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Biological, Ecological and Structural Monitoring Report: Southwest Recreational Fishing Artificial Reef Trial, Geographe Bay, Western Australia

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Fisheries Research Report No. 293

Biological, Ecological and Structