery fully transitioned to ITQ in 2010. From the 2010/11 season onwards, fishers have been required to submit trip specific Catch Disposal Records (CDR). The CDR provides finer spatial resolution of reporting (10 x 10 nm blocks) for catch (kgs) and effort (pot lifts) (de Lestang et al., 2012) (Figure 2.1.2 B). Prior to transition to ITQ, the WCRLMF operated in the A Zone (including the Abrolhos FHPA) between 15th March and 30th of June. A staged extension of the season from 2011-2013 resulted in year-round fishing, with a season running from the 15th of January to the 14th of January the following year. For this report, pre-ITQ seasons in A Zone / Abrolhos FHPA (15th March – 30th of June) are described in the year they occurred (e.g., WCRLMF season 2008/09 is 2009). Post-ITQ seasons are described as the year most of the fishing occurred (e.g., 15th January 2017 to 14th January 2018 is 2017).

To quantify the annual A Zone effort as inside or outside of the Abrolhos FHPA and assess long term changes in catch and effort, WCRLMF data was collated from three DPIRD fishery dependent datasets, CAES, Rock Lobster Quota Management System (RLQMS) and CDR. The CAES data was used from 1976 to 2009, in line with confidence in reporting accuracies (de Lestang et al., 2012), RLQMS for the 2010/11 and 2011/13 seasons and CDR from the 2013/14 season onwards. A brief summary of the data source harmonisation is described below:

1. CAES data was based on catch and effort reported in CAES block 97000 (Figure 2.1.2A). Over the 35-year data collection period, boundaries within the CAES block 97000 (Abrolhos Island Area) evolved due to management and reporting changes (e.g., transects 97011-97015) however, some of these

reporting changes have been voluntary. For consistency in reporting, catch and effort data was aggregated to CAES block 97000 and proportioned based on depth from the WCRLMF voluntary logbook data (see de Lestang, et al., 2012). Within the WCRLMF A Zone, the Abrolhos FHPA comprises the majority of the <=20 fathoms (<= ~36 m) waters. Therefore, WCRLMF CAES catch and effort data between 1975 and 2009 in <=20 fathoms (<=~36 m) was attributed to the Abrolhos FHPA. Catch and effort reported in >20 fathoms (>~36 m) was used to represent the remainder of the WCRLMF A Zone, outside the Abrolhos FHPA.

2. From 2009 onwards, the RLQMS and CDR data provide finer spatial resolution (10 x 10 nm) for improved catch and effort delineation within or outside of the Abrolhos FHPA (Figure 2.2.1B). For long term comparison to the historical CAES data, all CDR blocks occurring within the original CAES block 97000 were aggregated to quantify annual catch and effort. Catch and effort in <=36 m was defined as within the Abrolhos FHPA and catch and effort >36 m as outside the Abrolhos FHPA.

The collation of these datasets allows for a long term (45 years) assessment of historical fishing catch and effort trends inside the Abrolhos FHPA. The methods used to apportion WCRLMF effort as inside or outside of the Abrolhos FHPA provide a general estimate.

Finer-scale assessment of catch and effort for the Abrolhos FHPA was performed using the CDR data only, following the implementation of the RLQMS data collection, due to the improved spatial reporting of this dataset. The CDR catch and effort data as well as the depth range (m) between 2011 and 2020 were aggregated for each CDR block within the A Zone. The proportion of catch and effort inside and outside of the Abrolhos FHPA was defined by CDR blocks which occur wholly within or outside the Abrolhos FHPA respectively. Any CDR blocks that intersect the Abrolhos FHPA boundary (i.e., reported catch and effort may have been inside or outside the FHPA) were assumed to have had an even spatial distribution of catch and effort and were proportioned as such, to create a spatially proportioned CDR dataset (Figure 2.1.2 B). For example, if 40% of the A Zone spatial area of a CDR block occurs within the Abrolhos FHPA, then 40% of the WCRLMF catch and effort from that block was allocated as to have occurred within the Abrolhos FHPA and 60% was allocated as outside the FHPA.

As the depth data in the CDR dataset were provided as a range, (e.g., 10-20 fathoms), a mid-range point in which fishing occurred (e.g., 15 fathoms or 27.4 m) was generated. These were then binned into five depth categories (0 – 10 m, 10 – 20 m, 20 – 50 m, 50 – 100 m and 100+ m). The spatially proportioned CDR data was also used to calculate annual catch per unit effort (CPUE), expressed as kilograms per pot lift, for each depth zone inside the Abrolhos FHPA. While the proportioned CDR dataset provides an improved spatial resolution of WCRLMF catch and effort compared to CAES, this method relies on the assumption of even spatial distribution and therefore is still an estimate.

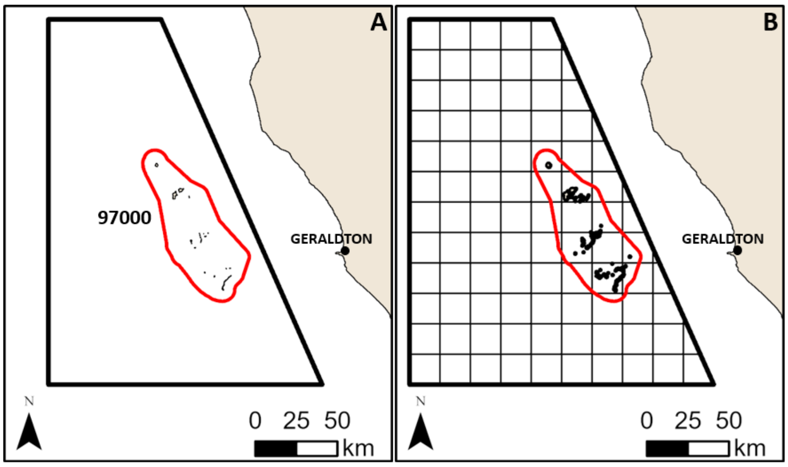

Figure 2.1.2. Historical WCRLMF A Zone reporting blocks (A) CAES single block (1975- 2008) (B) CDR blocks (2009 onwards), with the Abrolhos FHPA outlined in red.

2.1.3.2 *Results Summary*

Following the WCRLMF transition to ITQ in 2010, there has been an ~81% reduction of fishery effort within the Abrolhos FHPA, from a mean pre-ITQ effort (1976-2009) of ~811,400 pot lifts per year (pl/y) to ~152,700 pl/y post-ITQ (2010-2020) (Figure 2.1.3, Table 2.1.1). Similarly, a ~74% reduction of effort is observed outside the Abrolhos FHPA from a mean of ~425,600 pl/y (1976-2009) to ~110,100 pl/y (2010-2020) (Figure 2.1.3, Table 2.1.1). This reduction in effort within and outside the Abrolhos FHPA, following the introduction of ITQ, are comparable to that observed by de Lestang et al. (2016) across the WCRLMF.

Prior to the fishery transition to ITQ, the proportion of total A Zone effort was highest inside the Abrolhos FHPA, with a mean of 65.5% (min = 56.1% in 1979; max 77.5% in 1977) (Figure 2.1.3). The effort remained relatively consistent over the 32-year reporting period ranging from a low of ~715,000 pl/y (1979 and 1999) to a high of ~1,013,000 pl/y (1991), with the exception of 2009 which observed a record pre-ITQ low of ~288,500 pl/y in response to a significant effort reduction (pot usage) as a management response to low puerulus settlement (de Lestang et al., 2010) (Figure 2.1.3). Following transition to ITQ in 2010, the A Zone effort data (2010-2020) shows a reduction in effort inside versus outside the Abrolhos FHPA, with a mean proportion of 58.6% (min = 46.0% in 2010, max = 70.6% in 2012) of effort observed within the Abrolhos FHPA (Figure 2.1.3). A continued decrease in the proportion of A Zone effort inside the Abrolhos FHPA has been observed post introduction of ITQ from ~70% in 2011 and 2012 to 55.4% and 51.0% respectively for 2019 and 2020 (Table 2.1.1).

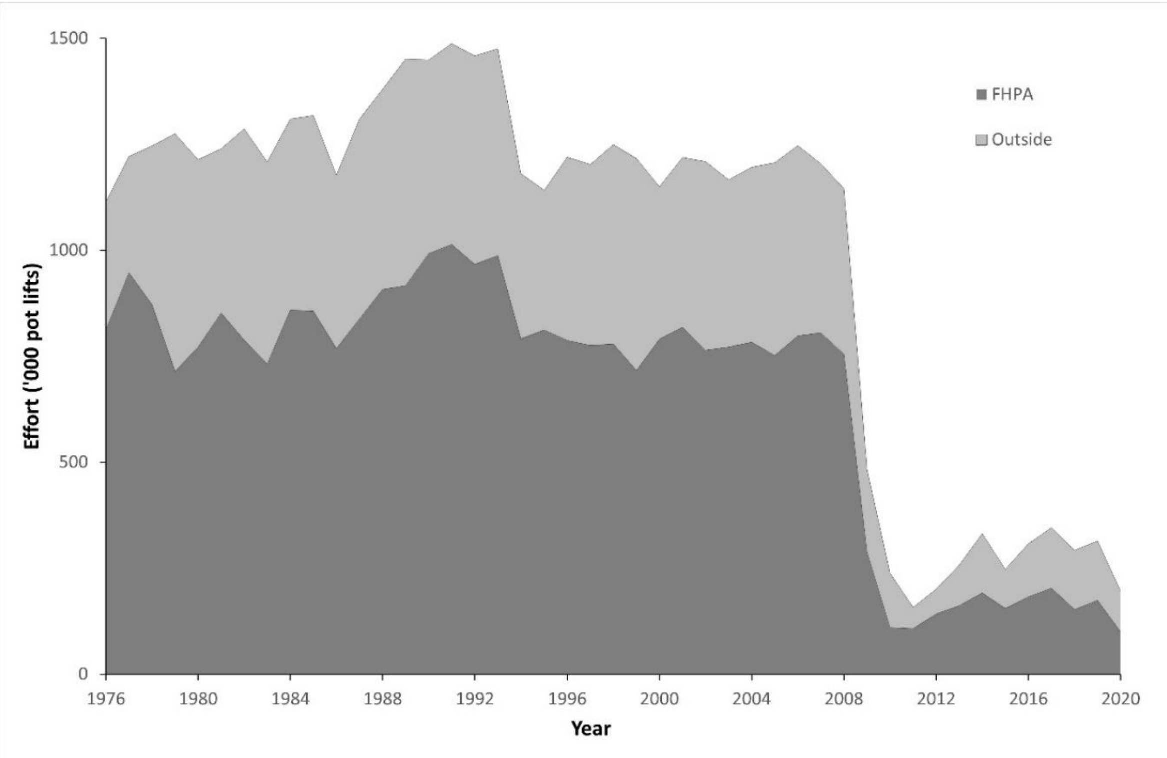

Figure 2.1.3. Annual WCRLMF A Zone total fishing effort (pot lifts) proportioned into estimates of effort inside (bottom) and outside (top) of the Abrolhos FHPA.

Table 2.1.1. The annual A Zone WCRLMF effort (number of pot lifts and proportion (%)) from CDR data, by depth, inside and outside of the Abrolhos FHPA between 2010 and 2020.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Inside FHPA	109,900 (46.0%)	107,500 (68.3%)	141,800 (70.6%)	161,500 (62.8%)	191,800 (57.8%)	155,300 (62.8%)	182,100 (59.1%)	202,800 (58.7%)	152,500 (52.2%)	174,000 (55.4%)	100,200 (51.0%)
Outside FHPA	128,800 (54.0%)	50,000 (31.7%)	59,100 (29.4%)	95,500 (37.2%)	140,100 (42.2%)	91,900 (37.2%)	125,800 (40.9%)	142,800 (41.3%)	139,800 (47.8)	140,300 (44.6%)	96,300 (49.0%)
Total	238,700	157,500	200,900	257,000	331,900	247,200	307,900	345,600	292,300	314,400	196,500

Catch inside the Abrolhos FHPA also reduced following the introduction of ITQ, from a mean of ~1033 tonnes per year (t/y) pre-ITQ (min = ~703 t/y in 1986, max = ~1240 t/y in 2007) to ~501 t/y post-ITQ (min = 276.4 t/y in 2020, max = 621.9 t/y in 2013) (Figure 2.1.4). While the A Zone catch outside the Abrolhos FHPA remained relatively consistent with a mean of ~618 t/y pre-ITQ (min = ~287 t/y in 1977, max = 1037 t/y in 2005) and ~556 t/y post-ITQ (min = ~290 t/y in 2012, max = 750 t/y in 2018) (Figure 2.1.4). The A Zone catch proportion from within and outside the Abrolhos FHPA also varied post-ITQ introduction. Prior to transition to ITQ 63.0% of catch, on average, was from within the Abrolhos FHPA (min = 52.4% in 1999, max = 78.3% in 1977) compared to an average of 47.7% post-ITQ (min = 32.3% in 2020, max = 67.5% in 2012) (Figure 2.1.4). This change in fishing pattern can also be seen in the CPUE, pre and post ITQ, with a 2.5-fold increase within the Abrolhos FHPA and a 5-fold increase in the A Zone area outside the FHPA, through fishers being able to access the highly catchable whites migration outside the Abrolhos FHPA.

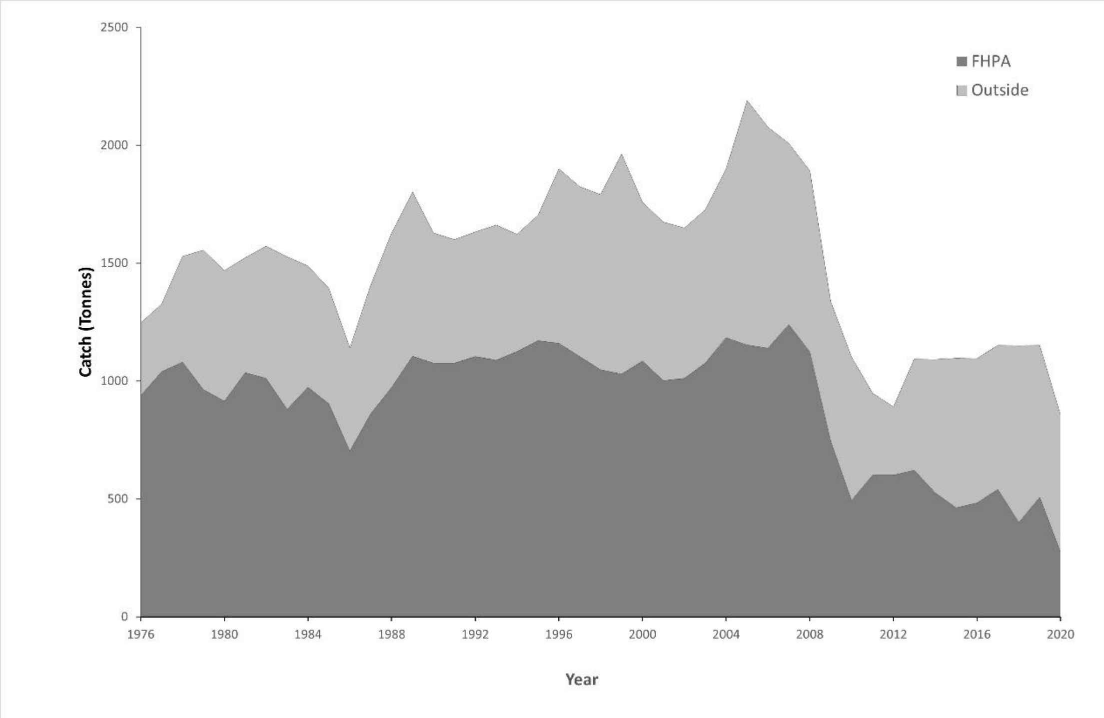

Figure 2.1.4. Annual WCRLMF A Zone total catch (tonnes) proportioned into estimates of catch inside (bottom) and outside (top) of the Abrolhos FHPA zone.

Spatial representation of CDR effort data between 2011 and 2019 shows that WCRLMF effort is predominately focused on the shallower eastern areas of the A Zone, which includes the Abrolhos FHPA (Figure 2.1.5). Within the Abrolhos FHPA, the highest intensity of effort generally occurs around the shallow reefs surrounding each of the three groups, with the North Island / Wallabi Group having higher concentration of annual effort (Figure 2.1.5). Outside the Abrolhos FHPA, the time-series shows an increase in the fishery's effort footprint in the south-eastern and northern areas, particularly between 2012 and 2013 (Figure 2.1.5). This spatial expansion outside of the Abrolhos FHPA post-2012 coincides with the extension of the A Zone season to year-round fishing which allows for fishing during the 'white' migratory period that occurs in austral summer (Figure 2.1.5).

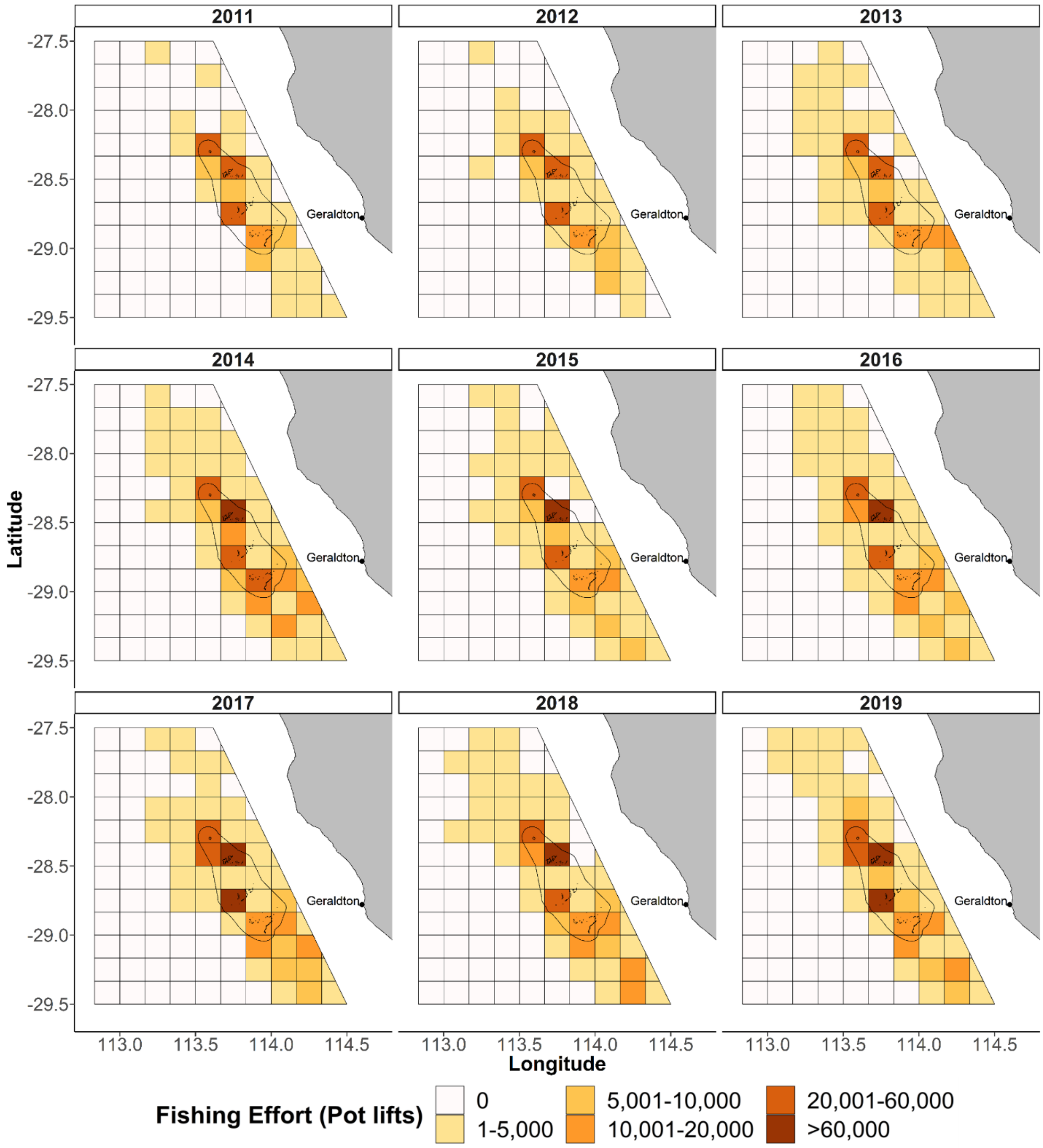

Figure 2.1.5. Recent trends in WCRLMF A Zone CDR block annual effort (pot lifts) post-ITQ (2011 – 2019).

The CDR catch data shows that high annual catch is typically associated with areas of relatively high effort (Figures 2.1.5 and 2.1.6). The highest concentration of catch in the WCRLMF A Zone, throughout the time-series, occurs within CDR blocks that encompass the island groups of the Abrolhos FHPA (Figure 2.1.6). Generally, the north and south-eastern areas of the A Zone, where the spatial expansion of effort occurred after 2012, provide less than 25 t per annum per block, with the exception of a number of blocks in the south-eastern area.

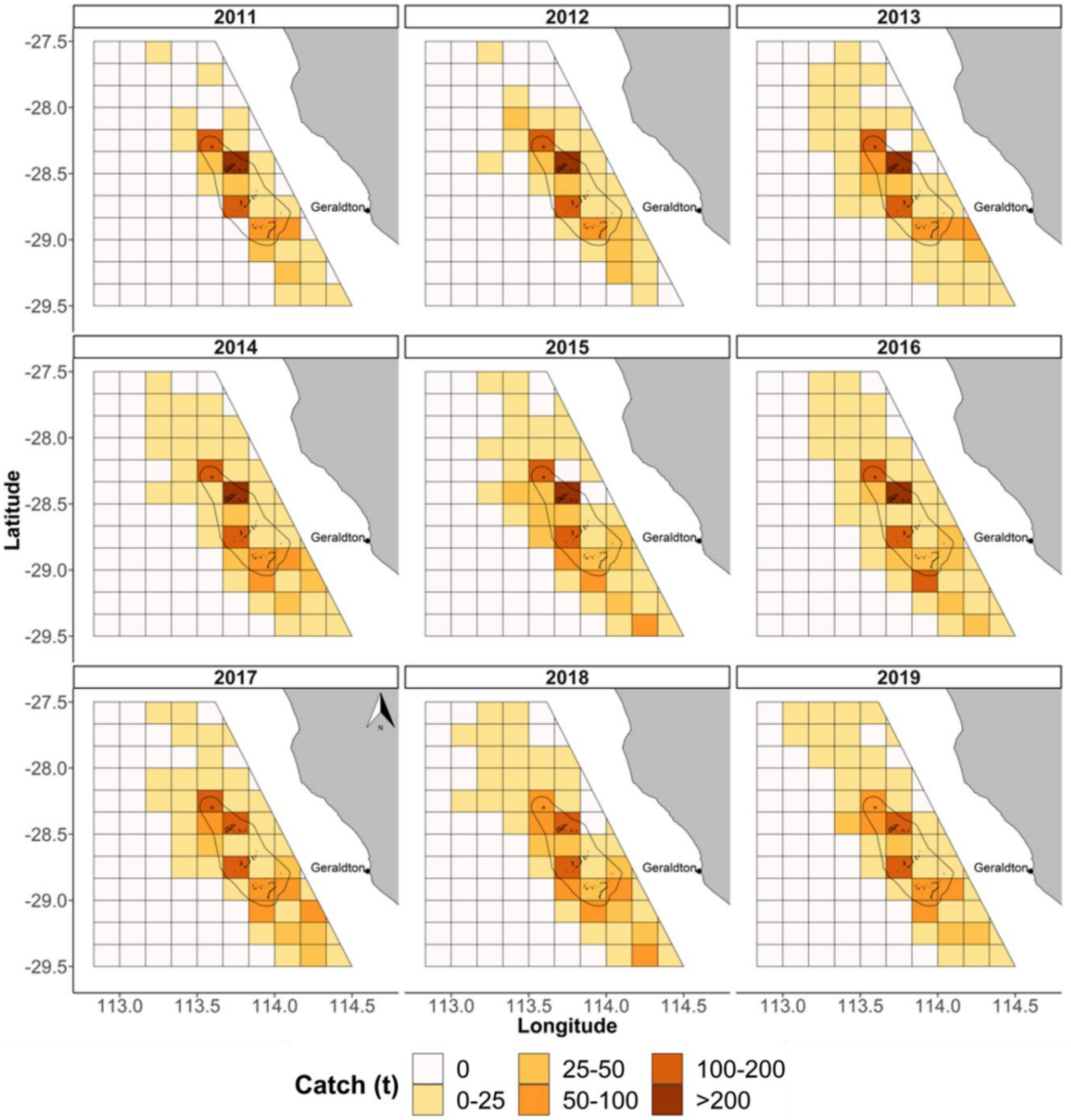

Figure 2.1.6. Recent trends in WCRLMF A Zone annual catch (tonnes) by CDR block post-ITQ (2011 – 2019).

From 2011, the intra-annual A Zone CDR effort data shows a shift away from the traditional fishing season (March 15th – June 30th) towards year-round effort by 2013, both inside and outside the Abrolhos FHPA (Figure 2.1.7). From 2013 onwards, effort in both areas has occurred predominately between February and May with a second smaller spike between September and November (Figure 2.1.7).

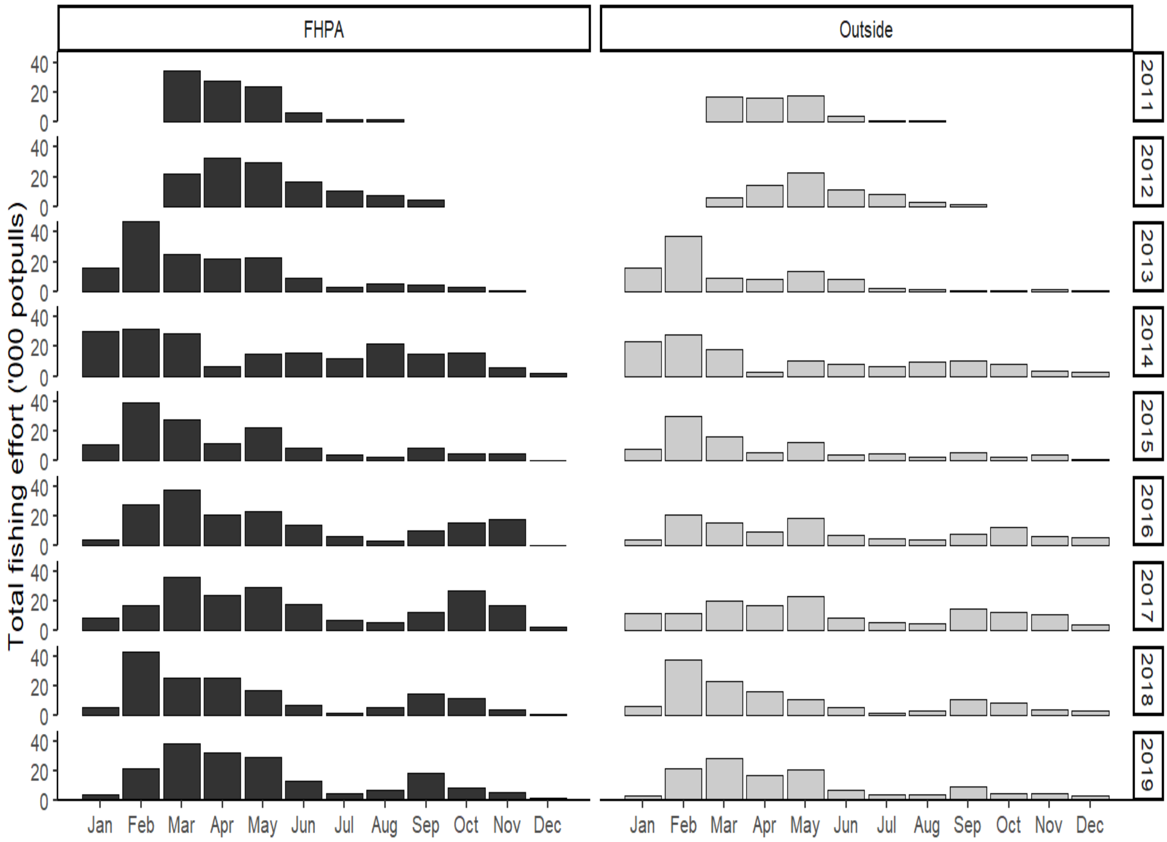

Figure 2.1.7. Monthly WCRLMF A Zone effort ('000 pot lifts) within and outside the Abrolhos FHPA between 2011 and 2019.

Within the Abrolhos FHPA, CDR data by depth zone between 2011 and 2019 shows that a range of between 44.2% (2013) and 59.9% (2015) of fishery effort occurs in shallow water (<20 m) (Table 2.1.2). Fishing effort in the >100 m depth zone within the Abrolhos FHPA has increased from no pot lifts (0%) in both 2011 and 2012 to between 3% and 7.6% from 2014 to 2019 (Table 2.1.2 and Figure 2.1.8). This increase represents a high proportion of effort given the >100 m depth zone is estimated to be approximately 1.0% of the spatial area of the Abrolhos FHPA and is likely a function of the assumption that effort is evenly distributed. Regardless, there appears to have been a level of increase in effort in this depth zone throughout the A Zone which has coincided with the shift to year-round fishing that allows fishers to target the 'white' migratory WRL phase in the austral summer which can occur in very deep (>100 m) waters (Figure 2.1.8).

Table 2.1.2. Annual WCRLMF Abrolhos FHPA effort (%) per depth zone between 2011 and 2019.

Depth Zone	Percentage of FHPA in depth zone	2011	2012	2013	2014	2015	2016	2017	2018	2019
0-10m	22.5	18.3	1.1	9.9	10.7	14.0	14.3	15.3	15.7	13.4
10-20m	8.0	33.2	35.8	34.3	37.2	45.9	37.9	40.3	33.4	34.0
20-50m	56.1	40.2	46.1	41.5	40.0	28.9	34.4	32.5	34.4	41.5
50-100m	12.4	8.2	6.9	12.8	9.0	5.1	8.1	9.1	9.0	8.0
100m +	1.0	0	0	1.5	3.0	6.1	5.3	2.9	7.6	3.0

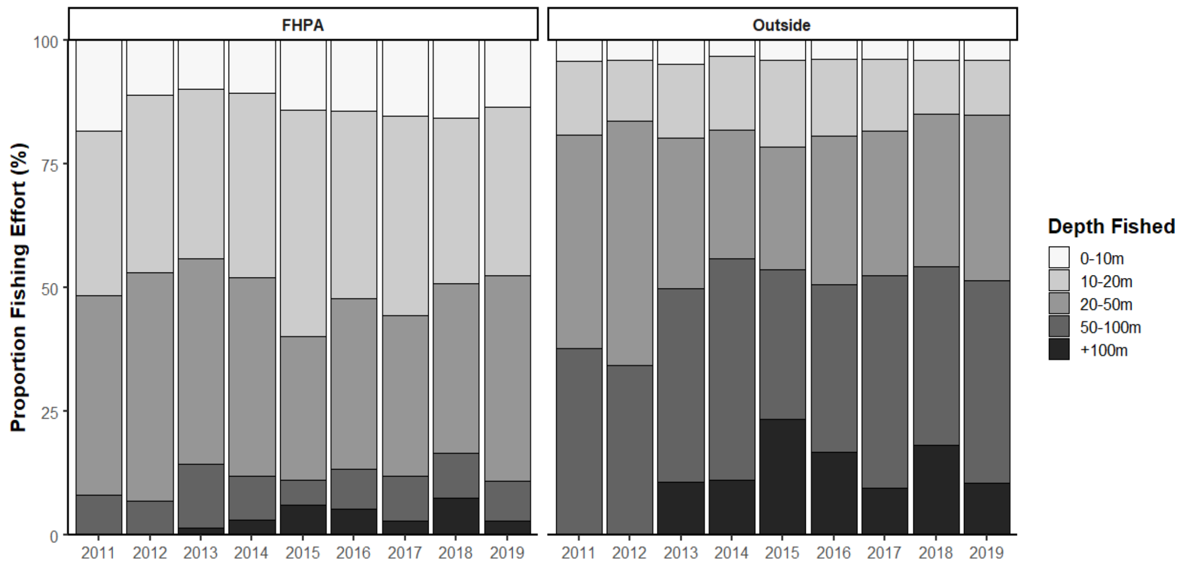

Figure 2.1.8. Annual WCRLMF A Zone fishing effort (%) by depth zone, inside and outside of the Abrolhos FHPA between 2011 and 2019.

The CDR data for the Abrolhos FHPA suggests the lowest annual WCRLMF CPUE occurred in the 0-10m depth zone between 2011 and 2019 (Figure 2.1.9). Decreases in CPUE were observed in the 10-20 m and 20-50 m depth ranges between 2011 and 2014, coinciding with the shift to year-round fishing (Figure 2.1.9). The deepest zone (>100 m) reported the highest CPUE of ~7 kg/pot lift for the seven most recent years of data (2013 – 2019) with no catch reported in 2011 and 2012 (Figure 2.1.9).

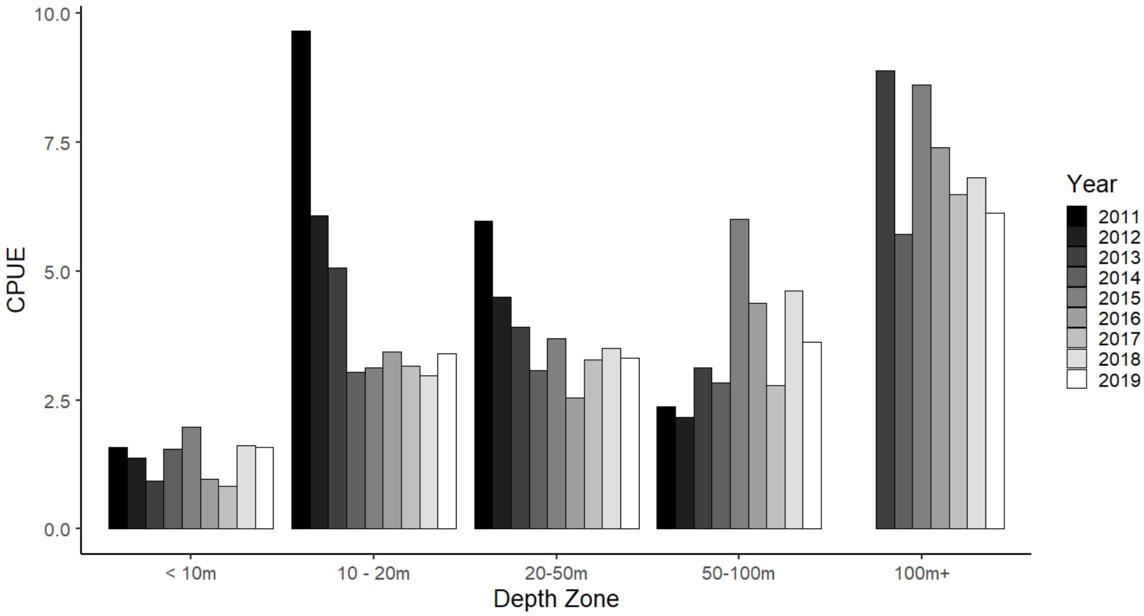

Figure 2.1.9. Annual WCRLMF A zone CPUE (kg/pot lift) for each depth zone within the FHPA between 2011 and 2019.

2.1.4 *Fishery Independent Effort Association and the Abrolhos FHPA*

2.1.4.1 *Methodology*

A fishery independent, aerial pot count survey was developed to provide finer spatial scale estimates of WCLRMF fishing activity within the shallow waters (<20 m) of the Abrolhos FHPA. The aerial survey was a structured grid, with transects separated by one minute of latitude (~1850 m) (Figure 2.1.10), flown by a fixed wing aircraft at an altitude of 150 m (~550 ft) and speed of ~180 to 200 km/h (100 to 110 kts). Surveys were conducted with an observer positioned on each side of the plane recording the number of individual pot float rigs (pots) per one minute of longitude (~1630 m at the Abrolhos FHPA) with a latitudinal spatial viewing angle of 73 degrees, equating to 500 m viewing extent per side (~1000 m total). This provides an approximate survey area of 1.63 km^2 per block, with the total number of pots recorded by both observers summed for total number of pots per block (Figure 2.1.10).

Aerial surveys commenced in 2006 and were conducted over two consecutive low (<12kts) wind days with Pelsaert and Easter groups surveyed on day one and North Island / Wallabi Group surveyed on day two (Table 2.1.3). Seven aerial surveys were conducted between 2006 and 2019, with four surveys undertaken in 2014 to assess intra-annual variation (Table 2.1.3). The initial 2006 survey consisted of 398 blocks (648.7 km^2) with nine additional blocks added on the northern end of Pelsaert Group from 2011 for a total of 407 blocks and a survey area of ~663.4 km^2 or ~26% of the total Abrolhos FHPA area (Figure 2.1.10).

Table 2.1.3. Survey period and WCRLMF management arrangement for each aerial pot count survey.

Year	Survey Period	Management	Season
2006	7 – 9th June	ITE	15th March – 30th June
2011	5-6th April	ITQ	15th March – 31st August
2014	16-17th January 16-17th April 23-24th July 8-9th October		All year (No closed season)
2019	2-3rd May		

Fine-scale patterns in fishing activity in shallow water (<~20 m) before, during, and after the transition to ITQ is presented for the historical (pre-ITQ) A Zone fishing seasons (15th March to 30th June). Intra-annual seasonal spatial fishing activity (four surveys) was compared for one year only, in 2014 (Table 2.1.3). A cumulative spatial assessment of fishing activity, including data from all seven surveys between 2006 and 2019 (Table 2.1.3) was also assessed. It is acknowledged that this data represents a snapshot of fishing activity, which may vary depending on environmental or economic factors.

2.1.4.2 *Results Summary*

Aerial surveys undertaken in 2006, 2011, 2014 and 2019 suggest a reduction in WCRLMF fishing activity over this time period for the Abrolhos FHPA shallow water environments (<~20 m) (Table 2.1.4 and Figure 2.1.10). The aerial survey data suggests that fishing activity was consistent between 2006 and 2011, then reduced substantially in 2014 (~91%) following full transition to ITQ. An increase in fishing activity (~363%) was observed in 2019 compared to 2014, however, it was still ~59% lower than that observed in 2011 (Table 2.1.4 and Figure 2.1.10). The aerial survey data supports the reduction in WCRLMF effort in the Abrolhos FHPA that is observed in the fishery dependent CDR data post-2011 (see section 2.1.3). However, the reduction of fishing activity observed from the aerial survey in April 2014 and the subsequent increase in activity in March 2019 was not observed in the CDR effort data, illustrating the limitations of the aerial survey conducted as an annual one-off snapshot. Acknowledging these limitations, in the absence of fine-scale fishery dependent effort reporting on pot locations, the aerial surveys provide an indicative spatial assessment of fishing activity for the shallow waters of the Abrolhos FHPA.

At the island group level, between 2006 and 2019 the aerial survey data shows that the highest reduction of fishing activity (84%) was observed in the Easter Group, followed closely by the Pelsaert Group (83%) (Table 2.1.4 and Figure 2.1.10). North Island / Wallabi Group showed the lowest reduction of fishing activity (40%) following transition to ITQ (2006 and 2019) (Table 2.1.4 and Figure 2.1.10).

Table 2.1.4. Total WCRLMF pot counts per island group derived from aerial pot count survey observations (March – June surveys).

Island Group	**Number of Pots Observed**			
	2006	**2011**	**2014**	**2019**
Pelsaert	614	367	3	104
Easter	643	618	18	100
North Island / Wallabi	973	924	148	579
Total	**2230**	**1909**	**169**	**783**

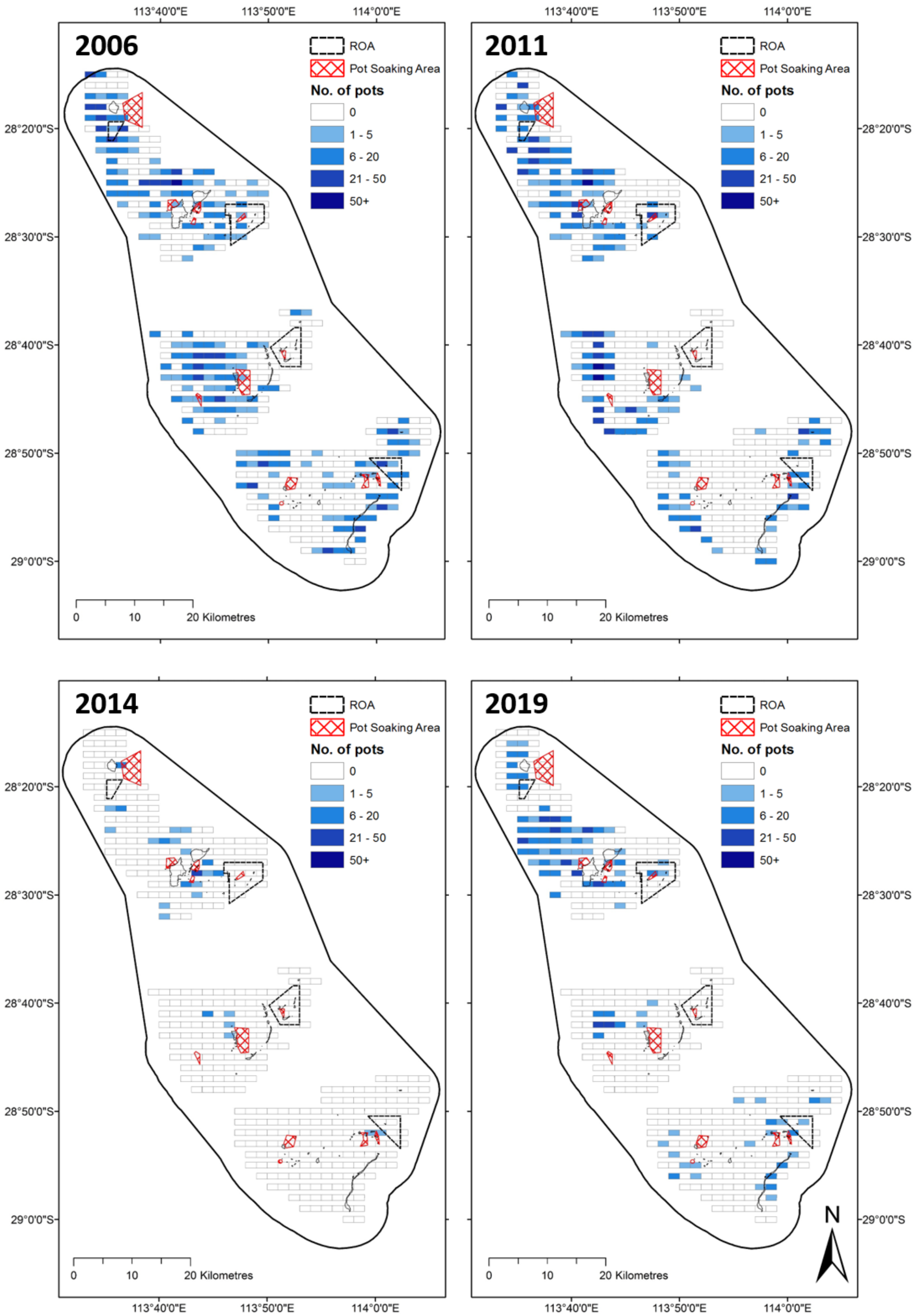

Figure 2.1.10. Spatial distribution and intensity of WCRLMF fishing activity (aerial pot count surveys) during historical fishing season (March to June) on the shallow (<20m) waters of the Abrolhos FHPA.

Comparisons of the four intra-annual aerial surveys in 2014 suggests, at the Abrolhos FHPA level, fishing activity peaks in the summer and winter seasons (Table 2.1.5 and Figure 2.1.11). However, this trend was not consistent between island groups, with the Pelsaert Group having consistent, albeit low, fishing activity through summer, winter and spring and negligible activity in autumn (Table 2.1.5 and Figure 2.1.11). Easter Group showed the lowest fishing activity in autumn and the highest in winter. The North Island / Wallabi Group recorded its highest fishing activity in summer and autumn and the lowest in spring (Table 2.1.5 and Figure 2.1.11). The timing of the ITQ WCRLMF season, which begins on the 15th of January, supports the data shown in the aerial surveys in that less effort is often applied to the fishery as fishers approach their quota limit (de Lestang et al., 2016).

Table 2.1.5. Seasonal distribution of WCRLMF fishing activity (aerial pot count surveys) in the Abrolhos FHPA shallow (<20m) waters during 2014.

Island Group	**Number of Pots Observed**				
	Summer	Autumn	Winter	Spring	Total
Pelsaert	36	3	49	34	122
Easter	97	18	166	59	340
North Island / Wallabi	301	148	93	39	581
Total	**434**	**169**	**308**	**132**	**783**

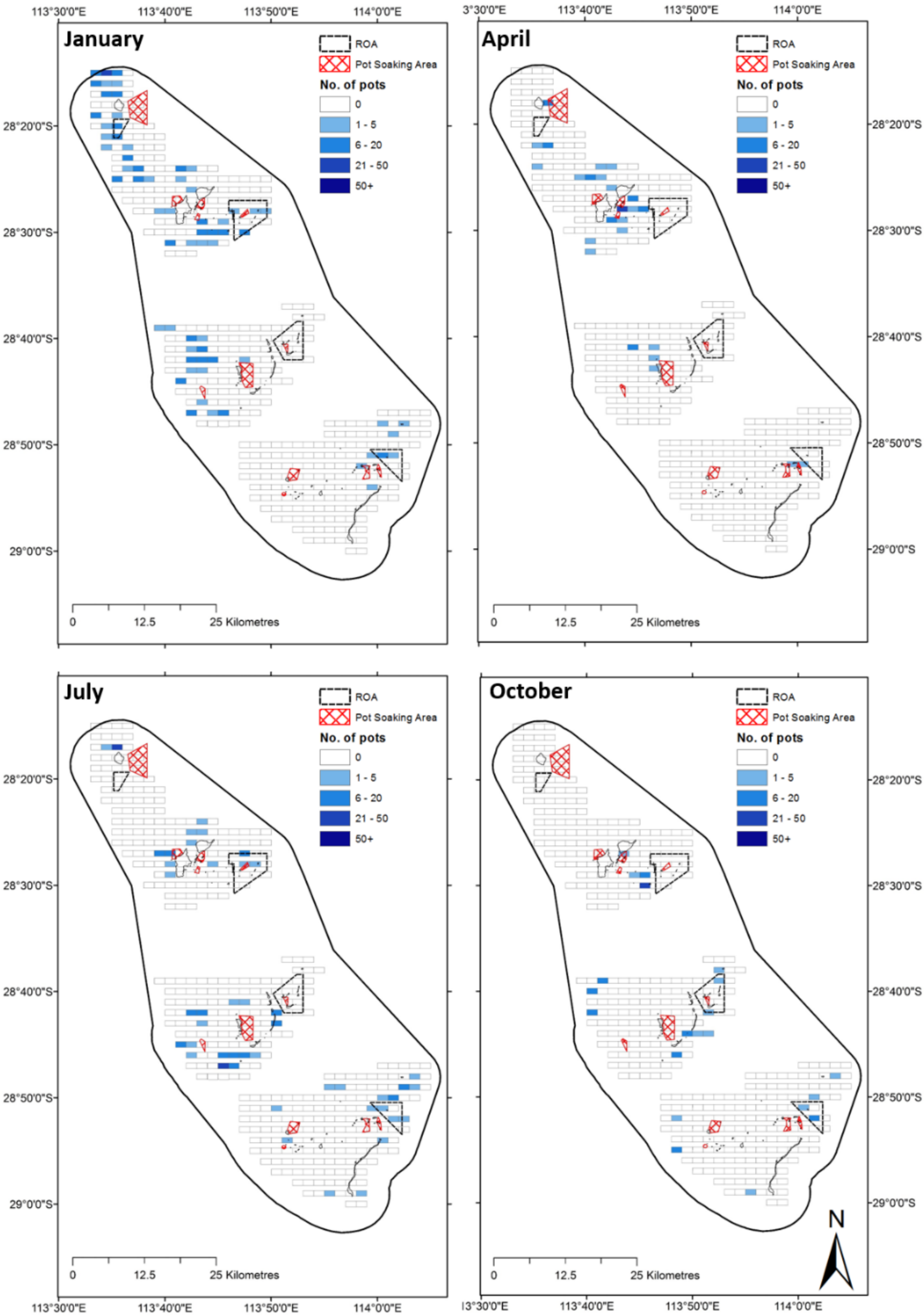

Figure 2.1.11. Seasonal distribution of WCRLMF fishing activity (aerial pot count surveys) in the Abrolhos FHPA shallow (<20m) waters during 2014.

The cumulative pot counts from all aerial survey years (2006, 2011, 2014, 2019) suggests fishing activity in the North Island / Wallabi Group was the most spatially distributed, while the Pelsaert Group was the lowest (Figure 2.1.12). In general, fishing activity is concentrated in the north-west areas of the Easter and North Island / Wallabi Groups and outer reef edges of the Pelsaert Group (Figures 2.1.10, 2.1.11 and 2.1.12). However, fishing activity was observed in the shallow lagoon within island groups and within the reef observation areas (ROA), particularly in North Island / Wallabi and Pelsaert Groups (Figures 2.1.10, 2.1.11 and 2.1.12). Notably, some of the highest cumulative pot counts in the Pelsaert and North Island / Wallabi Groups occurred inside the ROAs at these groups (Figure 2.11). However, this fishing activity appeared to be seasonal (Figure 2.1.11) and declined following the WCRLMF transition to ITQ (Figure 2.1.10).

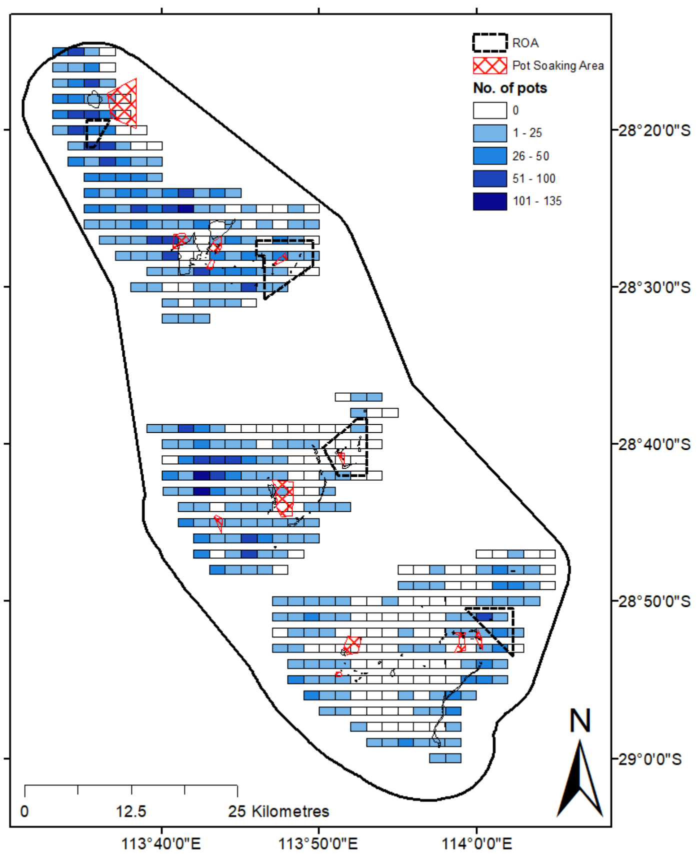

Figure 2.1.12. Distribution of WCRLMF fishing activity (aerial pot count surveys) in the Abrolhos FHPA shallow (<20m) waters, derived from all seven surveys undertaken between 2006 and 2019.

2.1.5 *The WCRLMF and Abrolhos FHPA Benthic Environment*

2.1.5.1 *Methodology*

The WCRLMF independent aerial pot count data (section 2.1.4) was used to associate fishing activity to the shallow water (<~20 m) benthic environments of the Abrolhos FHPA. The aerial pot count data was selected for its improved spatial resolution compared to the fishery dependent CDR (10 x 10 nm) resolution. There is limited benthic environment mapping for the Abrolhos FHPA which incorporates all depths, geomorphological and biota types, however three publicly available spatial data maps were obtained which are at an appropriate scale to match the aerial pot count survey. The first maps date from 1988 and describe the geomorphological classes (Figure 2.1.13) and sensitivities (Figure 2.1.14) for the shallow water (<~20 m) benthic environment of all three island groups (Hatcher et al., 1988). The second map, published in 2012, is a satellite remote sensing derived map which describes the shallow water (<~20 m) benthic biota for the Wallabi Islands area of the North Island / Wallabi Group only (Figure 2.1.15) (Evans et al., 2012). The third data set is bathymetry data which was sourced from DoT (2009) and was compiled from multiple sources including, but not limited to, the RAN AUS chart series and Department of Mines, Industry Regulation and Safety datasets. The DoT (2009) bathymetry dataset is binned into six depth zones, of which four intersect with the WCRLMF aerial pot count spatial data, these being: 0-10 m, 10-20 m, 20-50 m and 50-100 m. Although fine-scale LiDAR bathymetry data captured in 2016 is available for the Abrolhos FHPA (DoT, 2021), this higher resolution was disproportionate to either the fishery dependent CDR effort data or fishery independent aerial pot count surveys fishing activity data.

The Hatcher et al. (1988) geomorphological classes (Figure 2.1.13) and sensitivities (Figure 2.1.14) are primarily based on the composition and topography of the substrate reflecting its geological history. These geomorphological maps provide a unique opportunity to assess the sensitivity of the Abrolhos FHPA benthic environment to WCRLMF fishing activity, with the measures of geomorphological sensitivity based on the potential physical damage caused by WRL pots and rope hauling, jet boat hulls, and the deployment of anchors (Hatcher et al., 1988). The geomorphological classes were also based on the evolutionary development of the benthic substrate, therefore, although the maps are over 30 years old, they maintain relevance. However, the biological communities map described in Hatcher et al. (1988) have not been validated in over 30 years and therefore are not used for this report. Estimates of fishing activity on biological communities were undertaken on the biota classes described Evans et al. (2012) (Figure 2.1.15).

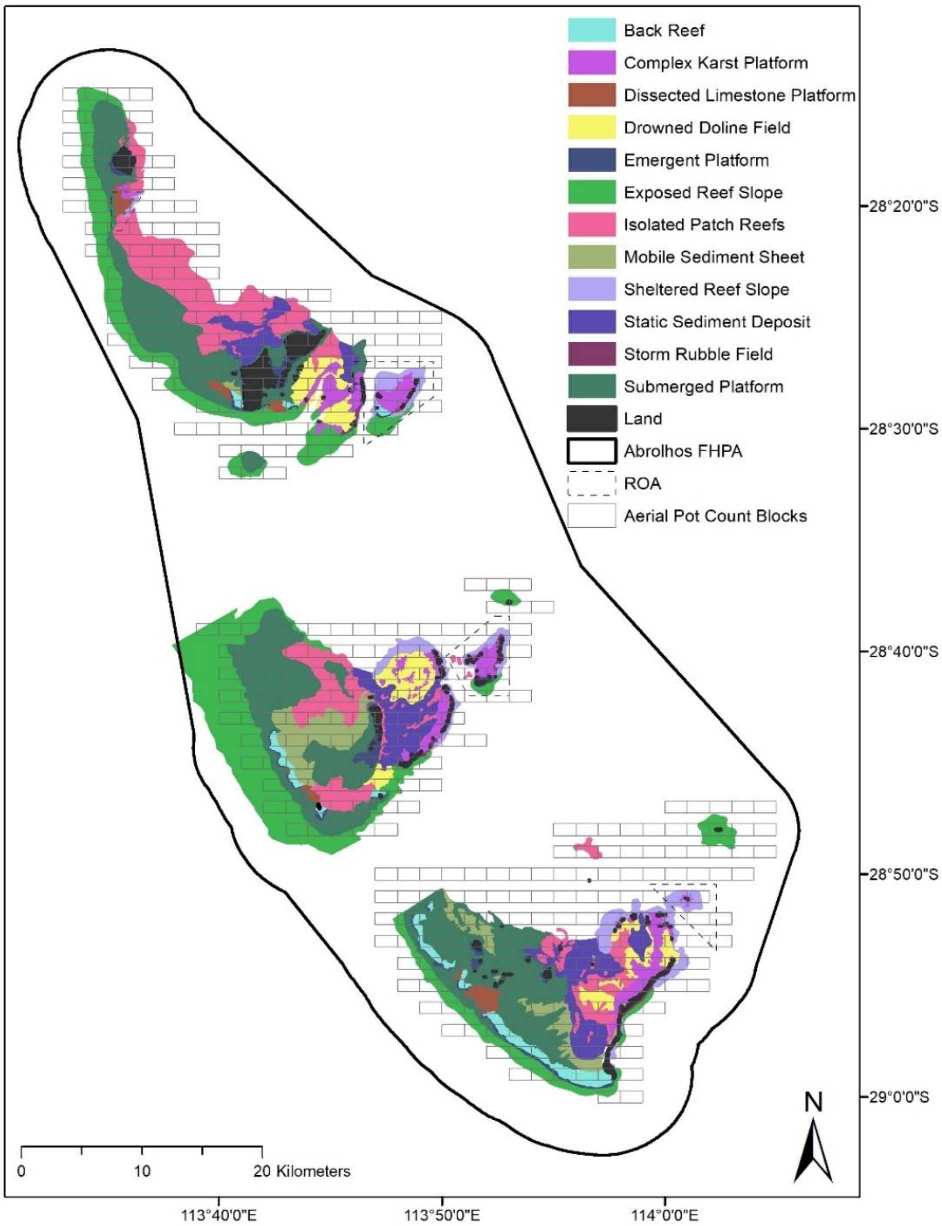

Figure 2.1.13. Geomorphological classes for Abrolhos FHPA shallow (<20m) waters (Hatcher et al., 1988) with WCRLMF aerial pot count survey grid overlay.

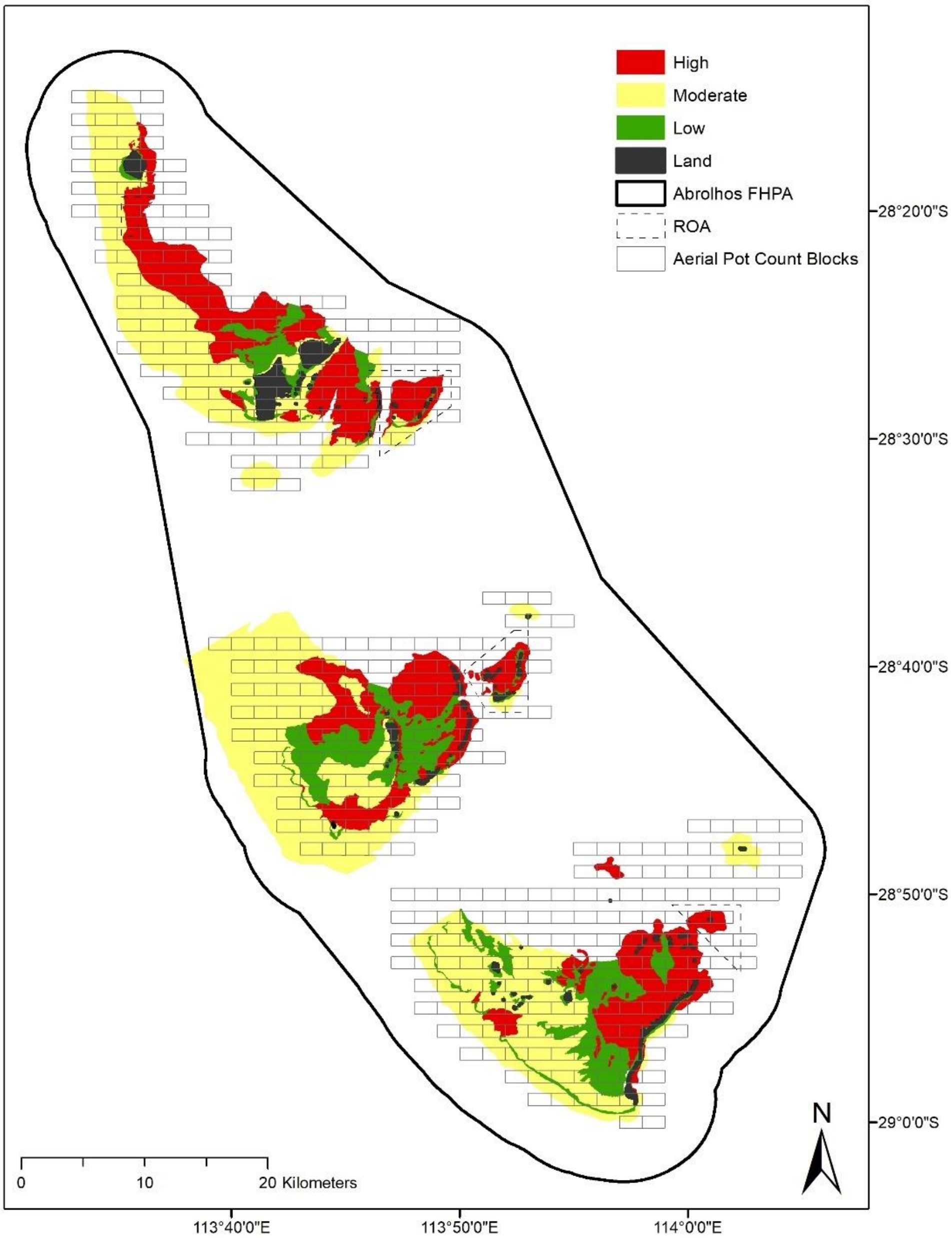

Figure 2.1.14. Geomorphological sensitivities for Abrolhos FHPA shallow (<20m) waters (Hatcher et al., 1988) with WCRLMF aerial pot count survey grid overlay.

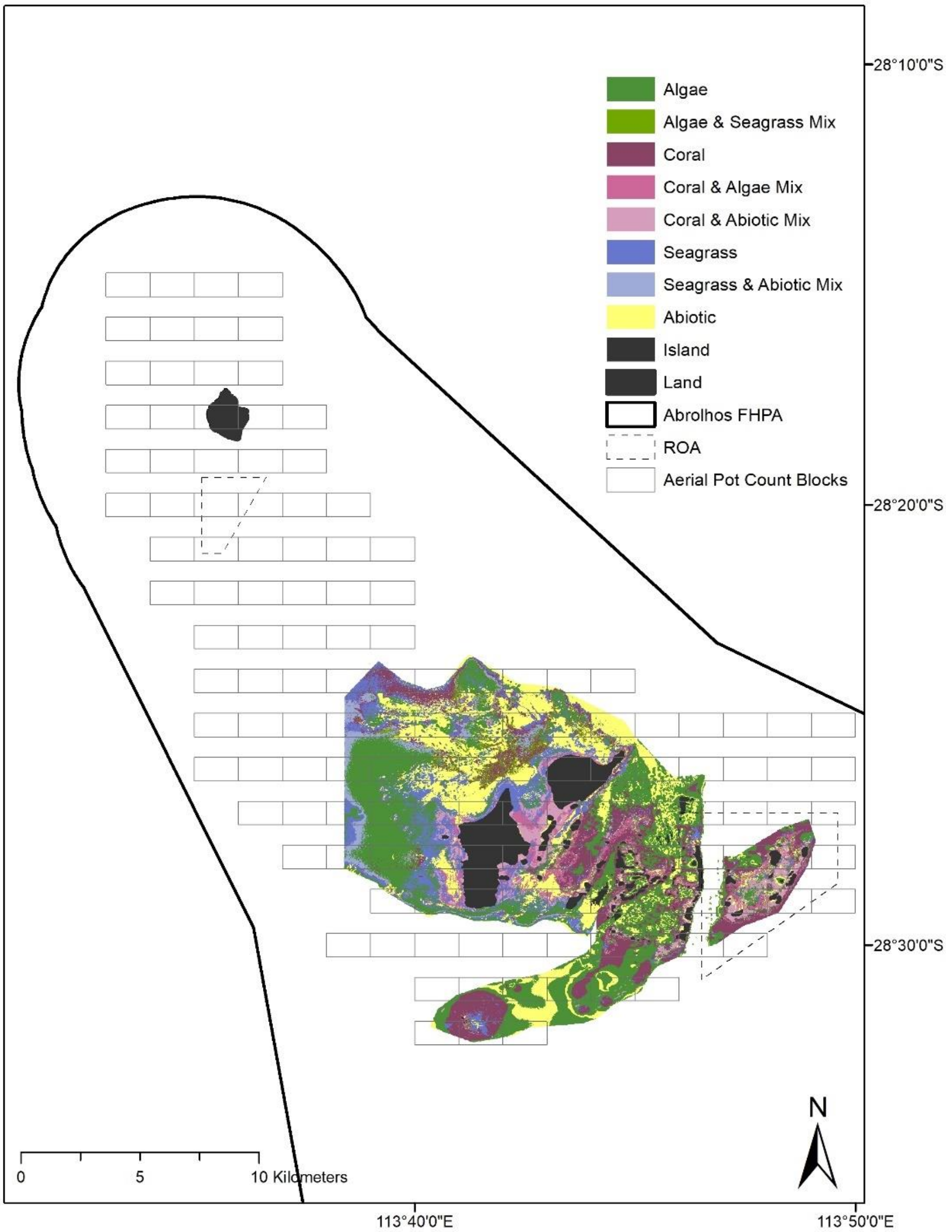

Figure 2.1.15. Biota classes of the Abrolhos FHPA Wallabi Islands area shallow (<20m) waters (Evans et al., 2012) with WCRLMF aerial pot count survey grid overlay.

To explore WCRLMF fishing activity association to the benthic environments within the Abrolhos FHPA, a spatial overlay of the four years (2006, 2011, 2014, 2019) of aerial pot count survey data (section 2.1.4) collected during the historical A Zone fishing season (March 15th to June 30th) was undertaken on the geomorphological classes and sensitivities maps described in Hatcher et al. (1988), biological communities from Evans et al. (2012) and bathymetry from DoT (2009). Overlaying the two spatial datasets (i.e., aerial pot counts and benthic environment maps) was based on the total area (km^2) of the benthic environment (e.g., Hatcher et al., (1988); Evans et al., (2012)) which the aerial pot count survey grid overlapped (Figures 2.1.13, 2.1.14 and 2.1.15). For example, the Hatcher et al. (1988) geomorphological classes and sensitivities mapping covered a spatial area of ~737.5 km^2 across all three island groups of the Abrolhos FHPA, while the aerial pot count survey grid covered a total spatial area of ~663.4 km^2 (Figures 2.1.13 and 2.1.14). When the ~663.4 km^2 aerial pot count survey grid was overlaid on the 737.5 km^2 Hatcher et al., (1988) geomorphological class map, an area of ~371 km^2 or ~50% of the Hatcher et al., (1988) geomorphological class map and ~56% of the aerial pot count survey grid intersected (Figure 2.1.13 and Figure 2.1.14). For the biological classes from Evans et al. (2012) for the Wallabi Islands, an area of ~74.5 km^2 or ~49% of the total 153 km^2 area of the biological classes intersected (Figure 2.1.15). All aerial pot count survey data was overlaid on the DoT (2009) bathymetry zones.

Total pot counts from the aerial pot count surveys were aggregated to presence/absence of pots (fishing activity) per aerial survey grid block. This presence/absence of fishing activity was associated to all benthic environments that occurred within a specific aerial pot count survey grid block, regardless of the proportion of the differing benthic environments which occurred within the block (e.g., if one benthic environment accounted for 1% of the grid block and another accounted for 99%, both environment types were attributed the presence or absence of fishing activity equally). This is a precautionary estimate that does not account for possible benthic preferences of either WRL or WCRLMF fishing activity. It is acknowledged that this may over or underestimate fishing activity for some benthic classes (e.g., when overlaying fishing activity data, an aerial grid block with one pot observed is treated equally to a block that may have 10 pots). However, with limited data available from the aerial pot count survey (i.e., four time points over a 13-year period), fishing activity based on intensity (i.e., total number of pots per block) was not examined. Further, due to the low level of WCRLMF pot count effort observed in some of the 2014 intra-annual surveys (Figure 2.1.11), a comparison of intra-annual habitat association was not undertaken for this report.

2.1.5.2 *Results Summary*

Spatial overlays of the aerial pot count survey data, for all four individual survey years, and the Hatcher et al. (1988) geomorphological sensitivity maps (Figure 2.1.14) suggests that the majority (mean = 48.1%) of the WCRLMF fishing activity for the Abrolhos FHPA shallow water habitats (<~20 m) targets moderately sensitive benthic environments (Table 2.1.6). The aerial pot count survey data suggests the remaining fishing activity, on average, targets high (39%) and low (13%) geomorphologically sensitive benthic environments (Table 2.1.6). The trend of fishing activity preference for moderately geomorphological sensitive habitats has remained consistent between 2006 and 2019, even when fishing activity more than halved post 2011 (e.g., 1909 pots observed in 2011 and 783 in 2019), except for 2014 which is likely a factor of substantially lower pot counts (169 pots) in that year (Table 2.1.6).

Table 2.1.6. Proportion (%) of total WCRLMF fishing activity (aerial pot counts) by geomorphological sensitivity classes in Hatcher et al. (1988).

Geomorphological sensitivity (Number of pots)	**2006 (2230)**	**2011 (1909)**	**2014 (169)**	**2019 (783)**
High	30.9	29.1	60.1	34.8
Moderate	53.6	61.7	21.0	56.0
Low	15.5	9.2	18.9	9.2

While WCRLMF fishing activity maintained a preference for targeting moderate and high geomorphological sensitive benthic environments of the Abrolhos FHPA between 2006 and 2019, the association of total fishing activity (pots observed) to the area of each sensitivity class (e.g., fishery footprint) has reduced by approximately half in all geomorphologically sensitive types (Table 2.1.7). Between, 2006 and 2019 there has been an approximate 46%, 50% and 71% reduction of fishing activity on the high, moderate and low sensitive geomorphological benthic environments, respectively (Table 2.1.7). In 2019, approximately 30% of the high, 30% of the moderate and 14% of the low geomorphologically sensitive areas, within the aerial pot count survey grid, observed an association with fishing effort (Table 2.1.7).

Table 2.1.7. Proportion (%) of the differing geomorphological sensitivity types (Hatcher et al., 1988) with observed WCRLMF fishing activity from the aerial pot count surveys.

Geomorphological sensitivity	2006	2011	2014	2019
High (118.9km^2)	55.1	37.4	16.3	29.6
Moderate (184.9km^2)	61.3	51.1	3.7	30.6
Low (67.0 km^2)	48.8	20.9	9.2	14.0

At the geomorphological class level (Figure 2.1.13), although fishing activity reduced between the 2006 and 2019 aerial pot count surveys, the preference for fishing remained primarily to three classes: isolated patch reefs (16.5 – 34.3%), submerged limestone platform (11.5- 39.2%), and exposed reef slope (8.4 – 26.6%) (Table 2.1.8). This result is consistent with previous geomorphological associations of WCRLMF at the Abrolhos FHPA reported in Webster et al. (2002) which was based on data derived from interviews with WCRLMF fishers.

Table 2.1.8. Proportion (%) of total WCRLMF fishing activity (aerial pot counts) by geomorphological benthic classes (Hatcher et al., 1988).

Geomorphological class	Sensitivity	Sensitivity Rank	2006	2011	2014	2019
Isolated Patch Reefs	High	2	16.5	19.0	34.4	19.7
Complex Karst Platform	High	2	4.1	3.1	9.0	3.3
Dissected Limestone Platform	High	3	2.2	2.1	2.9	3.0
Drowned Doline Field	High	1	4.1	1.5	11.2	3.2
Sheltered Reef Slope	High	2	4.0	3.5	2.8	5.7
Exposed Reef Slope	Moderate	5	20.5	26.6	8.4	15.7
Back Reef	Moderate	4	3.6	1.8	1.0	0.9
Submerged Limestone Platform	Moderate	5	29.6	33.2	11.5	39.2
Mobile Sediment Sheet	Low	7	6.9	2.1	4.3	2.4
Static Sediment Deposit	Low	7	5.6	4.6	13.1	4.4
Storm Rubble Field	Low	7	0.8	1.1	0.0	0.8
Emergent Limestone Platform	Low	6	2.1	1.4	1.4	1.7

As with the reduction of fishing activity association to the total area of all geomorphological sensitivities (i.e., high, medium and low), fishing activity for the total area of each geomorphological class has also decreased between the 2006 and 2019 aerial pot counts surveys (Table 2.1.9). In 2006, all 12 of the geomorphological classes were observed to have over 35% of the observed area associated with fishing activity (range of 35.9% and 85.0%) (Table 2.1.9). This reduced substantially by 2019 with only two geomorphological classes reporting fishing activity at over 35% of the observed area; dissected limestone platform; 55.3%, submerged limestone platform; 36.7% (Table 2.1.9).

Table 2.1.9. Proportion (%) of the differing geomorphological class types (Hatcher et al., 1988) with observed WCRLMF fishing activity from the aerial pot count surveys.

Geomorphological class	Sensitivity	Sensitivity Rank	2006	2011	2014	2019
Isolated Patch Reefs	High	2	61.8	51.5	19.4	34.7
Complex Karst Platform	High	2	40.8	22.1	13.6	15.6
Dissected Limestone Platform	High	3	85.0	57.8	17.1	55.3
Drowned Doline Field	High	1	48.2	12.3	20.0	18.0
Sheltered Reef Slope	High	2	48.6	30.5	5.2	33.2
Exposed Reef Slope	Moderate	5	65.1	61.5	4.1	24.1
Back Reef	Moderate	4	74.1	26.4	3.3	9.3
Submerged Limestone Platform	Moderate	5	57.8	47.1	3.5	36.7
Mobile Sediment Sheet	Low	7	69.7	15.1	6.7	11.4
Static Sediment Deposit	Low	7	35.9	21.4	13.1	13.6
Storm Rubble Field	Low	7	52.8	52.6	0.0	24.4
Emergent Limestone Platform	Low	6	46.0	21.4	4.7	17.2

At the island group level, the proportion of the total WCRLMF fishing activity associated with geomorphological sensitive classes was variable (Table 2.1.10). The aerial pot count survey data shows the North Island / Wallabi Group had the highest proportion of total fishing activity, increasing from ~48% in 2006 / 2011 to ~74% in 2014 / 2019 (Figure 2.1.10 and Table 2.1.10). This is in contrast to the Easter and Pelsaert Groups where the proportion of total fishing activity has reduced over the same time period from ~35% in Easter Group and 17% in Pelsaert Group in 2006 / 2011 to ~15% in Easter Group and ~11% in Pelsaert Group for 2014 / 2019 (Figure 2.1.10 and Table 2.1.10). The proportion of fishing activity attributed to each geomorphologically sensitive classes in each group was also not consistent between years (Table 2.1.10). Between 2006 and 2019, a general decrease in fishing activity was observed in the Easter Group on all geomorphological sensitivities (Table 2.1.10). A decrease in the moderate sensitivity areas of the Pelsaert Group was also observed, however, increase was observed in the high sensitivity regions (Table 2.2.10). Variable changes were observed in North Island / Wallabi Group for high and moderate geomorphological sensitivity classes, however an overall increase was observed with the moderate and high classes combined (Table 2.1.10).

Table 2.1.10. Total WCRLMF fishing activity (%) per aerial pot count survey year and per year and geomorphological benthic sensitivity (Hatcher et al., 1988) within each island group.

Geomorphological sensitivity	**Easter Group**				**Pelsaert Group**				**North Island / Wallabi Group**			
	2006	**2011**	**2014**	**2019**	**2006**	**2011**	**2014**	**2019**	**2006**	**2011**	**2014**	**2019**
Total Fishing Activity	*38.6*	*32.2*	*18.5*	*11.8*	*20.2*	*13.8*	*6.7*	*14.7*	*41.2*	*54.0*	*74.8*	*73.5*
High	11.0	4.0	7.4	2.9	3.8	2.9	6.2	6.2	16.1	22.2	46.6	25.9
Moderate	19.1	25.8	2.9	7.2	13.6	9.5	0.0	5.8	20.9	26.4	18.1	42.8
Low	8.5	2.4	8.2	1.7	2.8	1.4	0.5	2.7	4.2	5.4	10.1	4.8

Although the proportion of fishing activity between aerial pot count surveys was variable between the groups from 2006 and 2019 (Table 2.1.10) an overall decrease in fishery activity to the observed areas of all geomorphological sensitivity types was observed (Table 2.1.11). This result is expected due to the substantial reduction in fishing effort in the Abrolhos FHPA, evident in both the fishery dependent CAES, CDR and fishery independent aerial pot count survey data. The aerial pot count survey data suggest that the North Island / Wallabi Group shows the lowest reductions in fishery activity to observed geomorphological sensitive areas between 2006 and 2019 from 66.2% to 51.5% in high, 65.9% to 64.8%% in moderate and 64.5% to 35.4% in low sensitive areas (Table 2.1.11). This is compared to Pelsaert Group with reductions of 38.3% to 19.8% in high, 52.4% to 10.7% in moderate and 22.3% to 10.5% in low and 62.1% to 7.7% in high, 64.1% to 11.6% in moderate and 66.7% to 6.4% in low in Easter Group (Table 2.1.11).

Table 2.1.11. Proportion (%) of the differing geomorphological sensitivity types (Hatcher et al., 1988) with observed WCRLMF fishing activity from the aerial pot count surveys, by island group.

Geomorphological sensitivity	Easter Group				Pelsaert Group				North Island / Wallabi Group			
	2006	2011	2014	2019	2006	2011	2014	2019	2006	2011	2014	2019
High	62.1	16.2	6.4	7.7	38.3	14.8	6.4	19.8	66.2	66.5	29.7	51.5
Moderate	64.1	62.6	1.5	11.6	52.5	26.1	0.0	10.7	65.9	60.4	8.8	64.8
Low	66.7	13.7	10.0	6.4	22.3	8.2	0.6	10.5	64.5	59.3	10.1	35.4

Fishery activity associations with biological communities (i.e., biota), as described in Evans et al. (2012) for the Wallabi Islands area (see Figures 2.1.14 and 2.1.15), show no distinct change in biota preference for fishery activity between 2006 and 2019 (Table 2.1.12). In the Wallabi Island area, fishery activity was targeted towards algae (~35%) and abiotic (~19%) biological communities (Table 2.1.12). The remaining ~46% of fishing activity occurs on seagrass (~16%), coral (~15%) or mixed biota (~15%) (Table 2.1.12).

Table 2.1.12. Proportion (%) of total WCRLMF fishing activity (aerial pot counts) by biological (biota) class (Evans et al., 2012).

Biota class	2006	2011	2014	2019
Abiotic	19.1	20.5	18.5	16.9
Algae	35.9	35.9	30.5	36.4
Algae and Seagrass Mix	3.3	3.0	4.2	1.9
Coral	17.8	13.4	15.1	14.0
Coral and Abiotic Mix	4.4	4.2	6.6	5.3
Coral and Algae Mix	3.5	2.8	5.1	3.5
Seagrass	12.1	15.7	18.1	17.6
Seagrass and Abiotic Mix	3.9	4.5	1.9	4.4

As with the reduction in the fishing activity between 2006 and 2019, the observed area of fishing activity association from aerial pot count surveys on the biota in the Wallabi Islands has also decreased. In 2006, all four individual biota classes observed fishery associations between 61.0% (seagrass) and 68.4% (coral) (Table 2.1.12). In 2019, three of the four individual biota classes observed decreases in association with a ~50% reduction in the coral environment, ~30% reduction in algae and ~40% reduction in abiotic (Table 2.1.12). Fishing activity association with seagrass has remained constant (Table 2.1.12).

Table 2.1.12. Proportion (%) of the differing biological (biota) classes (Evans et al., 2012) with observed WCRLMF fishing activity from the aerial pot count surveys.

Biota class	2006	2011	2014	2019
Abiotic	64.9	65.2	20.0	40.0
Algae	66.3	62.2	18.0	46.8
Algae and Seagrass Mix	96.3	84.5	39.8	40.0
Coral	68.4	48.4	18.5	37.4
Coral and Abiotic Mix	43.1	38.8	20.4	35.9
Coral and Algae Mix	46.7	34.7	21.4	32.1
Seagrass	61.0	74.1	29.1	61.6
Seagrass and Abiotic Mix	86.3	94.0	13.4	68.8

Finally, comparing the spatial extent of the aerial pot count surveys fishing activity and DoT (2009) bathymetry data confirms that the aerial pot count surveys were focussed on the shallow Abrolhos FHPA waters, with ~70% or greater of the fishing activity attributed to the <20 m depth range each survey year (Table 2.1.13). Fishing activity was consistently highest in the 0 – 10 m depth range (~55 – 65% of fishing activity), while ~10 - 20% of fishing activity occurred in the 10 – 20 m depth range (Table 2.1.13). The 20 – 50 m depth range had the second highest pot counts in all survey years (except the 2019) and ranged between 15.5% (2019) and 29% (2016) of observed fishing activity (Table 2.1.13). The high level of fishing activity in the 0 - 10 m and 20 – 50 m depth ranges is expected as these ranges comprise the largest proportion of the aerial survey grid at 45.7% and 37.1% respectively (Table 2.1.13). However, this result is not consistent with data reported from fishery dependent CDR data, which reports higher effort in the 10 - 20 m and 20 - 50 m depth zone compared to the 0 - 10 m. This may be driven by the timing of the snap-shot aerial surveys and specific seasonal fishing practices in the shallow water, or an artefact of CDR depth data reported as a range, where the midpoint may be slightly higher if some deeper areas were fished.

Table 2.1.13. Proportion (%) of total WCRLMF fishing activity (aerial pot counts) on observed areas of differing depth zones, derived from DoT (2009) bathymetry data.

Depth	2006	2011	2014	2019	Proportion (%) of aerial survey grid per depth zone
0-10m	55.4	55.6	79.3	63.1	45.7
10-20m	13.5	20.4	12.7	21.1	14.9
20-50m	29.0	21.7	8.0	15.5	37.1
50-100m	2.1	2.3	0	0.3	2.3

2.1.6 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the WCRLMF and the Abrolhos FHPA:

- Update WCRLMF ERA and specifically include risks associated to the Abrolhos FHPA
- Investigate methods for improving spatial and depth resolution reporting of WCRLMF catch and effort data specific to Abrolhos FHPA
- Prioritise habitat mapping and monitoring programs to further investigate and quantify potential impacts of WCRLMF fishing activity on benthic habitats and ecosystems of the Abrolhos FHPA
- Investigate the merit of WCRLMF spatial closures, particularly in areas identified as highly sensitive environments, e.g., ROAs, or areas with potential resource sharing inconsistencies
- Investigate the potential of WCRLMF bycatch and ETP reporting specific to fishing activity within the Abrolhos FHPA
- Maintain regular updates and assessments of WCRLMF fishing activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.2 Abrolhos Islands and Mid-West Trawl Managed Fishery

2.2.1 *Fishery Description*

The Abrolhos Islands and Mid-West Trawl Managed Fishery (AIMWTMF) is a low-opening demersal otter trawl fishery that targets saucer scallops (*Ylistrum balloti*). The second largest scallop fishery in WA, the AIMWTMF operates in the temperate waters off the mid-west coast of WA, between 27°51' S and 29°03' S, on the landward side of the 200 m isobath (Figure 2.2.1) (DoF, 2004; Kangas et al., 2021a). Records of commercial scallop fishing in the AIMWTMF date back to the late 1960's and, although the fishery area extends out into Commonwealth waters, the principal grounds are within State waters (Figure 2.2.1) (DoF, 2004). In 1986, the fishery moved from open entry to limited entry fishery, with a maximum of 30 licences available (Joll, 1989). As of 2021, the AIMWTMF remains a limited entry fishery with 10 managed fishery licences permitted to operate (usually 5 to 6 vessels) along with a range of additional management measures including, for example, gear restrictions, temporal and spatial closures (Chandrapavan et al., 2020; Kangas et al., 2021a).

Fishing effort within the AIMWTMF has been variable within the last few decades, primarily driven by scallop abundance and condition, which is strongly influenced by environmental conditions (Kangas et al., 2019; Chandrapavan et al., 2020). For example, there was no fishing in the AIMWTMF in 2009 due to small meat size and poor quality of scallops (Kangas et al., 2010) and the fishery was closed between 2012-2016 due to a significant stock decline as a result of the marine heatwave in 2010/11 (Caputi et al., 2015; Chandrapavan et al., 2020). Since the fishery reopened in 2017, four of the 10 licences were operational in 2017 and 2018, and five in 2019 (Kangas et al., 2021a). The value of the AIMWTMF is also highly variable, however in 2017 it was valued at $4.5 million (Kangas et al., 2019) and had increased in 2019 to $5.8 million with reported scallop landings of 159.1 t meat weight (Kangas et al., 2021b).

The AIMWTMF has a harvest strategy (DPIRD, 2020a) and an ERA (DPIRD, 2020b), which support the decision-making process of the fishery, consistent with the principles of ESD and EBFM (Fletcher, 2002; Fletcher et al., 2012). In October 2021, the AIMWTMF achieved MSC certification for its sustainable fishing practices (MRAG Americas, 2021).

For further descriptions of AIMWTMF legislation, regulations (e.g., fleet restrictions, trawl gear size, temporal and spatial closures) and history, as well as biological and ecological traits of Saucer Scallops (*Ylistrum balloti*) see:

- DPIRD. (2020a). Saucer Scallop Resource of the Abrolhos Islands Harvest Strategy 2020 – 2025 Version 1.1. Fisheries Management Paper No. 299. Department of Primary Industries and Regional Development, Western Australia. 31pp.
- Kangas, M.I., Chandrapavan, A., Wilkin, S, Fisher, E.A., & Evans, S.N. (2021a). Resource Assessment Report Abrolhos Island and Mid-West Trawl Managed Fishery Resource. Western Australian Marine Stewardship Council Report Series No. 20. Department of Primary Industries and Regional Development, Western Australia. 75pp.
- DPIRD. (2020b). Ecological Risk Assessment of the Abrolhos Islands and Mid-West Trawl Managed Fishery. Western Australian Marine Stewardship Council Report Series No. 15. Department of Primary Industries and Regional Development, Western Australia. 56pp.

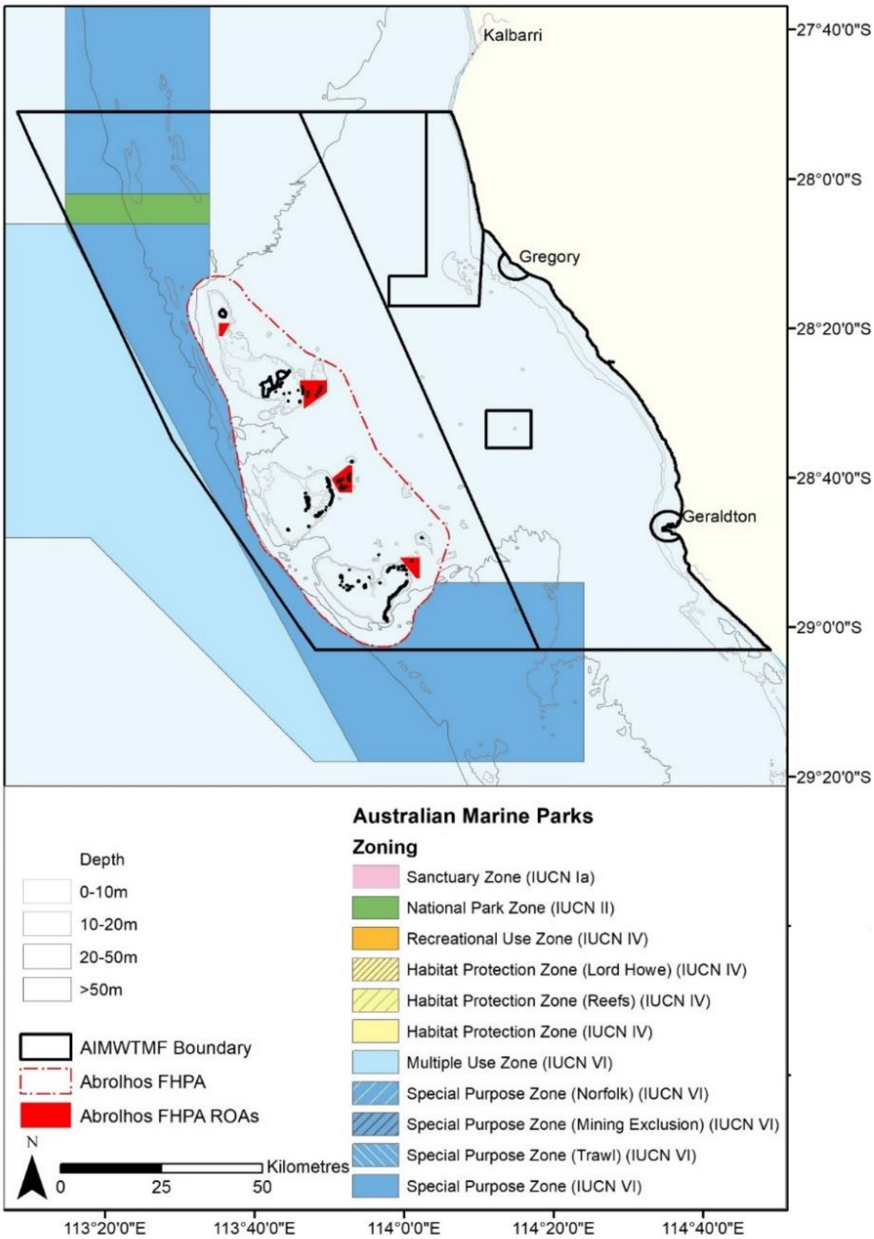

Figure 2.2.1. Management boundaries for the AIMWTMF and the Abrolhos FHPA.

2.2.2 *The AIMWTMF and the Abrolhos FHPA*

The waters of the Abrolhos have been fished commercially for scallops since the late 1960's (DoF, 2004) and as part of a limited entry fishery since 1986 (Joll, 1989). Fishing has occurred within the Abrolhos FHPA since its designation in 1999 (Abrolhos Island Fish Habitat Protection Order 1999, FRMA) and as an MSC certified fishery since 2021 (MRAG Americas, 2021). Historically, the fishery operated for between one and eight weeks, with the season dependent on scallop distribution and abundance. In 2017, following a significant stock decline and subsequent recovery, the season was set at five months (1st of March to 1st of August) to allow industry to optimise meat quality (Kangas et al., 2019). The season length may also be modified based on fishery independent survey results on scallop abundance and commercial catch rates. Trawling is undertaken during both the day and night with trawls typically ranging from 30 minutes up to 3 hours in duration, depending on catch rates (Kangas et al., 2019). Within the Abrolhos FHPA, scallops are generally found on the sandy bottom in the leeward side of the islands (Chandrapavan et al., 2020). The Abrolhos FHPA accounts for ~30% (~2494 km^2) of the spatial area of the AIMWTMF (~8366 km^2). The ROAs within the Abrolhos FHPA are legislatively closed to the AIMWTMF.

2.2.3 *Fishery Dependent Spatial Footprint Association and the Abrolhos FHPA*

2.2.3.1 *Methodology*

To calculate the spatial extent of fishing for the AIMWTMF and its association to the Abrolhos FHPA, data was collated and cross-referenced from two separate DPIRD datasets. The first database contained the compulsory, fishery dependent logbook data and the second was the DPIRD managed fishery independent satellite Vessel Monitoring System (VMS). The logbook data provides (amongst other data) a start location (latitude and longitude), date and time (AWST) and duration for each trawl shot. The VMS data provides (amongst other data) time and date stamped spatial information for each vessel operating in the AIMWTMF, including vessel call signs, location (latitude and longitude), date and time (UTC), speed and bearing, and is securely stored by DPIRD. To create a spatial fishery footprint database, these two DPIRD datasets were cross-referenced using a unique identifier which included vessel name, date and time. Active fishing times for all vessels were calculated from the logbook data based on the start of each shot (trawl) plus the duration, which was used to derive the trawl end time. Spatial location data for actively fishing vessels was then obtained by sub-setting the VMS dataset to the logbook defined active fishing times (this subset dataset is hereafter referred to as VMSLB data).

To estimate the spatial extent of the trawl footprint per fishing season, the VMSLB spatial location data was aggregated into a grid containing 500 x 500 m blocks that incorporated the entire AIMWTMF, excluding areas that are permanently closed to fishing (e.g., ROAs). Effort was defined as presence or absence of any VMSLB spatial data within a grid block. It is acknowledged that this method may overestimate the actual trawled area (km^2), however, it enables standardisation for different gear sizes, spread-ratios and tow speeds within the fishery.

The proportion of the fishery footprint inside and outside of the Abrolhos FHPA was defined by the 500 x 500 m grid blocks which occur wholly within or outside the Abrolhos FHPA. Any presence / absence of effort data that occurred within the intersected grid blocks (i.e., reported effort may have been inside or outside the FHPA) was assumed to have occurred in both zones and proportioned as such. It is acknowledged that this method for proportioning effort as inside or outside of the Abrolhos FHPA is a general estimate.

2.2.3.2 *Results Summary*

Fishery effort data between 2010 and 2019, from the VMSLB dataset, reports AIMWTMF effort occurred in only five of the ten years (2010, 2011, 2017, 2018 and 2019), with fishery closures in place in the remaining five years (Table 2.2.1). Combining the spatial extent (i.e., total area of benthic environment) for those five years that were fished shows a total AIMWTMF cumulative (2010-2019) fishery footprint of 573 km^2 (Table 2.2.1). Of this total fishery footprint, 380 km^2, or 66.3%, occurred within the Abrolhos FHPA (Table 2.2.1). This equates to 15.2% of the total spatial area of the Abrolhos FHPA having some level of association with the AIMWTMF footprint between 2010 and 2019 (Table 2.2.1).

Examining annual historical (from 2004 onwards) fishery data from the VMSLB dataset shows the spatial extent of the AIMWTMF footprint within the Abrolhos FHPA ranged from a low of 40 km^2 (2007) to a high of 291 km^2 (2005). However, irrespective of annual changes in the spatial extent of the fishery footprint, consistently over 70% of the total AIMWTMF footprint has occurred within the Abrolhos FHPA since 2004, with exception of 2019 (Table 2.2.1). This highlights the importance of the Abrolhos FHPA to this fishery. Although, in general, over 70% of the total AIMWTMF footprint occurred within the Abrolhos FHPA, this level of fishing activity equated to between 1.6% (2007) to 11.7% (2005) of the total spatial area of the Abrolhos FHPA (Table 2.2.1). Noting that the five years of cumulative data available between 2010-2019 shows a slightly higher (15.2%) spatial association with the Abrolhos FHPA, this suggests the fishery grounds each year are variable within the Abrolhos FHPA (Table 2.2.1). In addition, the number of vessels operating with the AIMWTMF has declined from 17 in 2005 to five in 2019 (Table 2.2.1).

The total AIMWTMF catch was not proportioned based on the VMSLB footprint estimation methods for this report. However, the economic significance of the Abrolhos FHPA for this multi million dollar fishery is evident based on the high levels of effort within its waters (Table 2.2.1, Figure 2.2.2).

Table 2.2.1. Annual (2004–2019) and cumulative (2010-2019) AIMWTMF footprint and association to the Abrolhos FHPA.

Year	Total fishery footprint (km^2)	Fishery footprint within Abrolhos FHPA (km^2)	Fishery footprint within Abrolhos FHPA (%)	Fishery footprint association with total area of Abrolhos FHPA (%)	Vessels Operating
2004	93	66	71.0	2.6	16
2005	416	291	70.0	11.7	17
2006	79	71	89.9	2.8	14
2007	47	40	85.1	1.6	14
2008	210	190	90.5	7.6	15
2010	188	170	90.4	6.8	15
2011	237	229	96.6	9.2	8
2017	139	120	86.3	4.8	4
2018	107	95	88.8	3.8	4
2019	333	156	46.8	6.3	5
2010-19	573	380	66.3	15.2	5-15

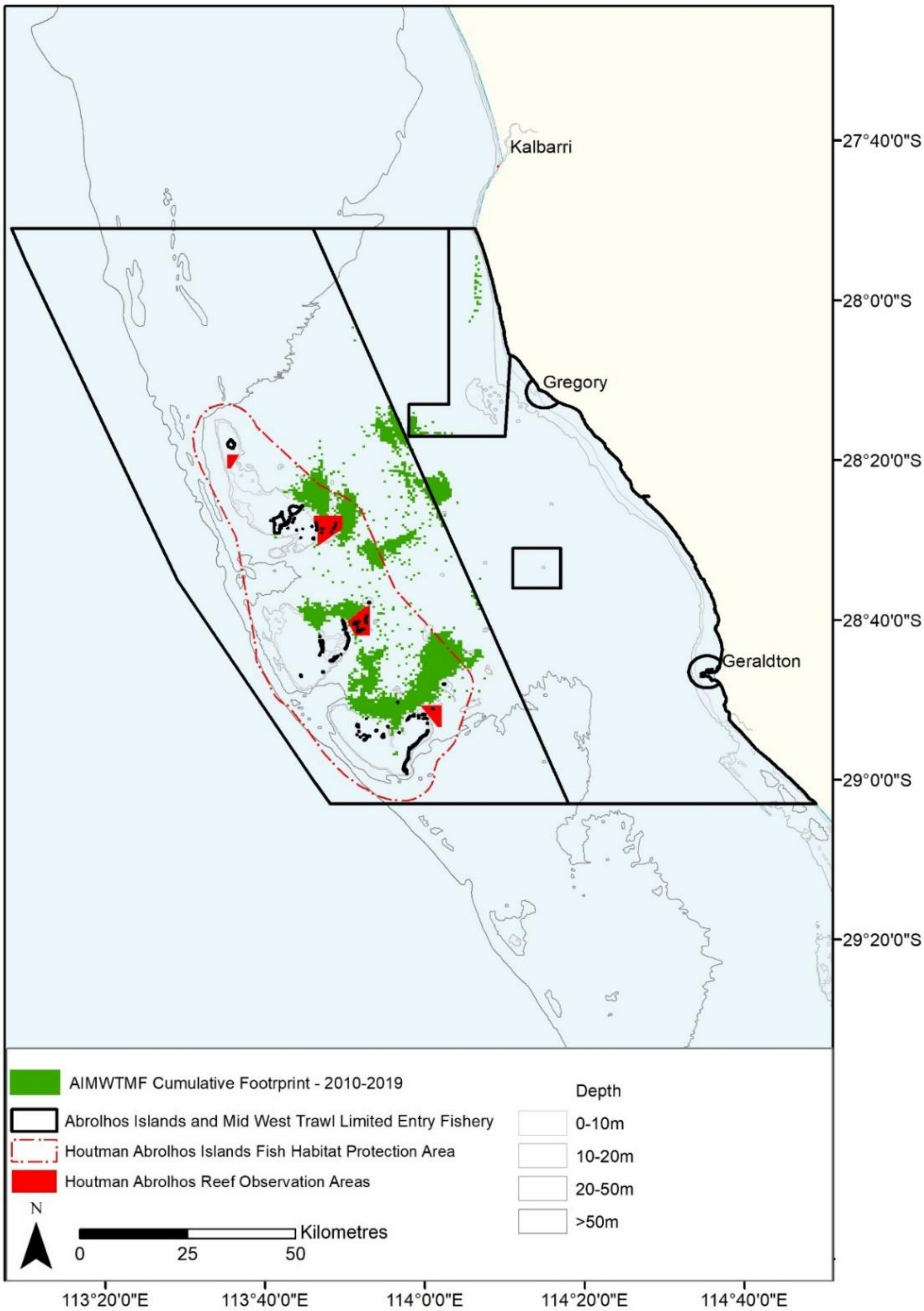

Figure 2.2.2. AIMWTMF 2010-2019 cumulative spatial effort footprint (green shaded).

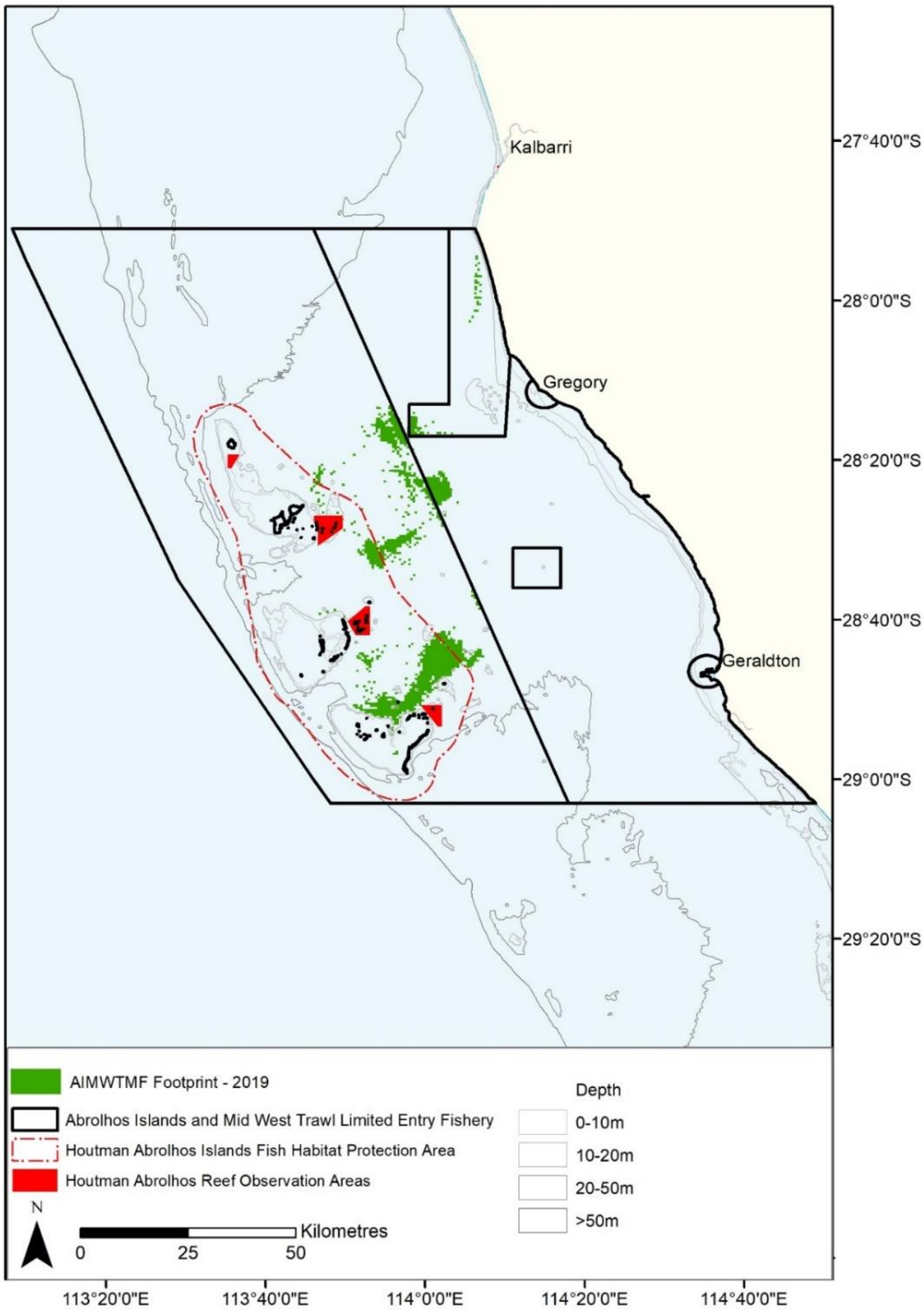

Figure 2.2.3. AIMWTMF 2019 spatial effort footprint (green shaded).

2.2.4 *The AIMWTMF and Abrolhos FHPA Benthic Environment*

2.2.4.1 *Methodology*

There are currently two publicly available fine-scale benthic environment maps that encompass the Abrolhos FHPA deeper water where AIMWTMF activity occurs (Figures 2.2.2 and 2.2.3); Radford et al. (2008) and DPIRD (2020b). The Radford et al. (2008) map is a “ground-truthed” multibeam hydroacoustic map developed, in combination with a spatial predictive modelling framework, to produce a fine-scale benthic environment map showing the extent of reef, sand and vegetated structures for a large area of the Zeewijk channel (Figure 2.2.2 and 2.2.4). Similarly, the DPIRD (2020b) map is a “ground-truthed” single beam hydro-acoustic map that was developed, in combination with a spatial predictive modelling framework, to produce a fine-scale benthic environment map showing the extent of sand, reef, mixed assemblage and mixed habitats.

To explore the associations of the AIMWTMF with the benthic environments within the Abrolhos FHPA, a spatial overlay of the 2010-2019 cumulative footprint (the largest spatial footprint within this time-series) was undertaken on the substrate classes in Radford et al. (2008) and DPIRD (2020b). The spatial overlays were based on the area (km^2) of the two maps which associated with the 500 x 500 m grid blocks (Figures 2.2.2, 2.2.3, and 2.2.4). It is acknowledged that neither map incorporates the entire fishery footprint. However, both maps were developed independent of the AIMWTMF and it is suggested, based on the known habitat preference of the target species, that they are representative of the benthic environment targeted by the fishery.

2.2.4.2 *Results Summary*

Spatial overlays of the AIMWTMF 2010-2019 cumulative 500 x 500 m grid footprint on the Radford et al. (2008) map (Figure 2.2.4A) suggest that the fishery predominantly targets sand (57.9%), with the remaining footprint on mixed assemblage (38.1%) and reef habitat (3.3%). An additional 0.7% is defined as “none modelled with confidence”. This is supported by the DPIRD (2020b) map which suggests 91.9% of the fishery footprint is on sand, 1.4% sparse mixed assemblage, 1% mixed assemblage, 0.2% reef and 0.2% sand/mixed assemblage (Figure 2.2.4B). An additional 5.3% is defined as “none modelled with confidence”. This result is expected based on the known habitat preference of the species and AIMWTMF fishing practices (Chandrapavan et al., 2020). Noting the limitations of modelling accuracies of the maps provided and the gear type, fishing patterns and reporting requirements of the fishery, the low levels of fishery associations with the reef habitats is highly likely to be driven by either confidence levels within the predictive mapping or the footprint estimation methods within the VMSLB 500 x 500 m grids and not an indication of fishing activity on reef habitat.

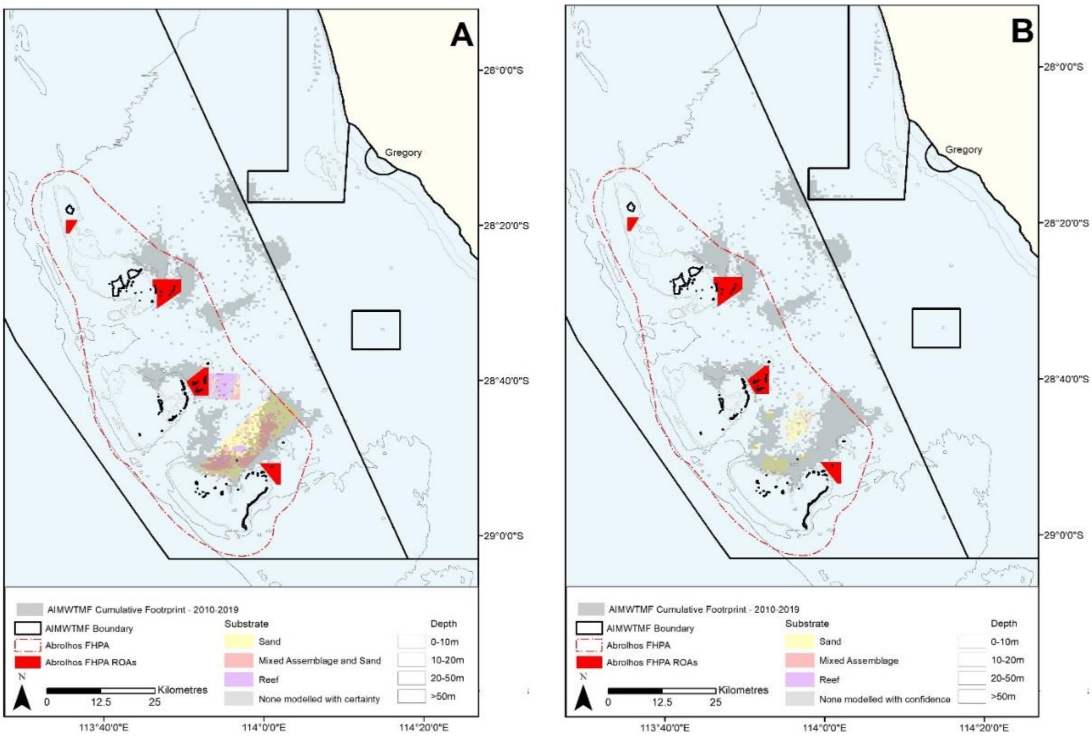

Figure 2.2.4. AIMWTMF 2010-2019 cumulative footprint and benthic environment associations from (A) Radford et al. (2008) and (B) DPIRD (2020b)**.**

2.2.5 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the AIMWTMF and the Abrolhos FHPA:

- Maintain the AIMWTMF ERA, with specific reference to the Abrolhos FHPA
- Investigate the merit of AIMWTMF legislative spatial closures of sensitive habitats (e.g., <20m deep reef systems) of the Abrolhos FHPA, to formalise voluntary compliance of the fishery exclusion from these areas and potential resource sharing inconsistencies
- Investigate the potential of AIMWTMF fishery bycatch and ETP reporting specific to activities within the Abrolhos FHPA
- Prioritise habitat mapping and monitoring programs to include representative areas of the AIMWTMF spatial effort footprint
- Maintain regular updates of AIMWTMF fishing activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.3 West Coast Demersal Scalefish (Interim) Managed Fishery

2.3.1 *Fishery Description*

The West Coast Demersal Scalefish (Interim) Managed Fishery (WCDSIMF) is a limited entry fishery that operates between 26°30'S (north of Kalbarri) and 115°30'E (east of Augusta) and includes the Abrolhos FHPA (Figure 2.3.1). The WCDSIMF commenced in 2008, following the restructure of the previous open access wetline fishery (Fairclough et al., 2008; DPIRD, 2021a). The fishery is divided into four management areas (Kalbarri, Mid-West, Metropolitan and South-West) that extend from the WA coast to the boundary of the Australian Fishing Zone, with the exception of the Metropolitan Area which extends to a line which approximates the 250 m depth contour (Figure 2.3.1) (DPIRD, 2021a). Interim Managed Fishery Permits (Permit) are required to access the Fishery, with the access right based on unit entitlements that are allocated in "hours" of fishing time, and are required to fish in the Kalbarri, Mid-West and South-West areas (Fairclough et al., 2014; DPIRD 2021a). No units of entitlement have been allocated to the Metropolitan Area (i.e., this area is closed to the Fishery). Line fishing ("wetline") is the only fishing method allowable in the WCDSIMF and catch is reported as daily returns in 10 x 10 nm data blocks (DoF, 2013a; DPIRD, 2020c).

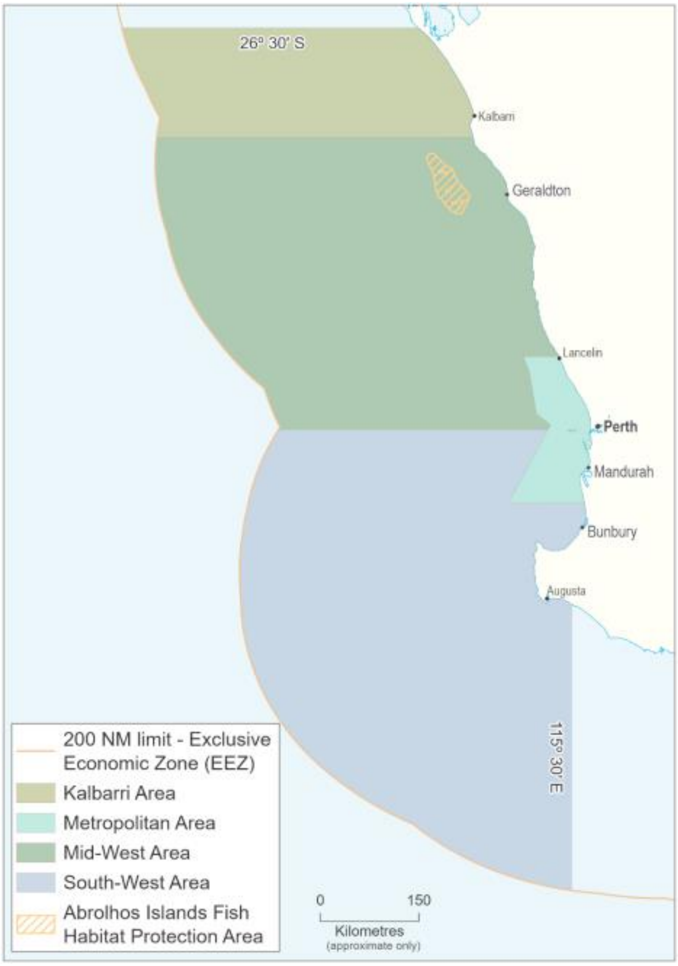

Figure 2.3.1. Boundaries and management areas of the WCDSIMF including the Abrolhos FHPA (Fairclough & Walters, 2021)

The WCDSIMF permit holders have access to the West Coast Demersal Scalefish Resource (WCDSR) which contains over 200 demersal scalefish species (see (DoF, 2013a) for full species suite). The WCDSR has a harvest strategy (DPIRD, 2021a) which supports the decision-making process for this resource, consistent with the principles of ESD, EBFM and harvest strategy policy (Fletcher, 2002; Fletcher et al., 2012; DoF, 2015). In 2019, the WCDSIMF reported 271 t total landing of catch, valuing the fishery at $1 - 5 million (Fairclough & Walters, 2021). For further descriptions of this and other WCDSIMF and WCDSR legislation, regulations (e.g., gear restrictions, temporal and spatial closures) and history, as well as biological and ecological traits of targeted species see:

- DPIRD. (2021a). West Coast Demersal Scalefish Resource Harvest Strategy 2021 – 2025 Version 1.0. Fisheries Management Paper No. 305. Department of Primary Industries and Regional Development, Western Australia.

2.3.2 *The WCDSIMF and the Abrolhos FHPA*

Commercial wetline fishing commenced in the waters around Geraldton and the Abrolhos in the late 1800's and increased in the early 1900's, with 58 wetline vessels operating by the 1930's (Cooper, 1996). The popularity of wetline fishing declined with the rise of WRL fishing at the Abrolhos and by 1995 there were approximately 16 wetline-only vessels working mainly from Geraldton (DoF, 1998). Effort data between 1995 and 2001 showed that the number of wetline-only vessels that fished within the Abrolhos FHPA was variable and had reduced to 3 by 2001 (Webster et al., 2002). However, the open-access arrangement of this fishery to fishers in other commercial fisheries, (e.g., WCRLMF) prior to the introduction of the WCDSIMF in 2008, made reporting complex and difficult to quantify (Crowe et al., 1999).

Currently there are several management tools (e.g., spatial closures, a temporal closure for baldchin groper (*Choerodon rubescens*) and gear restrictions) that apply to the WCDSIMF within the Abrolhos FHPA. As a wet-line fishery, the WCDSIMF gear type is deemed to have little physical impact on benthic habitats (Fairclough & Walters, 2021) and as a result is likely to pose a negligible risk to the marine benthic habitats of the Abrolhos FHPA.

2.3.3 *Fishery Dependent Catch Association to the Abrolhos FHPA*

2.3.3.1 *Methodology*

For this report, WCDSIMF data was based on DPIRD source data, where WCDSIMF catch data is provided as live weight (kg) of retained species within 10 x 10 nm data blocks (DPIRD 2020c) (represented by CDR blocks in Figure 2.1.2). For detailed information, please see the West Coast Demersal Scalefish Resource Harvest Strategy (DPIRD, 2021a).

The WCDSIMF catch (live weight - kg) data were extracted for each of the 17 data blocks (that had 3 or more operators) that fall within or intersect the Abrolhos FHPA boundary. The catch totals from the data blocks that intersected the Abrolhos FHPA boundary were then proportioned based on the spatial allocation that fell within, or outside, of that boundary (e.g., if 40% of the data block area fell within the FHPA boundary then 40% of the catch for that block was attributed to within the FHPA). This is the same methodology used to proportion the WCRLMF CDR catch and effort data within the Abrolhos FHPA (section 2.1.3.1) and assumes that catch has an even spatial distribution within each block.

Finalised data between 2008 and 2019 was used to provide a summary and to assess broad trends in WCDSIMF activity, specifically in relation to the Abrolhos FHPA. Data analysis for this report looked solely at a broad level daily catch in relation to the Abrolhos FHPA and does not account for management changes within the fishery, which can be found in the respective fisheries science and management reports. Cumulative data are presented for the period from 2008 to 2019 and for the 5-year period from 2015-2019 for individual data blocks. The recent 5-year data are presented to compare recent trends to the longer-term data.

2.3.3.2 *Results Summary*

The total live weight of WCDSIMF catch within the Abrolhos FHPA increased from 14,507 kg in 2008 to a peak of 26,227 kg in 2012, before declining to 6,020 kg in 2019 (Figure 2.3.2, Table 2.3.1). This trend was also observed across the entire WCDSIMF over this period (Table 2.3.1). Between 2008 and 2019, the annual WCDSIMF catch within the Abrolhos FHPA contributes a small proportion (~2-6%) to the total catch of the fishery, with this proportion generally declining since 2009 (Table. 2.3.1). In 2019, the catch from the Abrolhos FHPA was 2.4% of the total WCDSIMF (Table 2.3.1). The reductions in catch are concomitant to reductions in the effort allocation implemented in 2015 (DPIRD 2021a).

Table 2.3.1. Total catch of the WCDSIMF and of the WCDSIMF within the Abrolhos FHPA.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total WCDSIMF catch (kg)	415,256	303,382	367,192	411,392	389,063	379,531	335,571	271,659	234,758	229,722	229,722	255,803
Total WCDSIMF catch within Abrolhos FHPA (kg)	14,507	19,711	21,873	23,701	26,227	21,760	18,815	16,125	11,488	10,019	8,086	6,020
Percentage of WCDSIMF catch within Abrolhos FHPA	3.5%	6.5%	6.0%	5.8%	6.7%	5.7%	5.6%	5.9%	4.9%	4.4%	3.5%	2.4%
No. of vessels in Abrolhos FHPA	21	18	21	20	20	21	17	17	16	15	13	12

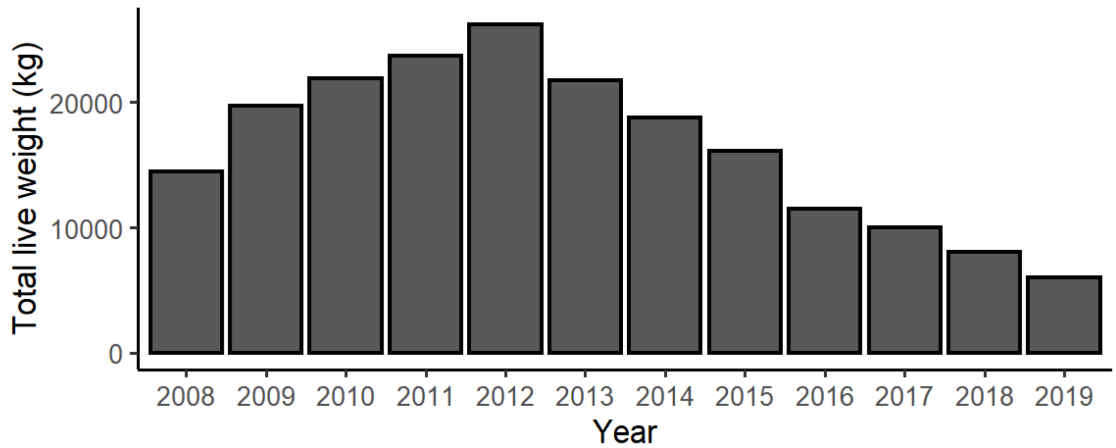

Figure 2.3.2. Total annual catch (kg) of the WCDSIMF within the Abrolhos FHPA.

The WCDSIMF total catch (2008 – 2019) for the Abrolhos FHPA was highest in the North Island / Wallabi Group and Middle Channel (Figure 2.3.3). The highest total catch between 2008 and 2019 was from the data block that encompasses North Island, with a total live weight of 28,096 kg proportioned to inside the Abrolhos FHPA (Figure 2.3.3). The block that encompasses the Wallabi Islands area had only slightly less with 27,681 kg, however, this was from a proportionally larger area (Figure 2.3.3).

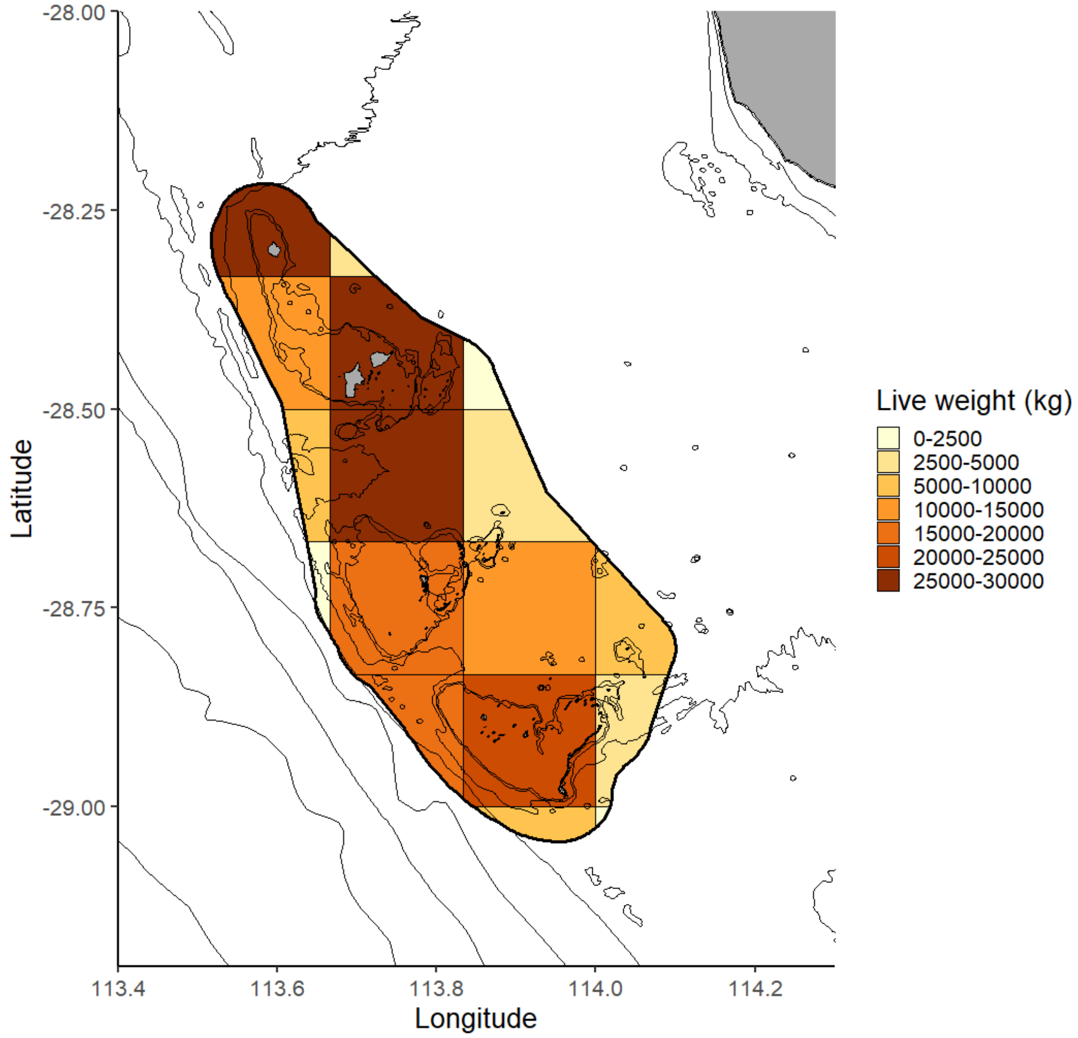

Figure 2.3.3. Total (2008 – 2019) WCDSIMF catch (kg) within the Abrolhos FHPA.

The total catch for the five more recent years (2015-2019) shows a similar trend to the 2008-2019 cumulative dataset, with the highest catches from the North Island / Wallabi Group (Figure 2.3.4). The block that encompasses North Island had the highest total catch within the Abrolhos FHPA (10,300 kg) (Figure 2.3.4).

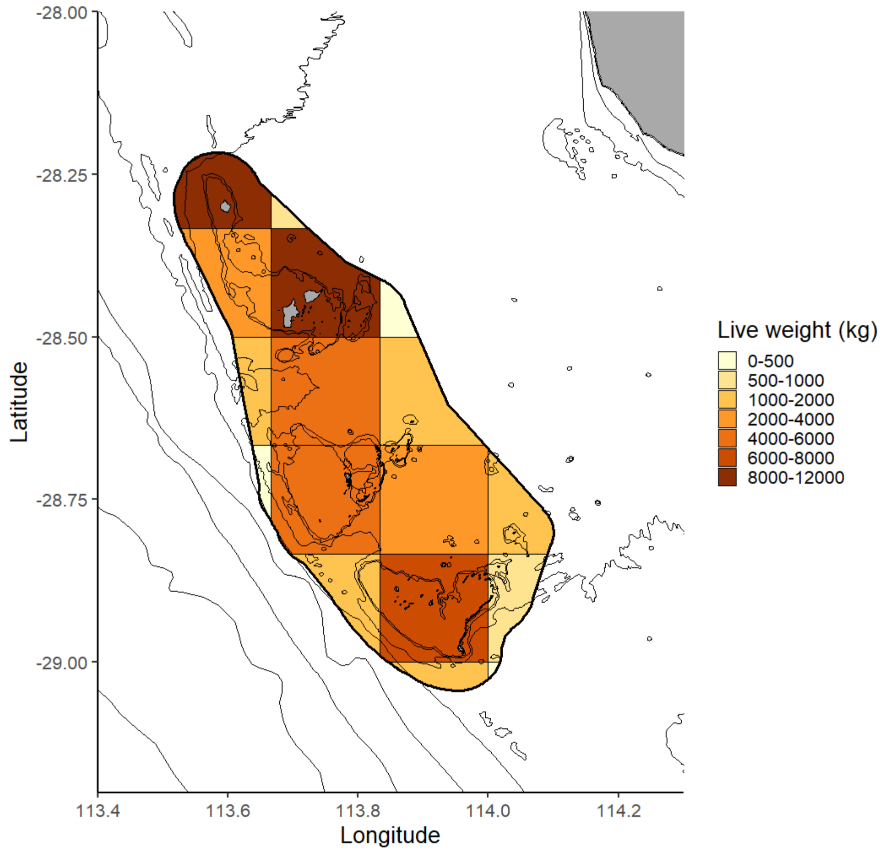

Figure 2.3.4. Cumulative (2015-2019) WCDSIMF catch (kg) within the Abrolhos FHPA.

There were 87 species (or species categories) landed by the WCDSIMF within the Abrolhos FHPA across all years of data. Annually, the number of species recorded has remained relatively consistent at between 39 and 51 in 2009 and 2019, respectively (Figure 2.3.5).

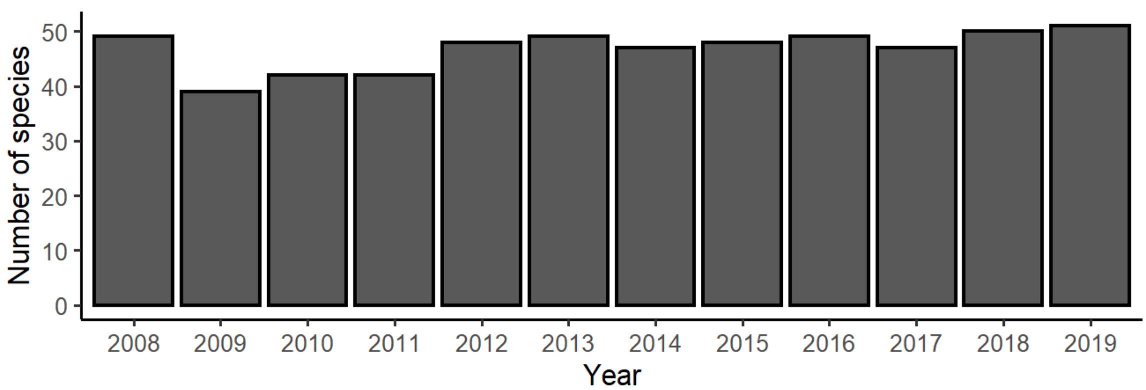

Figure 2.3.5. Number of species (and species categories) recorded as WCDSIMF catch from the 17 data blocks associated with the Abrolhos FHPA.

Between 2008 and 2019, the five most frequently recorded species within the Abrolhos FHPA were pink snapper (*Chrysophrys auratus*), redthroat emperor (*Lethrinus miniatus*), WA dhufish (*Glaucosoma hebraicum*), baldchin groper (*Choerodon rubescens*) and spangled emperor (*Lethrinus nebulosus*). By live weight, pink snapper was the largest component (33.3%) of the catch, followed by WA dhufish (16.3%), baldchin groper (15.8%), redthroat emperor (13.4%) and spangled emperor (5.6%). The remaining species reported each constitute <5% of the overall live weight, with the common coral trout (*Plectropomus leopardus*) accounting for 3.5%. By weight, pink snapper was the largest component of the annual catch for all years, except 2009 and 2018, when the largest components were baldchin groper and redthroat emperor, respectively (Figure 2.3.6).

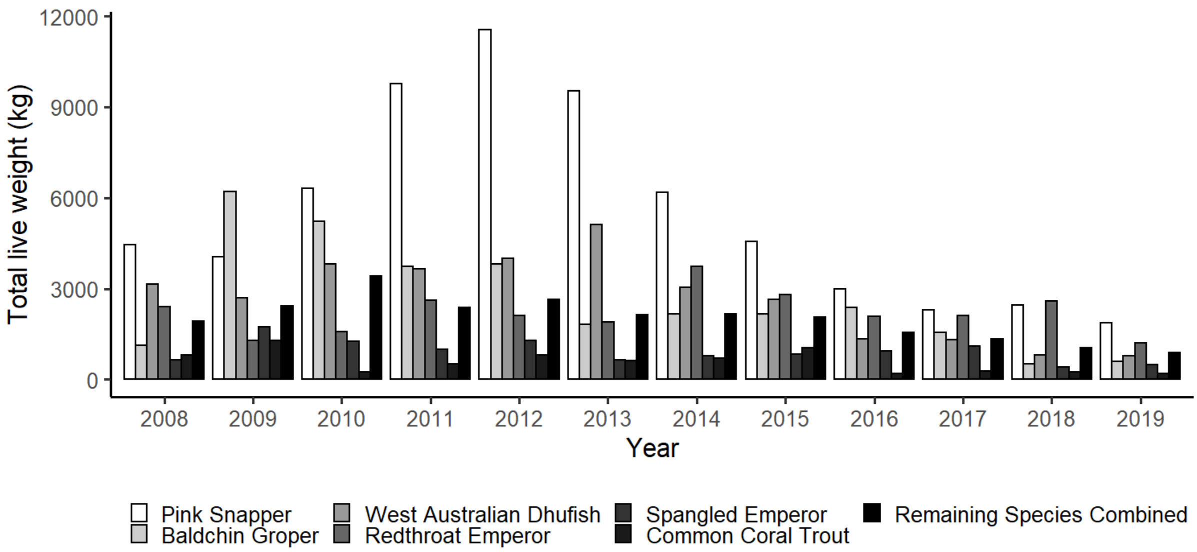

Figure 2.3.6. Annual total live weight (kg) for six of the most common species and for the remaining species combined.

When the total WCDSIMF catch from the Abrolhos FHPA between 2008 and 2019 is compared at the species level to the catch for the whole WCDSIMF, 31.0% of common coral trout, 25.8% of baldchin groper, 11.3 % of spangled emperor, 5.4% of WA dhufish, 4.7% of pink snapper and 4.6% of redthroat emperor were from the Abrolhos FHPA. When looking at the total catch for the five most recent years (2015 – 2019), the percentage contribution of the Abrolhos FHPA to the WCDSIMF total catch has decreased slightly for five of the six species summarized in this report (common coral trout: 29.4%; baldchin groper: 20.9%; spangled emperor: 8.1%; pink snapper: 4.2%; WA dhufish: 3.9%), with redthroat emperor showing a slight increase to 5.1%. These changes are likely to reflect the reduced capacity available within the fishery.

2.3.4 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the WCDSIMF and the Abrolhos FHPA:

- Maintain the WCDSIMF ERA, with specific reference to the Abrolhos FHPA
- Investigate incorporating WCDSIMF effort data into future Abrolhos FHPA reporting
- Investigate the potential for WCDSIMF catch and effort reporting specific to fishing activity within the Abrolhos FHPA
- Investigate methods for the collation of WCDSIMF logbook and DPIRD VMS data for reporting of spatial effort within the Abrolhos FHPA
- Maintain regular updates of WCDSIMF fishing activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.4 West Coast Purse Seine Fishery

2.4.1 *Fishery Description and Association to the Abrolhos FHPA*

The West Coast Purse Seine Fishery (WCPSF) is a limited entry purse-seine net-based fishery that operates in WA waters from Lancelin (31º00°S latitude) to Cape Bouvard (33º00°S) (Figure 2.4.1). Fishing for Australian sardines began during the 1950’s around Fremantle. However, the development of purse seining in the 1970’s led the fishery to expand around the WA coast (Blazeski et al., 2021). The development of the *West Coast Purse Seine Limited Entry Fishery Notice 1989* in September of 1989 regulated the fishery to include restrictions on the size of vessels, net length and mesh size and well as spatial closures and limits on the mechanical assistance to haul nets (Blazeski et al., 2021). The fishery has since expanded to include two development zones, one in the south (to Cape Leeuwin) and one in the north (to the Northern Territory border) with the northern development zone including the entirety of the Abrolhos FHPA (Figure 2.4.1).

The WCPSF accesses the West Coast Small Pelagic Scalefish Resource (WCSPSR), which is comprised of five species, the scaly mackerel ('tropical sardine' *Sardinella lemuru*), Australian sardine (*Sardinops sagax*), Australian anchovy (*Engraulis australis*), yellowtail scad (*Trachurus novaezelandiae*) and maray (*Etrumeus jacksoniensis*) (Norriss & Blazeski, 2021). The species captured by the WCPSF in the development zones are primarily Australian sardine and tropical sardine, with the remaining species comprising a small proportion (Blazeski et al., 2021). Until 31 March 2005, the WCPSF had a TACC that was gazetted under the management plan (Blazeski et al., 2021). Since 2005 there has been a notional combined TACC, with the northern development zone (which includes the Abrolhos FHPA) set a notional TACC of 2,700 tonnes for tropical sardines (Norriss & Blazeski, 2021). In 2019, for the entire WCPSF and development zones, five vessels were reported to have operated, contributing a GVP of <$1million (Norriss & Blazeski, 2021), with tropical sardines recently constituting 70-98% of the catch from the northern development zone (Blazeski et al., 2021; Norris & Blazeski, 2021).

Currently there are several spatial closures (e.g., ROAs) within the Abrolhos FHPA that apply to the WCPSF. As the WCPSF gear type is used in the pelagic environment, away from shore and does not involve significant impact with the seabed (Blazeski et al., 2021) it is likely to pose negligible risk to the marine benthic habitats of the Abrolhos FHPA. In addition, the WCSPSR has an ERA (Blazeski et al., 2021) which supports the decision-making process for this resource, including the WCPSF and development zones, consistent with the principles of ESD and EBFM (Fletcher, 2002; Fletcher et al., 2012). The WCPSF has current Commonwealth export approval under the EPBC Act (1999) for approved wildlife trade operation (Department of the Environment and Energy, 2020). Further descriptions WCSPSR and WCDSR legislation, regulations (e.g., gear size, and spatial closures) and history, as well as biological and ecological traits see:

- Blazeski, S., Norris, J., Smith, K. A., & Hourston, M. (2021). Ecological Risk Assessment for the State-Wide Small Pelagic Scalefish Resource. Fisheries Research Report 320. Department of Primary Industries and Regional Development, Western Australia.
- Department of the Environment and Energy. (2020). Assessment of the Western Australian West Coast Purse Seine Managed Fishery and Development Zones, January 2020. Commonwealth of Australia.

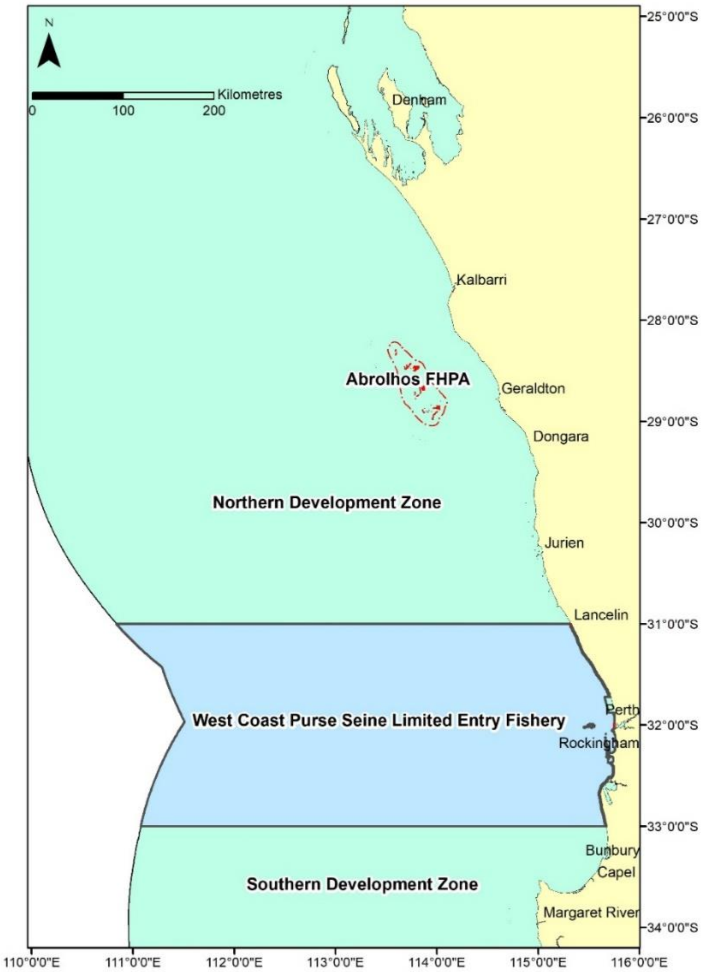

Figure 2.4.1. Management zones for the WCPSF and the Abrolhos FHPA

2.4.1.1 *Methodology*

The WCPSF and development zones report catch in CAES blocks, of which three (97012, 97013 and 97014) cover the Abrolhos FHPA (see Section 2.1.3.1 for more information regarding CAES). For this report, WCPSF data was based on DPIRD source data, where catch and effort data were extracted for these three CAES blocks from DPIRD databases and summarised by licence number and year.

2.4.1.2 *Results Summary*

Between 1994 and 2020 less than three WCPSF operators have reported catch and effort from within CAES blocks 97012, 97013 and 97014. Therefore, for confidentiality reasons, historical catch and effort data is unavailable for association to the Abrolhos FHPA.

2.4.2 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendation in relation to the WCPSF and the Abrolhos FHPA:

- Maintain regular updates of WCPSF fishing activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.5 Mackerel Managed Fishery

2.5.1 *Fishery Description and Association to the Abrolhos FHPA*

The Mackerel Managed Fishery (MMF) is a limited entry troll or handline fishery that operates in WA waters from Cape Leeuwin (~34°S latitude) to the WA / Northern Territory border (Figure 2.5.1). The earliest report of commercial fishing for Spanish Mackerel (*Scomberomorus commerson*) in WA was from the Geraldton / Midwest area, which likely included the waters of the Abrolhos Islands, in the 1950s, before expanding into the north of WA in the 1960’s (Lewis, 2020). The MMF was established in 2006, developed from the open access wetline fishery, and transitioned from an interim managed fishery to managed fishery on 1st of January 2012 (Lewis, 2020). The MMF operates under an ITQ, including setting of TACC for each area of the fishery (Lewis, 2020). The MMF accesses the Large Pelagic Finfish Resource (LPFR), with the fishery predominately targeting Spanish Mackerel. In 2019, a total catch of 291 t of Spanish Mackerel was reported for the entire MMF for a reported value of $2.5

million (Lewis, 2020). This included a catch rate of ~200kg/day from the 18 licences operating in Area 3 of the fishery, which includes the Abrolhos FHPA (Lewis, 2021).

Currently there are several spatial closures (e.g., ROAs) within the Abrolhos FHPA that apply to the MMF. As the MMF gear type is used in the pelagic environment, away from shore and does not involve significant impact with the seabed (DEWHA, 2009), it is likely to pose negligible risk to the marine benthic habitats of the Abrolhos FHPA. The MMF currently reports catch and effort as daily returns in 10 x 10 nm data blocks (DPIRD, 2020c). For further descriptions of this and other MMF and LPFR legislation, regulations (e.g., gear size and spatial closures) and history, as well as biological characteristics see:

- Lewis, P. (2020). Statewide Large Pelagic Resource in Western Australia. Resource Assessment Report No.19. Department of Primary Industries and Regional Development. Western Australia.

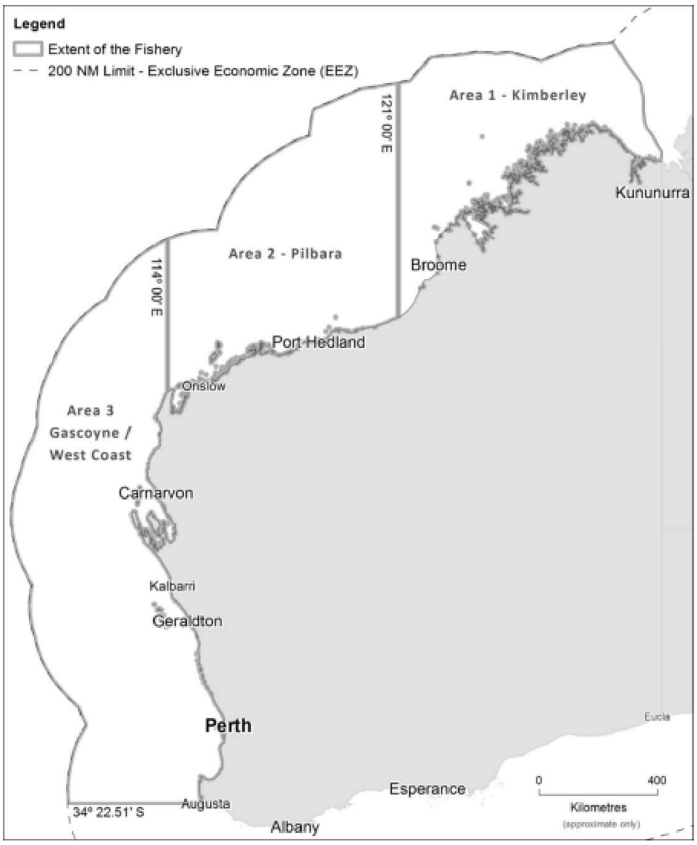

Figure 2.5.1. Map showing the management zones of the MMF and the Abrolhos FHPA.

2.5.1.1 *Methodology*

For this report, MMF data was based on DPIRD source data, where catch data associated to the Abrolhos FHPA from the MMF was collated for the 17 data blocks (DPIRD 2020c) that either fell entirely within the Abrolhos FHPA boundary or intersected it (Figure 2.1.2B). Catch data from the remaining data blocks within Area 3 of the MMF were considered outside the Abrolhos FHPA. Data was collated for all years between 2006 and 2019 from DPIRD databases and summarised by licence number, year and species. It is acknowledged that this methodology may over represent catch within the Abrolhos FHPA.

2.5.1.2 *Results Summary*

Catch data for the MMF associated with the Abrolhos FHPA was available for all years between 2006 and 2019, however, not all years contained data from more than three licences. For confidentiality reasons, catch data associated to the Abrolhos FHPA and area 3 of the MMF is reported as a cumulative totals for 2006 to 2019.

Cumulatively between 2006 and 2019, the total live weight for all species in Area 3 of the MMF was 586.7 t. The Abrolhos FHPA 17 data blocks reported a total live weight catch of ~38.1 t or 6.5% of the total MMF Area 3 catch. Five species were reported in the Abrolhos FHPA; Spanish Mackerel (~37.6 t; 98.6% of total catch). The remaining Abrolhos FHPA catch of ~0.5 t (1.4%) contained Spotted Mackerel (*Scomberomorus munroi*), Yellowfin Tuna (*Thunnus albacares*), Grey Mackerel (*Scomberomorus semifasciatus*) and Shark Mackerel (*Grammatorcynus bicarinatus*).

2.5.2 ***Recommendations***

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the MMF and the Abrolhos FHPA:

- Investigate the potential of MMF fishery bycatch and ETP reporting specific to the Abrolhos FHPA
- Maintain regular updates of MMF fishing activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.6 Marine Aquarium Fish Managed Fishery

2.6.1 *Fishery Description and Association to the Abrolhos FHPA*

The Marine Aquarium Fish Managed Fishery (MAFMF) is a low-volume, high-value, primarily diver-based fishery that has operated in the State waters of WA since the late 1960's (DPIRD, 2018a). Management of the MAFMF has evolved from conditions on professional fishing licences to commercial fishing licences and components of the resource through a managed fishery (finfish) with other components through subsidiary legislation (DPIRD, 2018a). With the introduction of the *Marine Aquarium Fish Managed Fishery Management Plan 2018* and other subsidiary legislation of the FRMA (1994), the MAFMF has capacity to target more than 1500 marine aquarium resources. However, the majority of effort is focussed on the shallow water <30m of the South-West Capes, Perth, Exmouth, Dampier and Geraldton region, including the Abrolhos FHPA (DPIRD, 2018a). A limited entry fishery, MAFMF is managed via a combination of output and input controls, including ITQ on some species groups (e.g., coral, giant clam, Sygnathiforms, 'live rock'), spatial closures, and restrictions on gear type, vessels and collectors (DPIRD, 2018a). Historically, the MAFMF reported catches in 60 x 60 nm blocks, however the spatial resolution has been increased to 10 x 10 nm data blocks (DPIRD, 2020c). Since 2010, there have been twelve licences within the fishery, down from 25 licences in the 1990's (DPIRD, 2018a). In 2019, ten of the twelve licences were active, with a total state-wide catch of 69,446 fishes, 36.325 t of coral, live rock and living sand and 12L of marine plants and live feed, with the value estimated at between $1-5 million (Newman et al., 2021).

The MAFMF access the Marine Aquarium Fish Resource (MAFR). The MAFR includes all species that are collected for marine aquarium ornamental display purposes through WA waters (e.g., hard coral, soft coral, clams, other invertebrates, algae, seagrasses and 'live rock') (DPIRD, 2018a). The MAFMF is the primary fishery accessing this resource, along with several commercial aquaculture licences authorised to culture marine aquarium fish species. There is no documented recreational or customary fishing in the MAFR, however members of the public are permitted to collect specimens for their own private aquarium use within the recreational bag and size limits (DPIRD, 2018a).

The MAFR has a harvest strategy (DPIRD, 2018a) and ERA (DPIRD, 2018b) which support the decision-making process of the aquatic resource and fishery, consistent with the principles of ESD and EBFM (Fletcher, 2002; Fletcher et al., 2012). In November of 2021, the MAFMF conducted an updated external ERA process, with a published report pending. The MAFMF has current Commonwealth export approval under the EPBC Act (1999) for approved wildlife trade operation (Department of the Environment and Energy, 2019).

The MAFMF has limited access to the Abrolhos FHPA, with no take permitted within several spatial closures (e.g., ROAs). In addition, the collection of live coral of the Order Scleractinia (e.g., hard corals) is prohibited under the Fisheries Resource Management Regulations (FRMR) 1995 (Schedule 2, Part 2, Division 2) of the FRMA (1994) within the entire CAES block 97000 (Figure 2.2.1B), which includes the MAFMF for the entire Abrolhos FHPA.

Further descriptions of this and other MAFMF and MAFR legislation, regulations (e.g., gear size, and spatial closures) and history, as well as biological and ecological traits see:

- DPIRD. (2018a). Marine Aquarium Fish Resource of Western Australia Harvest Strategy 2018-2022 Version 1.0. Fisheries Management Paper No. 292. Department of Primary Industries and Regional Development, Western Australia.
- DPIRD. (2018b). Ecosystem-Based Fisheries Management (EBFM) Risk Assessment of the Marine Aquarium Fish Managed Fishery 2014. Fisheries Management Paper No. 293. Department of Primary Industries and Regional Development, Western Australia.

2.6.1.1 *Methodology*

For this report, MAFMF data was based on DPIRD source data, where catch associated to the Abrolhos FHPA was collated for the 17 data blocks (DPIRD, 2020c) that either fell entirely within the Abrolhos FHPA boundary or intersected it (e.g., Figure 2.2.1B). Data was collated from DPIRD databases, for a 10-year cumulative catch (2010 - 2019). Catch data was reported, where available (e.g., reported by 3 licences or more), specific to the Abrolhos FHPA and compared to MAFMF state-wide totals. For the 10-year cumulative catch, data was summarised into four main categories, fish (finfish), invertebrates, soft coral and ‘living rock’. Similarly, annual catch data was reported for 2015 to 2019 in the Abrolhos FHPA compared to state-wide MAFMF total catch. For 2015 to 2019 this was available for invertebrates (bubble-tip anemone and general starfish) and soft coral (corallimorph coral-like anemones), with ‘living rock’ available in 2018 and 2019 only. Fish and invertebrate data are provided as number of individuals, with soft coral and ‘living rock’ in kilograms.

2.6.1.2 *Results Summary*

The 2010-2019 cumulative catch data shows that the Abrolhos FHPA provides a substantial proportion of the overall take of the MAFMF soft coral (28.9%), ‘living rock’ (20.1%) and invertebrates (12.8%) catch, with a negligible catch of fish (Table 2.6.1). In terms of weight or number this equates to 15,724 kg of soft coral, 31,176 kg of ‘live rock’ and 55,987 invertebrates caught from the Abrolhos FHPA between 2010 and 2019. It is noted that the proportion of MAFMF soft coral catch from the Abrolhos FHPA has increased from 27.8% in 2015 to 55.1% in 2019. The overall soft coral catch in kilograms from the Abrolhos FHPA has also increased from 1916 kg and 997 kg in 2015 and 2016 respectively, to 2595 kg in 2018 and 2953 kg in 2019. The proportion of the fishery catch of invertebrates from the Abrolhos FHPA appears to be relatively stable, with catches ranging from a low of 3522 individuals in 2016 to a high of 8236 individuals in 2018. In 2019, there were 4057 invertebrates caught from the Abrolhos FHPA. As only two annual data points are available for ‘live rock’, annual trends were not able to be assessed, however 4490kg of live rock was caught in 2018 and 1889 kg in 2019.

Table 2.6.1. Proportion (%) of total MAFMF catch from within the Abrolhos FHPA.

Year	Fish	Invertebrates	Soft Coral	Living Rock
2015	N/A	14.6	27.8	N/A
2016	N/A	11.9	23.2	N/A
2017	N/A	9.2	30.4	N/A
2018	N/A	13.4	46.4	21.8
2019	N/A	7.4	55.1	10.8
2010-19	0.4	12.8	28.9	20.1

Two invertebrate and one soft coral species categories can be reported with the publicly available data for the Abrolhos FHPA. Cumulatively between 2010 and 2019, the fishery caught 13,012 bubbletip anemones (*Entacmaea quadricolor*), 3478 general starfish and 7579.5 kg of corallimorphs from within the Abrolhos FHPA. This equates to 57.2% of all bubbletip anemones caught in the MAFMF, 30.1% of general starfish and 46.6% of corallimorphs (Table 2.6.2). In recent years (2015 to 2019), where data is available, the proportion of bubbletip anemone coming from the Abrolhos FHPA is higher than the 10-year cumulative percentage, ranging from 60.8% in 2016 to 76.3% in 2019 (Table 2.6.2). These four years also account for 81.4% (10,596 individuals) of the 10-year cumulative catch. This trend is also true for general starfish with 85.5% (2973 individuals) and 77.2% (5849.5 kg) of corallimorphs of the MAFMF catch for the Abrolhos FHPA landed between 2015 and 2019.

Table 2.6.2. Annual proportion (%) of total MAFMF catch (2015-19) and 10-year cumulative catch (2010-19) of primary targeted invertebrate and soft coral species from within the Abrolhos FHPA

Year	Bubbletip Anemone	General Starfish	Corallimorph
2015	75.1	66.6	44.2
2016	60.8	42.8	42.6
2017	N/A	44.2	45.0
2018	71.7	46.5	56.8
2019	76.3	N/A	66.3
2010-2019	57.2	30.1	46.6

Although data limited, the 10-year cumulative catch (2010-19) reports lower catch than the annual data between 2015 and 2019, which suggest the level of MAFMF catches at the Abrolhos FHPA has increased in recent years (2015 to 2019). This may be an artefact of market drivers, or improved access to the Abrolhos FHPA, e.g., vessels and weather forecasting, for what was traditionally a small vessel fishery. However, it should be noted that catches within the Abrolhos are within the TACC for this fishery and was not highlighted as at risk in the MAFMF ERA process (DPIRD, 2018b).

2.6.2 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the MAFMF and the Abrolhos FHPA:

- Investigate incorporating MAFMF effort data into future Abrolhos FHPA reporting
- Investigate assessing relative abundance of bubbletip anemone and other target species categories in relation to the Abrolhos FHPA
- Maintain regular updates of MAFMF fishing activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.7 Specimen Shell Managed Fishery

2.7.1 *Fishery Description and Association to the Abrolhos FHPA*

The Specimen Shell Managed Fishery (SSMF) is a limited entry fishery which operates in WA state waters to the 200 m isobath, with effort primarily occurring in shallow nearshore waters, including the Abrolhos FHPA. On average, 200 species of specimen shell are collected each year by the entire SSMF across a broad range of marine shellfish from the phylum Mollusca (such as cowries (*Cypraeidae*), murex (*Muricidae*), cone shells (*Conidae*) and volutes (*Volutidae*)) for the purpose of display, collection, cataloguing, classification and sale (Hart et al., 2021a). The SSMF is managed through input controls via limited entry, gear restrictions (hand or remotely operated underwater vehicle), and permanently closed areas (e.g., sanctuary zones and ROA's). Catch and effort is reported via mandatory daily logbooks, reported in 10 x 10 nm data blocks. In 2019, for the entire SSMF, 17 of the permitted 31 licences fished for a combined 460 fishing days and total catch of 7,232 shells over 241 species (Hart et al., 2021a).

The SSMF is permitted to operate within the Abrolhos FHPA, with the exception of the ROAs, with the fishery gear type collection likely to have negligible overall ecosystem impacts, in line with the Abrolhos FHPA Management plan (DoF, 2012a).

For further information on the Specimen Shell Managed Fishery please refer to the *Specimen Shell Fishery Management Plan 1995*.

2.7.1.1 *Methodology*

For this report, SSMF data was based on DPIRD source data, where catch associated with the Abrolhos FHPA was collated for the 17 data blocks (DPIRD, 2020c) that either fell entirely within the Abrolhos FHPA boundary or intersected it (Figure 2.2.1B). Data was collated from DPIRD databases for a 10-year cumulative catch (2010 - 2019). Catch data was reported, where available (e.g., reported by 3 licences or more), specific to the Abrolhos FHPA and compared to SSMF state-wide totals. It is acknowledged, that this method may slightly overestimate catch and effort within the Abrolhos FHPA, but based on bathymetry of the Abrolhos FHPA, this would likely be limited to deep water ROV collection only.

2.7.1.2 *Results Summary*

Between 2010 and 2019, six licensees reported catch and effort from the Abrolhos FHPA data blocks which equates to 21.4% of the 28 licences that reported effort over the entire SSMF for the same period. Cumulatively, between 2010-2019, a total of 226 individuals were caught from the Abrolhos FHPA, which equates to ~0.2% of the entire SSMF catch. It should be noted that the proportion of catch is based on all species caught within the SSMF and not specific to the species targeted at the Abrolhos FHPA. The main specimen shells targeted at the Abrolhos FHPA are from the family Cypraeidae (cowries) and a small proportion from the family Volutidae (volutes).

In all years except one, less than three licences reported catch and effort from the blocks associated with the Abrolhos FHPA and therefore detailed annual comparisons could not be made. For the one year that data was able to be reported, 0.6% of the entire SSMF catch was from the Abrolhos FHPA.

2.7.2 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the SSMF and the Abrolhos FHPA:

- Investigate assessing relative abundance of Cypraeidae in relation to the Abrolhos FHPA
- Maintain regular updates of SSMF fishing activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.8 Octopus Interim Managed Fishery

2.8.1 *Fishery Description and Association to the Abrolhos FHPA*

The Octopus Interim Managed Fishery (OIMF) is a limited-entry fishery ranging from north of Kalbarri (27 °S) to the WA / South Australia border (129 °E) (Figure 2.8.1). The OIMF accesses the Octopus Resource of WA which almost entirely consists of the western rock octopus (*Octopus djinda*) (Amor et al., 2014; Hart et al., 2018). Historically, octopus were commercially caught as WCRLMF by-catch, before a developmental strategy for octopus fishing was implemented in the late 1990s which led to the establishment of a limited entry developmental octopus fishery in 2001 (Hart et al., 2018). The developmental octopus fishery subsequently transitioned into the OIMF under more formal management arrangements in November 2015 with the introduction of the *Octopus Interim Managed Fishery Management Plan 2015* (Hart et al., 2018). The OIMF uses two types of unbaited traps/pots: primarily active trigger traps with a small amount of effort also associated to passive shelter pots (Hart et al., 2021b). The fishery targets similar benthic environment to the WCRLMF, as well as sandy and seagrass habitats (Hart et al., 2021b).

The OIMF is divided into three fishing zones and as of 2018, fishing capacity is split into 18.0% in Zone 3, 51.6% in Zone 2, and 30.4% in Zone 1, which includes fishing within the Abrolhos FHPA (Figure 2.8.1) (Hart et al., 2018). Recently, the number of vessels in the OIMF has grown across all zones of the fishery, but particularly in Zone 1 (Hart et al., 2021b). The OIMF fishing method is deemed to be low risk to benthic habitats due to the long gear soak times (average = ~10 days) and the robust nature of the habitats fished (Hart et al., 2021b). Within the Abrolhos FHPA, there are several spatial closures (e.g., ROAs) that also apply to the OIMF. The Octopus Resource of WA has a harvest strategy (DPIRD, 2018c) which supports the decision-making process of the aquatic resource and fishery, consistent with the principles of ESD and EBFM and the Abrolhos FHPA Management Plan (Fletcher, 2002; Fletcher et al., 2012; DoF, 2012a). In October 2019, the OIMF obtained MSC certification for its sustainable fishing practices (Daume et al., 2019).

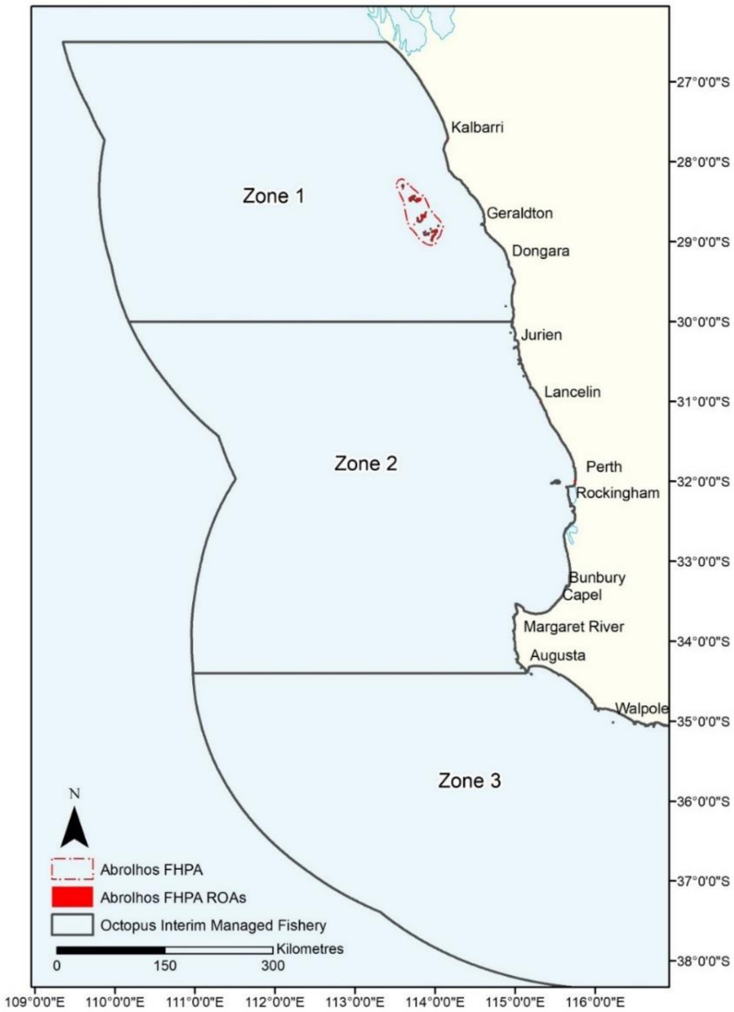

Figure 2.8.1. Map of the OIMF and the Abrolhos FHPA.

In 2019, the total commercial catch of the OIMF was 453 t with an estimated gross value product of $5.9 million (Hart et al., 2021b). For detailed descriptions of the OIMF and Octopus Resource of WA see:

- DPIRD. (2018c). Octopus Resource of Western Australia Harvest Strategy 2018 – 2022, Version 1.0. Fisheries Management Plan No. 286. Department of Primary Industries and Regional Development. Perth, Western Australia.
- Hart, A.M., Murphy, D.M., Harry, A.V. and Fisher, E.A. (2018). Resource Assessment Report Western Australian Octopus Resource. Western Australian Marine Stewardship Council Report Series No. 14. Department of Primary Industries and Regional Development, Western Australia. 114pp.

2.8.1.1 *Methodology*

For this report, OIMF data was based on DPIRD source data, where catch (live weight in kg) and effort (fishing days) data associated to the Abrolhos FHPA was collated for the 17 data blocks (DPIRD, 2020c) that either fell entirely within the Abrolhos FHPA boundary or intersected it (Figure 2.2.1B). In addition, catch and effort data was collated for Zone 1 and the entire OIMF. Where available (e.g., reported by 3 licences or more), data were reported specific to the Abrolhos FHPA and compared to Zone 1 and the OIMF state-wide totals. It is acknowledged, that proportioning catch and effort to within the Abrolhos FHPA from data blocks that intersect the boundary (i.e., effort could be within or outside) may over-estimate catch and effort of the OIMF within the Abrolhos FHPA. However, at the current spatial level of reporting this method is consistent between years.

2.8.1.2 *Results Summary*

Cumulative OIMF catch and effort data in the Abrolhos FHPA was available for 2017-2019 and shows a live weight catch of 2258.3 kg over 12 fishing days within the Abrolhos FHPA, which equates to ~1.2% of the total live weight catch from Zone 1 (185,169 kg) and 0.3% (855,886 kg) of the entire OIMF, exclusively using trigger pots. Fishery effort data is similar with 1.1% (12 days) of zone 1 effort (1075 days) and 0.3% of the entire OIMF effort (4,093 fishing days) from the Abrolhos FHPA.

2.8.2 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the OIMF and the Abrolhos FHPA:

- Investigate the potential for OIMF catch and effort reporting, specific to the Abrolhos FHPA
- Investigate the potential of OIMF fishery bycatch and ETP reporting, specific to the Abrolhos FHPA
- Investigate the merit of OIMF spatial closures, particularly in areas identified as highly sensitive or with potential resource sharing inconsistencies in the Abrolhos FHPA

- Maintain regular updates of OIMF fishing activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.9 Abalone Managed Fishery

2.9.1 *Fishery Description and Association to the Abrolhos FHPA*

The Abalone Managed Fishery (AMF) is a limited entry fishery managed through a TACC that is set annually and allocated to licence holders as ITQ (DoF, 2005). The fishery is MSC certified and targets three species by hand collection: Roe's abalone (*Haliotis roei*), Greenlip abalone (*H. laevigata*) and Brownlip abalone (*H. conicopora*), across eight spatial management areas that cover all coastal WA state waters between the Northern Territory and South Australian borders (DoF, 2005). The Abrolhos FHPA is covered entirely by Area 8 of the fishery which has been closed following a marine heatwave event in the summer of 2010/11 that caused large-scale mortalities in the northern distribution of the species (DPIRD, 2021b).

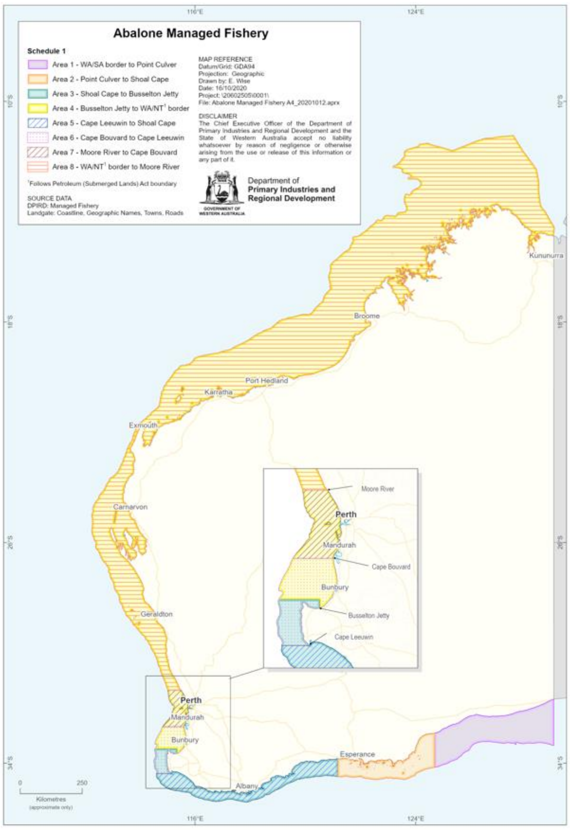

Figure 2.9.1. Management areas of the AMF.

2.9.1.1 *Methodology*

For this report, AMF data was based on DPIRD source data, where catch (live weight in kg) and effort (fishing days) were collated to the Abrolhos FHPA for the 17 data blocks (DPIRD, 2020c) that either fell entirely within the Abrolhos FHPA boundary or intersected it (Figure 2.2.1B).

2.9.1.2 *Results Summary*

No catch or effort data has been reported from within the Abrolhos FHPA for the AMF from 1990 onwards. Note - 1990 was chosen as an arbitrary point in time, ~30 years ago, to look through DPIRD source data for Abrolhos FHPA effort for this fishery.

2.9.2 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendation in relation to the AMF and the Abrolhos FHPA:

- Maintain regular updates of AMF fishing activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.10 Fishing Tour Operator Industry

2.10.1 *Industry Description and Association to the Abrolhos FHPA*

Fishing tour operators in WA provide a high level of fishing expertise, using large vessels equipped with modern, state-of-the-art fishing equipment, to fee-paying clients (Telfer, 2010). Prior to formal management arrangements, fishing charters and aquatic tours were conducted from surveyed passenger vessels in accordance with general recreational fishing rules. In late 1998, the development of a management framework for the ‘Aquatic Tour Industry’ included the introduction of two licence types; Fishing Tour Operators Licence (FTOL) for extractive fishing activities, and an Aquatic Eco-Tourism Operators Licence (AETOL) which included non-extractive aquatic tourism operations (e.g., snorkelling or sightseeing tours). The requirement to hold either operating licence (FTOL or AETOL) for a commercial purpose came into effect on 1

July 2001, in line with a formal management framework (DoF, 2012b). Subsequent changes came into effect in 2004, with the introduction of the Restricted Fishing Tour Operators Licence (RFTOL), which allowed 'Aquatic Tour Industry' clients to fish for a meal whilst on tour, while all fishing activity remained prohibited for AETOL holders (DoF, 2012b), with AETOL abolished in July 2014 (DoF, 2016)

The fishing tour operator industry is divided into four management zones, Pilbara/Kimberley, Gascoyne, South Coast and West Coast, which includes the Abrolhos FHPA (Figure 2.10.1). The Abrolhos FHPA has long been a destination of choice for the fishing tour operator industry due to the unique and diverse experience it provides. In terms of RFTOL holders, it has a rich history (e.g., European shipwrecks, western rock lobster fishery), unique passive marine (e.g., snorkelling, diving and surfing) and land based (e.g., birdwatching, the HAINP) experiences. For the FTOL, the Abrolhos FHPA has a broad and unique range of tropical and temperate key targeted recreational finfish species, including pink snapper, common coral trout and baldchin groper, as well as the iconic WRL.

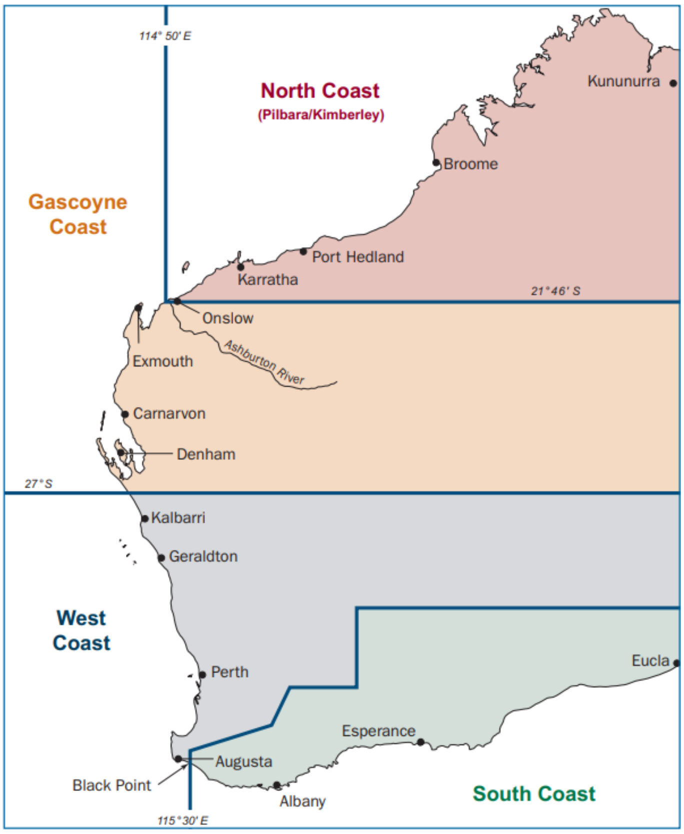

Figure 2.10.1. Fishing Tour Operator Industry management zones in Western Australia.

The Abrolhos FHPA management plan supports the access of the Fishing Tour Operator Industry, in line with the principles of ESD and EBFM (Fletcher, 2002; Fletcher et al., 2012*)*.

For further information on management arrangements for the Fishing Tour Operator Industry see:

- DoF. (2012b). A review of the management arrangements and licensing framework for the aquatic tour industry in Western Australia. Fisheries Management Paper No. 258. Department of Fisheries, Western Australia.
- DoF. (2016). Results of the review of the management arrangements and licensing framework for the aquatic tour industry in Western Australia. Fisheries Occasional Publication No.128. Department of Fisheries, Western Australia.

2.10.1.1 *Methodology*

For this report, data was based on DPIRD source data that contain Fishing Tour Operator Industry fishery-dependent daily returns, which are completed for each trip. A 'trip' is defined as any day there has been an attempt to fish. Although unlikely to be relevant for the Abrolhos FHPA, it is also possible for a tour operator to conduct multiple trips per day if they return to the marina/ramp to get a new group of customers. Catch and effort data are aggregated in 10 x 10 nm data blocks (DPIRD 2020c) by year, where possible, and as 19-year (2002-2020) and five-year (2016-2020) cumulative totals. Effort is reported as the number of trips per data block and catch is the number of individuals of each species kept. Data associated to the Abrolhos FHPA was collated for the 17 data blocks that either fell entirely within the Abrolhos FHPA boundary or intersected it (e.g., Figure 2.2.1B). In addition, catch and effort data were collated for 10 x 10 nm data blocks throughout the entire West Coast Management Zone (WCMZ). It is acknowledged that proportioning catch and effort to within the Abrolhos FHPA from the blocks that intersect the boundary (i.e., effort could be within or outside) may slightly over-estimate catch and effort of the Fishing Tour Operator Industry within the Abrolhos FHPA. Data were extracted for all Fishing Tour Operators, including both FTOL and RFTOL operators.

2.10.1.2 *Results Summary*

Between 2002 and 2020, the total number of Fishing Tour Operators within the Abrolhos FHPA ranged between 15 (2012) and 31 (2019) which, since 2011, has comprised ~30-40 % of licences within the WCMZ (Figure 2.10.2).

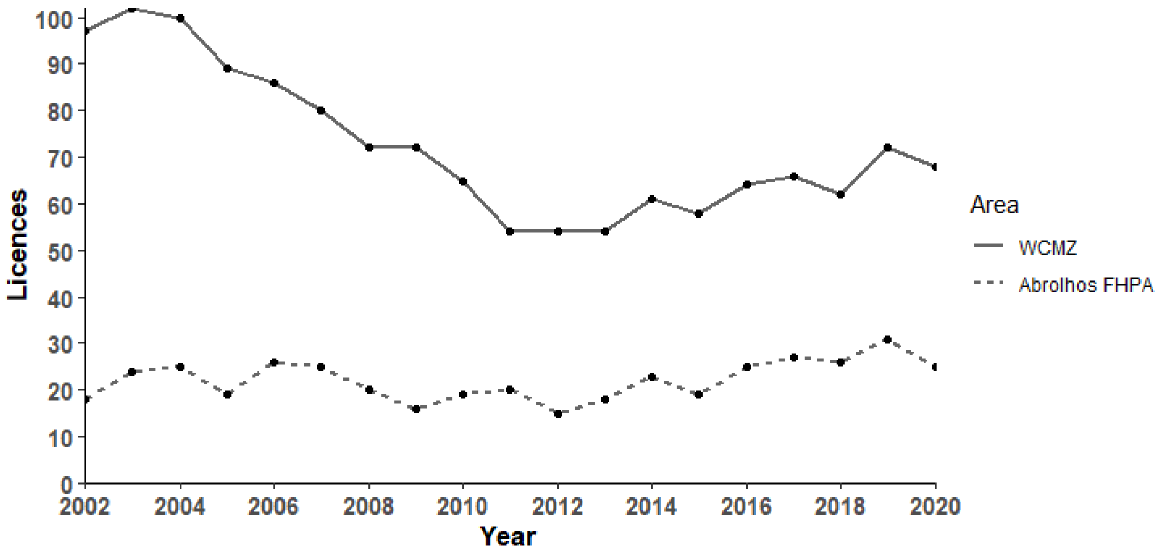

Figure 2.10.2. The annual number of Fishing Tour Operator licences that submitted returns in the WCMZ and the Abrolhos FHPA.

Annual trip numbers by Fishing Tour Operators within the Abrolhos FHPA ranged from 314 in 2002 to 625 in 2016 (Figure 2.10.3). There was a decrease in trip numbers within the Abrolhos FHPA between 2019 (622) and 2020 (528). However, the five years prior to 2020 (2015 – 2019) were the five highest since 2002 at around 600 trips per year (Figure 2.10.3). In the last decade, the Abrolhos FHPA has comprised ~20-30% of the total Fishing Tour Operator trips in the WCMZ, but between 2002 and 2020, this percentage has varied considerably ranging from 8.5 % in 2002 to 30.2 % in 2016.

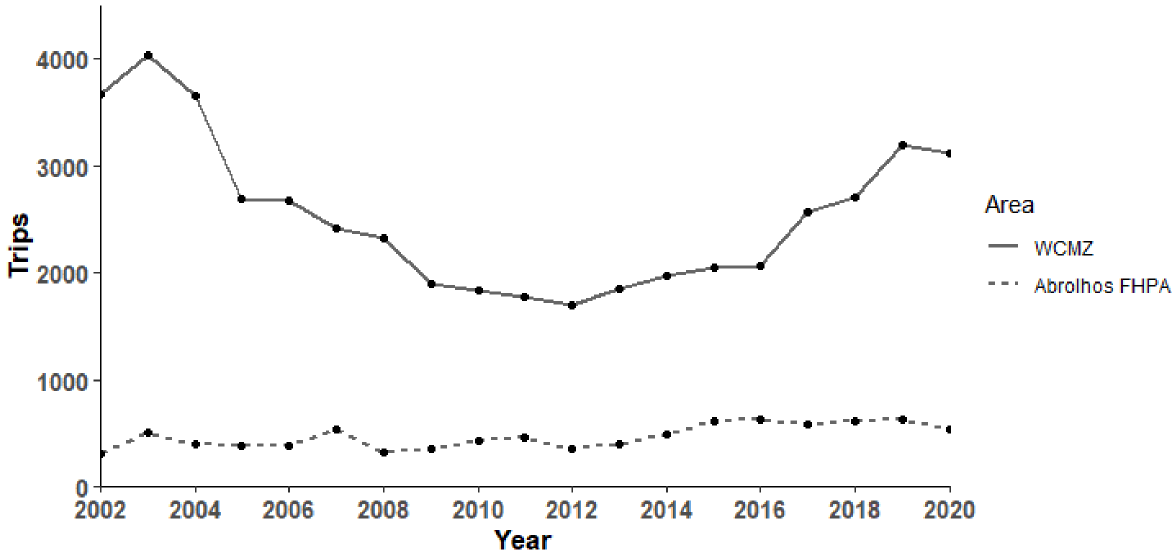

Figure 2.10.3. Annual trip numbers recorded by Fishing Tour Operators in the WCMZ and those that recorded trips associated with the Abrolhos FHPA.

Cumulatively for all years between 2002 and 2020, the annual effort (trips) by Fishing Tour Operators for the Abrolhos FHPA was highest in the Easter Group and the Wallabi islands of the North Island / Wallabi Group, with moderate effort in the Pelsaert Group and channels between island groups (Figure 2.10.4). There was relatively low reported effort from Fishing Tour Operators for the block that encompasses North Island (Figure 2.10.4). A similar spatial trend in cumulative effort is also observed between 2016 and 2020 but with relatively less effort concentrated on the Wallabi Islands compared to the 2002 and 2020 dataset (Figure 2.10.5).

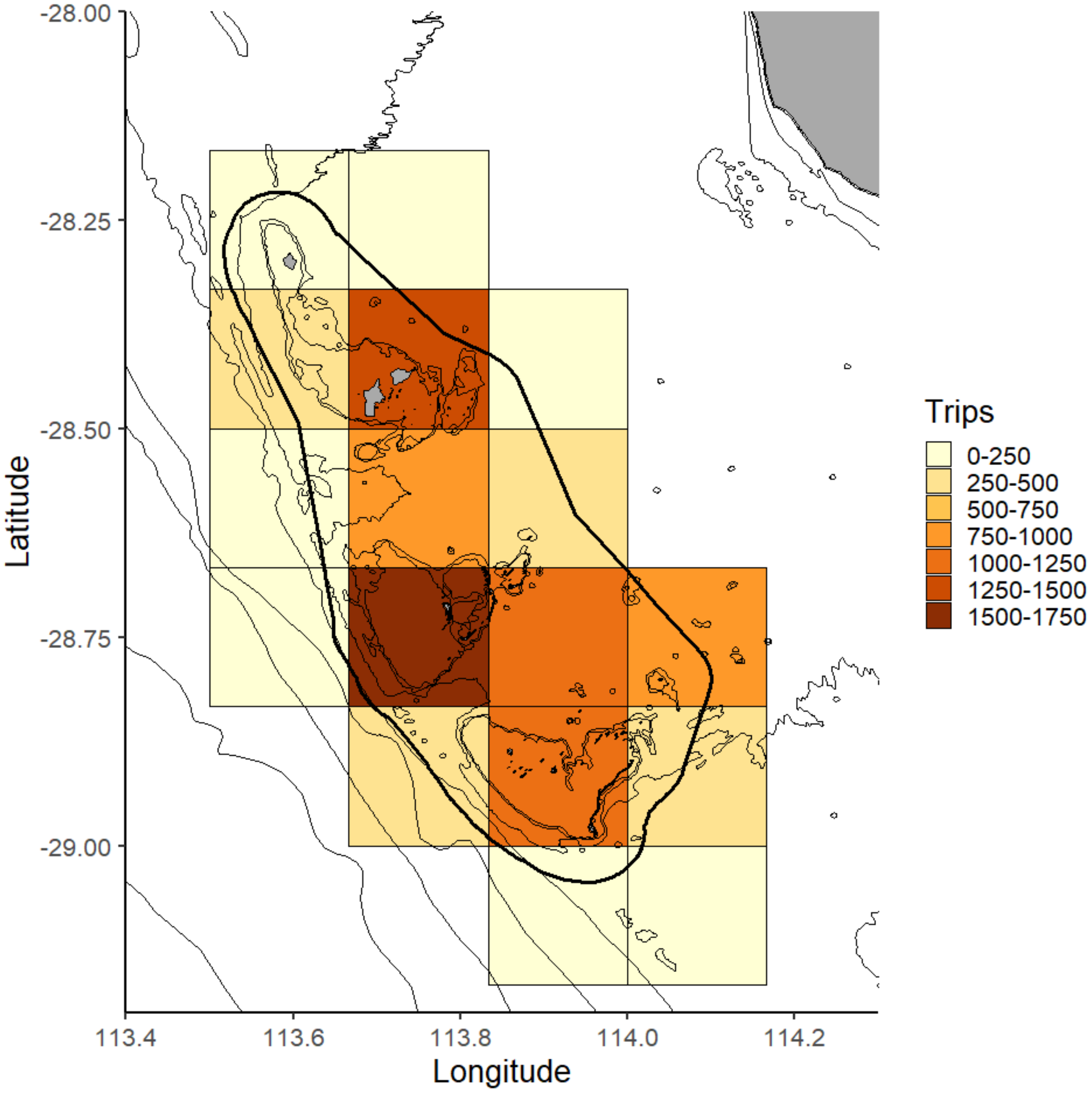

Figure 2.10.4. Spatial distribution of cumulative fishing effort (trips) by Fishing Tour Operators associated with the Abrolhos FHPA between 2002 and 2020.

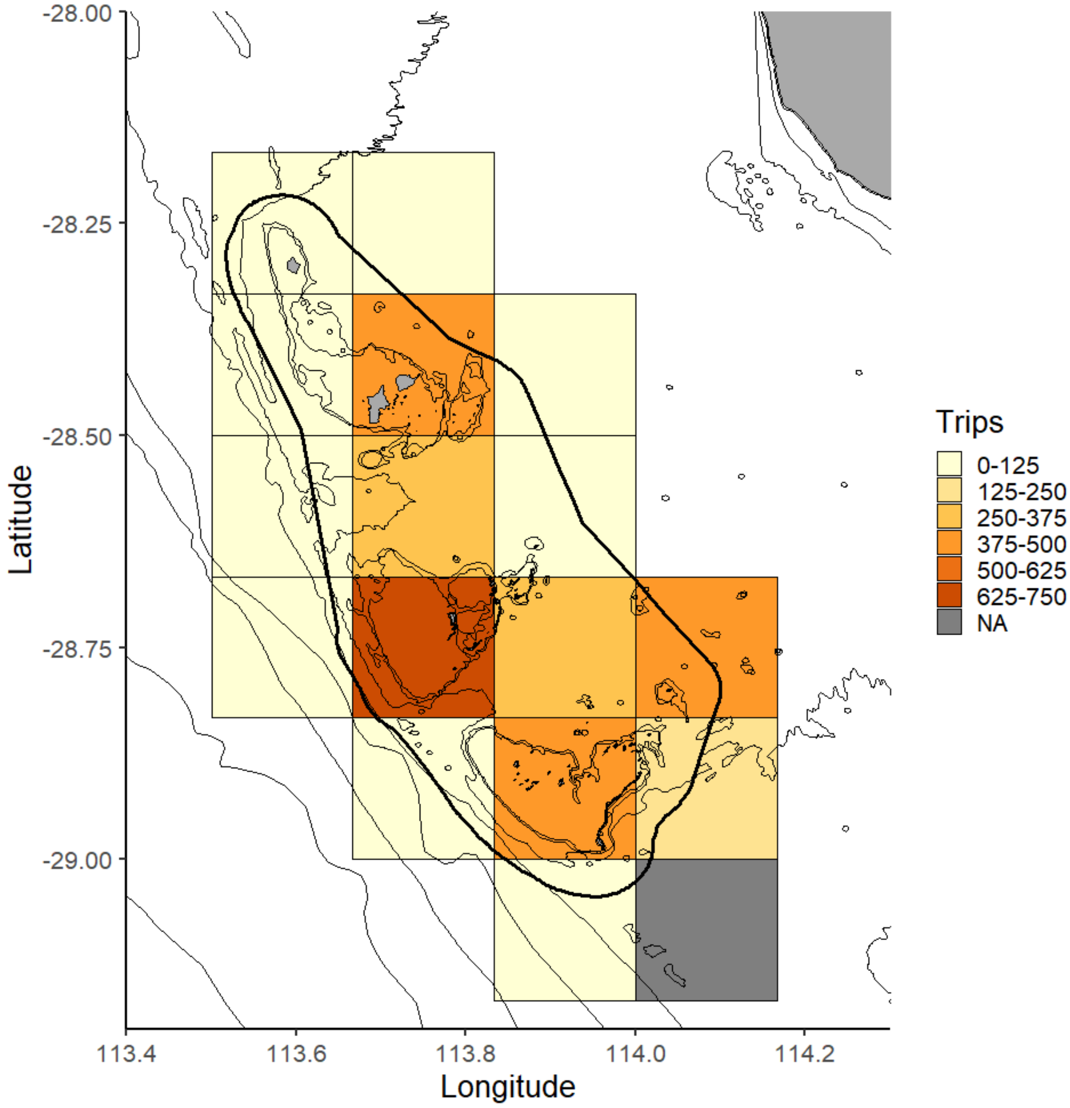

Figure 2.10.5. Spatial distribution of cumulative fishing effort (trips) by Fishing Tour Operators associated with the Abrolhos FHPA between 2016 and 2020. For confidentiality purposes, data were excluded for blocks with less than three operators and displayed as NA.

The annual reported catch (number of fish kept) from the Fishing Tour Operator Industry within the Abrolhos FHPA decreased between 2003 (12,509 fish) and 2012 (5,041 fish) but since this time increased steadily to 12,169 in 2020 (Figure 2.10.6). This trend was also observed through the WCMZ, with 58,629 in 2003 decreasing to 23,093 in 2012, then increasing to 56,218 in 2020 (Figure 2.10.6). The number of fish kept from the Fishing Tour Operator Industry from the Abrolhos FHPA was generally ~ 25% of the WCMZ total but ranged from 11.3% in 2002 to 30.3% in 2011.

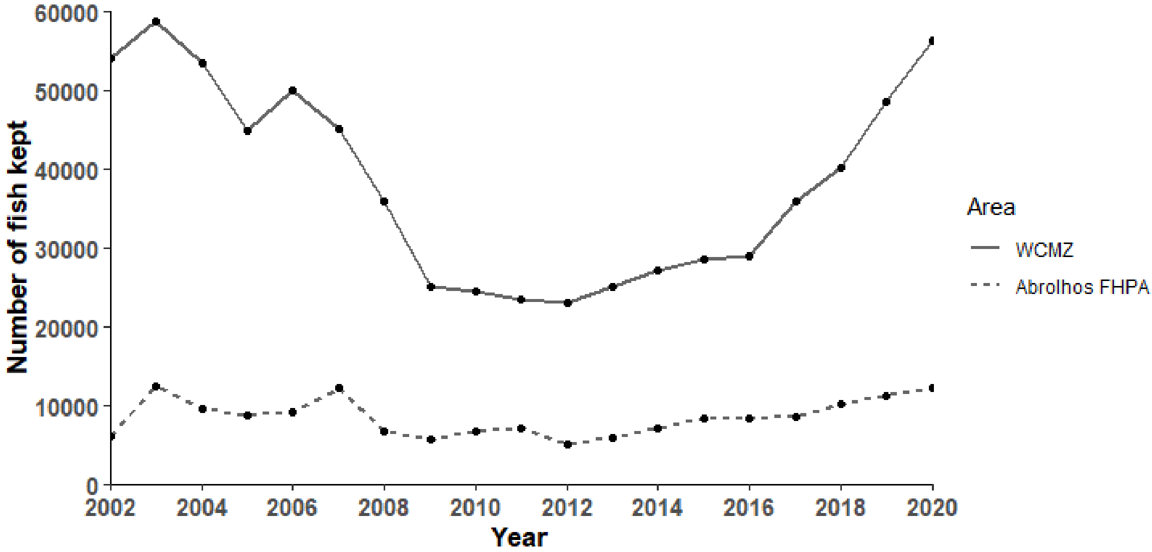

Figure 2.10.6. Annual number of fish kept recorded by Fishing Tour Operators in the WCMZ and the Abrolhos FHPA

There were 191 species (or groups of species) recorded as caught (kept or released) by the Fishing Tour Operator Industry within the Abrolhos FHPA between 2002 and 2020, of which 159 species were recorded as kept at least once. The composition of finfish species that were most commonly kept from the Abrolhos FHPA are similar to those that comprise the WCDSIMF (Section 2.3). These species include pink snapper, baldchin groper, redthroat emperor, WA dhufish, spangled emperor and common coral trout (Figure 2.10.7). In most years, pink snapper and baldchin groper were the most commonly kept finfish species. However, between 2002 and 2008, redthroat emperor accounted for a high number of fish kept and was the most common species kept in 2003, 2004 and 2006. This trend was consistent with McLean et al., (2010) and length-frequency data from that study suggested this was likely the result of a strong recruitment pulse.

Between 2009 and 2020, pink snapper and baldchin groper have been kept in much higher numbers than any other finfish species, and recently, the annual number of WRL kept by charter fishing has increased rapidly with 5,531 kept in 2020 (Figure 2.10.7). The number of WRL kept is likely to continue to increase with a three-year trial of increased lobster pot and boat limits for charter vessels announced in 2019 (DPIRD, 2019).

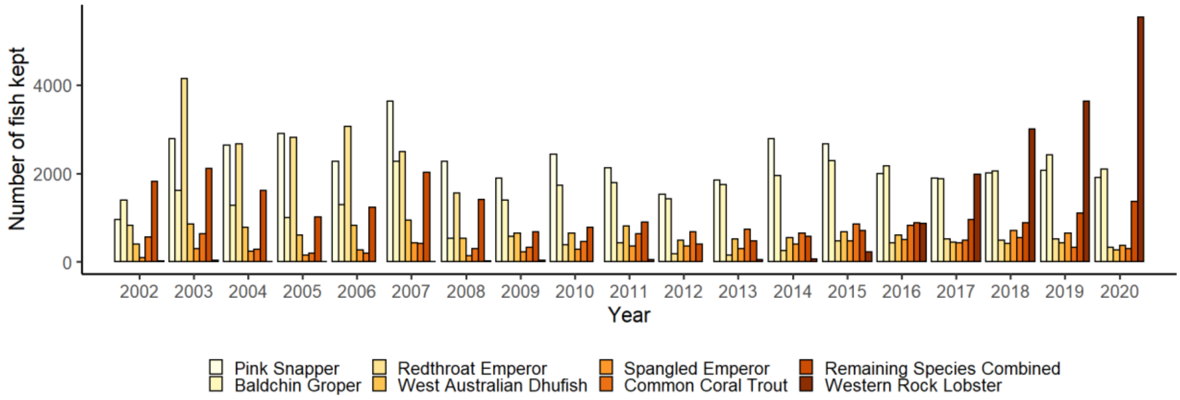

Figure 2.10.7. Annual composition of the seven most commonly kept fish species (finfish and invertebrates) by the Fishing Tour Operators within the Abrolhos FHPA.

When the cumulative total number of fish kept between 2002 and 2020 was proportioned by species, the highest proportion of spangled emperor (83.3%) and common coral trout (76.1%) kept by the Fishing Tour Operator Industry in the WCMZ were from within the Abrolhos FHPA. The Abrolhos FHPA also recorded greater than half the catch of baldchin groper (55.1%) and redthroat emperor (58.8%), while pink snapper (28.5%) and WA dhufish (23.6%) accounted for smaller proportions that were more in line with the proportion of effort (number of trips) and the proportion of fish kept, which are both generally ~20-30%. Western rock lobster accounted for 14.5% of the total kept in the WCMZ between 2002 and 2020.

2.10.2 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the Aquatic Tour Industry and the Abrolhos FHPA:

- Investigate the potential for Aquatic Tour Industry to report catch and effort specific to activities occurring within the Abrolhos FHPA
- Maintain regular updates of Aquatic Tour Industry activity associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, aquaculture, recreation and tourism)

2.11 Aquaculture

2.11.1 *Industry Description*

Western Australia's long (~20,800 km) and rugged coastline supports a variety of aquaculture industries including pearl oyster, rock oyster, barramundi, coral, marine finfish, seaweed, mussels, abalone and scallops (DPIRD, 2020d). In WA, the Minister for Fisheries and DPIRD are responsible for the regulatory framework for aquaculture, including the assessment and applications for the grant of aquaculture licences and leases and industry management, pursuant to relevant sections of the FRMA (1994) and FRMR (1995) (DPIRD, 2017a). The WA State Government is committed to further growth of the aquaculture industry supported by an economic and environmentally sustainable framework (DPIRD, 2020d). This support is evident through the declaration of three Government supported aquaculture development zones throughout the State, including the Mid-West Aquaculture Development Zone (MWADZ) within the Abrolhos FHPA, as well as shellfish hatcheries and proposed finfish nurseries (DPIRD, 2020d). As of December 2021, there are 205 licensed aquaculture sites, pearl farms or holdings within WA, which equates to <0.02% of total area of the WA's combined marine bioregions (~2,286,039 km^2) (Gaughan & Santoro, 2021) or ~0.3% of the nearshore (to 3 nm) WA coastal waters (~114,400 km^2), noting large areas of these regions are unsuitable for aquaculture due to remoteness, exposure or depth. In addition to the current licences, at the time of preparing this report, there were 14 applications in process.

The grant of an aquaculture licence in WA provides authority to conduct aquaculture activities for commercial purposes. DPIRD has a range of guidelines which inform not only the initial aquaculture development applications (e.g., site selection, species suitability, biosecurity) but also other aspects including ongoing legislative reporting requirements, environmental and biosecurity impacts and monitoring (e.g., Management and Environmental Monitoring Plans). An aquaculture licence does not provide approval to collect fish from the wild for farming purposes, including broodstock collection for propagation, or juvenile collection for grow out (DPIRD, 2017b). Broodstock for aquaculture can only be obtained by; purchase from commercial fishers (e.g., MAFMF), purchase from other aquaculture licence holders or by making an application for a Ministerial Exemption under Section 7 of the FRMA (DPIRD, 2017b).

For further descriptions of DPIRD aquaculture and broodstock guidelines, legislation and regulations see:

- DoF. (2013b). Aquaculture Management and Environmental Monitoring Plan: Guidance Statement. Department of Fisheries, Western Australia.
- DPIRD. (2017a). Assessment of Applications for Authorisations for Aquaculture and Pearling in Coastal Waters of Western Australia. Administrative Guideline No.1. Department of Primary Industries and Regional Development, Western Australia.
- DPIRD. (2017c). Aquaculture Development Plans, Principles and Guidelines Relation to Aquaculture Development Plans to address Performance Criteria for Aquaculture Licences and Leases. Fisheries Occasional Publication No. 134. Department of Primary Industries and Regional Development, Western Australia.
- DPIRD. (2020d). Aquaculture Development Plan for Western Australia: Focusing on the key foundations for growth. Department of Primary Industries and Regional Development, Western Australia.
- DPIRD. (2020e). Principles for Grant and Management of Aquaculture Leases in Coastal Waters of Western Australia. Administrative Guideline No.2. Department of Primary Industries and Regional Development, Western Australia.

2.11.2 *Aquaculture and the Abrolhos FHPA*

Although the waters of the Abrolhos have long been identified as potentially suitable for aquaculture development, the industry is relatively new in comparison to other commercial fisheries within the Abrolhos FHPA. The first aquaculture licence within the Abrolhos FHPA was issued in 1996 to produce black-lip pearl oysters (*Pinctada margaritifera*) (Cropp et al., 2011) increasing to two licences in 2000, with both sites in the Pelsaert Group (DoF, 2000). By 2011, Cropp et al. (2011) reported that the Abrolhos FHPA aquaculture industry had increased to eight licences (all pearling) and expanded to include farming of Akoya oysters with licences spread between all three groups, four in the Pelsaert Group and two each in the Easter and North Island /

Wallabi Groups. In late 2011, DPIRD on behalf of the Minister of Fisheries, managed the establishment of the MWADZ in the Abrolhos FHPA, for establishing large scale commercial marine finfish aquaculture operations. Gazetted in 2017, the MWADZ has the two largest licensed aquaculture sites in the Abrolhos FHPA (Figure 2.11.1) at ~22km^2 and 8km^2 for the northern and southern areas respectively (BMT Oceanica, 2017). Aquaculture products farmed in the Abrolhos FHPA have expanded to also include sponges, coral, live rock, algae and finfish. Currently all aquaculture, including non-*P. maxima* south sea pearls, at the Abrolhos FHPA is managed by aquaculture licences.

The Abrolhos FHPA management plan (DoF, 2012a) and the Houtman Abrolhos Islands FHPA Draft Management Plan (2022) supports aquaculture within the Abrolhos FHPA, under the provision that aquaculture activities are managed consistent with an ecosystem-based approach, with the purpose of maintaining the environmental and cultural heritage values of the Abrolhos. The Aquaculture Plan for the Houtman Abrolhos (DoF, 2000), which is currently under review, provides guidance and recommendations for the development of aquaculture in the Abrolhos FHPA, specifically mollusc, crustacean and finfish aquaculture. This includes recommendations for site selection, including areas not compatible with aquaculture (e.g., ROA's, areas of high conservation values or significant social importance or high visual amenity), potentially suitable aquaculture species and other environmental, economic, and social aspects to be considered for granting aquaculture licences. Decisions regarding the approval of aquaculture licences, and sites, at the Abrolhos FHPA are guided by these two plans, in addition to the guidelines, legislation and regulations such as those described in section 2.11.1 of this report.

As with coastal aquaculture, broodstock for aquaculture at the Abrolhos FHPA can currently be obtained by the same three processes, with further approval potentially required for any translocation of broodstock into the Abrolhos FHPA (DPIRD, 2017b). In addition, any persons permitted to collect marine aquarium fish species for aquaculture broodstock purposes (e.g., hard coral, live rock, corallimorphs, anemones) are required, under the MAFR harvest strategy, to maintain and submit accurate records of all fishing activity (DPIRD, 2018a). This is of relevance to hard coral broodstock collection specifically at the Abrolhos FHPA, where the MAFMF is not permitted to harvest hard coral.

2.11.3 *Data Collection, Collation and Comparison Methodology*

Aquaculture and pearl licence and lease data (e.g., licence number and area) were obtained from the DPIRD geographic information system spatial databases (as of 9 December 2021) for the entire state (including the Abrolhos FHPA) and then specifically for those that fell within the Abrolhos FHPA boundary only. The Hatcher et al. (1988) geomorphological benthic sensitivity maps were used to show distribution of aquaculture sites over the Abrolhos FHPA shallow water (<20 m) benthic environment. As described in section 2 of this report in relation to the WCRLMF, these habitat data maintain relevance due to it classification of the geomorphological substrate, rather than biota, and provides complete coverage over the Abrolhos FHPA shallow water environments (<20 m). Separate habitat data is also available for the MWADZ sites (which occurs in <20 m) and can be found at BMT Oceanica (2017) or DPIRD (2020b). Aquaculture production, both by number and weight (kgs), is provided from the DPIRD aquaculture production databases up to the 2018/19 season, when reporting is possible based on confidentiality (i.e., more than three licences reporting).

2.11.4 *Aquaculture Spatial Footprint and the Abrolhos FHPA*

As of December 2021, the Abrolhos FHPA has 21 aquaculture licences, which is 29.2% of the 72 aquaculture licences within WA, noting that pearling at the Abrolhos FHPA is undertaken on aquaculture licences and is therefore not considered as part of the 133 pearl farms and holdings. The licensed aquaculture sites at the Abrolhos FHPA, including the MWADZ, have a combined spatial footprint of ~45.9 km^2, which is ~2% of the entire Abrolhos FHPA (Figure 2.11.1), compared to the state-wide aquaculture footprint of ~0.3% of the total area in the nearshore WA coastal waters. Aquaculture licenses at the Abrolhos FHPA have steadily increased since the first licence and site were granted in 1996. No reference could be found regarding any aquaculture licenses or sites being discontinued between 1996 and 2021. Therefore, the ~45.9 km^2 baseline licensed aquaculture footprint reported here is the largest spatial footprint that has occurred within the Abrolhos FHPA to date. As of December 2021, an additional four aquaculture licence applications are being assessed for the Abrolhos FHPA.

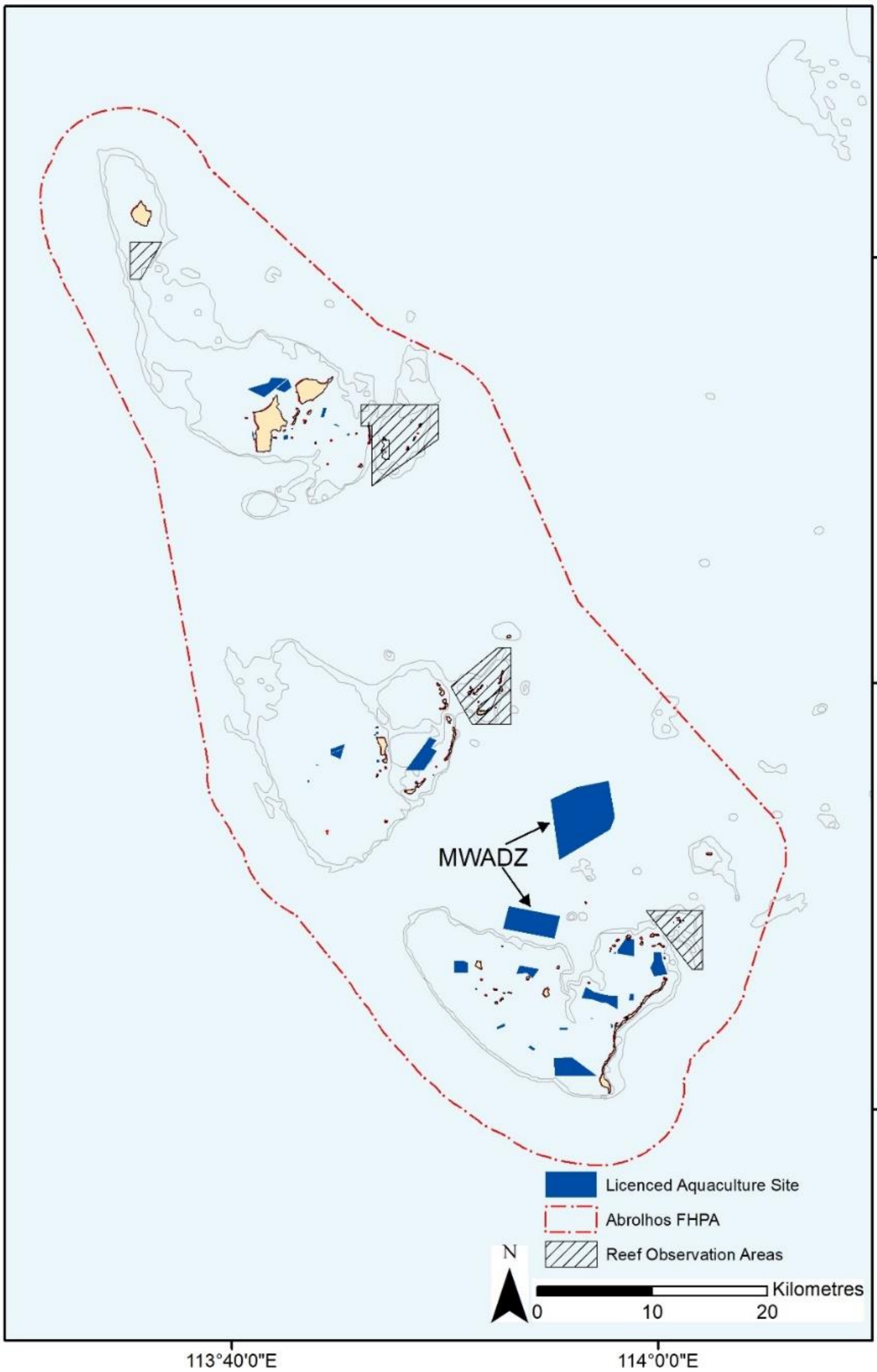

Figure 2.11.1. Licensed aquaculture sites (as of December 2021) within the Abrolhos FHPA (grey line demonstrate 10-20 m depth contour).

Within the Abrolhos FHPA, 19 of the 21 licensed aquaculture sites occurred within shallow waters (<~20 m), with the two largest sites (MWADZ) found outside this depth range (Figure 2.11.1). Of the 19 shallow water aquaculture sites (excludes MWADZ), ten are within the Pelsaert Group, six are in the Easter Group and three in the North Island / Wallabi Group (Figure 2.11.1). The spatial footprint of aquaculture sites is highest at the Pelsaert Group, with ~5.5% of the shallow water area occupied by aquaculture licences, 1.5% of the Easter Group and 1.3% of the North Island / Wallabi Group (Figure 2.11.1). Overlaying the Abrolhos FHPA licensed aquaculture sites with the Hatcher et al. (1988) geomorphological sensitivity classes show that ~55% of the licensed areas are located within the low geomorphological sensitivity (Figure 2.11.2). The remaining 45% of licensed areas are within moderate (~15%) and high (~30%) sensitive areas (Figure 2.11.2), which is not in line with the guidelines recommended within the Aquaculture Plan for the Houtman Abrolhos (DoF, 2000). However, although the mapping presents the best available full-scale data for the shallow water Abrolhos FHPA, it is noted that Hatcher et al. (1988) did not have access to high resolution aerial and satellite imagery available in the current day, that may better account for sand areas within the higher sensitivity classes. In addition, no fine-scale assessment on the placement of anchoring and types of aquaculture gear installed within the different sensitivity classes was available for this report.

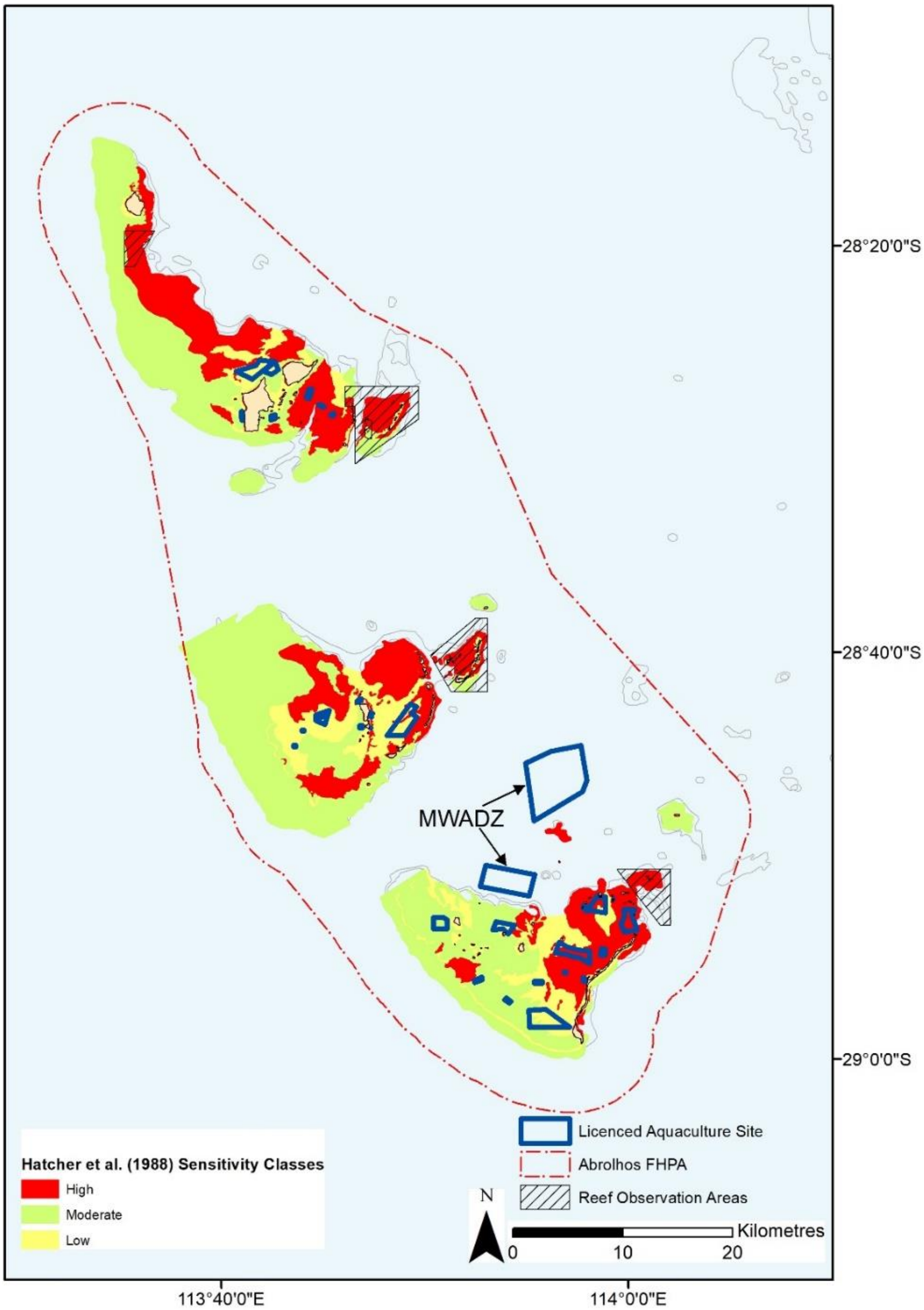

Figure 2.11.2. Abrolhos FHPA aquaculture sites overlaid on geomorphological benthic sensitivity classes (Hatcher et al., 1988).

2.11.5 *Aquaculture Production Data and the Abrolhos FHPA*

Aquaculture production information for this report was based on DPIRD source data where, for data collated between 2000-01 and 2018-19, a total of 12 licenses reported annual production for the aquaculture of algae, anemones, coral, live rock, pearl oysters or zoanthids within the Abrolhos FHPA. This has ranged on an annual basis from less than three licenses per year to a maximum of seven licenses. For the latest five years of data available (2014-15 to 2018-19) annual production has been reported by between four and seven licenses (mean = five). Due to the low level of production returns available for the different aquaculture products farmed at the Abrolhos FHPA, no further reporting of production level was undertaken to ensure commercial confidentiality of operators is maintained.

2.11.6 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to Aquaculture and the Abrolhos FHPA:

- Review aquaculture activities at the Abrolhos FPHA, in relation to both the Aquaculture Plan for the Houtman Abrolhos and the Abrolhos FHPA Draft Management Plan (2022)
- Update the Aquaculture Plan for Abrolhos FHPA, including:
    - a framework for the development of aquaculture proposals in the Abrolhos FHPA
    - suitable zones and total spatial area for aquaculture development, specific to species to be farmed
    - assessment of resource sharing compatibilities
    - a clear outline for both environmental and economic sustainability
- Review of current Abrolhos FHPA aquaculture licenses including:
    - the submission of production returns by industry
    - the capacity to restitute under-utilised sites back to DPIRD for repurposing
- Review aquaculture broodstock collection allowances for the Abrolhos FHPA, according to need
- Consolidate reporting on broodstock and exemption collections from the Abrolhos FHPA
- Maintain regular updates of Aquaculture associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing, recreation and tourism)

3.0 Recreational Use

The terrestrial and marine environments of Abrolhos have a long history of recreational interest which dates back to the early 1900s (DoF, 2001). Historically, this recreational activity has been closely aligned to commercial operations (e.g., guano mining, WCRLMF) (DoF, 2001; Webster et al., 2002). However, more recently recreational activity has also increased in relation to the aquatic tourism industries (Section 2.10) and privately owned recreational vessels. The Abrolhos FHPA is rich in unique reef structures, temperate and tropical coral, algae and fish species, historic shipwrecks (e.g., *Batavia*), all of which provide for unparalleled diving and snorkelling experiences (including seven dive trails). There are reliable, consistent seasonal winds for kite and wind surfing, remote surf breaks and an abundance of marine mammal life (e.g., whales, dolphin and Australian sea lions) and seabirds to appreciate. Although there is a paucity of published information to quantify the levels of recreational activity at the Abrolhos or the Abrolhos FHPA, the limited available published literature suggests the major attraction of the Abrolhos FHPA is its unique recreational fishing experiences by way of line fishing, spearfishing and looping and potting for WRL (DoF, 2001; Webster et al., 2002; Sumner, 2008).

With all types of recreational tourism activity at the Abrolhos FHPA and HAINP expected to increase further through improved accessibility and marketing, understanding and reporting on patterns of recreational usage within the Abrolhos FHPA is critical to its effective ongoing management and resource sharing allocations. This section summarises data currently collected or collated by DPIRD for recreational private vessel use of the Abrolhos FHPA. All commercial aquatic tourism industry data are provided in Section 2.10. Unless otherwise stated, data collation, data manipulation, analysis, and figures were performed in R (R Core Team, 2021) or Microsoft Excel, and spatial analysis and mapping undertaken using ArcGIS® software by ESRI or R (R Core Team, 2021).

3.1 Recreational Vessel Accessibility to the Abrolhos FHPA

The Abrolhos FHPA is accessible by water or air only. Locally, trailered vessels can travel to the Abrolhos FHPA within 50-60km from the mainland from boat ramps in Geraldton (to Pelsaert Group), Horrocks and Port Gregory (to North Island / Wallabi Group) and within ~80 to 90 km from Dongara (to Pelsaert Group) and Kalbarri (to

North Island / Wallabi Group). These boat ramps range in size and capacity, with Geraldton and Dongara currently having more developed boat ramps suitable for launching larger vessels (>5 m). It is likely that these two locations are where most trailered vessels visiting the Abrolhos FHPA are launched. In addition, there are multiple marinas along the WA coast (e.g., Geraldton, Dongara, Jurien, Hillarys, Swan River, Fremantle, Cockburn Sound, Mandurah) that berth non-trailered vessels capable of making the extended voyage to the Abrolhos FHPA. Currently there are no on-island provisions for any supplies at the Abrolhos (e.g., water, food, fuel) so all recreational vessel visitation to the Abrolhos FHPA must be self-sufficient and not access any of the privately owned jetties or infrastructure on the islands. There are 38 public moorings maintained by DPIRD that are situated in key locations of the Abrolhos FHPA for vessels up to 25 m in length and 40 T in weight as well as a public access jetty on East Wallabi Island and one under development on Beacon Island. Visitors may also join a vessel or access the Abrolhos FHPA for a day trip (e.g., swimming, snorkelling or shore fishing) via a small plane or helicopter landing at one of the three gravel airstrips in the HAINP including the Big Rat Island (Easter Group), East Wallabi Island (North Island / Wallabi Group) or North Island (North Island / Wallabi Group). These aircrafts typically leave from Geraldton airport, however some also travel from Jandakot in the Perth metropolitan region or other small airports throughout WA.

3.1.1 *Recreational Vessel Associations to the Abrolhos FHPA*

3.1.1.1 *Background*

Historically, quantifying the number of recreational vessels visiting the Abrolhos FHPA has not been possible (DoF, 2001; Webster et al., 2002). Prior to the WCRLMF transition to ITQ, it was assumed that most recreational vessel activities occurred during the traditional WCRLMF A Zone (including the Abrolhos FHPA) fishing season (March 15th – June 30th). This also coincided with generally favourable weather conditions and increased vessel presence (for support) from the WCRLMF (Sumner, 2008). Outside of this period, visitation to the Abrolhos FHPA was assumed to be limited due to lack of land-based facilities and support, generally unfavourable weather conditions and WCRLMF A Zone licence holders only permitted to access their camps via an application for care and maintenance (DoF, 2001; Sumner, 2008). Private yachts or larger vessels entering the Abrolhos FHPA, outside of the traditional

WCRLMF season, were also required to register their intent with DPIRD, however the level of compliance with this requirement is unknown (DoF, 2001).

With the WCRLMF's transition to ITQ and advances in digital marine weather forecasting and recreational vessel technology, DPIRD recognised a change in the patterns of visitation to the Abrolhos FHPA. In March 2016, DPIRD introduced a regulatory requirement that any visitation to the Abrolhos FHPA by boat would notify their intent. The Abrolhos FHPA Vessel Notification System (VNS) provides DPIRD with valuable information in relation to the number, timing and spatial association of recreational vessels and their activities in the Abrolhos FHPA. It can also be used as another data source in the case of medical emergencies, provisions for evacuation advice and biosecurity risks. Initially notifications in the VNS were via a manual notification form physically lodged or emailed to DPIRD. However, the system developed to a fully online submission platform by 2018 (www.fish.wa.gov.au/Sustainability-and-Environment/Abrolhos-Islands/Pages/Notification-of-travel-to-the-Abrolhos-Islands-Fish-Habitat-Protection-Area-(FHPA).

The data summarised in this section relates to historical trends for recreational vessel registrations within WA to show patterns in vessel ownership over time and general assumptions in relation to the Abrolhos FHPA. Private recreational/tourism activities patterns and trends at the Abrolhos FHPA are explored in more detail from data provided to the DPIRD VNS.

3.1.1.2 *Department of Transport, WA, vessel registration data summary*

Recreational vessel registration is based on raw data obtained from the Department of Transport, WA (DoT) for every fifth year between 1990 and 2015 and then annually between 2016 and 2018, providing an overall data set spanning 28 years. The DoT data provides the annual number of new and renewed recreational vessel registrations which, for this report, were summed to provide a total number of vessel registrations per year for WA. Location of the licence holder of the registered vessel (postcode) as well as vessel type and length are also provided. For this report, vessel location was grouped based on the postcode of the licence holder to either the 'Mid-West' (postcodes 6500 – 6599), 'Perth' (postcodes 6000 – 6210) or 'Other' (all other WA postcodes) to allow for broadscale comparisons of recreational vessels in relation to the Abrolhos FHPA. Individual vessel lengths were grouped into four categories, small (0 – 4.99 m), medium (5 – 9.99 m), large (10 – 19.99 m) or extra-large (>20 m). All vessel types (e.g., cabin cruiser, catamaran, yacht jet boat, houseboat, hovercraft, canoe) were included in the analysis for vessels that may have been used for private recreational or tourism activities at the Abrolhos FHPA.

The DoT registration data shows the total number of private recreationally registered vessels in WA increased by 51,157 vessels between 1990 and 2015. This amounts to a doubling of the total number of vessels between 1990 and 2015 from 47,710 to 98,867, with ownership then remaining relatively consistent for the years between 2015 and 2018 (Table 3.1.1). Similarly, vessel registrations in the Mid-West almost doubled from 3105 in 1990 to 5849 in 2015 and then again remained relatively consistent between 2015 and 2018 (Table 3.1.1). A similar trend is observed in the 'Other' areas of the WA (Table 3.1.1).

Table 3.1.1. Total number vessel registrations in WA and by region between 1990 and 2018.

Vessel Registrations	1990	1995	2000	2005	2010	2015	2016	2017	2018
All of WA	47710	53120	65056	79246	93768	98867	98829	98809	98142
Perth	29557	32711	40084	48455	58153	62135	61791	61488	60847
Midwest	3105	3446	4095	4999	5721	5849	5886	5835	5813
Other	15048	16963	20877	25792	29894	30883	31152	31486	31482

There was also an increase in vessel length between 1990 and 2018, with an overall increase in medium (32.7% to 38. 8%), large (2.6% to 3.9%) and extra large (0.03% to 0.08%) vessels, as a proportion of the total private recreational vessels registered within WA. There was a decrease in small vessels across this same time period (64.7% to 57.3%). Although all three regions (Perth, Mid-West and Other) showed an overall increase in registration, increase by vessel length category and region were not uniform (Figure 3.1.1). The greatest increase in vessel registrations between 1990 and 2018, was in the small (i.e., unlikely to independently travel to the Abrolhos FHPA) and medium (i.e., trailered vessels likely able to day trip to the Abrolhos FHPA from Geraldton) length vessel categories (Figure 3.1.1). There was also an increase, albeit smaller, in the large and extra large vessels across all areas of the WA which could also transit to the Abrolhos FHPA from their home marinas (Figure 3.1.1). This DoT vessel registration data highlights the large increase in vessel ownership in WA between 1990 and 2015 and demonstrates the substantial increase in private recreational vessels (>5 m in length) which have the capability to access the Abrolhos FHPA for private recreational / tourism purposes.

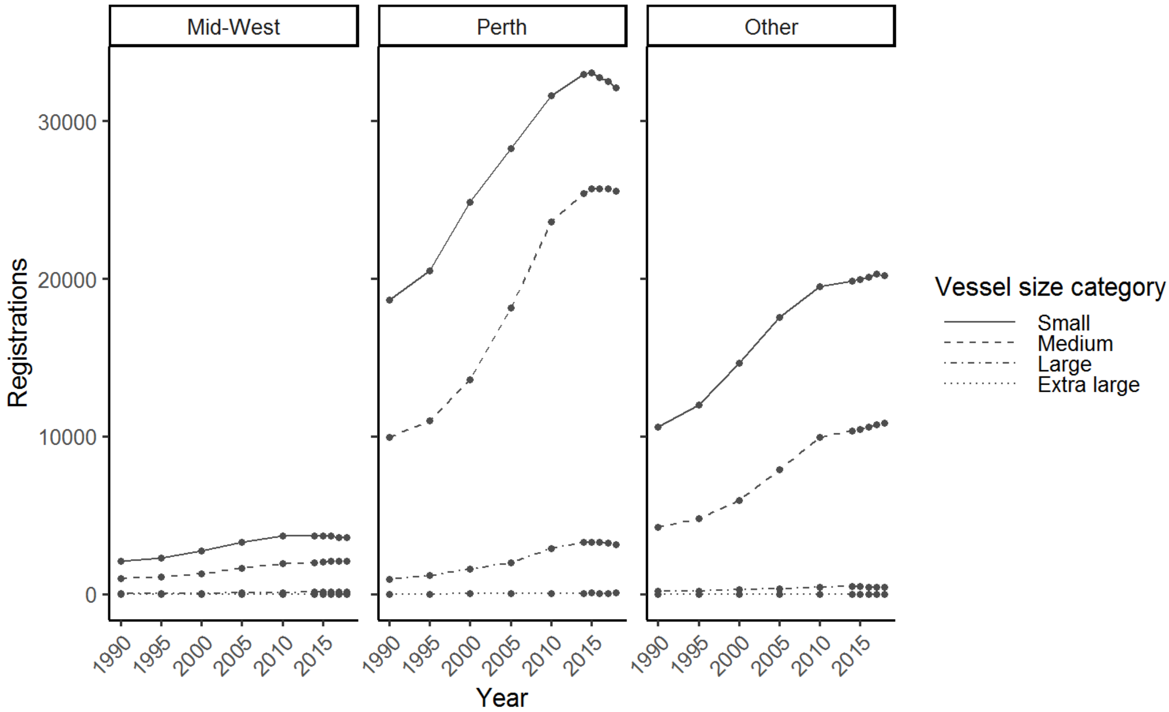

Figure 3.1.1. Number of vessel registrations for each vessel category in the Mid-West, Perth and all other locations (Other).

3.1.1.3 *DPIRD Vessel Notification System for Abrolhos FHPA - private recreational / tourism activities data*

3.1.1.3a Program Description

Data from the DPIRD Abrolhos FHPA VNS was obtained from January 2018. The VNS captures a range of data submitted by the vessel Master with regards to their intent at the Abrolhos FHPA. Identifying details (e.g., vessel name, Masters name, address) were not extracted from the VNS for confidentiality reasons. Additional pooling of other data variables such as postcode of Master, reason for travel (e.g., private recreation, charter, commercial fishing), vessel length (grouped into 10 m categories) and weight, vessel home port, number of people on board, scheduled arrival date, duration of visitation at Abrolhos FHPA and island group/s intended to visit was also undertaken. Further, the postcode of the Master was pooled to match that of the DoT data (section 3.1.1 of this report) into ‘Mid-West’ (Postcodes 6500 – 6599), ‘Perth’ (Postcodes 6000 – 6210) or ‘Other’ (all other WA postcodes) to define the region from which visitors were travelling.

Data collected in the VNS captures the intent of the Master upon entering the Abrolhos FHPA. Although a regulatory requirement to answer the questions truthfully (e.g., people on board and reason for travelling), other aspects such island group/s intended to visit, may vary before or during the visitation due to changes such as weather conditions, lack of mooring availability or cancelled overall trip. There is currently no requirement for the notification to be updated once submitted. The VNS also allows for a selection of four island groups for visitation, with North Island and Wallabi Group considered separately. For consistency within this report these two ‘groups’ were merged to be North Island / Wallabi Group. Data was collated by calendar year from 2018 to 2020, with 2021 also presented as a full year up to and including the 13th of December 2021.

3.1.1.3b Results Summary

Between the 1st of January 2018 and 13th of December 2021, a total of 4482 of the 6075 Masters (~74%) that notified to enter the Abrolhos FHPA listed their primary purpose as “private recreational/tourism activities”. There were an additional 24 notifications over the four-year period (4 in 2018, 4 in 2019, 8 in 2020 and 8 in 2021) that listed ‘private recreational/tourism activities’ as a secondary activity from their main purpose (e.g., commercial fishing, aquaculture, research, transit, charter, carrier vessel or other). As these were few and listed as secondary (therefore may not have occurred) they were not included in the reporting for private recreational/tourism activities at the Abrolhos FHPA in this report. Of the 4482 private recreational/tourism activities notifications, 98.7% were from within WA, 1% from interstate and 0.3% international (Table 3.1.2). For intrastate visitations, private recreational / tourism activities notifications remained reasonably consistent ranging between 1050 notifications (2021) and 1177 notifications (2019) (Table 3.1.2). There appears to be an upward trend of interstate and international notifications from 2020, although the numbers are low compared to intrastate visitation (Table 3.1.2).

Between 2018 and 2021 most (~90%) notifications for visiting the Abrolhos FHPA for private recreational/tourism activities listed 1- 5 people on board the vessel. The remaining 10% had 6-10 people (8.9%), 11-15 people (0.8%), 16-20 people (0.11%), 21-25 people (0.02%) or 25+ people (0.11%). This trend was reasonably consistent between years, however, 2021 shows an increase in the 6-10 people on board category from 85 to 142 vessels. Assuming the maximum number of people were aboard each vessel this accounts for 5990 private recreational / tourism activities visitors to the Abrolhos FHPA in 2018, 6455 in 2019, 6210 in 2020 and 6310 in 2021.

Table 3.1.2. Number of vessel notifications, and their broad home location, notifying to enter to Abrolhos FHPA 2018 to 2021. *note 2021 is until 13th of December only.

Year	Intrastate	Interstate	Overseas	Total
2018	1071	14	2	1087
2019	1177	3	4	1184
2020	1126	6	2	1134
2021	*1050*	*21*	*6*	*1077*
Total	4424	44	14	4482

For intrastate visitation between 2018 and 2021, 63.8% of the Masters notifying (and therefore assumed vessel location) were based in Mid-West region, 39.4% in the Perth Metropolitan region and 6.8% from elsewhere in WA (Table 3.1.3). Annually, the total notifications by region also remained relatively consistent (Table 3.1.3). The impact of COVID-19 in terms of visitation to the Abrolhos FHPA from intrastate vessels appears limited, likely due to the relatively limited intrastate restrictions in 2020 and 2021. However, there was a noticeable ~100 notification decline in visitation from the Perth metropolitan region in 2020 and an increase in notifications from the Mid-West, perhaps driven by the short intrastate COVID-19 related travel restrictions in that year (Table 3.1.3). The highest visitation reported from the Perth Metropolitan region over the four years, by 49 notifications, was in 2021, again perhaps as a factor of COVID-19 travel restrictions. This increase appears to be offset by the lowest number of notifications in 2021 from the Mid-West region, noting that this period does not yet account for the Christmas holiday period of 2021 and may increase (Table 3.1.3).

Table 3.1.3. Number of notifications, by Masters postcode region, notifying to enter to Abrolhos FHPA 2018 to 2021 *note 2021 is until 13th of December only.

Year	Mid-West	Perth	Other	Total
2018	688	323	60	1071
2019	731	350	96	1177
2020	814	247	65	1134
2021	*589*	*382*	*79*	*1077*
Total	2822	1302	300	4424

The timing of visitation for private recreation / tourism activities to the Abrolhos FHPA is variable throughout the year. The VNS data for 2018 to 2021 shows the highest notification to visit occurs between February and May, peaking in April each year at ~300 notifications (vessels) (Figure 3.1.2). This aligns, generally, with favourable weather conditions along the WA Mid-West coast and Abrolhos FHPA. The remaining months (June to January) have overall lower visitation, with a slight peak observed in September and the lowest visitation in November (Figure 3.1.2). The low visitation in November is likely driven by strong wind conditions at that time of year and recreational demersal finfish closures during that period. Anomalous low visitation notifications observed in April to June 2020 and February 2021 were also likely driven by travel restrictions in relation to COVID-19 and likely not representations of usual visitation trends (Figure 3.1.2).

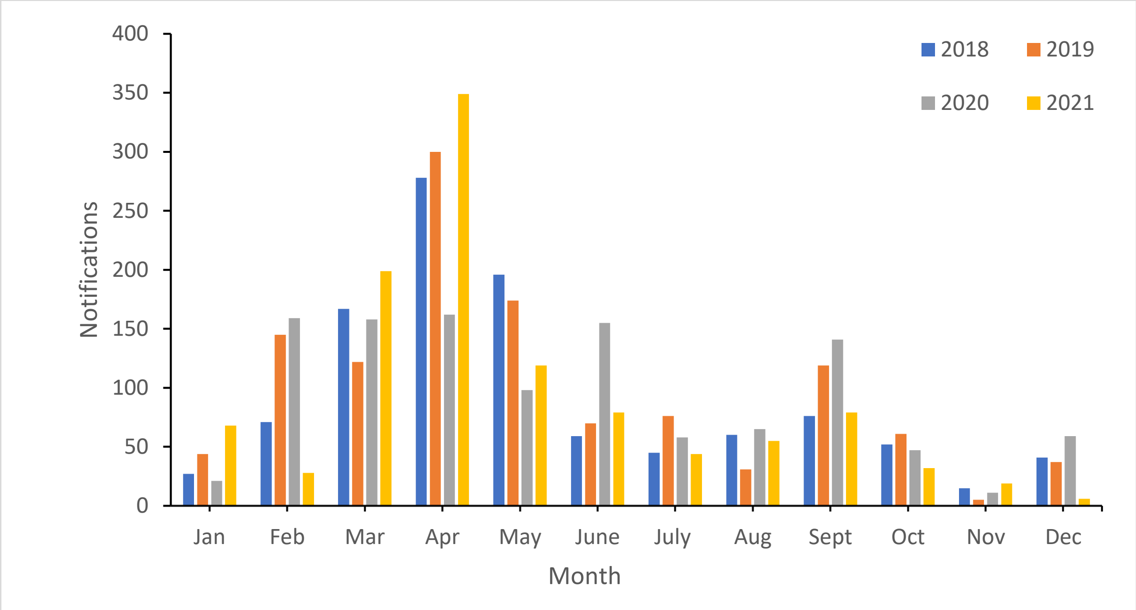

Figure 3.1.2. Annual Abrolhos FHPA visitation by month, all vessels.

Visitation notifications from Masters whose home base is outside the Mid-West (Figure 3.1.3A) and the Mid-West only (Figure 3.1.3B) shows slightly different trends. For all notifications from Masters whose home base is outside the Mid-West, there is an observed preference for private recreation and tourism activity travel to the Abrolhos FHPA in March to May, peaking in April (excluding the 2020 COVID-19 anomalous year) (Figure 3.1.3A). Limited notifications to visit the Abrolhos FHPA (<25 notifications per month) are generally observed from outside the Mid-West in other months of the year, with typically very low levels observed for November through to January (Figure 3.1.3A). Timing of visitation trends is similar for the Mid-West, however the April peak is not as prominent with visitation spreading from February to May and higher overall visitation year round (Figure 3.1.3B). The data also shows that the spike in visitation in September each year is driven by local (Mid-West) Masters notifying (Figure 3.1.3B).

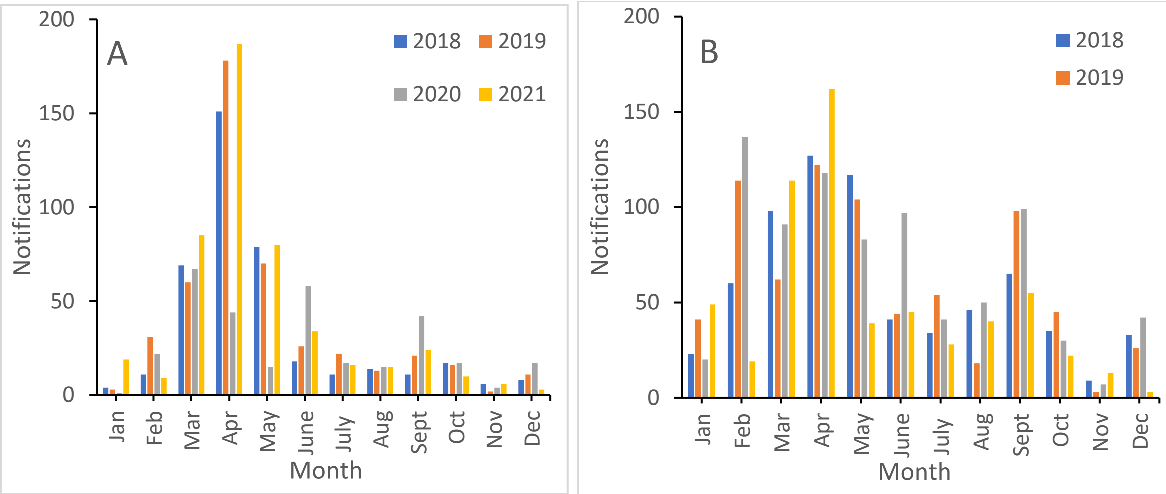

Figure 3.1.3. Annual Abrolhos FHPA notifications by month for all areas excluding the Mid-West (A) and the Mid-West only (B)**.**

The duration of visit to the Abrolhos FHPA is also typically short (<5 days), on average for the four years of data, with ~20% being day trips and a further ~53% being for one to five nights (Table 3.1.4). This trend has remained relatively consistent over the four years (Table 3.1.4). A shorter stay is also more common for Masters from the Mid-West with, on average, ~30% visiting for day trips and further ~56% for one to five nights (Table 3.1.4). This result is expected for the Mid-West given the Abrolhos FHPA's proximity to the region. Interestingly, the data suggests a trend for visitors from the Mid-West to stay longer in recent years, with the percentage of day trips declining from 36.9% in 2019 to 25.5% in 2021, with the number of Mid-West masters notifying to stay 1 night in 2021 now the same level as day trippers (~25% each) (Table 3.1.4).

Table 3.1.4. Proportion (%) of all notifications duration of stay at the Abrolhos FHPA between 2018 and 2021. Mid-West based Masters only are in brackets. *note 2021 is until 13th of December only.

Year	Day Trip	1 Night	2 Nights	3-5 Nights	6–10 Nights	11-15 Nights	16-20 Nights	>21 Nights
2018	24.7 (36.9)	16.6 (19.5)	13.8 (15.8)	19.9 (15.6)	12.1 (7.8)	5.6 (2.2)	1.7 (0.6)	5.6 (1.6)
2019	19.0 (28.0)	17.8 (20.9)	16.7 (18.6)	19.4 (17.6)	14.1 (9.7)	5.4 (1.5)	1.4 (0.3)	6.2 (3.4)
2020	21.5 (28.5)	20.5 (23.8)	15.9 (16.1)	18.7 (17.1)	10.8 (7.7)	3.9 (2.2)	1.6 (0.7)	7.1 (3.9)
2021	14.9 (25.5)	16.0 (23.8)	15.2 (15.3)	22.6 (21.1)	13.6 (7.3)	7.6 (2.7)	2.3 (0.2)	7.8 (4.1)

The Pelsaert Group had an average of 48% of all private recreational/tourism activity notifications between 2018 and 2021 (Table 3.1.5). This is followed by Easter Group with 29% and North Island / Wallabi Group with 23%, with only minor fluctuations between years (Table 3.1.5). This preference is more prominent when looking at notifications from Masters based in Mid-West which shows, on average for the four years, 56 % visit Pelsaert Group (Table 3.1.5). This may be due its proximity to the more developed mainland boat ramps (Geraldton and Dongara) and being the first island group encountered when travelling from the Perth Metropolitan region. There is a similar level of preference for the Easter Group from Mid-West based Masters (28%) compared to overall notifications. There is a lower preference for the North Island / Wallabi Group at 16% (Table 3.1.5), which may be due to the group's remoteness. It is also consistent with expectations that vessels coming from outside the Mid-West region may explore more island groups per trip (Table 3.1.6) given the logistical constraints of accessing the Abrolhos FHPA from outside the Mid-West region (e.g., steaming or towing vessels from Perth). Whilst Mid-West based Masters may prefer the convenience of the closest areas to mainland for recreational activities (e.g., recreational fishing).

Table 3.1.5. Proportion (%) of all notifications which visited specific island groups of the Abrolhos FHPA between 2018 and 2021. Mid-West based Masters only in brackets. *note 2021 is until 13th of December only.

Year	Southern Group	Easter Group	North Island / Wallabi Group
2018	48.0 (56.4)	28.1 (26.0)	23.9 (17.6)
2019	47.4 (56.9)	28.6 (26.5)	24.0 (16.6)
2020	51.5 (57.4)	28.6 (27.5)	19.9 (15.0)
2021	*44.4 (53.0)*	*30.2 (30.2)*	*25.4 (16.7)*

Table 3.1.6. Proportion (%) of all notifications which visit multiple island groups, on a single notification, between 2018 and 2021. Mid-West based Masters only in brackets. *note 2021 is until 13th of December only

Year	1 Island Group	2 Island Groups	3 Island Groups
2018	59.2 (70.8)	18.2 (18.2)	22.5 (11.0)
2019	58.3 (69.2)	18.5 (18.9)	23.2 (11.9)
2020	59.3 (68.5)	20.5 (19.6)	20.3 (11.9)
2021	*53.8 (70.1)*	*18.8 (17.8)*	*27.5 (12.1)*

In terms of length of vessels, the majority (~61%) of private recreational vessels visiting the Abrolhos FHPA between 2018 and 2021 were 0-10m in length. Of the remaining 39%, ~34% were 11-20 m, ~4% were 21-30 m and ~1% were greater than 30m (Table 3.1.7). The proportion of vessels of differing lengths visiting the Abrolhos FHPA has remained relatively consistent over the four-year period, although an overall decrease in 0-10 m vessels and increase in 11-20 m vessels was observed in 2021 (Table 3.1.7)

Table 3.1.7. Length of vessels notifying to enter to Abrolhos FHPA between 2018 and 2021 *note 2021 is until 13th of December only

Year	0-10 m	11- 20 m	21-30 m	>30 m
2018	661	367	50	9
2019	746	381	49	8
2020	750	333	46	5
2021	*597*	*421*	*46*	*13*
Total	2822	1302	300	4424

3.1.2 *Recreational Fishing and the Abrolhos FHPA*

With participation rates in recreational fishing estimated to be above 25% of the WA population, this activity provides important social benefits to the estimated 619,000 people who engage in the activity in WA (Ryan et al., 2019). In addition, there are significant economic benefits to WA, with expenditure related to recreational fishing reported to be in the order of $2.4 billion in 2015 /16 (McLeod & Lindner, 2018). With its remote location, unique ecosystem and diverse suite of recreationally targeted temperate and tropical demersal finfish (e.g., pink snapper, baldchin groper, redthroat emperor, WA dhufish, spangled emperor and common coral trout), pelagic finfish (e.g., spanish mackerel, yellow tail kingfish and samsonfish) and invertebrate species (e.g., WRL, squid), the Abrolhos FHPA provides for a world class recreational fishing experience. To ensure this experience remains sustainable there are a number of Abrolhos FHPA specific fishing regulations (e.g., reduced possession limits and species specific seasonal closures) and ongoing assessments of their effectiveness, in addition to that which apply within the West Coast Bioregion (www.fish.wa.gov.au/Documents/recreational_fishing/rec_fishing_guide/recreational_fishing_guide.pdf).

While recreational fishing is very popular at the Abrolhos FHPA, to date there is no ongoing Abrolhos FHPA specific catch and effort recreational fishing survey. However, every 2-3 years a state-wide survey collects data on boat based recreational fishing using a combination of phone diary, boat ramp and remote camera surveys (Ryan et al., 2019; Lai et al., 2021). This data is currently reported to a state-wide, bioregional and zone level (e.g., Mid-West, Perth Metropolitan). The Mid-West zone encapsulates the Abrolhos FHPA and the 2017/18 survey estimated the retained catch (as individuals) for the most commonly caught species to be: WRL (90,558), baldchin groper (9762), WA dhufish (7202), pink snapper (4876), redthroat emperor (1916), coral trout (1640) and breaksea cod (1149) (Ryan, et al., 2019). An earlier survey of recreational fishers in the Abrolhos FHPA in 2005/06 also found similar species caught to that reported in the Mid-West zone in 2017/18 with baldchin groper, pink snapper, WA dhufish, coral trout, spangled emperor and redthroat emperor the most frequently recorded (Sumner, 2008).

3.1.3 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to Recreational Use and the Abrolhos FHPA:

- Prioritise a science and monitoring plan to further improve spatial resolution of private recreational visitation trends to the Abrolhos FHPA
- Investigate opportunities to combine data obtained in Abrolhos FHPA vessel notification system into recreational fishing surveys, including methods for estimating effort, e.g., how many fishers per vessel
- Prioritise a science plan to collect and quantify recreational fishing catch and effort data specific to the Abrolhos FHPA e.g., digital diaries or Abrolhos FHPA specific phone surveys
- Maintain regular updates of private recreational visitation trends and associations with Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing and aquaculture)

4.0 Ecological Attributes

Located in a convergence between northern tropical and southern temperate waters, the Abrolhos FHPA is heavily influenced by the poleward flowing Leeuwin Current which carries warm, low-nutrient tropical water southward from north-western Australia and maintains winter seawater temperatures at the Abrolhos between 20ºC and 22ºC (Pearce, 1997). The influence of the Leeuwin Current and its southern geographical location makes the coral reef system within the Abrolhos FHPA the southernmost in the Indian Ocean and one of the highest latitude reef systems in the world (28º to 29º S, 113º35´ to 114º03´ E) (Webster et al., 2002; Lough, 2008; Abdo et al., 2012). The Abrolhos FHPA also supports a diverse assemblage of temperate and tropical marine algae and fish fauna (Huisman, 1997; Hutchins, 1997; Phillips & Huisman, 2009; Watson & Harvey, 2009). This section summarises fisheries independent data currently collected or collated by DPIRD in relation to the ecological condition of the aquatic resources of the Abrolhos FHPA. Unless otherwise stated, data collation, data manipulation, analysis, and figures were performed in R (R Core Team, 2021) or Microsoft Excel, and spatial analysis and mapping undertaken using ArcGIS® software by ESRI or R (R Core Team, 2021).

4.1 Coral Reef Health Monitoring

4.1.1 *Program Description and Methodology*

The Abrolhos FHPA supports one of the highest latitudinal true coral reef systems in the world and the southernmost in the Indian Ocean (Webster et al., 2002; Abdo et al., 2012). Geographically isolated in a temperate / tropical transitional zone (Figure 4.1.1) but in the pathway of the warm poleward flowing Leeuwin Current (Cresswell & Golding, 1980), the Abrolhos FHPA has an exceptional range of coral fauna with 184 species from 42 genera reported (Veron & Marsh, 1988). Most hard corals reported at the Abrolhos FHPA are from the genus *Acropora,* with the sheltered reefs often dominated by the branching form (Blakeway & Hamblin, 2015). Despite its uniqueness, there are relatively few studies on the coral and associated ecosystem dynamics found within the Abrolhos FHPA, as is common with many WA reef systems in comparison to east coast Australian reefs (Gilmour et al., 2019). Recent studies also show that due to the unique features of the Abrolhos FHPA, complex patterns in hard coral diversity are likely, such as the intra-island group genetic differences observed in the coral species *Acropora spicifera* (Thomas et al., 2015). In addition, the coral reefs of the Abrolhos FHPA are being influenced by a changing marine environment with the 2010/11 WA marine heatwave causing the first recorded mass hard coral bleaching event at the Abrolhos FHPA (Abdo et al., 2012).

With concerns to having sufficient data to quantify natural and anthropogenic impacts on the coral reef system at the Abrolhos FHPA, between 2007 and 2010 DPIRD commenced implementation of 10 long term reef monitoring sites throughout the Abrolhos FHPA (Figure 4.1.1). The 10 sites include three sites in the Pelsaert Group, three in the Easter Group and four in the North Island / Wallabi Group, established to represent the sheltered lagoon and reef networks. The sites range in depth from 5m to 25m and consist of three permanently marked replicate 100m transects. Each site also has an in-situ temperature logger, recording every 20 minutes. Sites were surveyed in February each year, which is towards the peak of Abrolhos FHPA summer water temperature, using diver operated video (DOV) ~1m above the substratum. Between 2007 and 2012 the sites were surveyed annually and since 2012 the sites have been surveyed every three years.

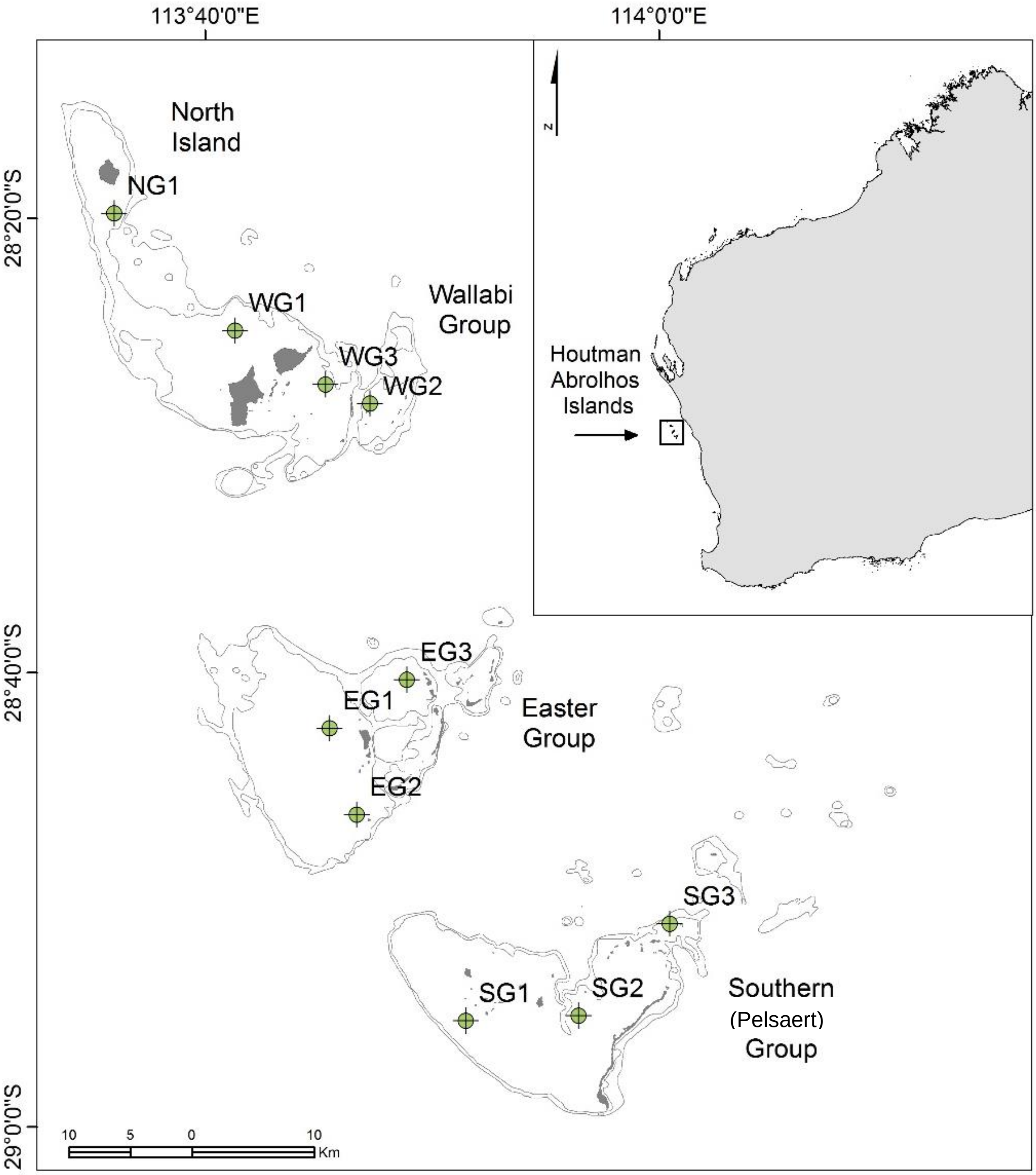

Figure 4.1.1. DPIRD long term benthic monitoring sites of the coral reefs of the Abrolhos FHPA. SG = Southern (Pelsaert) Group; EG = Easter Group; WG = Wallabi Group; NI = North Island.

Post collection, point-count software TransectMeasure© (http://www.seagis.com.au) was used to overlay an established matrix of points onto the video to discriminate benthic composition as percent cover. The analysis was undertaken on 40 frames per transect with the use of a 12-point matrix (4 x 3 points) per frame. Each of the points was then categorised into one of five main categories: hard coral (Scleractinia), soft coral, macroalgae, abiotic substrate, and other. The category 'abiotic substrate' consisted of sand, coral rubble, rock, relic reef, and dead hard coral. Whereas 'other' comprised of benthic organisms such as bryozoans, echinoderms, sponges, molluscs, seagrass and hydroids. Hard corals were further categorised to genera, morphotype (e.g., branching, plate) and health (e.g., signs of bleaching, disease and damage). The analysis was performed by trained hard coral analysts, with repeat and cross validation being performed regularly to help mitigate observer drift.

A summary of the long term trends from the DPIRD Abrolhos FHPA long term reef monitoring program is presented for six time points between 2008 and 2021. This includes two time points prior and four after the 2010/11 WA marine heatwave, which peaked in February to April 2011. A peer reviewed paper (Evans et al., *in prep*) will be submitted for publication in 2022 further detailing fine-scale trends and patterns of the coral reef systems of the Abrolhos FHPA.

4.1.2 *Results Summary*

The composition of the Abrolhos FHPA reef communities consists primarily of three broad classes; hard coral, macroalgae and abiotic substrate (Figure 4.1.2). Soft corals, sponges and all other subcategories of habitat comprised <5% each and were not examined further for this report. Between 2008-2010 and 2021, hard coral cover at the Abrolhos FHPA has shown a decrease from an average of 41.5% ± 3.7 (2008 - 2010) to 23.5% ± 3.3 in 2012 and 17.9% ± 3.9 in 2021 (Figure 4.1.2). Percent cover of algae at the Abrolhos FHPA also showed a decline following the 2010/11 WA marine heatwave from 25.0% ± 5.3 in 2008 to 15.9% ± 3.4 in 2012 (Figure 4.1.2). However, this has since increased to 45.7% ± 5.1 in 2021 (Figure 4.1.2).

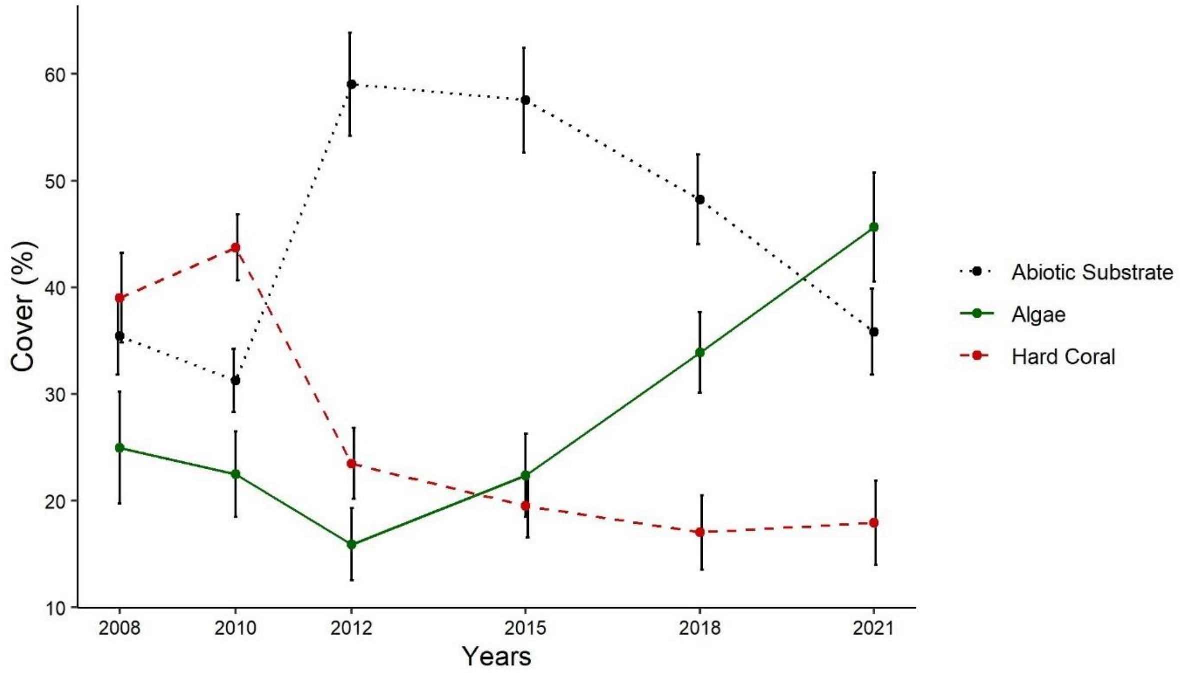

Figure 4.1.2. Benthic environment composition (percentage cover) of three broad benthos categories for the Abrolhos FHPA reef monitoring program between 2008 and 2021.

The initial impact to the Abrolhos FHPA from the 2010/11 WA marine heatwave varied between the monitoring sites. Declines in percent cover of hard coral were observed across all sites between 2010 and 2012 with the largest declines observed at the Pelsaert (Southern) Group (SG)2 site from 55.8% in 2010 to 0% in 2012 followed by the Wallabi Group (WG)3 and SG1 sites from 59.3% to 15.6% and 29.2% to 1.1%, respectively (Figure 4.1.3). The smallest decreases in hard coral cover were observed in SG3 (34.5% to 30.3%) and Easter Group (EG)2 (20.0% to 14.0%) (Figure 4.1.3) Since 2012, SG1 and SG2 hard coral cover increased from 0.4% ± 0.2% and 0.3% ± 0.2%, respectively, to 9.8% ± 3.9% in 2015 and 15.1% ± 4.0% in 2021 (Figure 4.1.3). However, this is still substantially lower than the hard coral cover observed in 2008 and 2010. WG3 has continued to decrease in hard coral cover with only 2.4% ± 0.7% in 2021 (Figure 4.1.3). Of the remaining seven sites, as of 2021, SG3 remained relatively stable with a decline in observed cover to 20.3%. Hard coral cover increases have also been observed at EG1, EG3 and WG2, with EG1 and WG2 at or near pre 2010/11 WA marine heatwave levels, 44.2% and 54.7% respectively (Figure 4.1.3). However, EG2, WG1 and North Island (NI)1 continue to show declines in percent coral cover. In 2021, EG2 and NI1 observed <0.5% coral cover, down from 20.0% and 30.5% (respectively) in 2010, while WG1 reported 2.6% coral cover in 2021, down from 56.4% in 2010 (Figure 4.1.3).

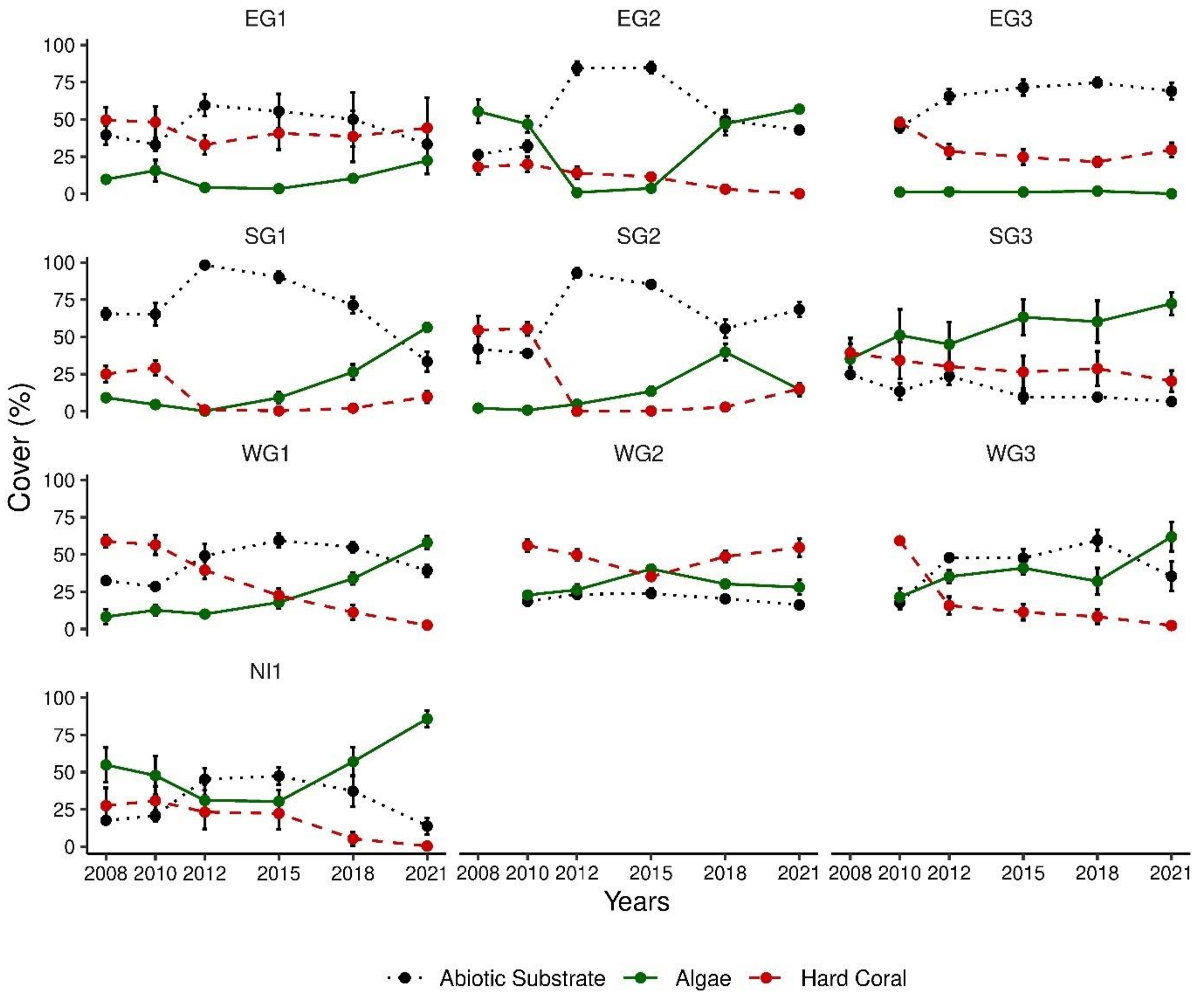

Figure 4.1.3. Benthic environment composition (percentage cover) of three broad benthos categories for the ten individual Abrolhos FHPA reef monitoring program sites between 2008 and 2021. *no data available in 2008 for EG3, WG2, WG3.

Algae cover increased following the impacts of the 2010/11 WA marine heatwave at all sites, except for EG3 which has had consistently low levels (Figure 4.1.3). The largest observed increases have occurred at SG1 with the proportion increasing from 4.6% in 2010 to 56.4% in 2021. Over the same time-period, WG1 increased from 12.7% to 58.1%, WG3 from 21.6% to 61.9%, NI1 from 48.0% to 85.8% and SG3 from 50.9% to 72.4% (Figure 4.1.3). Although an initial increase in algae cover was observed at SG2 between 2010 and 2018, levels have declined in 2021 in line with an increase in hard coral cover (Figure 4.1.3).

Overall, the DPIRD Abrolhos FHPA reef monitoring program has identified thirty-five hard coral genera (see Appendix A). From 2012, following the 2010/11 WA marine heatwave, hard corals in the genera *Acanthastrea, Alveopora, Astreopora, Echinopora, Leptoseris, Lobophyllia, Montigyra, Oxypora, Pavona, Platygyra, Turbinaria* were no longer observed in the monitoring program, whereas *Fungia, Pachyseris, Pectinia, Psammocora* were observed in 2021 and not in 2010 (Table 4.1.4 and 4.1.5, Appendix A). The hard coral genus *Acropora* is the most abundant genera observed in the Abrolhos FHPA reef monitoring program observed at between 25% to 30% cover in 2010 (Table 4.1.4) and 15% to 20% in 2021 (Table 4.1.4 and 4.1.5, Figure 4.1.4). The second most abundant genera were *Montipora* at 10-15% cover in 2010, however this decreased to <1% in 2021 (Table 4.1.4 and 4.1.5, Figure 4.1.4). Generic richness was highest in 2010 with 25 different genera recorded and lowest in 2021 with 18 genera recorded. Unknown and other coral genera comprised <1% of the biota in each survey year.

Table 4.1.4. Hard coral genera observed in 2010, in decreasing order of abundance.

Coral Genera - 2010 (10 Sites)				
Genera 25 - 30%	**Genera <1%**			
1. *Acropora*	3. *Porites*	9. *Pocillopora*	15. *Oxypora*	21. *Acanthastrea*
	4. *Favites*	10. *Galaxea*	16. *Lobophyllia*	22. *Leptoseris*
Genera 10-15%	5. *Echinopora*	11. *Turbinaria*	17. *Goniastrea*	23. *Montigyra*
2. *Montipora*	6. *Favia*	12. *Goniopora*	18. *Platygyra*	*24. Hydnophora*
	7. *Merulina*	13. *Mycedium*	19. *Alveopora*	25*. Pavona*
	8. *Cyphastrea*	14. *Echinophyllia*	20. *Astreopora*	

Table 4.1.5. Hard coral genera observed in 2021, in decreasing order of abundance.

Coral Genera - 2021 (10 Sites)				
Genera 15-20%	**Genera <1%**			
1. *Acropora*	2. *Montipora*	7. *Hydnophora*	12. *Goniopora*	17. *Pectinia*
	3. *Echinophyllia*	8. *Goniastrea*	13. *Porites*	18. *Pocillopora*
	4. *Merulina*	9. *Galaxea*	14. *Favites*	
	5. *Favia*	10. *Mycedium*	15. *Fungia*	
	6. *Psammocora*	11. *Cyphastrea*	16.*Pachyseris*	

At the Abrolhos FHPA level, the three algae categories reported (*Sargassum, Ecklonia* and 'Other' algae) showed different trends in percent cover change with *Sargassum* declining between 2008 (5.7% ± 2.4%) and 2012 (1.7% ± 0.9%) before increasing to 11.5% ± 3.7% by 2021 (Figure 4.1.4). *Ecklonia* declined after 2010 (~3.3% ± 1.9% between 2008-2010) and has since remained stable (~1.7% ± 1.2% between 2012-2021) (Figure 4.1.4). The percent cover of 'Other' algae has more than doubled since 2012, increasing from an average of 14.9% ± 3.2% between 2008-2012 to 32.5% ± 4.0% in 2021 (Figure 4.1.4).

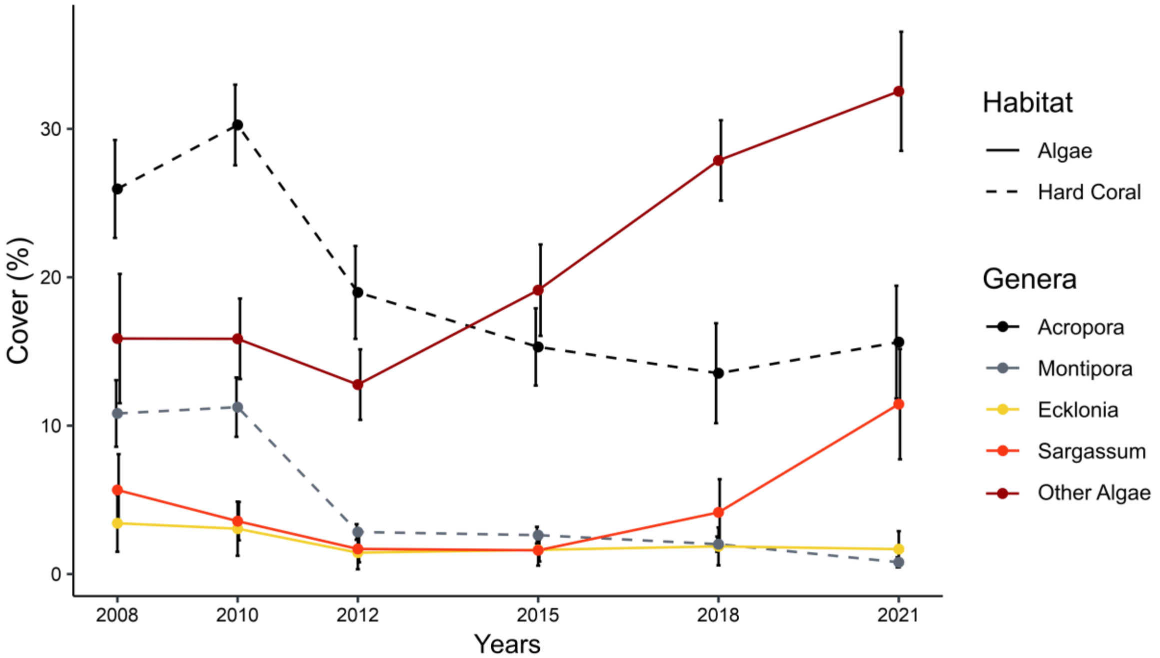

Figure 4.1.4. Benthic environment composition (percentage cover) of specific hard coral and algae genera categories for the Abrolhos FHPA reef monitoring program between 2008 and 2021. Hard coral biota, *Acropora* and *Montipora,* indicated by dashed lines.

Since 2008 there have been varied responses to the percent cover of the two dominant hard coral genera (*Acropora* and *Montipora*) throughout the 10 monitoring sites. Between 2010 and 2021 *Acropora* has declined at a number of sites including, WG1 (37.5% to 0.1%), NI1 (27.4% to 0.0%), WG3 (21% to 0.3%), SG3 (30.3% to 17.3%) and EG2 (10.6% to 0%) (Figure 4.1.5). *Acropora* also declined at SG2, EG3 and SG1 between 2010 – 2018, however these sites observed a slight increase between 2018 and 2021 (Figure 4.1.5). The percent cover of *Acropora* at EG1 and WG2 fluctuated throughout the surveys but is observed at similar levels in 2008 / 2010 and 2021 (Figure 4.1.5). Declines in the percent cover of *Montipora* was observed at all sites from a mean of 11.2% ± 3.2% in 2010 to 0.8% ± 0.4% in 2021, with all sites except EG1, EG3 and SG3 now observing <0.5% cover. Substantial declines were observed at WG3 (36.2% to 0.4%), SG2 (18.5% to 0.0%), WG1 (13.3% to 0.0%), EG1 (14.9% to 1.0%), and EG2 (6.3% to 0%) (Figure 4.1.5).

At a site level, *Ecklonia* cover was low at all sites apart from SG3, which averaged 25.1% between 2008-2010 and 14.8% in 2021(Figure 4.1.5). In 2010, *Sargassum* cover comprised ≤5% for all sites except NI1 and WG2. At NI1 *Sargassum* ranged from 22.3% in 2008 to 7.5% in 2015 before increasing to 28.9% in 2018 and 62.2% in 2021. At WG2 *Sargassum* cover peaked at 8.6% in 2010 before steadily decreasing to 0% in 2018 followed by an increase to 2.6% in 2021 (Figure 4.1.5). As of 2021, *Sargassum* cover has also increased to >5% at SG1 and WG1 to 20.3% and 13.8%, respectively (Figure 4.1.5). Observations of the percent cover of 'Other' algae species has been variable throughout sites and years, with little variation observed at EG3 and NI1, whereas other sites have shown a marked increased between 2010 and 2021; SG3 (19.4% to 53.6%), WG1 (10.7% to 44.3%) and WG3 (16.9% to 57.1%) (Figure 4.1.5). The remaining sites have had mixed responses with smaller gradual increases observed in EG1 and SG1, while WG2 and SG2 showed initial increases (until 2015 and 2018 respectively) followed by decreases to near pre-2010/11 WA marine heatwave levels by 2021 (14.2% to 25.5% and 0.9% to 9.6%, respectively). In contrast, EG2 showed a steep decline between 2010 and 2012 (45.4% to 0.8%) and a subsequent increase in 2018 and 2021 to near pre-2010/11WA marine heatwave levels (2021 = 56.9%) (Figure 4.1.5).

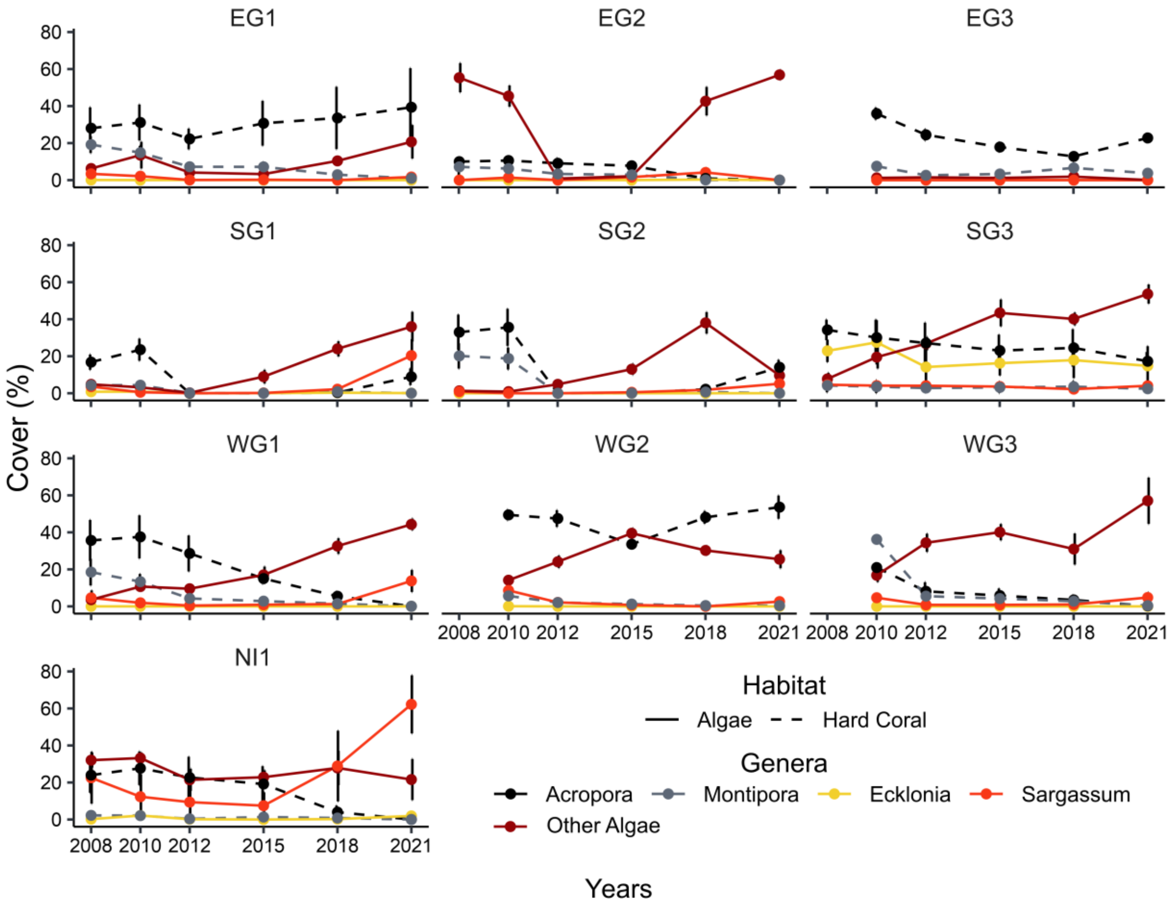

Figure 4.1.5. Benthic environment composition (percentage cover) of specific hard coral and algae genera categories for the ten individual Abrolhos FHPA reef monitoring program sites between 2008 and 2021. *no data available in 2008 for EG3, WG2, WG3. Hard coral biota, *Acropora* and *Montipora,* indicated by dashed lines.

Data from this Abrolhos FHPA reef monitoring program shows a varied response and recovery of the Abrolhos FHPA reef system to the 2010/11 WA marine heatwave, with a slow recovery of hard corals, at most sites, and a trend for an increase in percent cover of algae. Further analysis of the long-term trends will be reported through a peer-reviewed publication in 2022 (Evans et al., *in prep*). Based on the data presented in this report, a precautionary level of anthropogenic association (e.g., commercial fishing, aquaculture and recreational activities) in relation to the Abrolhos FHPAs coral reefs will provide the opportunity for the ecosystem to recover, whilst allowing for the continued social and economic benefits that this ecosystem provides.

4.1.3 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to Coral Reef Monitoring and the Abrolhos FHPA:

- Maintain the Abrolhos FHPA hard coral reef monitoring program to inform long term ecological trends
- Review the current program to determine if the spatial scale is adequate to address management needs e.g.,
    - Is the spatial resolution of sites adequate to quantify abundance and distribution of coral reef habitats, particularly in high use or highly sensitive areas?
    - Is there a need to expand to include algal dominated sites to monitor for long term ecological trends across the diversity of Abrolhos FHPA benthic environments?
- Implement precautionary levels of permitted extractive activities (e.g., commercial fishing, aquaculture and recreational activities) on the Abrolhos FHPAs coral reefs to mitigate ecological pressures and allow recovery, whilst allowing for the continued social and economic benefits

4.2 Hard Coral Recruitment

4.2.1 *Program Description*

Hard corals at the Abrolhos FHPA are likely self-recruiting, with large scale coral larval input from the tropical north limited due to its regional isolation, despite the influence of the Leeuwin Current (Markey et al., 2016). Further, localised genetic patchiness described by Thomas et al. (2015), particularly in the Pelsaert Group, suggest a greater reliance on self-recruitment both between and within the island groups. Historically, the Abrolhos FHPA has reported low levels of coral recruitment from broadcast spawning corals (e.g., *Acropora* or *Pocilloporids*) (Harriott & Simpson, 1997), consistent with other Australian sub-tropical reefs (Cameron & Harrison, 2016). A study by Harriot and Simpson (1997) reported that from 54 pairs (n=108) of ceramic recruitment tiles deployed in March 1994 across three sites of the Easter Group at the

Abrolhos FHPA (East, Central / Rat Island, West) only 68 recruits were recorded, with mean recruitment rates of 0.3 to 5.4 recruits per tile. The highest recruitment was observed at the Central / Rat Island location with, overall, recruits identified as *Acropora* (83%), *Pocilloporids* (15%) and unidentified (2%) (Harriott & Simpson, 1997).

Hard coral communities (particularly *Acropora*) at the Abrolhos FHPA are important for aspects such as structural complexity and reef building capacity, therefore understanding patterns of local larval dispersion and coral recruitment into the ecosystem is required, particularly in a changing environment with limited ability for thermal tolerant corals to travel south to assist with recovery (Markey et al., 2016). This may be of further importance for high latitudinal reefs where macroalgae increases, as seen at the Abrolhos FHPA following the 2010/11 WA marine heatwave (section 4.1 of this report), and low recruitment levels of hard corals may limit the capacity of these reefs to recover (Hoey, 2011). To understand these relationships at the Abrolhos FHPA, in February 2011 DPIRD commenced a seven year study to examine coral recruitment levels in the Easter Group.

4.2.2 *Methodology and Results Summary*

Three sites were selected to assess coral recruitment, Back of Rat, Sandy Island and Home Reef (Figure 4.2.1). These sites were selected to represent existing DPIRD long term reef monitoring sites (Back of Rat = EG1, Sandy Island = EG2) as well replicating sites described in Harriot and Simpson (1997) (Back of Rat = Western, Home Reef = Central / Rat Island). For the DPIRD study, each site consisted of three replicates, spaced at least 25 m apart, with five (120 x 120 x 10 mm) unglazed terracotta tiles installed 20 mm above a cement block and held in place by a central bolt (Mundy, 2000). Each site was between 8 and 12 m deep with tiles deployed in the summer (January or February) and retrieved in May of the same year, allowing >3 months for recruitment over the major coral spawning period (March/April) along the WA coast (Rosser, 2012). Tiles were carefully retrieved and sandwiched in situ into high density foam, transported to the surface, fixed in a chlorine solution and transported to the laboratory for analysis. Data was collected for six of the seven survey years of the study, with tiles not deployed in 2016. In the laboratory, the coral tiles were examined using a microscope with digital camera. A 10 x 10 grid was used on the top and underside of each tile, with each segment counted separately to prevent miscalculation. The sides of the tile were labelled and counted as 1 to 4. Coral recruits were identified to genus (where possible).

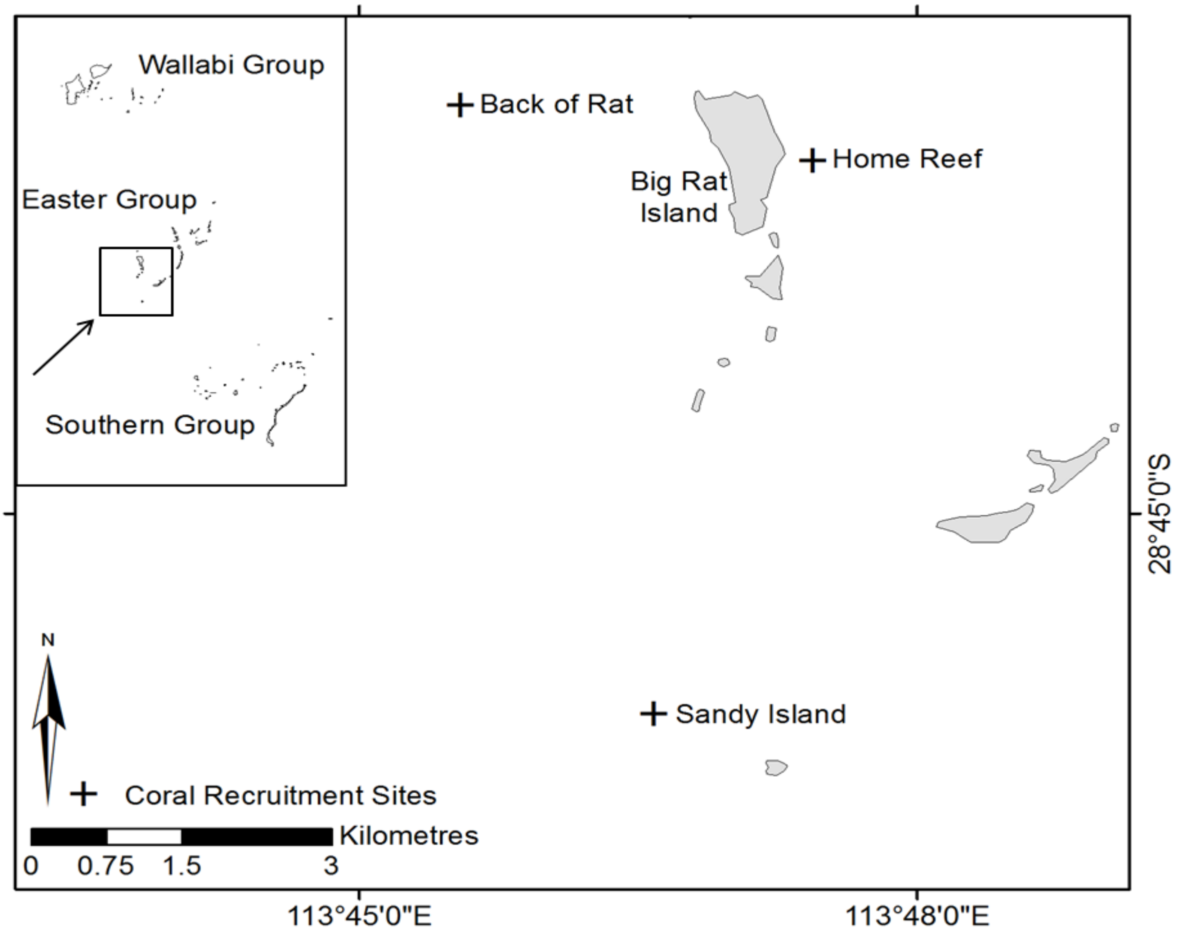

Figure 4.2.1. Abrolhos FHPA Easter Group coral recruitment sites.

Over the six survey periods, 99.8% of corals identified were *Acropora*, with the remaining 0.2% either *Pocilloporids* (nine individuals in total) or unidentified (Figure 4.2.2). Recruitment was lowest in 2011 (coinciding with the 2010/11 WA marine heatwave) with a mean of 0.42 hard coral recruits per tile and highest in 2013 at 133.47 recruits per tile. The remaining years observed a mean of ~20 recruits per tile per year, with the exception of 2017 when 1.7 recruits per tile per year were observed (Figure 4.2.2). Recruitment was strongest at the Home Reef site, with an exceptionally high recruitment year in 2013 (mean of 306.5 recruits per tile; Figure 4.2.2). The Back of Rat site recorded the next highest levels of recruitment, with Sandy Island recording the lowest levels of recruitment (Figure 4.2.2). This is consistent with that reported by Harriot and Simpson (1997) in relation to their Central / Rat Island and West sites, and expected based on Sandy Island (EG2) having less hard coral cover than Back of Rat (EG1) (section 4.1 of this report). Recruitment was also highly variable between years (Figure 4.2.2) supporting the theory that localised broadcast spawning at high latitudinal reefs, such as the Abrolhos FHPA, is not consistent.

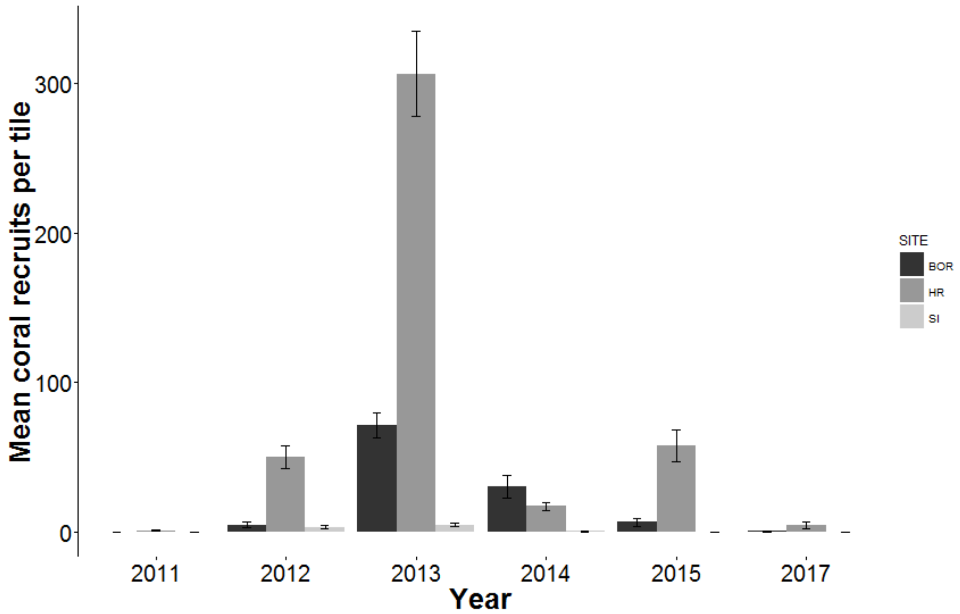

Figure 4.2.2. Mean numbers of coral recruits, per tile, for all Easter Group sites, 2011-2015, 2017. BOR = Back of Rat; HR = Home Reef; SI = Sandy Island.

4.2.3 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to Coral Recruitment and the Abrolhos FHPA:

- Investigate the need for a new three-year study to examine hard coral recruitment to the Abrolhos FHPA
- Investigate expanding coral recruitment program to include other island groups and genetic linkages
- Investigate factors that may influence broad scale hard coral recruitment patterns to the Abrolhos FHPA

4.3 Habitat Mapping

There is currently a paucity of recent (<5 years old) habitat maps that describe the spatial extent and / or abundance of the habitats and geomorphological structures of the Abrolhos FHPA. Historically, broad scale habitat mapping for the Abrolhos FHPA has been undertaken for specific one-off purposes, such as associating human uses with the shallow water reef habitats (Hatcher et al., 1988) or identifying the environment of deeper water potential aquaculture sites (BMT Oceanica, 2017; DPIRD, 2020b). In addition, a range of one-off scientific programs, which also assist with informing aquatic resource management decisions, have been undertaken such as the deeper water hydroacoustic Marine Futures program (Radford et al., 2008) and the DPIRD Wallabi Islands satellite remote sensing mapping (Evans et al., 2012). Recently advances in technology have allowed for the use of high-resolution satellite imagery and advanced analytics to map and monitor the worlds coral reefs, such as the Allen Coral Atlas (Allen Coral Atlas, 2020) which provide an excellent baseline for mapping but can lack availability of in-situ validation data to assess accuracy.

In the absence of a current validated Abrolhos FHPA specific mapping and monitoring program, available habitat mapping data sources are provided as a guide to the types of broad scale habitats and their spatial distribution within the Abrolhos FHPA. For detailed descriptions of the mapping methodology please refer to specific references. It should be noted that many of these data sources are more than 5-10 years old and the applicability, particularly of the biota descriptions, may be out-dated.

4.3.1 *Abrolhos Shallow Water (<20m) Biota and Geomorphological Mapping*

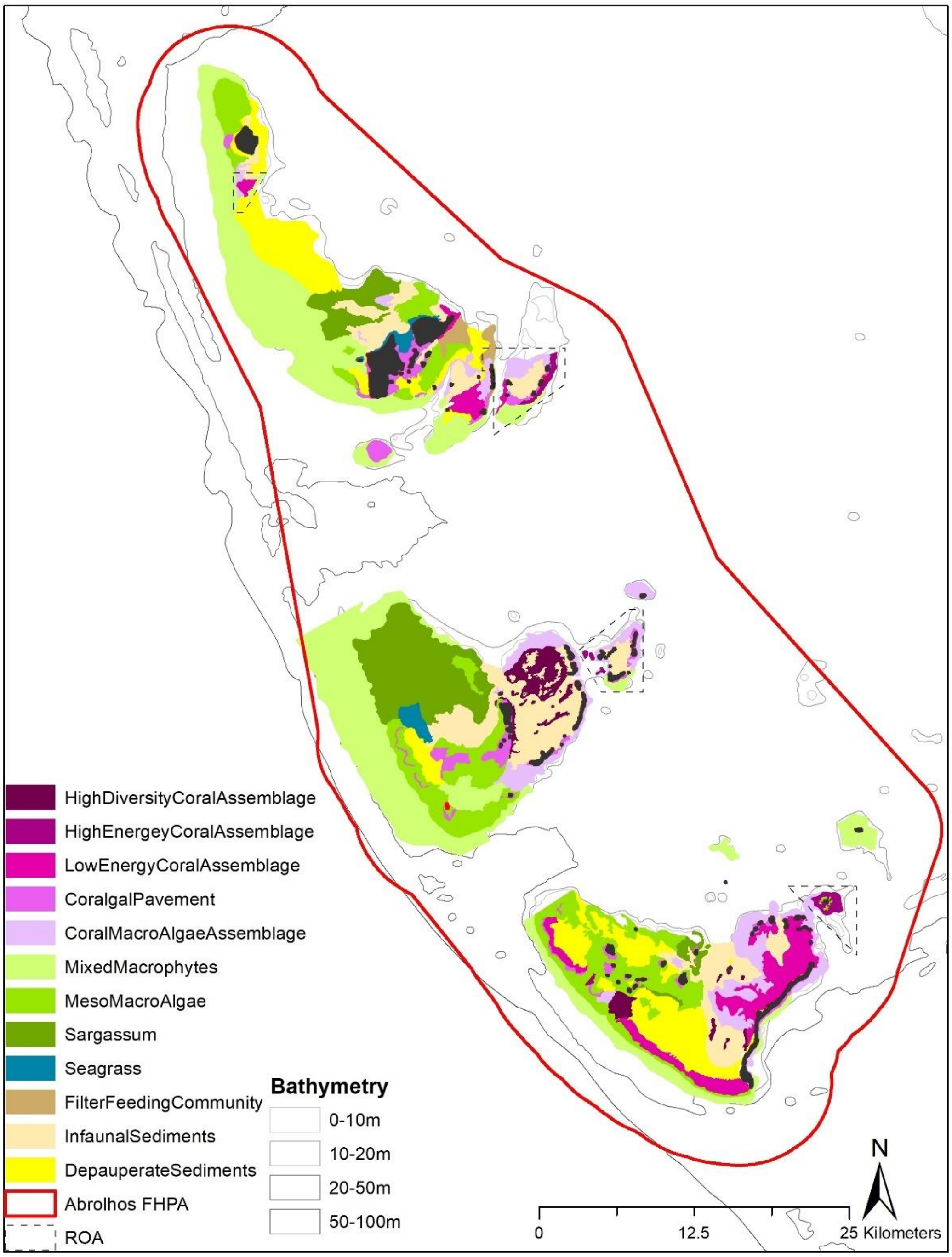

Figure 4.3.1. Hatcher et al*.* (1988) – Biota Mapping - All Groups.

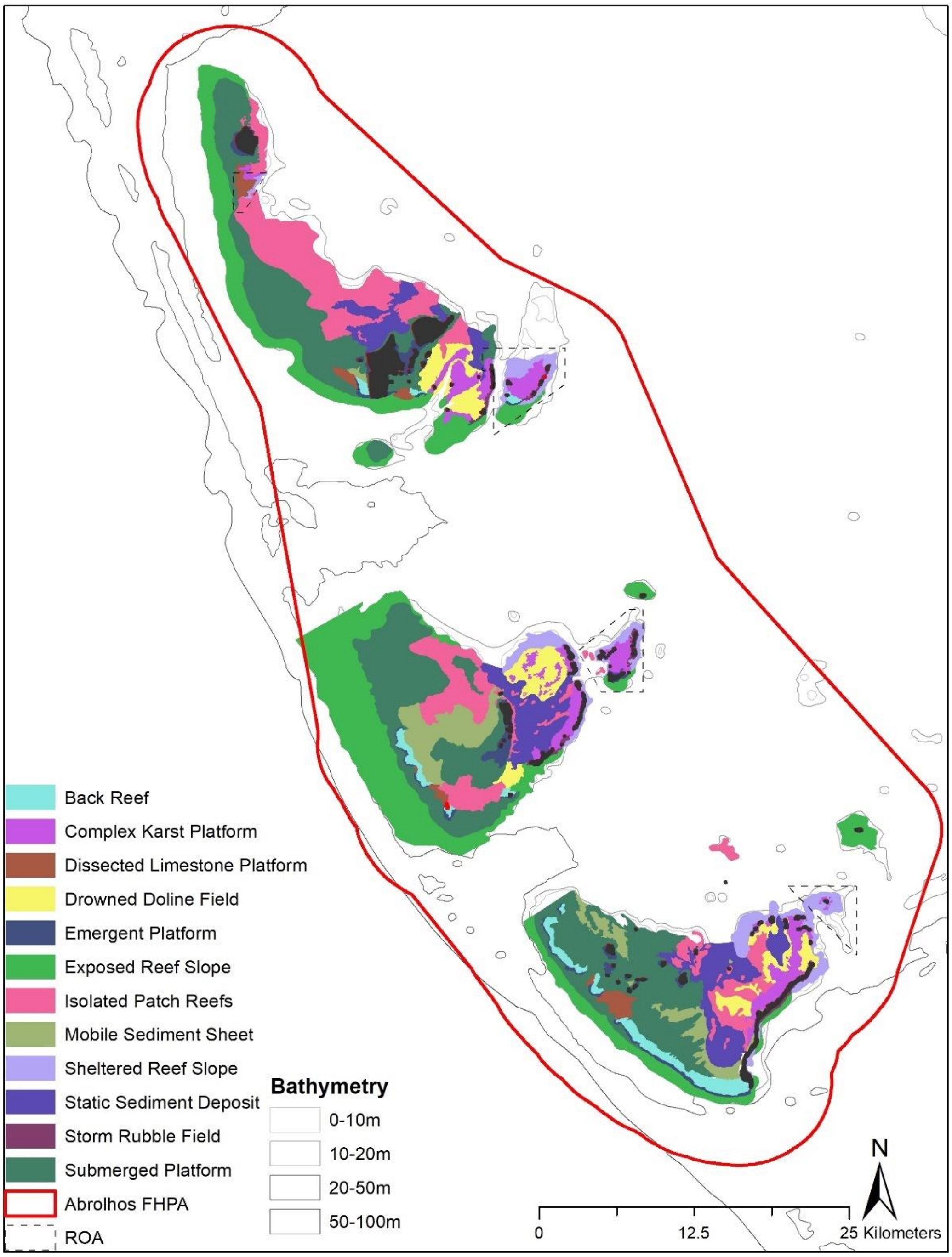

Figure 4.3.2. Hatcher et al. (1988) Geomorphological Mapping – All Groups.

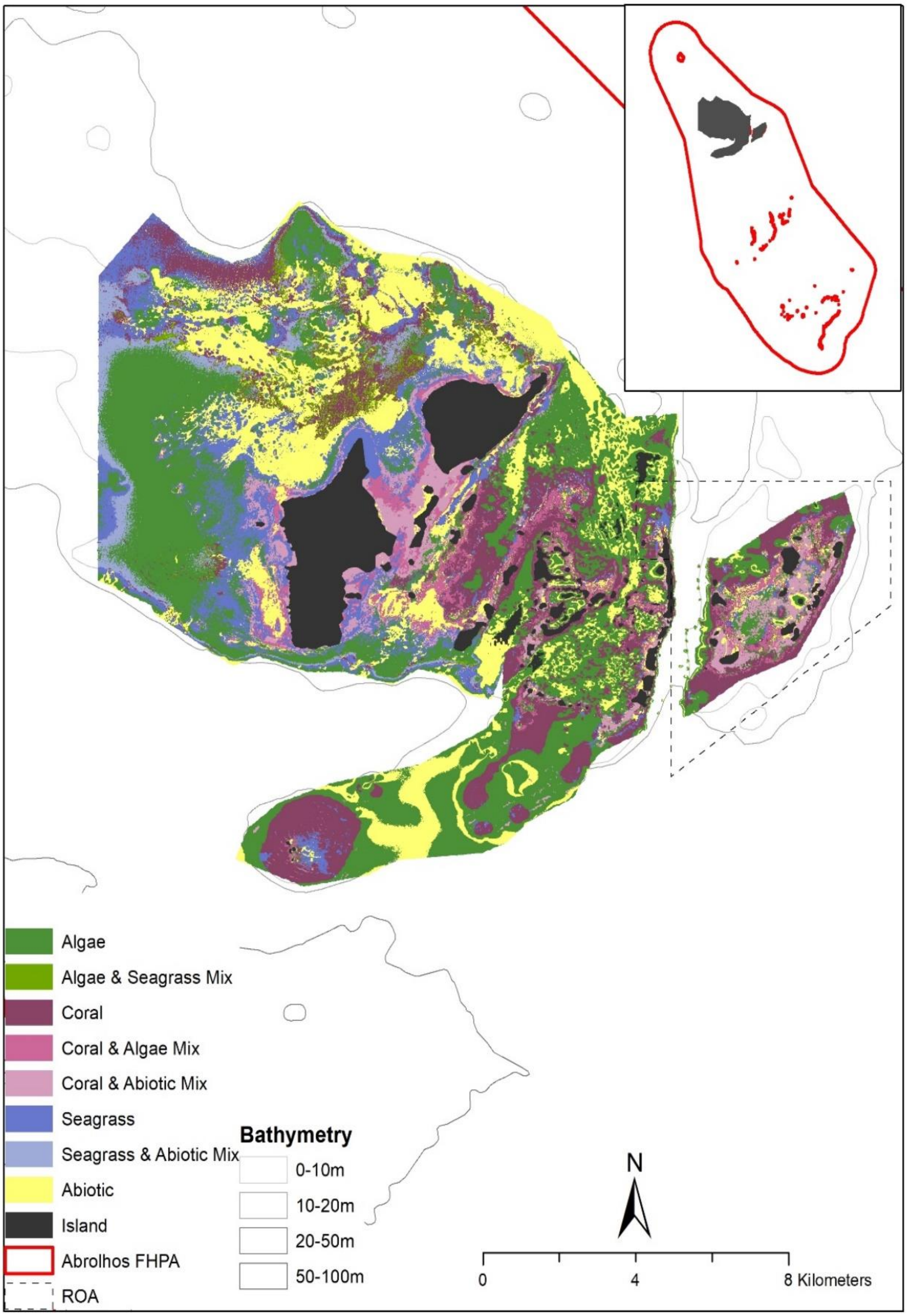

Figure 4.3.3. Evans et al. (2012) – Biota Mapping – Wallabi Islands.

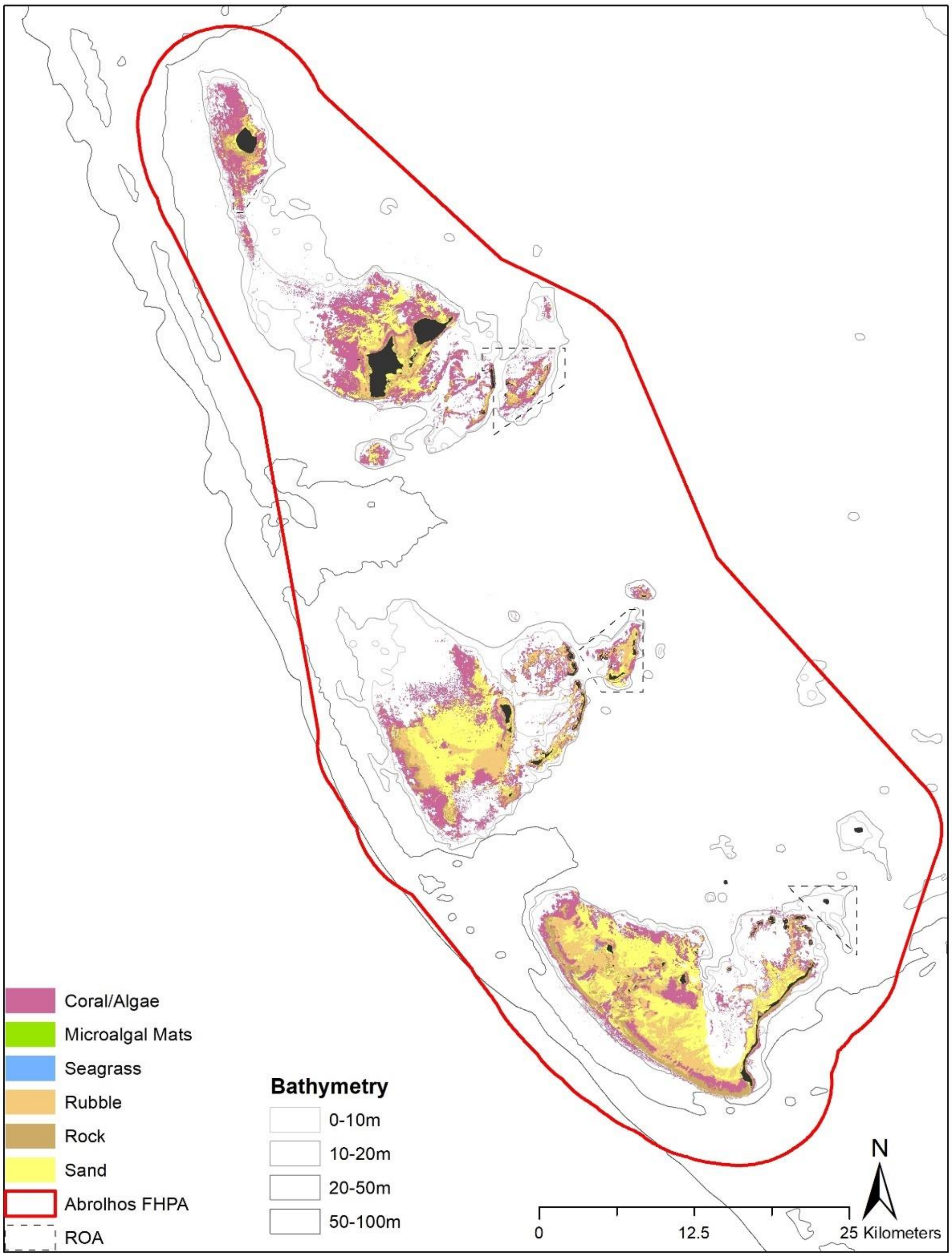

Figure 4.3.4. Allen Coral Atlas (2020) – Biota Mapping - All Groups.

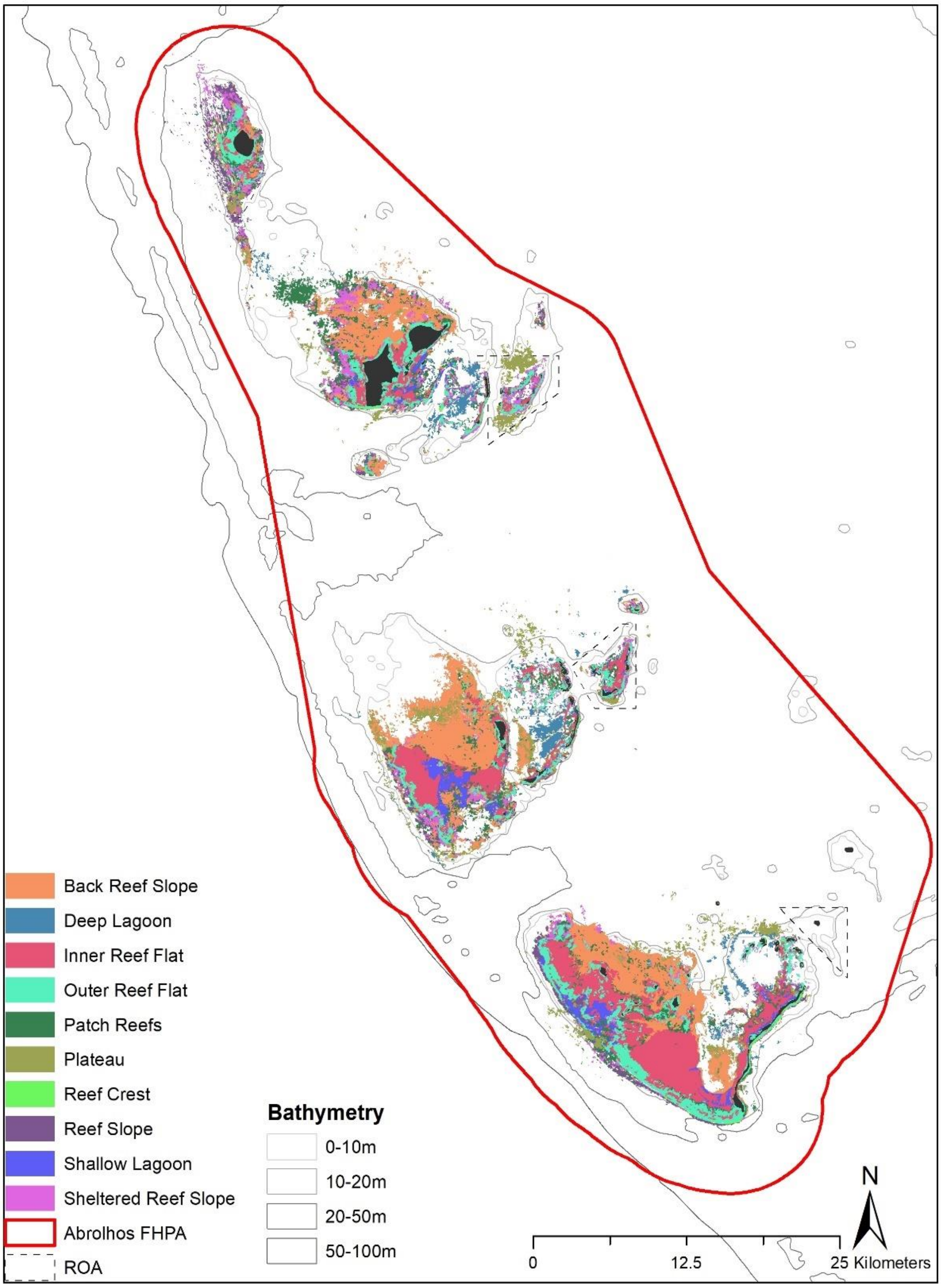

Figure 4.3.5. Allen Coral Atlas (2020) – Geomorphological Mapping - All Groups.

4.3.2 *Abrolhos Deep Water (>20m) Biota and Geomorphological Mapping*

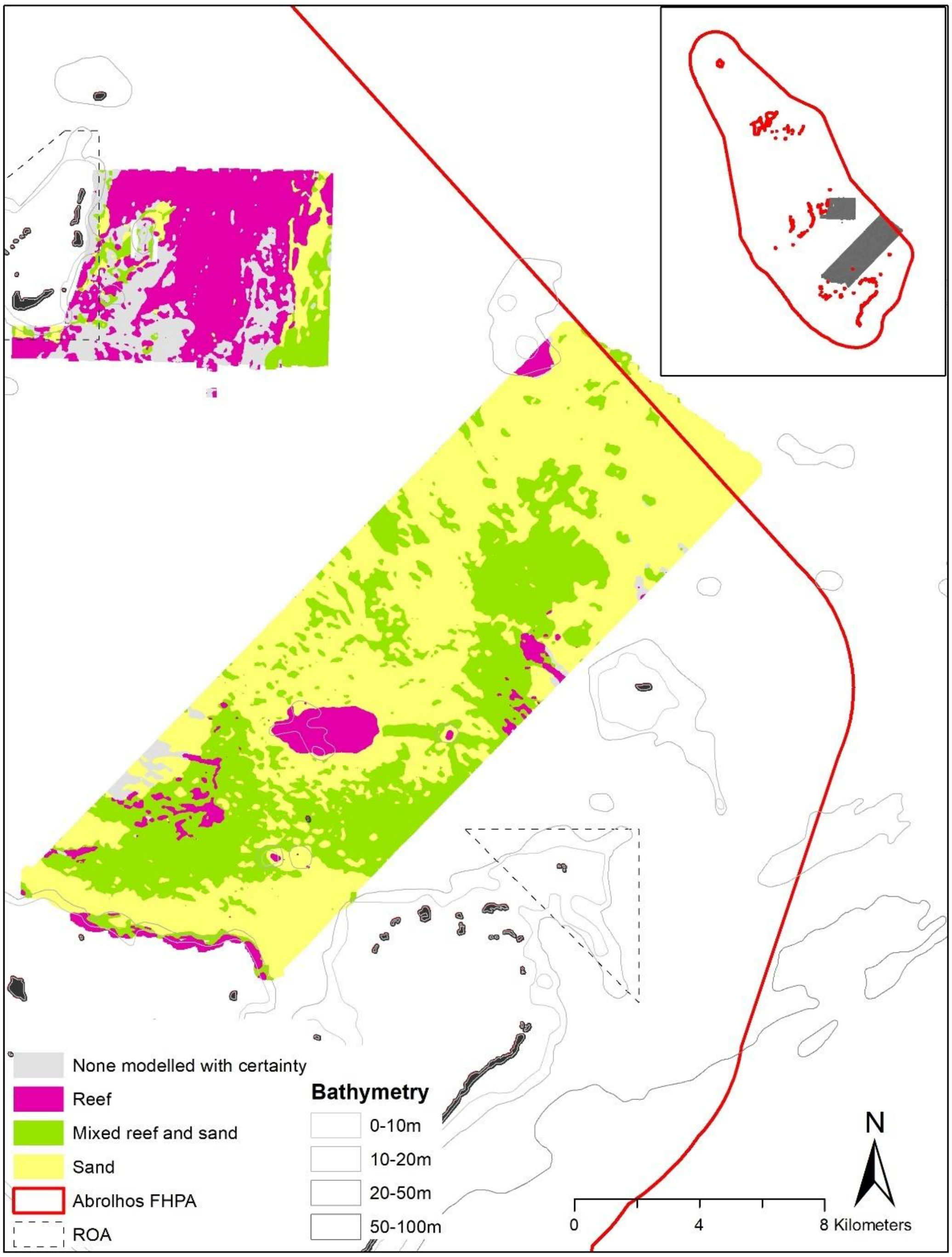

Figure 4.3.6. Radford et al. (2008) – Habitat Mapping - Zeewijk channel**.**

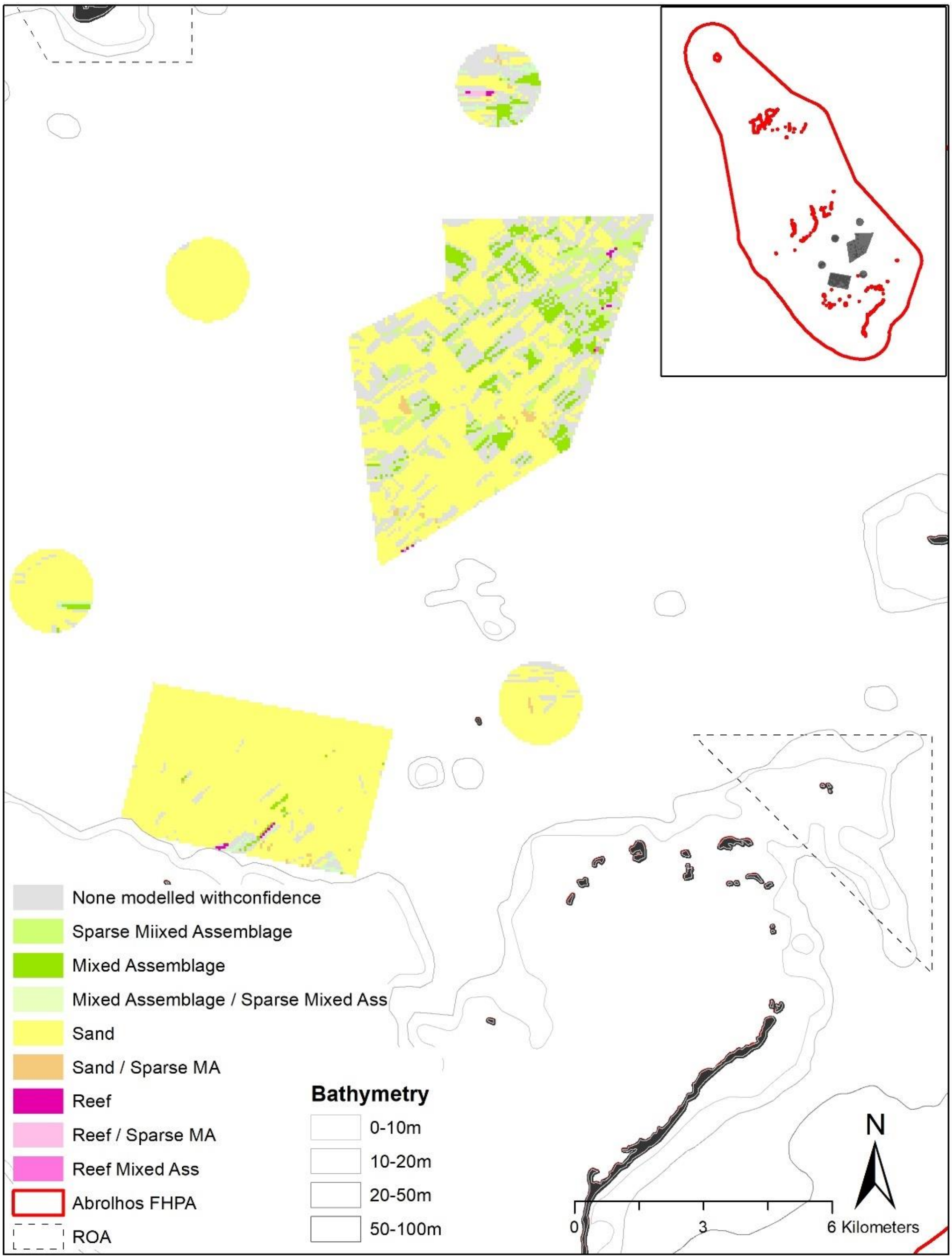

Figure 4.3.7. BMT (2017) and DPIRD (2020b) - Habitat mapping - Zeewijk channel.

4.3.3 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendation in relation to Habitat Mapping and the Abrolhos FHPA:

- Prioritise the development of ongoing habitat mapping and monitoring (at an appropriate scale) of the Abrolhos FHPA to support fisheries, aquatic resources and ecosystem management

4.4 Relative Abundance of Key Target Demersal Finfish Species – Long Term Monitoring of ROAs

4.4.1 *Program Description*

The demersal finfish assemblages of the Abrolhos FHPA are influenced by both its temperate geographic location and the southward flowing Leeuwin Current which brings warm waters from the north to moderate the winter water temperatures. This unique convergence of aquatic zones supports over 389 finfish species, of which 66% are tropical, 19% warm temperate and 13% subtropical (Hutchins, 1997; Watson & Harvey, 2009). Although it has been reported that tropical species at the Abrolhos FHPA are reliant on the Leeuwin Current to deliver recruits (Hutchins, 1997), studies have also shown a reliance on self-recruitment for at least some species, with the key targeted species *Plectropomus leopardus* (common coral trout) able to sustain a breeding population that is genetically distinct from northern populations (van Herwerden et al., 2006). The Abrolhos FHPA also provides important spawning grounds for many species including the WA endemic sub-tropical *Choerodon rubescens* (baldchin groper) and temperate *Glaucosoma hebraicum* (WA dhufish). In addition to state-wide regulations, there are a suite of specific regulations to the Abrolhos FHPA, including spatial closures (e.g., ROAs), temporal (seasonal) closures, and bag and possession limits, which aim to further support these unique finfish assemblages.

With the designation of the Abrolhos FHPA ROAs in 1994 to support the protection of localised fish species and areas of high-quality reef for observation and appreciation by visitors (DoF, 1998), the monitoring of the effectiveness of these spatial closures for localised finfish assemblages continues to be supported by DPIRD. An initial study by Nardi et al. (2004) used a before-after-control-impact experimental design to examine the response of two finfish species, *Cho. rubescens* and *P. leopardus* to protection from the ROAs in the Wallabi (n=1) and Easter Groups (n=1). Data were collected by underwater visual census from two surveys before closure (1993 and 1994) and four subsequent surveys between 1995 and 2002 (Nardi et al*.,* 2004). The study found contrasting effects of the ROAs with protection having no effect for *Cho. rubescens* over the entire study period while *P. leopardus,* which initially (first three years) showed no effect, showed a significant increase in abundance in the ROAs after eight years of protection, with a three-fold increase at the Easter Group and seven-fold increase in the Wallabi Group (Nardi et al., 2004). These results were supported by a survey conducted five years later (2007), utilising stereo-DOV over a single sampling period, which showed the Easter and Wallabi Group ROAs had variable responses for *Cho. rubescens* (Shedrawi et al., 2014). Interestingly, this study showed for the North Island ROA, there was no significant difference inside or outside for either species after 13 years of protection (Shedrawi et al., 2014), suggesting fish biology, movement and habitat association may also influence the effectiveness of the ROAs in supporting these two localised targeted finfish species.

In 2004, a stereo baited remote underwater video (BRUV) survey was developed to record the relative abundance and length of finfish inside and outside of the Abrolhos FHPA ROAs (Watson et al., 2007). Stereo-BRUV is a non-lethal, fishery independent technique that reduces observer bias and can provide highly accurate measurements of finfish through photogrammetry (Harvey & Shortis, 1995). As a methodology, stereo-BRUV has been found to be more effective at sampling key target species including *P. leopardus, Chrysophrys auratus* (pink snapper) and *Lethrinus nebulosus* (spangled emperor) at the Abrolhos FHPA and were also found to be more cost-effective and time-efficient than stereo-DOV (Langlois et al., 2010). As with the Nardi et al*.* (2004) and Shedrawi et al. (2014) studies, initial results from a two-year BRUV program in November 2004 and May 2005 found contrasting results to protection from the ROAs (Watson et al., 2007; Watson et al., 2009). For relative abundance, Watson et al. (2007) observed mixed responses to protection for six target fish species, dependent on survey month (2004 = November; 2005 = May), depth and target species. However, overall, the relative abundance of many of the target species within ROAs were greater compared with outside, particularly *G. hebraicum* (3.5-fold and 8-

fold in November 2004 and May 2005, respectively), *P. leopardus* (1.2-fold and 2.8-fold) and *L. nebulosus* (1.5-fold and 2.1-fold) (Watson et al., 2007). For length, five of the six targeted fish species (*Cho rubescens, Lethrinus miniatus* (redthroat emperor)*, L. nebulosus, Chr. auratus* and *P. leopardus)* were, on average, 48 mm (10%) larger inside ROAs than in areas open to fishing (Watson et al., 2009). This trend of contrasting protection of the ROAs for target finfish species was also observed from long term BRUV data (2005-2010, 2013) on the same sites developed by Watson et al. (2007) where target species were generally larger in ROAs versus open to fishing (with the exception of *Cho. rubescens* and *G. hebraicum*) but not consistently more abundant (Bornt et al., 2015).

Since 2015, DPIRD, has maintained the Abrolhos FHPA ROA's stereo-BRUV survey on a biennial basis to monitor trends in the responses of target finfish species to protection. This report provides an update of these trends for six targeted demersal finfish species (*Cho rubescens, L. miniatus, L. nebulosus, Chr. auratus, G. hebraicum* and *P. leopardus)* from each island group between 2015 and 2019.

4.4.2 *Methodology*

The survey sites, sampling technique and video analysis for data collected by DPIRD from 2015 follows that of Bornt et al. (2015) for consistency of reporting. Surveys were undertaken in May of each year (2015, 2017, 2019). At three of the groups (Pelsaert, Easter and Wallabi) five replicate drops were set in both deep (22-26m) and shallow (8-12m) areas over each of the four sites within the group (one inside the ROA, three outside), for a total of 120 stereo BRUV deployments (Figure 4.4.1). As with Bornt et al. (2015), an additional 20 BRUV deployments (four sites with five replicates) were undertaken in the shallow areas only at North Island due to insufficient comparable deep locations (Figure 4.4.1).

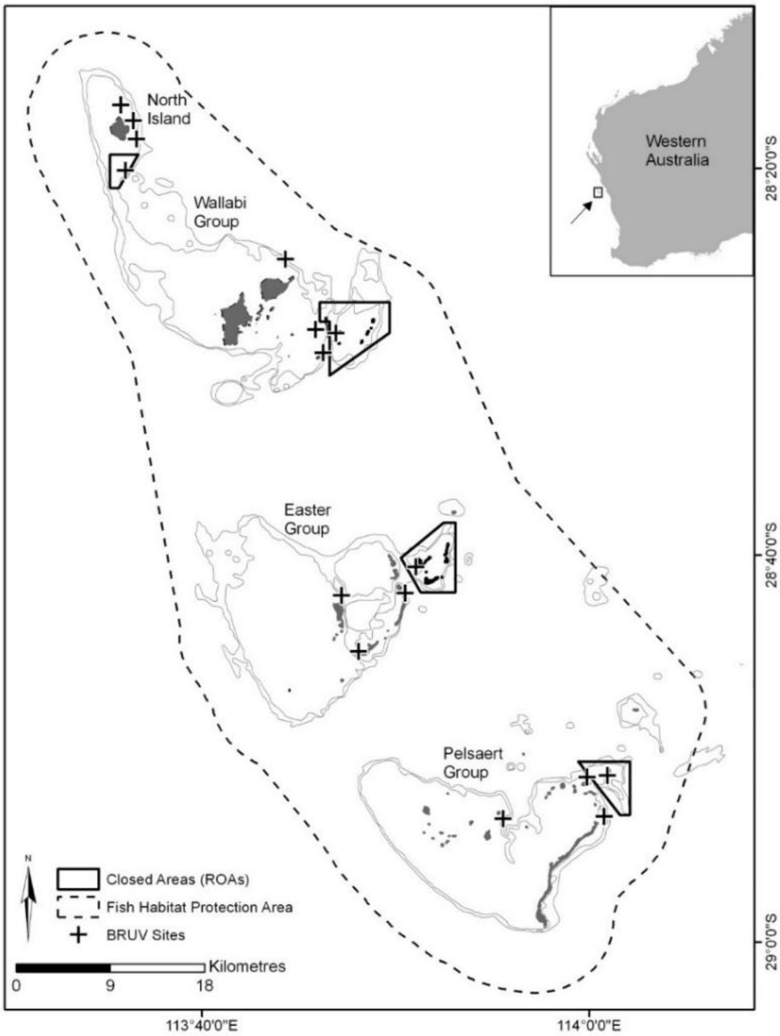

Figure 4.4.2. BRUV survey locations within the Abrolhos FHPA.

The stereo-BRUV systems used were equipped and calibrated, following standard protocols, with two high-definition cameras directed 8 degrees inwards and mounted 0.7m apart on a base bar with a wire bait basket attached to PVC electrical conduit positioned 1.2 m from the centre (Harvey & Shortis, 1998; Shortis et al., 2009) For the 2015 – 2019 surveys, ~800 g of crushed pilchards (*Sardinops spp.*) was used as bait per individual stereo BRUV deployment to match previous surveys. Field sampling was completed between 08:00 and 16:30 each day over a five-day period, with ten stereo-BRUV systems deployed concurrently, at a minimum separation of 250 m, and left on the benthos to record for 65 minutes. Captured video footage was analysed using the purpose-built software EventMeasure™ (SeaGIS, 2011) to identify the relative abundance (MaxN) and lengths of the six targeted demersal fish species across all BRUV deployments. To ensure that the sampling unit was standardised, only target finfish within 7 m of the camera were counted and measured. Relative abundance was calculated as the mean MaxN per deployment for each individual target species and for 'target species cumulative' which was calculated by summing the MaxN of all six target species at each deployment. Depending on species, fork length (FL) or total length (TL) measurements were taken at the time of MaxN to avoid measuring any individuals more than once. As TL is used as the minimum legal length (MLL) for retention of finfish in WA, FL measurements were then converted to TL using the parameters derived from boat ramp survey measurements (Smallwood et al., 2018). Kernel Density Estimates of the length frequency data was performed and plotted using the ggplot2 package (Wickham, 2016) for R.

Stereo-BRUV data presented in this report before 2015 is reproduced from DPIRD collaborations with the authors and institutes of the Watson et al. (2007) and Bornt et al. (2015) studies and is based on the methodologies and results provided within those publicly available, peer reviewed publications.

4.4.3 *Results Summary*

Between 2015 and 2019 a total of 3653 individuals (fished: 2585, ROA: 1068) were observed of the of the six target species (Table 4.4.1). The most abundant species observed was *P. leopardus*, regardless of protection status, for 2015 and 2017, while *Chr. auratus* were the most abundant species in both areas in 2019 (Table 4.4.1). This is a similar result to that observed in Bornt et al. (2015), where *P. leopardus* was the most abundant species amongst all survey years, except 2007 where *Chr. auratus* were more abundant in the fished areas. *Plectropomus leopardus* were also the most commonly encountered species inside the ROAs, present on >90% of deployments while *Cho. rubescens* was the most commonly encountered species in areas open to fishing, present on ~80 – 90% of deployments between 2015 and 2019 (Table 4.1.1). *Glaucosoma hebraicum* were the least observed species, with a total of 17 individuals between 2015 and 2019 which represents <1% of the total observed target species, and the least commonly encountered, present at < 3% of the fished area deployments and < 6% of the ROA deployments in the last three surveys (Table 4.4.1). Approximately 70% of the total MaxN drops were able to be analysed for length measurements. The number of length measurements for each species reflected the relative abundance with *P. leopardus* and *Cho. rubescens* having the most and second most measurements respectively (Table 4.4.1). Regardless of protection status, *L. miniatus* consistently had the highest percentage of measurements above the minimum legal length (MLL:280 mm) with 90-100% measured as legal size between 2015 and 2019 (Table 4.4.1). *Plectropomus leopardus* had the lowest percentage of measurements above MLL (450 mm) with ~20% measured as legal size in fished areas and ~30-40% in ROAs between 2015 and 2019 (Table 4.4.1).

Table 4.4.2. Annual relative abundance (MaxN) and measured lengths of six target species in fished areas (n= 105) and ROAs (n=35), between 2015 and 2019**.**

		2015		2017		2019	
		Fished	**ROA**	**Fished**	**ROA**	**Fished**	**ROA**
Total number of individuals observed	*Cho. rubescens*	197	77	232	67	156	60
	Chr. auratus	185	37	193	31	256	124
	G. hebraicum	4	2	5	2	4	0
	L. miniatus	87	25	55	26	22	11
	L. nebulosus	132	63	113	43	106	81
	P. leopardus	359	207	289	95	190	117
	Total (all species)	964	411	887	264	734	393
	Mean MaxN all target species per BRUV	9.3	11.7	8.4	7.5	7.6	11.2
Present at % of deployments	*Cho. rubescens*	85.6	88.6	82.9	74.3	80.2	80.0
	Chr. auratus	41.3	31.4	42.9	37.1	57.3	68.6
	G. hebraicum	2.9	5.7	2.9	5.7	3.1	0.0
	L. miniatus	34.6	40.0	27.6	40.0	15.6	22.9
	L. nebulosus	43.3	51.4	32.4	42.9	37.5	54.3
	P. leopardus	80.8	97.1	79.0	91.4	74.0	91.4
Total number of individuals measured	*Cho. rubescens*	140	57	164	43	115	39
	Chr. auratus	159	12	118	19	155	68
	G. hebraicum	3	2	5	2	2	-
	L. miniatus	65	15	38	20	13	10
	L. nebulosus	78	38	60	30	66	50
	P. leopardus	256	121	176	57	129	67
Maximum length recorded (mm, TL)	*Cho. rubescens*	615.0	478.9	707.1	622.0	605.9	613.2
	Chr. auratus	835.1	742.9	808.8	725.2	859.0	805.0
	G. hebraicum	666.9	695.4	692.2	818.7	818.6	-
	L. miniatus	446.5	435.1	484.0	442.3	465.2	481.4
	L. nebulosus	790.8	792.5	740.5	700.7	799.9	779.6
	P. leopardus	739.9	686.6	684.7	663.0	675.6	793.3
Minimum length recorded (mm, TL)	*Cho. rubescens*	97.7	165.1	117.9	208.0	162.4	208.4
	Chr. auratus	237.3	335.2	218.0	323.5	268.4	300.4
	G. hebraicum	595.1	399.7	344.4	405.3	778.3	-
	L. miniatus	291.5	268.3	282.1	320.1	319.8	338.9
	L. nebulosus	232.0	307.8	275.6	374.2	367.7	427.4
	P. leopardus	87.6	183.8	170.0	206.3	205.1	191.0
% > minimum legal length (MLL)	*Cho. rubescens (400mm)*	28.6	26.3	24.4	32.6	32.2	23.1
	Chr. auratus (410mm)	39.6	58.3	33.1	89.5	52.9	83.8
	G. hebraicum (500mm)	100.0	50.0	60.0	50.0	100.0	-
	L. miniatus (280mm)	100.0	93.3	100.0	100.0	100.0	100.0
	L. nebulosus (410mm)	84.6	92.1	90.0	96.7	97.0	100.0
	P. leopardus (450mm)	16.5	32.2	17.6	42.1	22.5	37.3

Between 2005 – 2019, the cumulative mean MaxN for all target species at all sites has remained generally stable at around 7 – 10 fish per deployment, with the exception of a large observed increase of ~70% from 7.4 in 2010 to a mean MaxN of 12.8 in 2013 (Figure 4.4.2). The increase in mean MaxN between 2010 and 2013 was observed in all target species but higher in the tropical species *P. leopardus* (2.5 to 4.7), *L. nebulosus* (0.9 to 1.8) and *L. miniatus* (0.1 to 0.7) (Figure 4.4.2). Post 2013, most target species have shown a general decreasing trend, except for *Chr. auratus* and *L. nebulosus* with increases between 2017 and 2019 of ~80% and ~30% respectively (Figure 4.4.2).

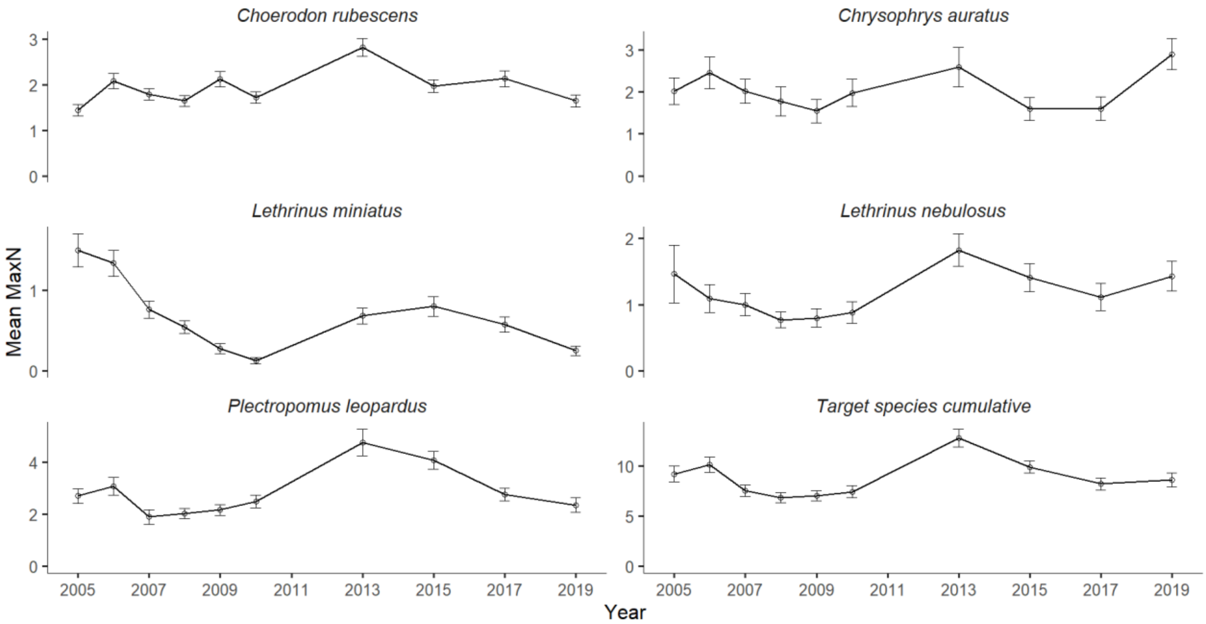

Figure 4.4.2. Relative abundance (mean MaxN) for five target species and the cumulative total of all six target species (excludes *G. hebraicum* due to low number of observations for all sites) between 2005 and 2019. Note varying y axis values.

When split by protection status, there was a large variation observed in the target species cumulative mean MaxN between the fished areas and ROAs in 2005 (ROA: 14.4; Fished: 7.5) which reduced steadily each year to 2009 (ROA: 7.5; Fished: 6.8) (Figure 4.4.3). Between 2009 and 2017 there was little difference in the observed cumulative mean MaxN by protection status, however in 2019 there was an increase in the mean MaxN of the ROAs to 11.2 while the fished areas slightly decreased to a relative abundance of 7.6 (Figure 4.4.3, Table 4.4.1). The variation in mean MaxN between protection status in 2005 was observed for all target species but was mostly driven by *P. leopardus,* which had a much higher abundance in the ROAs (mean MaxN = 5.2) compared to fished areas (mean MaxN = 1.8) (Figure 4.4.3). Since 2007, the mean MaxN in the two areas has been similar within years for all species, with only *P. leopardus* observed to have a markedly higher mean MaxN in the ROAs in 2015 (ROA: 5.9; Fished: 3.5) (Figure 4.4.3). The increase in the mean MaxN of *Chr. auratus* and *L. nebulosus* between 2017 and 2019 is shown to be mostly driven by higher relative abundances in the ROAs, with ~300% and ~90% increases respectively for this area, however, an increase of ~50% was also observed for *Chr. auratus* in the fished areas during this period (2017 = 1.8; 2019 = 2.7) (Figure 4.4.3).

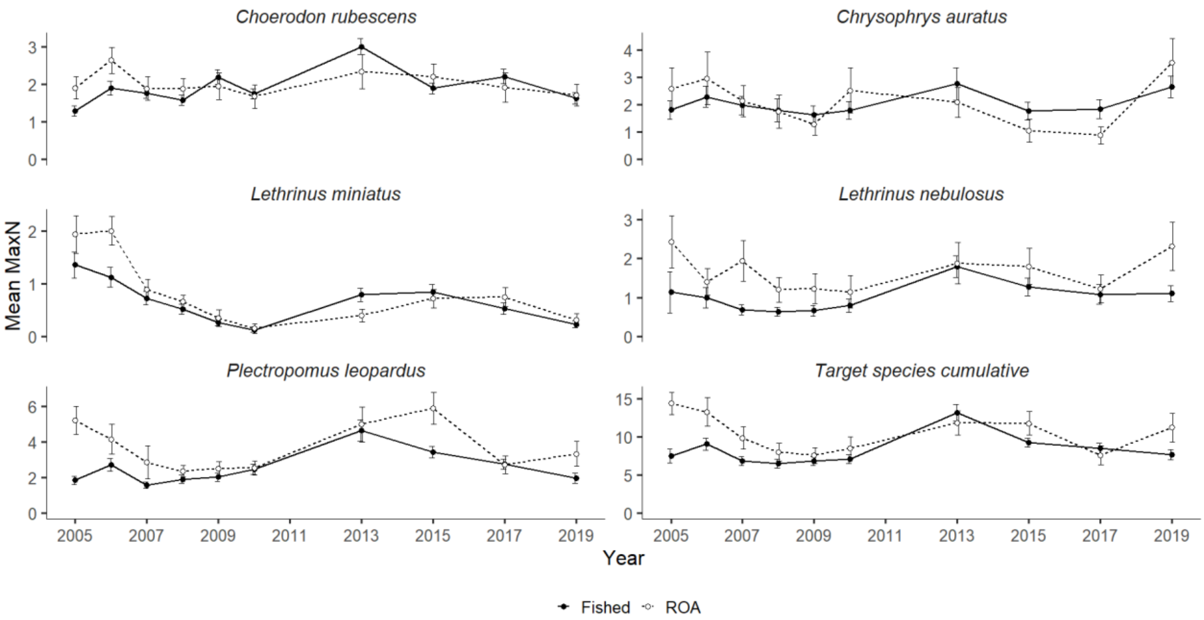

Figure 4.4.3. Relative abundance (Mean MaxN) for five target species, (excludes *G. hebraicum* due to low number of observations) and the cumulative total of all six target species by protection status between 2005 and 2019. Note varying y axis values.

The time series also shows that the mean MaxN of the cumulative target species is consistently higher in the shallow ROAs compared to the shallow fished areas for all years, but this trend is not observed in the deep areas which showed variable results between protection status (Figure 4.4.4). At a species level there is no consistent variation between protection status in either depth zone, except for *Chr. auratus* which is more abundant in the deep fished areas compared to deep ROAs for all years except 2006, and more abundant in the shallow ROAs than the shallow fished areas for all years except 2017 (Figure 4.4.4). Although *P. leopardus* showed a more than two-fold difference in mean MaxN between shallow ROA (5.3) and shallow fished areas (2.2) in the first year of the program (2005), little variation was further observed through to 2013. Since 2013 however, an almost two-fold difference was observed in 2015 (shallow ROA: 6.7; shallow fished: 3.7), and more than two-fold difference in 2019 (shallow ROA: 3.9; shallow fished: 1.6) (Figure 4.4.4).

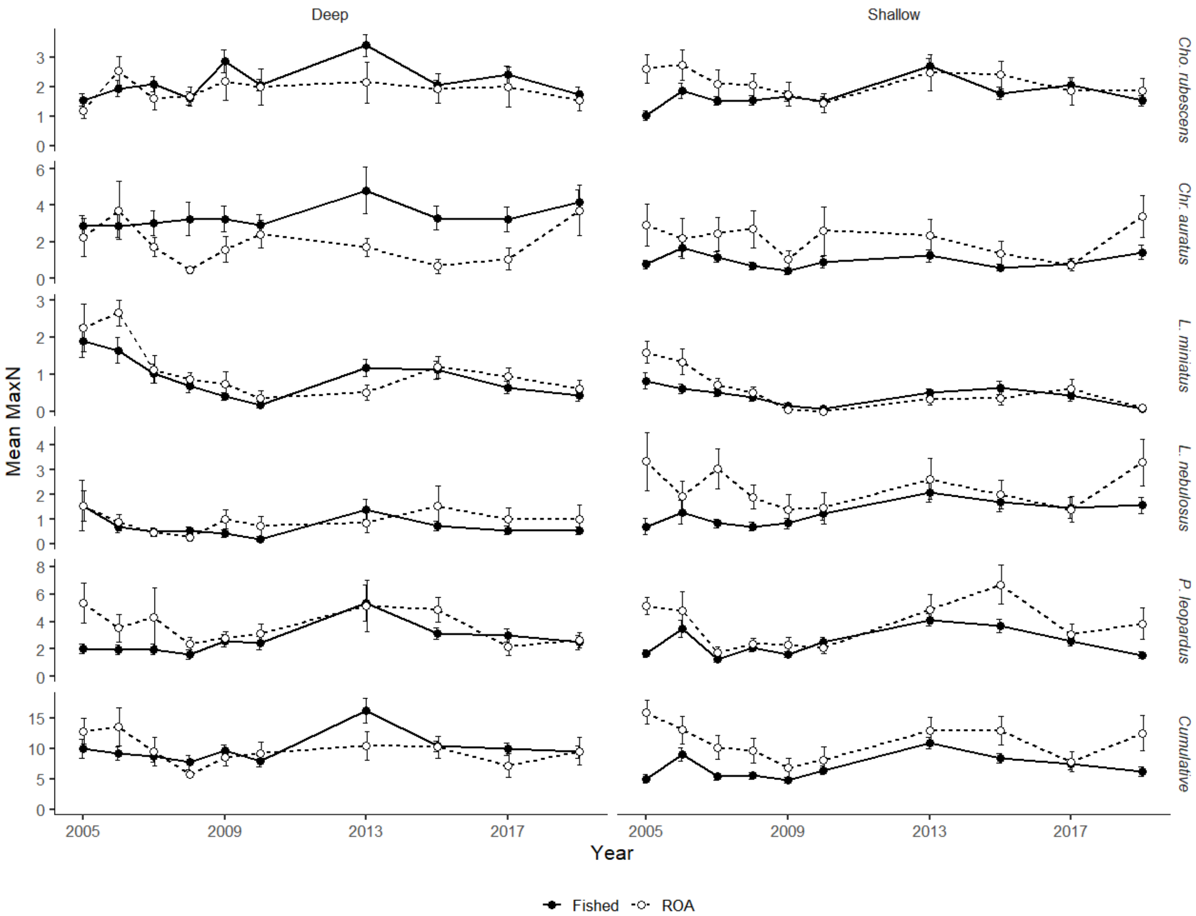

Figure 4.4.4. Relative abundance (mean MaxN) for five target species, (excludes *G. hebraicum* due to low number of observations) and the cumulative total of all six target species by depth in fished and ROAs between 2005 and 2019. Note varying y axis values.

With island group as a factor, the time-series of the target species cumulative mean MaxN showed a lower relative abundance was generally observed at the Pelsaert Group (range = 4 – 9), higher relative abundance at the Easter Group (range = 8 – 15) with the Wallabi Group and North Island showing varied results between years (Figure 4.4.5). Since 2013, there has been a decreasing trend in the target species cumulative mean MaxN at the Wallabi and Pelsaert Groups (Figure 4.4.5), however Easter Group and North Island have both trended upwards between 2017 and 2019 (Figure 4.4.5). Within species, the relative abundance of *Chr. auratus* was higher at Easter Group for all years, North Island had a much higher relative abundance for *L. nebulosus,* while relative abundance of *L. miniatus* at the Wallabi Group was higher in all years but particularly pronounced in years of relatively high abundance for this species with a 3-fold difference in 2013 (Figure 4.4.5). For *Cho. rubescens*, there was often a higher relative abundance observed at Wallabi Group than any other group, however, this was less marked and was not observed in 2019 (Figure 4.4.5). The mean MaxN of *P. leopardus* was observed to be higher at the Easter Group sites compared to other island groups in recent years (2015 – 2019), and is generally lowest at North Island, although this was not observed in 2019 (Figure 4.4.5).

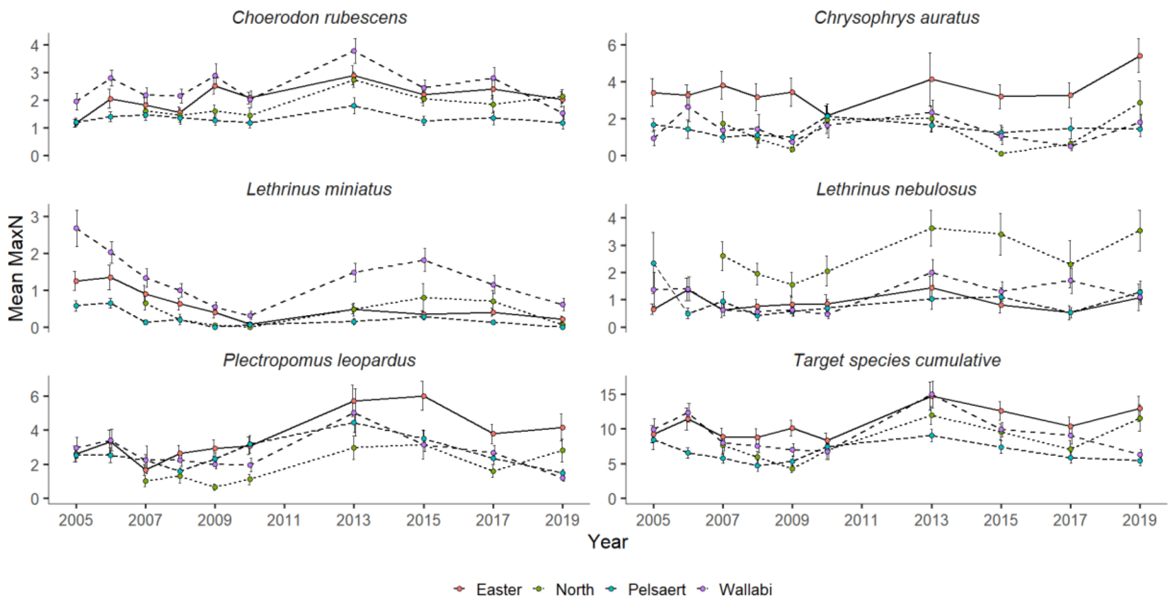

Figure 4.4.5. Relative abundance (mean MaxN) for five target species (excludes *G. hebraicum* due to low number of observations) and the cumulative total of all six target species for each island group between 2005 and 2019. Note varying y axis values.

When examined by island group and protection status, the time-series data shows that the total species cumulative mean MaxN does not vary greatly between fished areas and ROAs (Figure 4.4.6). The largest variations were observed in the Easter Group with much higher mean MaxN in the ROA in 2005, 2006, 2015 and 2019 (Figure 4.4.6). There was also some variation between areas at North Island, with a higher mean MaxN in the fished areas over the ROA in 2008, 2010, 2015 and 2019 (Figure 4.4.6). The variation in the total species cumulative mean MaxN between areas at Easter Group was driven mostly by *L. nebulosus* which was observed in much higher abundances in the ROA compared to the fished area for all years, and *P. leopardus* which recorded very high relative abundance inside the Easter Group ROA in a number of years (Figure 4.4.6). The variation at North Island was driven by *L. nebulosus* which was observed to display markedly higher mean MaxN in the fished areas for all years, post 2005 (Figure 4.4.6). Within species there was generally little variation between areas in the Pelsaert Group, except for *L. nebulosus* which displayed a higher mean MaxN in the ROA compared to the fished area for all years (Figure 4.4.6). Likewise, the Wallabi Group displayed little sustained variation in mean MaxN between areas for all species, except for in 2013 when both lethrinid target species showed higher relative abundance in the fished areas (Figure 4.4.6).

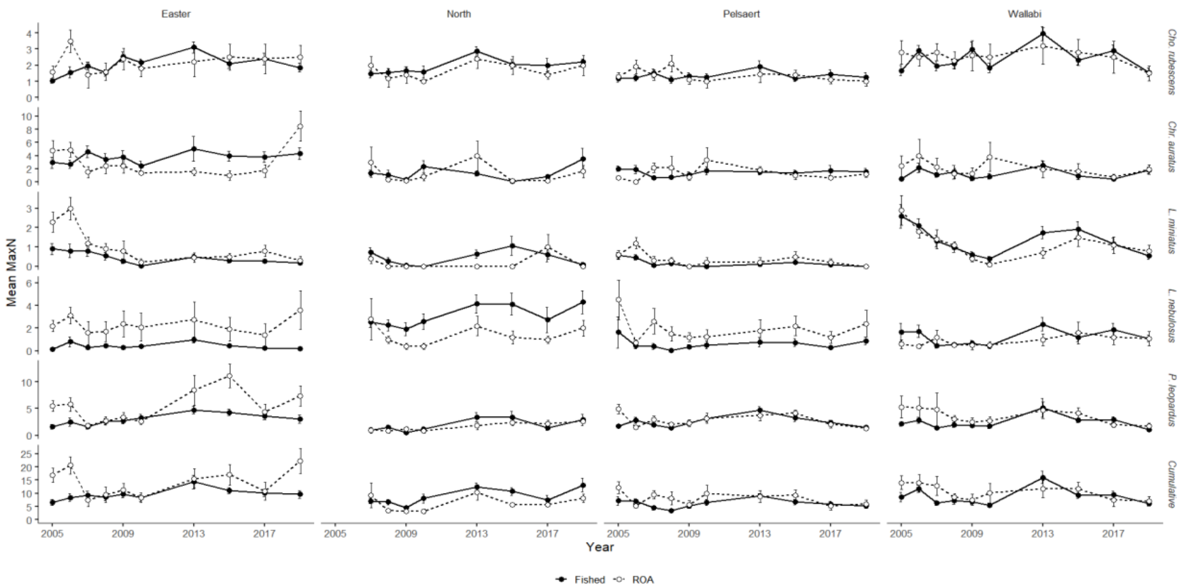

Figure 4.4.6. Relative abundance (mean MaxN) for five target species (excludes *G. hebraicum* due to low number of observations) and the cumulative total of all six target species in fished and ROAs for each island group between 2005 and 2019. Note varying y axis values.

Across all sites surveyed in the Abrolhos FHPA, the mean length of all measured target species (*G. hebraicum* excluded) was observed to increase between 2013 and 2019 (Figure 4.4.7). An increasing trend was observed over the past four surveys for most species. The mean length of *Cho. rubescens* increased from 355.0 ± 5.3 mm (n = 295) in 2013 to 377.6 ± 6.9 mm (n = 154) in 2019, as did *L. nebulosus* from 489.8 ± 12.5 mm (n = 168) to 603.8 ± 8.5 mm (n = 116) and *P. leopardus* from 329.0 ± 5.6 mm (n = 393) to 402.1 ± 7.7 mm (n = 196) (Figure 4.4.7). The mean length of measured *Chr. auratus* decreased from 457.9 ± 7.5 mm (n = 259) in 2013 to 429.0 ± 10.1 mm (n = 171) in 2015 before an increase to 477.6 ± 8.4 mm (n = 223) was observed in 2019 (Figure 4.4.7). There was a large increase in the mean length of *L. miniatus* from 324.4 ± 4.5 mm (n = 78) in 2013 to 384.0 ± 4.4 mm (n = 80) in 2015 after which it remained steady and was observed to be 387.4 ± 9.0 mm (n = 23) in 2019 (Figure 4.4.7).

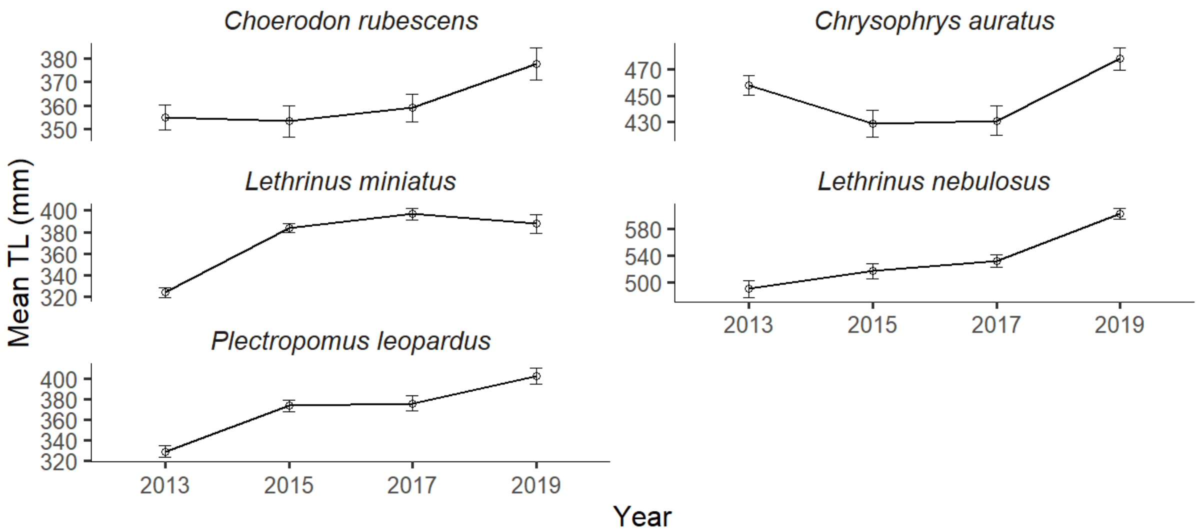

Figure 4.4.7. Mean total length (TL) for five target species (excludes *G. hebraicum* due to low number of observations) at all Abrolhos FHPA BRUV sites in the between 2013 and 2019. Note varying Y axis values and intercept.

When examined by protection status, the mean length for all measured target species was shown to be higher in the ROAs between 2013 and 2019 (Figure 4.4.8). This difference was most marked for *Chr. auratus*, *L. nebulosus* and *P. leopardus* which had between 7% (*L. nebulosus* in 2019) and 40% (*Chr. auratus* in 2017) higher mean length in the ROAs compared to the fished areas (Figure 4.4.8).

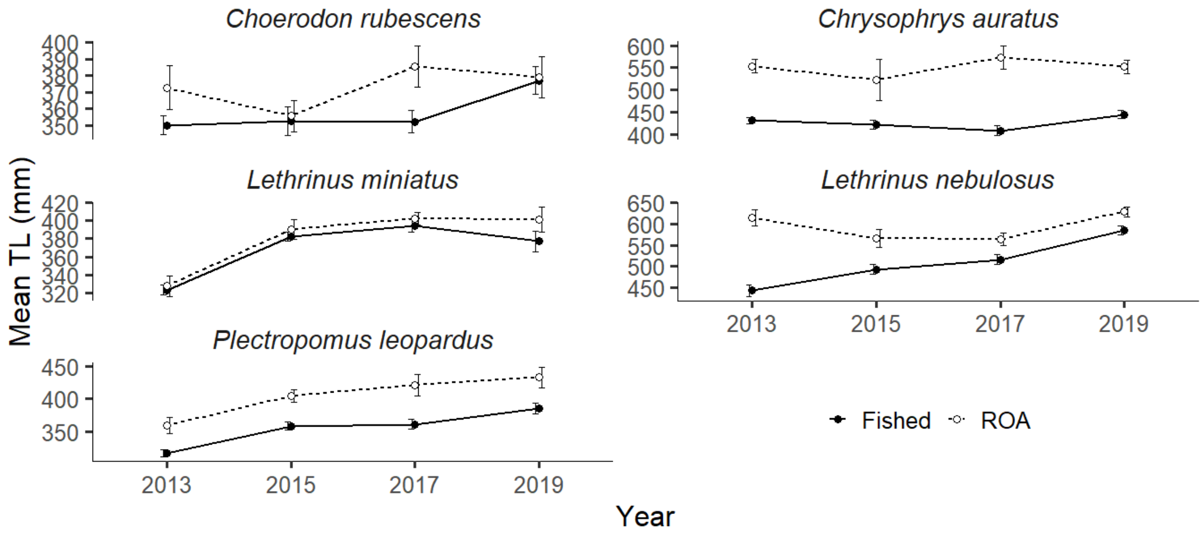

Figure 4.4.8. Mean total length for five target species (excludes *G. hebraicum* due to low number of observations) in fished and ROAs between 2013 and 2019.

Kernel density estimates of length frequency between the fished and ROAs showed variable results between species (Figure 4.4.9). Similar distributions of length between status and years were observed for *Cho. rubescens* with the distribution peak generally below the minimum legal length of 400mm (Figure 4.4.9). The estimated distribution of length for *Chr. auratus* showed similar results between years with a large variation between fished areas and ROAs, with the distribution peak for fished areas below the MLL of 410 mm in all years while ROAs are well above (Figure 4.4.9). The *L. miniatus* showed a relatively narrow distribution mostly above the MLL of 280 mm in all years (Figure 4.4.9). There was little variation between fished areas and ROAs for *L. miniatus* and there was an upwards shift in the distribution between 2013 and 2019 which led to an increase in size distribution of this species in 2017 and 2019 above the MLL (Figure 4.4.9, Table 4.4.1). In contrast, there was a large variation in the length distribution of *L. nebulosus* between areas in 2013, which reduced from 2015 to 2019 (Figure 4.4.9). Most of the distribution of *L. nebulosus* was also above the MLL of 410 mm in the ROAs, whilst the fished areas shifted from below the MLL in 2013 to above by 2019 (Figure 4.4.9, Table 4.4.1). Like *Cho. rubescens,* the distribution of *P. leopardus* did not vary greatly between status or years, with a peak that was generally below the MLL of 450 mm (Figure 4.4.9).

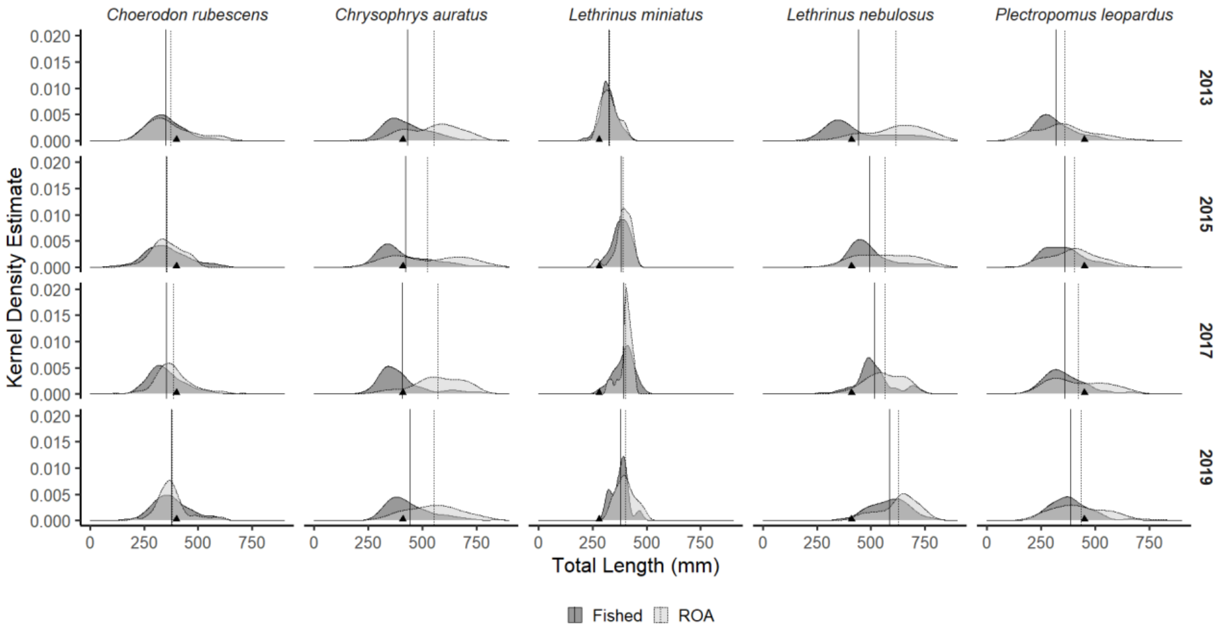

Figure 4.4.9. Length distribution (kernel density estimate) between fished (dark grey) and ROA (light grey) areas for five target species between 2013 and 2019. Triangle indicates species specific minimum legal length within the Abrolhos FHPA. Vertical line is mean TL (solid = fished, dashed = ROA).

4.4.4 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the BRUVS Long Term Monitoring of Relative Targeted Fish Abundance and the Abrolhos FHPA:

- Maintain the Abrolhos FHPA relative abundance of key target demersal finfish species long term monitoring of ROAs to inform long term localised trends
- Review the Abrolhos FHPA relative demersal finfish abundance program, including periodicity of surveys
- Investigate expanding the relative demersal finfish abundance program to include data collection across a broader range of habitats, water depths and localised ecosystems, e.g., channels, reef slopes
- Investigate identifying and incorporating ecosystem indicator finfish species into the Abrolhos FHPA relative demersal finfish abundance program

4.5 Environmental Data

4.5.1 *Seawater Temperature Monitoring and the Abrolhos FHPA*

4.5.1.1 *Sea Surface Temperature*

Sea surface temperature (SST) data were obtained from the Group for High Resolution Sea Surface Temperature (GHRSST) Level 4 Multi-scale Ultra-High Resolution (MUR) global foundation sea surface temperature analysis (V4.1). The GHRSST is a merged high temporal and spatial resolution SST multi-product ensemble, combining infrared (IR) sensors (e.g., AVHRR, METOP, MODIS, AATSR), geostationary satellites (GOES, MTSAT, SEVIRI/MSG), microwave sensors (e.g., AMSR-E, TMI) and in situ data, to estimate SST on a global 1 km^2 grid (Martin et al., 2012; Chin et al., 2017). Only night-time (local measurements from dusk to dawn) satellite retrievals are used for estimations (Chin et al., 2017). For this report, Abrolhos FHPA GHRSST data were obtained at a 1 km^2 resolution, using a nearest neighbour algorithm in R, with collated data constrained to within ≤ 1.2 km of the ten DPIRD Abrolhos FHPA reef monitoring sites (Figure 4.5.1). The SST data were further averaged to obtain a single daily SST value for the individual DPIRD Abrolhos FHPA reef monitoring sites and also for the Abrolhos FHPA as a whole between 2008 and 2018.

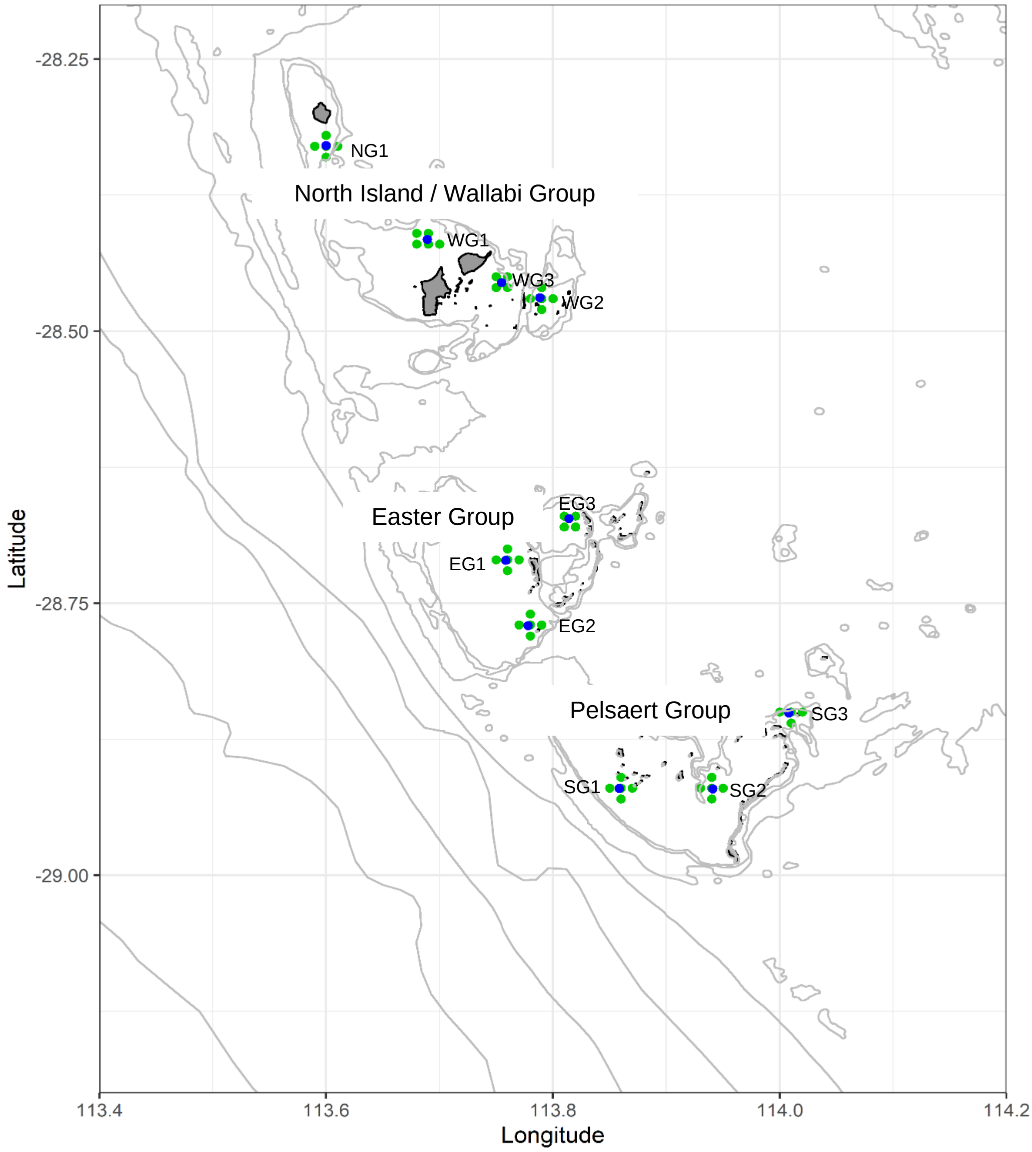

Figure 4.5.1. Location of Abrolhos FHPA *in situ* temperature loggers (dark blue) and GHRSST satellite locations (green) used for temperature analyses at the Abrolhos FHPA.

Based on GHRSST (daily temperature averages), the Abrolhos FHPA SST monthly average between 2008 and 2018 ranged from ~20.5 °C in winter and early spring to ~24.1 °C in late summer and early autumn (Figure 4.5.2). On an annual basis, the highest GHRSST monthly average (26.4 °C) was recorded in March 2011, during the 2010 / 2011 WA marine heatwave, and the lowest (19.2 °C) in September 2016 (Figure 4.5.3). Outside of this, generally, the average GHRSST at Abrolhos FHPA ranges from ~ 20 °C in late winter / early spring to ~24 °C in later summer / early autumn (Figure 4.5.2).

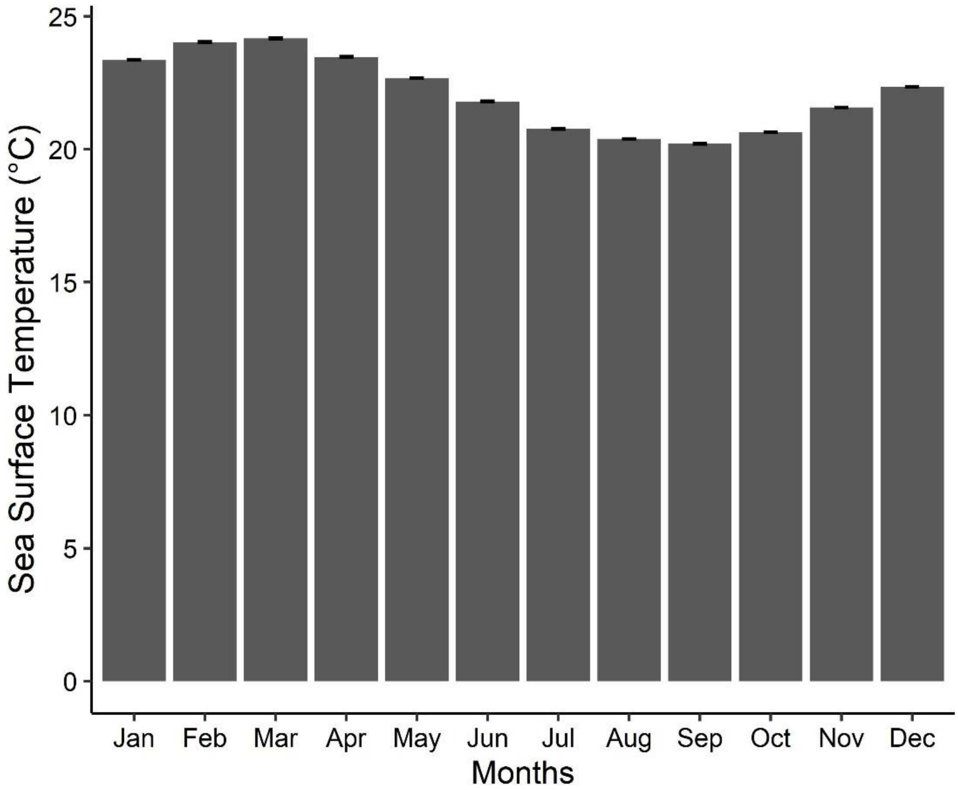

Figure 4.5.2. Monthly average GHRSST (°C) within the Abrolhos FHPA, between 2008 and 2018**.**

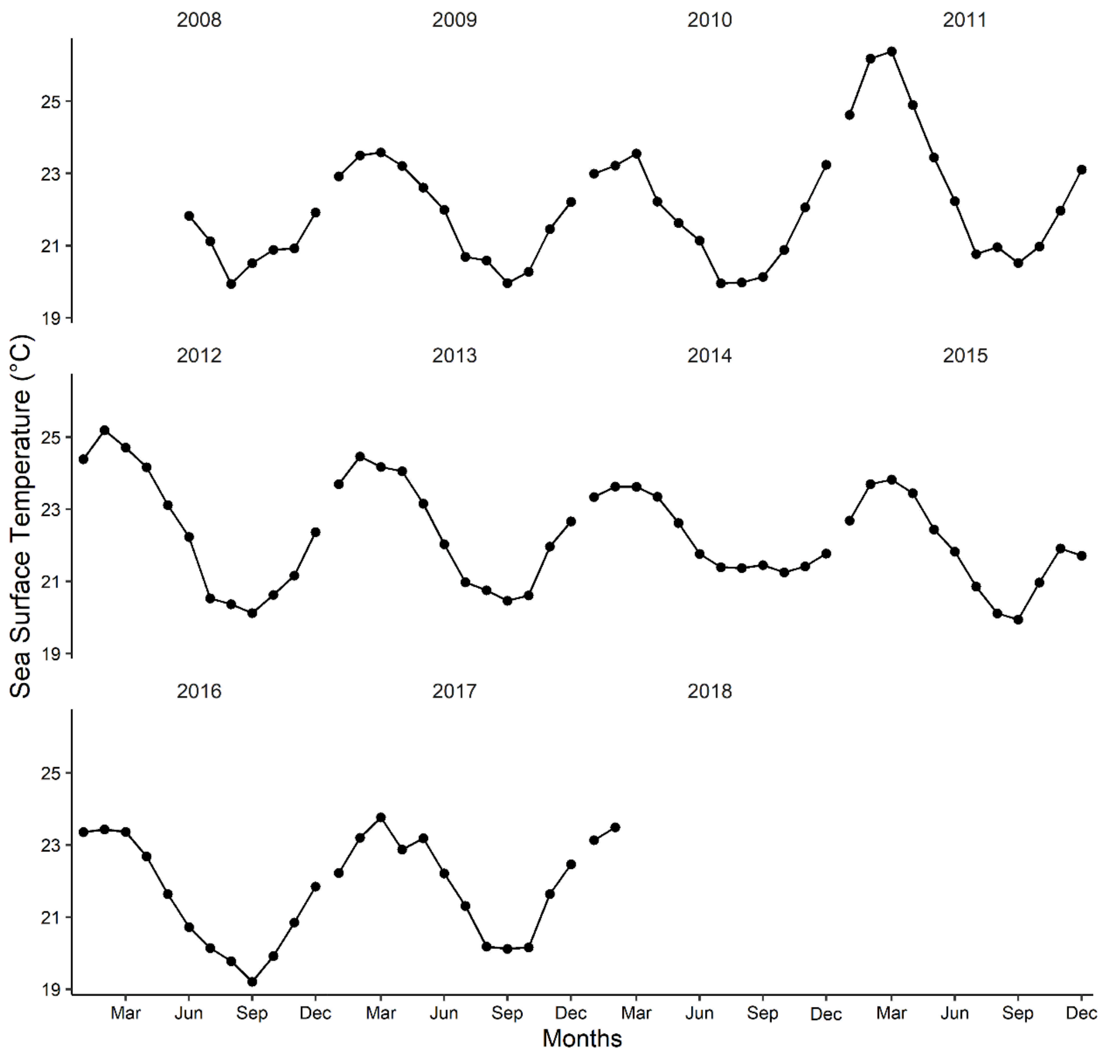

Figure 4.5.3. Abrolhos FHPA annual monthly average GHRSST (°C) between 2008 and 2018.

4.5.1.2 *Abrolhos FHPA SST and in-situ Logger Comparisons*

The GHRSST data were compared to *in situ* DPIRD Abrolhos FHPA temperature logger data between 2008 and 2018 to assess the effectiveness of using GHRSST to report benthic water temperatures for the Abrolhos FHPA. *In situ* temperature data has been recorded at 20-minute intervals at each of the DPIRD Abrolhos FHPA reef monitoring sites (Figures 4.1.1 and 4.5.1) since 2008. HOBO pendant data loggers (Onset Computer Co.) are mounted ~30 cm above the substrate and represent the typical depth of each of the reef monitoring sites (depth range = 5 to 25 m). Averaged daily GHRSST data (constrained to within ≤ 1.2 km of the ten DPIRD Abrolhos FHPA in situ logger sites) were compared to the ten DPIRD in situ logger datasets between

2008 and 2018 and further averaged as the Abrolhos FHPA as a whole. The DPIRD Abrolhos FHPA *in situ* logger dataset was subset to the hours between sunset and sunrise and a daily average obtained based on the hours of sunset_t – sunrise_{t+1}, obtained from the Australian Bureau of Meteorology (BoM), to match GHRSST data. All 'daily' *in-situ* temperature measurements are based on a centred five-day moving average using the roll mean function in R (Zeileis et al., 2020), to replicate the five-day composite provided by the GHRSST data (Chin et al., 2017). Initially, Pearson's correlation coefficient r-values were used to determine the strength of the correlation between *in situ* logger temperatures and GHRSST for all sites in all months and years. An initial linear model describing the relationship between *in situ* water temperature, L_{ijkl}, and GHRSST, SST_i, was

$$L_{ijkl} = \beta_0 + \beta_1 SST_i + \varepsilon_{ijkl}, \ \ \varepsilon \sim N(0, \sigma_\varepsilon^2)$$

where ε_{ijkl} are independent and identically distributed (*i.i.d*) realisations of ε. As initial exploration indicated differing slopes between in situ water temperature, L_{ijkl}, and GHRSST, SST_i, a multiple linear regression involving interaction terms between year (Y_j), month (M_k), and site (S_l) was used to further describe this relationship:

$$L_{ijkl} = \beta_0 + \beta_1 SST_i * \beta_2 Y_j * \beta_3 M_k * \beta_4 S_l + \varepsilon_{ijkl}, \ \ \varepsilon \sim N(0, \sigma_\varepsilon^2)$$

where Y_j is the year effect for years 2016 – 2020, M_k is the month effect, and S_l is the site effect. Due to autocorrelation between factors such as depth and water movement, these were not considered individually in the model, but were assumed to be representative of site, S_l.

Overall daily mean GHRSST and *in situ* logger data for the entire Abrolhos FHPA exhibited a positive relationship across the survey period, with in situ loggers recording daily mean temperatures of 22.0 °C (± 1.6) and GHRSST 22.3 °C (± 1.6). For *in situ* data, daily mean temperatures exhibited marked seasonality across all sites and years, ranging between 16.1 °C at SG1 in July 2011 and 28.9 °C in February 2011 at the same site (Figure 4.5.4). Winter GHRSST at the Abrolhos FHPA were similar to in situ temperatures at most sites across all years (Figure 4.5.4). However, the location and extent of the seawater minimum temperatures differed, with GHRSST reporting the lowest temperature from EG1 (~8m depth) at 18.6 °C in September 2016, 2.5 °C warmer than the 16.1 °C reported by the SG1 (~5m deep) in-situ logger in July 2011

(Figure 4.5.4). Variation in seawater temperature maximums were closer when comparing GHRSST and *in situ* loggers with SG1 reporting the highest maximum of 28.9 °C in February 2011 and the GHRSST reporting 29.2 °C in the same month but at EG1, both coinciding with the 2010/11 WA marine heatwave (Pearce & Feng, 2013) (Figure 4.5.4). In terms of mean daily temperatures, sites in the Easter Group had the greatest variability in monthly SST averages, whereas sites in the Wallabi Group had consistently higher mean SSTs than other sites (Figure 4.5.4).

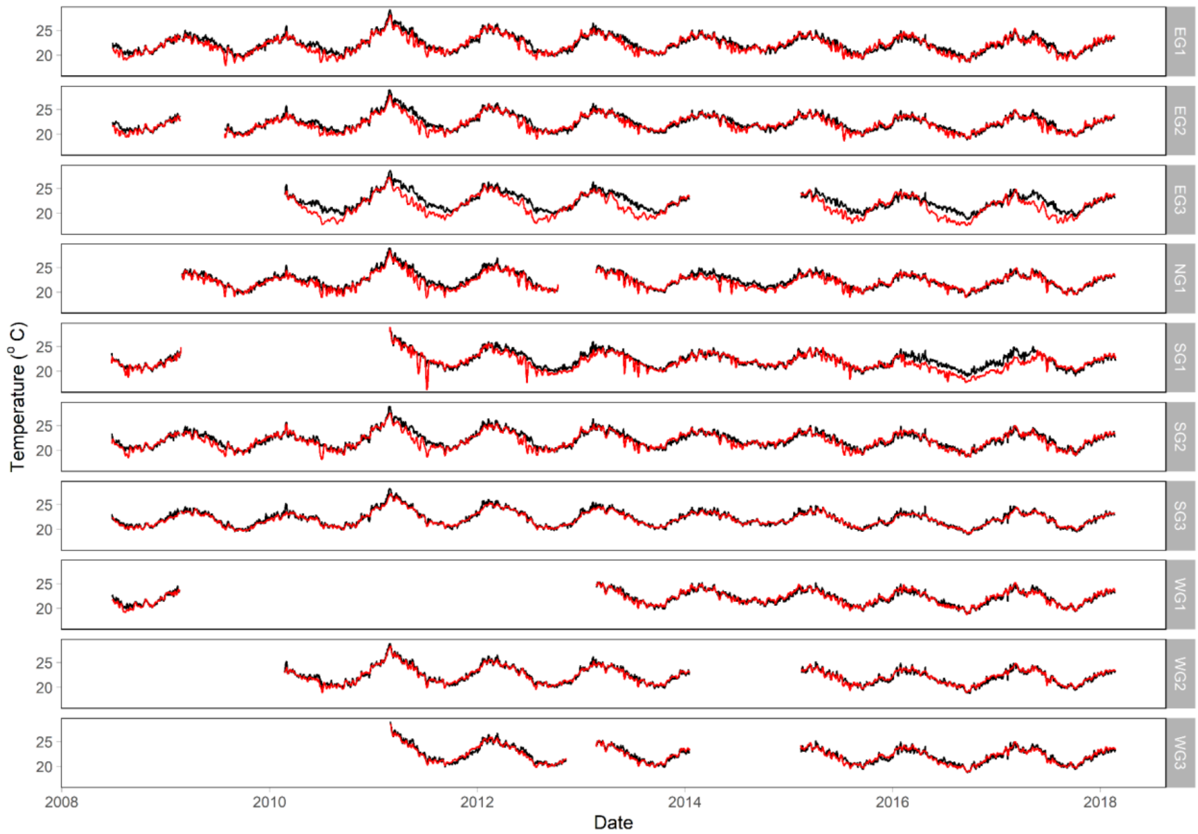

Figure 4.5.4. Comparison between the GHRSST (black line) and DPIRD Abrolhos FHPA *in situ* data (red line) from 2008 to 2018. SG = Southern Group; EG = Easter Group; WG = Wallabi Group; NG = North Island.

A three-way analysis of variance indicated significant interactions between year, month and site and when all sites were included in the model, SST explained 83.9% of the variation in logger temperature $(F_{(1947,27121)} = 343.72, p < 0.01)$. The least amount of variation between *in situ* temperature and GHRSST was within the Wallabi group sites, where all SST data were within 1 °C of the *in situ* temperatures across all years (Figures 4.5.4 and 4.5.5), and SST explained > 90% of the variation in the *in situ* logger temperature at all sites. A larger variation between GHRSST and *in situ* temperatures was observed at site EG3, in which satellite temperatures were higher than *in situ* temperatures in autumn and winter across all years (Figures 4.5.4 and 4.5.5). When modelling EG3 alone, SST explained 74.7% of the variation in logger temperature ($F_{(169,2357)} = 451.84, p < 0.01$). Site SG1 also exhibited a large amount of variation between in situ logger temperatures and GHRSST in which logger temperatures exhibited multiple cold spikes (> 4 °C) in most years and remained below SST from January 2016 - January 2017. SST accounted for 76.1% of the variation in logger temperature at site SG1 ($F_{(187,2612)} = 173.54, p < 0.01$) (Figure 4.5.5). These results suggest that although overall the GHRSST provides a strong correlation to benthic in situ loggers for daily mean and maximum temperatures, it is less reliable to capture cold waters events that may influence the benthic ecosystems of the Abrolhos FHPA.

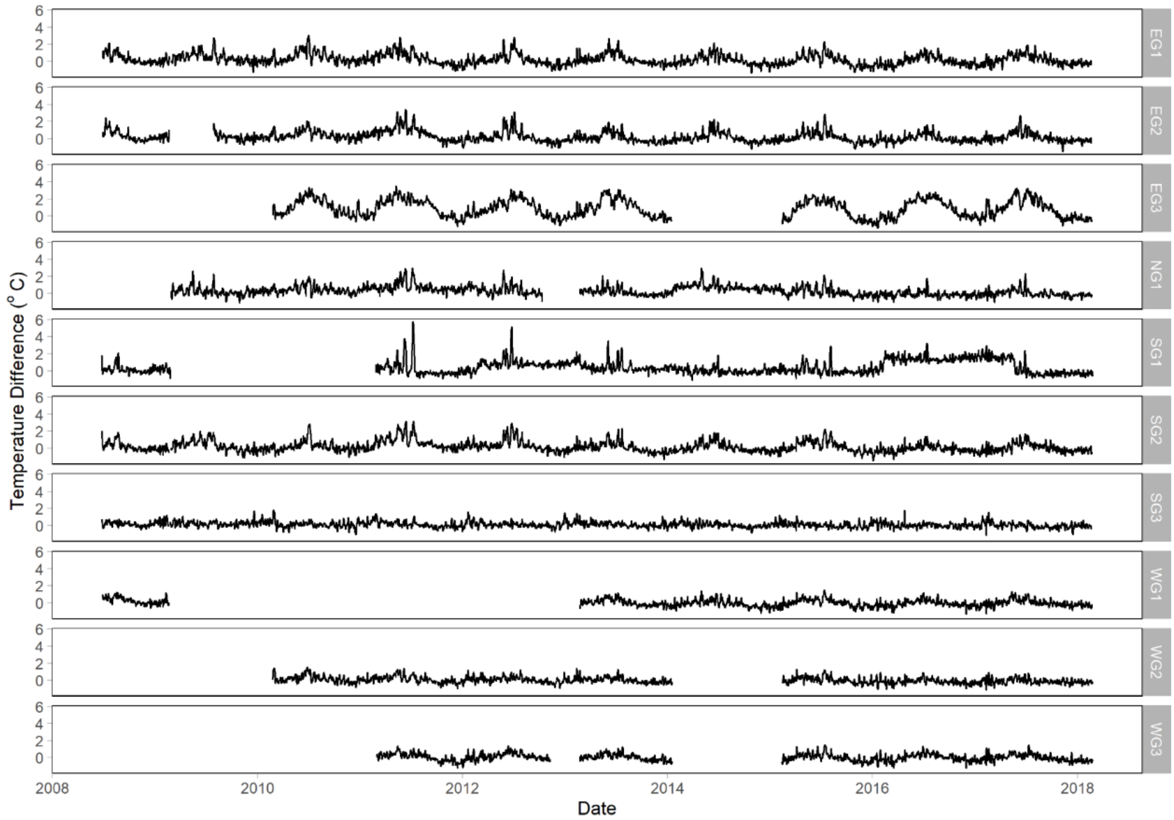

Figure 4.5.5. Difference (°C) between GHRSST and *in situ* logger temperatures for Abrolhos FHPA sites between 2008 and 2018. SG = Southern Group; EG = Easter Group; WG = Wallabi Group; NG = North Island.

4.5.2 *Wind and the Abrolhos FHPA*

Daily wind data for the Abrolhos FHPA were obtained from the BoM North Island weather station (station 008290). This data included 3-hourly wind measurements which includes wind direction (degrees) and speed (km/h). The wind speed and direction data were extracted daily for the 9am and 3pm readings between 1st of January 2000 and 31st of December 2020. Raw BoM wind speed and direction data was then grouped into 16 directional categories (e.g., N, NNE, NE, ENE, E, etc) from both the 9am and 3pm databases, with wind speed averaged by month (Figure 4.5.6 and 4.5.7).

The Abrolhos FHPA has two common wind patterns, driven by stronger (>40 km h^{-1}) winds predominately from the south or south-southeast between November and March and calmer (<40 km h^{-1}) more variable winds during May to September (Figure 4.5.6 and 4.5.7), however wind gusts >70 km h^{-1} do occur during winter storms. Winds in the morning are weaker than the afternoon, with 9am winds predominately from the south-southeast and stronger in November to March (Figure 4.5.6). The stronger afternoon winds (3pm) are from the south and again generally stronger in November to March (Figure 4.5.7).

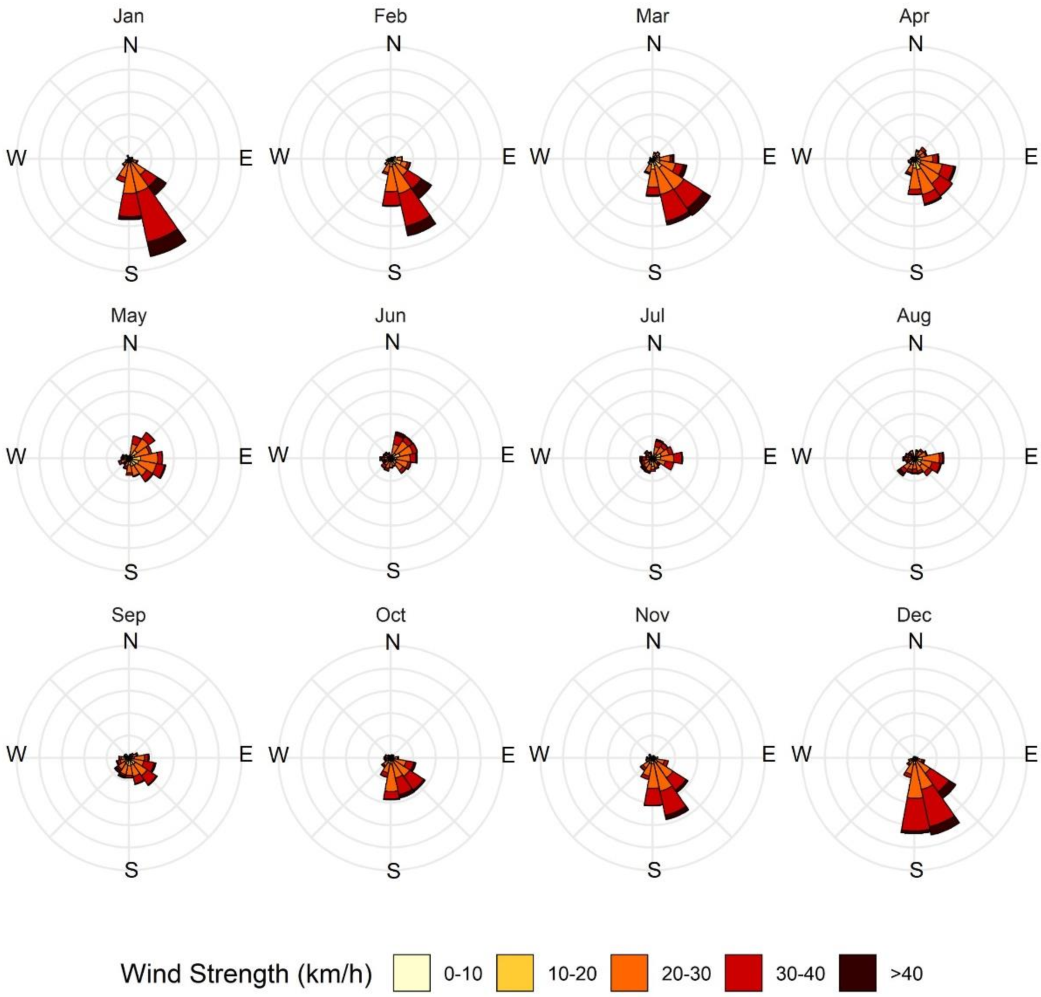

Figure 4.5.6. Abrolhos FHPA 9am mean monthly wind data between January 2000 and December 2020 (station 008290).

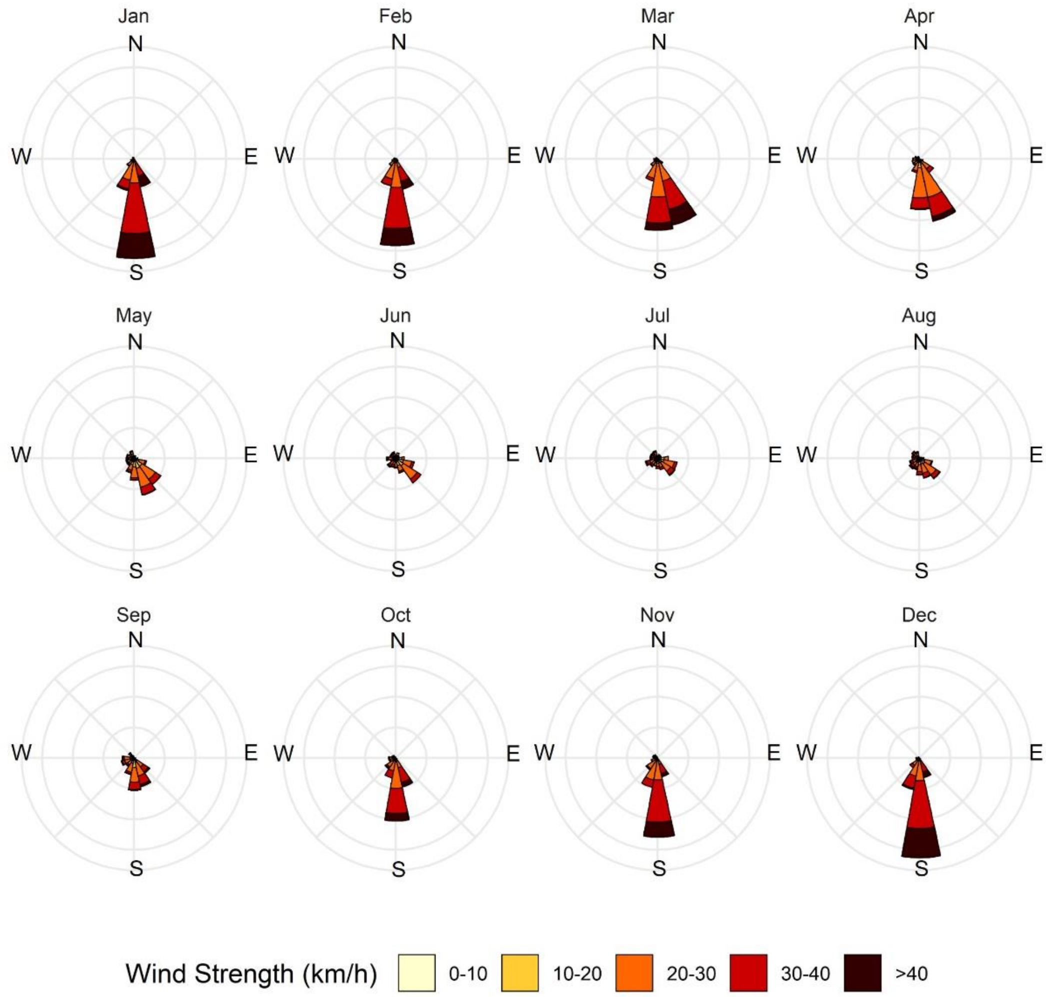

Figure 4.5.7. Abrolhos FHPA 3pm mean monthly wind data between January 2000 and December 2020 (station 008290).

4.5.3 *Tide, Swell and the Abrolhos FHPA*

Tide data available from BoM shows tides at the Abrolhos FHPA are predominately diurnal (one high and low tide), however, they can vary between a diurnal and semidiurnal (two high and low tides) regime throughout the year. The time of predicted maximum and minimum tides can also vary up to 3-4hrs between island groups and between Geraldton at certain times throughout the year. Tidal range within the Abrolhos FHPA is typically between 0.2 - 0.9 m, with maximum tides around 1.2 m observed. The closest tide station to the Abrolhos FHPA is located at Geraldton (GNGER02) and contains a long-term dataset of tide height (cm) recorded every five minutes between 1999 – 2021 (https://www.transport.wa.gov.au/imarine/tide-data-real-time.asp).

Wave height data was obtained from the DoT wave rider buoy data (https://www.transport.wa.gov.au/imarine/download-tide-wave-data.asp). The closest wave buoy (JUR40) to the Abrolhos FHPA is located approximately 170 km south, offshore of Jurien Bay (-30.291654, 114.914455) in ~42 m of water. It would be expected, based on its location, that this wave rider buoy would be exposed to a similar wave action and storm events as the Abrolhos FHPA, particularly from the south and west. Therefore, for this report data from this wave buoy is used as a proxy for the Abrolhos FHPA. The wave buoy records significant wave heights (Hs) (average of the highest third of waves) of swell (generated by distant storms) and sea waves (produced by local wind) to determine the total wave height or wave climate. For this report, mean monthly wave height in metres (Hsm), based on the DoT data, for each year between 1998 – 2020 are shown to indicate likely wave heights at the Abrolhos FHPA (Figure 4.5.8).

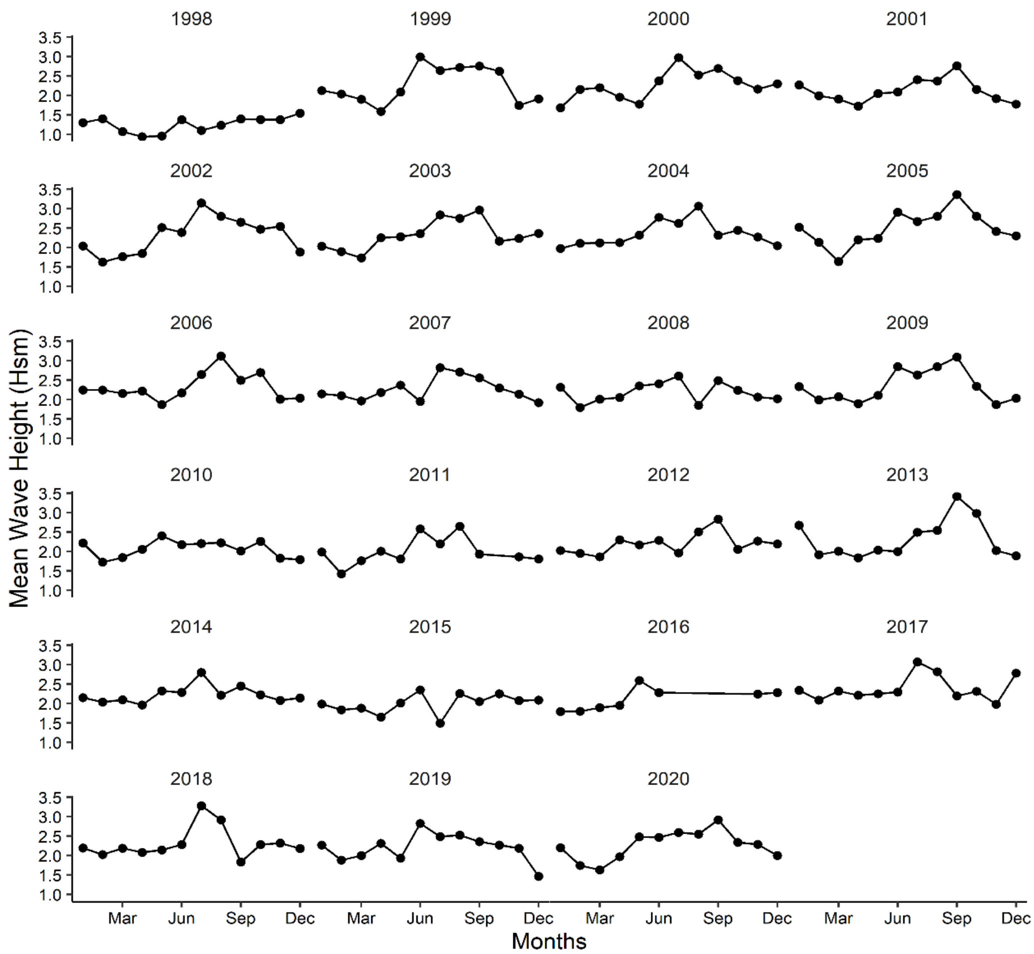

Figure 4.5.8. Mean annual monthly wave height (Hsm) between 1998 and 2020 (Wave Buoy JUR40).

Although, mean monthly wave heights varied between years (Figure 4.5.8), between 1988 and 2020 the highest average monthly wave climate (2.57 – 2.62 m) was recorded during winter and early spring (July – September) when low pressure systems and storms impact the coast (Figure 4.5.9). The lowest average monthly wave height usually occurs in February – March (1.91 - 1.94m) (Figure 4.5.9). Between 1998 and 2020 the highest mean wave height was recorded in July 2018 and August 2008 averaging 6.3m and the highest individual wave climate recording measured 8.24m in May 2020.

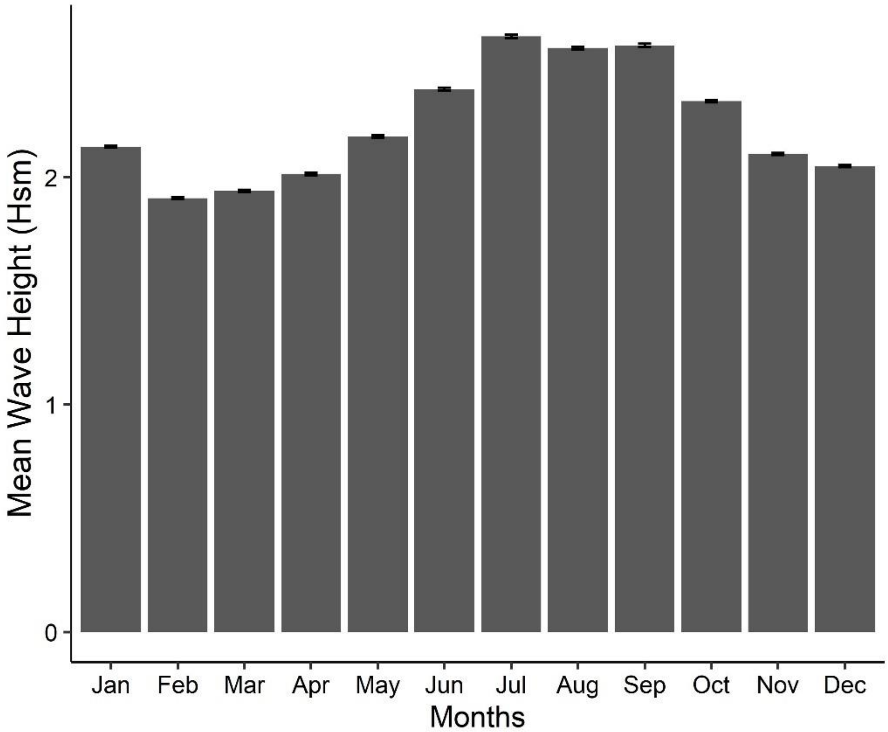

Figure 4.5.9. Mean monthly wave height (Hsm) between 1998 and 2020 (Wave Buoy JUR40).

4.5.4 *Chlorophyll-a and the Abrolhos FHPA*

Chlorophyll-a concentrations provide an indicator of phytoplankton abundance and biomass (productivity) in marine waters and can be an effective measure of trophic status (Jiang et al., 2017). Excessively high levels of chlorophyll-a concentrations can supply large amounts of organic matter to the water column and marine benthic environment, which may lead to anoxic and hypoxic events or high levels of shading affecting benthic aquatic resources (e.g., seagrass, algae, coral). In Australian waters, chlorophyll-a concentrations are generally lowest in the subtropical oceanic regions

(0.05-0.5 μgL^{-1}) and higher in the temperate regions (up to 1.5 μgL^{-1}) (Davies et al., 2018). Chlorophyll-a can be measured either *in situ* (which can be resource intensive) or via remote satellite products (which may need validation), or a combination of both. For this report, data is based on remote satellite derived data only to provide an indicative guide to chlorophyll-a levels at the Abrolhos FHPA.

Satellite chlorophyll-a information for the Abrolhos FHPA was based on data obtained from the European Copernicus Marine Environmental Service (https://marine.copernicus.eu/access-data) combining Moderate Resolution Imaging Spectroradiometer (MODIS), Medium Resolution Imaging Spectrometer (MERIS), Sea-viewing Wide Field-of-view Sensor (SeaWiFS), Visible Infrared Imaging Radiometer Suite (VIIRS) and Ocean and Land Colour Instrument (OLCI) data platforms (Saulquin et al., 2019). This data was available as daily observations at a 4 km^2 resolution (n =161 separate observations for Abrolhos FHPA), extracted from 2008-2018 and reported as mean monthly averages of chlorophyll-a concentration (μgL^{-1}) for the entire area covering the Abrolhos FHPA (Figure 4.5.9). Analysis of the data showed seasonality within the satellite chlorophyll-a measurements at the Abrolhos FHPA, which increased during late summer and peaked in the autumn months, between March and May (Figure 4.5.10). As would be expected, chlorophyll-a increased with proximity to the land (islands) within the Abrolhos FHPA and was lowest in areas of deeper open ocean (Figure 4.5.10). The highest mean monthly concentrations of chlorophyll-a were observed in April (0.73 μgL^{-1}) and May of 2018 (0.69 μgL^{-1}) and March of 2011 (0.69 μgL^{-1}). For March 2011, the range of chlorophyll-a measurements for the Abrolhos FHPA, throughout the 161 satellite observation points, was 2.99 μgL^{-1} (3.17 μgL^{-1} to 0.18 μgL^{-1}). The lowest mean monthly concentrations of chlorophyll-a were observed in December of 2011 (0.19 μgL^{-1}), with a range throughout the 161 satellite observation points of 0.57 μgL^{-1} (0.65 μgL^{-1} to 0.08 μgL^{-1}). High levels of chlorophyll-a in 2011 coincided with the timing of the 2010/11 marine heatwave (Figure 4.5.10). There was no subsequent heatwave reported in 2018 and the causation of high chlorophyll-a concentrations within this year in unknown.

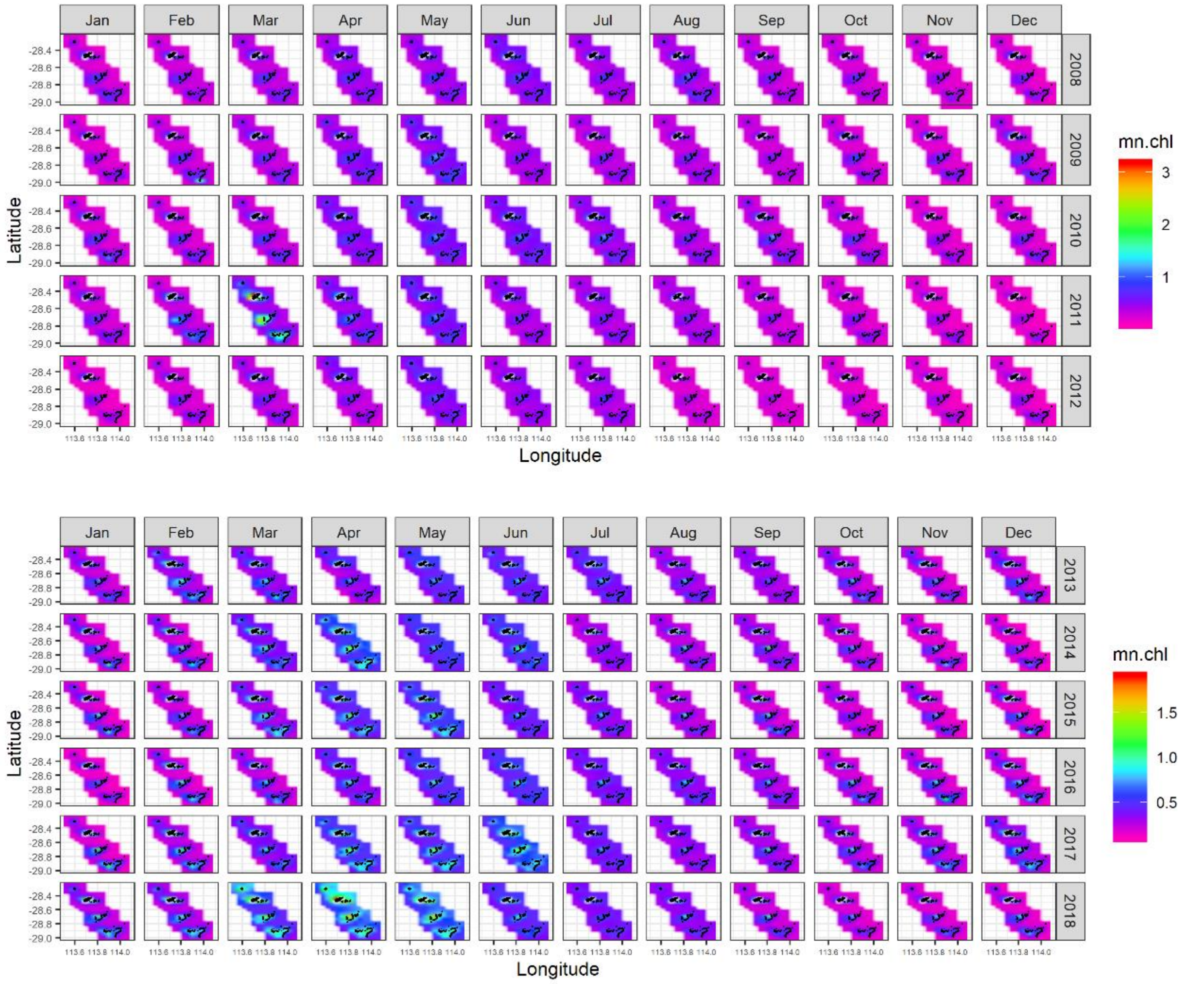

Figure 4.5.10. Annual (2008 – 2018) mean monthly chlorophyll-a concentration (μgL^{-1}) for the Abrolhos FHPA.

4.5.5 *Rainfall and the Abrolhos FHPA*

Daily rainfall data for the Abrolhos FHPA were based on data obtained from the BoM (station 8290) and further summarised by month and year. Between 2008 and 2020 the annual total rainfall at the Abrolhos FHPA has ranged between 200-300mm. The highest rainfall during this period was recorded in 2011 (477mm) and the lowest in 2018 (182.4mm). On average (2008 – 2020) the highest rainfall at the Abrolhos FHPA occurs in June (~64 mm) and lowest in January (2.5 mm) (Figure 4.5.11).

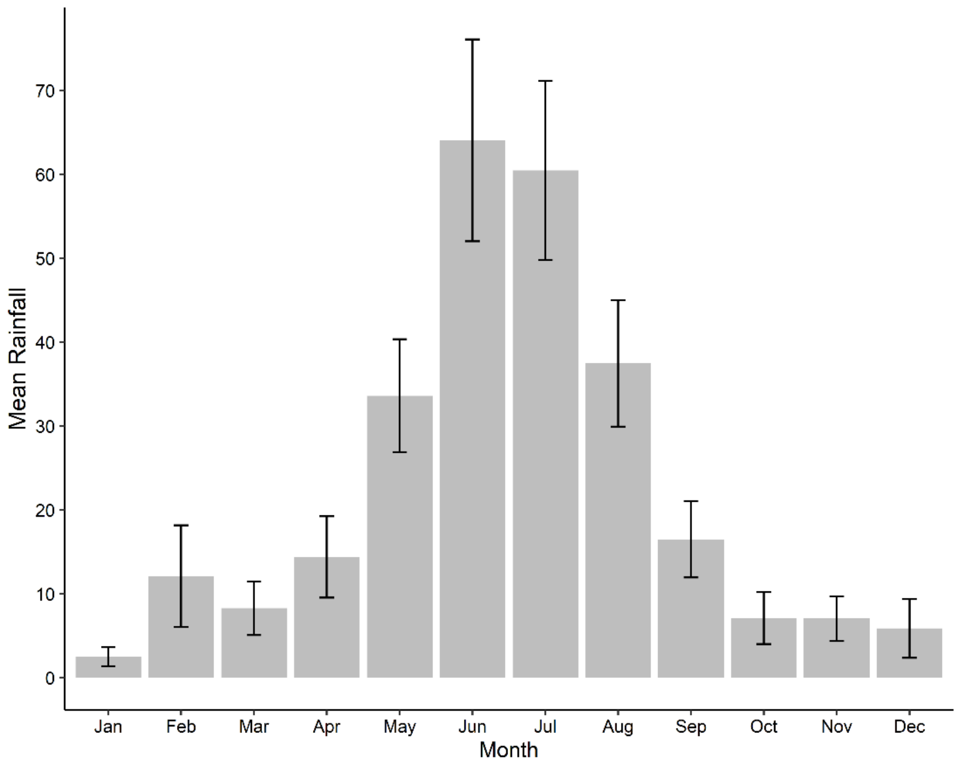

Figure 4.5.11. Abrolhos FHPA mean monthly rainfall (mm) between January 2008 and December 2020 (station 8290).

4.5.6 *Recommendations*

Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA make the following specific recommendations in relation to the Environmental Data and the Abrolhos FHPA:

- Maintain the monitoring of environmental parameters, including *in situ* measurements, at Abrolhos FHPA reef monitoring sites
- Investigate further incorporating of near real-time environmental satellite monitoring tools into Abrolhos FHPA ecosystem monitoring and reporting
- Maintain regular updates of environmental trends for the Abrolhos FHPA aquatic resources and other users (e.g., commercial fishing and aquaculture)

5.0 Strategic Recommendations

This report has provided an overview, including a summary of trends, of available DPIRD data for the Abrolhos FHPA to support the Abrolhos FHPA Draft Management Plan (2022). Based on the information presented in this report, the Ecological Monitoring and Assessment Group of DPIRD ASA has provided a number of fishery, industry or resource specific recommendations, where appropriate, to guide future science and management. In addition, the following strategic recommendations are provided by the Ecological Monitoring and Assessment Group of DPIRD ASA to support the ongoing sustainable use, resource sharing and management of the Abrolhos FHPA across all user groups:

- Develop, implement and support a DPIRD science and monitoring plan specific to the aquatic resources and ecosystems of the Abrolhos FHPA, to further inform and support the management of this systems unique aquatic resources and diverse marine user groups
- Update Abrolhos FHPA Ecological Risk Assessment (ERA)
- Maintain and expand the reporting of commercial and recreational activities and associations within the Abrolhos FHPA
- Prioritise and support a habitat mapping and monitoring program (at an appropriate scale), particularly in the <30m depth zone of the Abrolhos FHPA, to support aquatic resources and ecosystem management
- Investigate management measures to further support areas of ecological significance in the Abrolhos FHPA (e.g., sensitive habitats and fish spawning aggregations), especially in the <10m depth zone
- Investigate the effectiveness of management arrangements (e.g., ROAs) and potential expansion to ensure adequate protection and representation across the entire Abrolhos FHPA
- Prioritise and support an Abrolhos FHPA specific recreational fishing survey

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7.0 Acknowledgements

The authors would like to thank all past and present staff, students and volunteers within the Ecological Monitoring and Assessment team, over many years, who have contributed to aspects of the range of programs described within this report. Whether that be in logistics, data collection, laboratory analysis, data analysis, validations or figure preparation, your contribution is sincerely acknowledged and appreciated. This includes, but not limited to, Joshua Dornan, Keyley Hogan-West, Rachel Marks and Brae Price. The authors also specifically acknowledge Rachel Marks for the SST and chlorophyl-a statistical modelling components of this report.

We sincerely thank all past and present DPIRD Mid-West Houtman Abrolhos Island Fisheries and Marine Officers and Master/s and crew of the *P.V. Chalmers* including, but not limited to Mark Killick, Ben Doncon, Geoff Clarke and Greg Finlay for their support, local advice, guidance and commitment to the Ecological Monitoring and Assessment teams Abrolhos FHPA science program. This program would not be possible without their contribution and collaboration.

We also acknowledge the external collaborations support for aspects of the Ecological Attributes Section of this report, including Cathie Page Consultants for support in image analysis and coral identifications, the University of Western Australia and Curtin University for BRUV collaborations, Batavia Coast Maritime Institute for the 2017 coral recruitment field operations and the Department of Transport, Western Australia for providing extracts of vessel registrations.

Finally, we extend our gratitude the individual DPIRD ASA fishery scientists and managers for their reviews, comments and insight into the specific fishery, aquaculture, fishing tour industry and recreational fishing sections described within this report. We also thank Natalie Moore and Danielle Johnston for the overall review of this manuscript.

8.0 Appendix A

Hard Coral Genera	2008		2010		2012		2015		2018		2021	
	Mean Cover (%)	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error
Acanthastrea	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00
Acropora	**25.95**	3.30	**30.26**	2.72	**18.98**	3.13	**15.30**	2.60	**13.53**	3.37	**15.63**	3.80
Alveopora	**0.00**	0.00	**0.02**	0.02	**0.01**	0.01	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00
Astreopora	**0.01**	0.01	**0.01**	0.01	**0.02**	0.02	**0.06**	0.06	**0.00**	0.00	**0.00**	0.00
Coscinaraea	**0.00**	0.00	**0.00**	0.00	**0.01**	0.01	**0.02**	0.02	**0.00**	0.00	**0.00**	0.00
Cyphastrea	**0.02**	0.02	**0.10**	0.05	**0.04**	0.03	**0.01**	0.01	**0.03**	0.02	**0.03**	0.02
Echinophyllia	**0.16**	0.10	**0.04**	0.02	**0.03**	0.03	**0.07**	0.04	**0.01**	0.01	**0.22**	0.13
Echinopora	**0.00**	0.00	**0.12**	0.06	**0.15**	0.11	**0.03**	0.02	**0.00**	0.00	**0.00**	0.00
Favia	**0.19**	0.14	**0.11**	0.04	**0.23**	0.12	**0.26**	0.10	**0.11**	0.06	**0.08**	0.03
Favites	**0.27**	0.15	**0.25**	0.09	**0.18**	0.08	**0.16**	0.07	**0.22**	0.12	**0.01**	0.01
Fungia	**0.01**	0.01	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.01**	0.01
Galaxea	**0.01**	0.01	**0.06**	0.03	**0.02**	0.02	**0.07**	0.04	**0.04**	0.04	**0.04**	0.04

Hard Coral Genera	2008		2010		2012		2015		2018		2021	
	Mean Cover (%)	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error
Goniastrea	**0.00**	0.00	**0.04**	0.02	**0.02**	0.01	**0.01**	0.01	**0.02**	0.02	**0.05**	0.02
Goniopora	**0.09**	0.08	**0.05**	0.03	**0.12**	0.08	**0.07**	0.02	**0.07**	0.06	**0.03**	0.01
Hydnophora	**0.06**	0.04	**0.01**	0.01	**0.02**	0.02	**0.00**	0.00	**0.00**	0.00	**0.06**	0.04
Leptastrea	**0.00**	0.00	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00
Leptoseris	**0.00**	0.00	**0.01**	0.01	**0.01**	0.01	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00
Lobophyllia	**0.02**	0.02	**0.04**	0.03	**0.00**	0.00	**0.01**	0.01	**0.02**	0.02	**0.00**	0.00
Merulina	**0.23**	0.17	**0.11**	0.05	**0.05**	0.03	**0.21**	0.11	**0.21**	0.09	**0.14**	0.06
Montigyra	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00
Montipora	**10.82**	2.24	**11.25**	2.00	**2.84**	0.53	**2.62**	0.56	**2.01**	0.52	**0.80**	0.34
Mycedium	**0.21**	0.11	**0.05**	0.03	**0.00**	0.00	**0.13**	0.06	**0.01**	0.01	**0.04**	0.02
Oulastrea	**0.00**	0.00	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00
Oxypora	**0.02**	0.02	**0.04**	0.03	**0.02**	0.02	**0.05**	0.03	**0.13**	0.06	**0.00**	0.00
Pachyseris	**0.01**	0.01	**0.00**	0.00	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00	**0.01**	0.01

Hard Coral Genera	2008		2010		2012		2015		2018		2021	
	Mean Cover (%)	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error	**Mean Cover (%)**	Standard Error
Pavona	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00	**0.00**	0.00
Pectinia	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.01**	0.01
Platygyra	**0.10**	0.04	**0.03**	0.02	**0.10**	0.05	**0.07**	0.03	**0.07**	0.03	**0.00**	0.00
Pocillopora	**0.21**	0.18	**0.07**	0.05	**0.00**	0.00	**0.02**	0.02	**0.01**	0.01	**0.01**	0.01
Porites	**0.30**	0.18	**0.68**	0.21	**0.39**	0.11	**0.15**	0.05	**0.29**	0.09	**0.02**	0.02
Psammocora	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.06**	0.06
Scapophyllia	**0.07**	0.07	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00
Seriatopora	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.02**	0.02	**0.00**	0.00
Symphyllia	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.01**	0.01	**0.00**	0.00
Turbinaria	**0.08**	0.06	**0.05**	0.03	**0.06**	0.05	**0.04**	0.02	**0.05**	0.03	**0.00**	0.00
Unknown	**0.18**	0.05	**0.34**	0.10	**0.16**	0.05	**0.12**	0.05	**0.16**	0.05	**0.69**	0.15
Generic Richness	**21**		**25**		**22**		**22**		**21**		**18**	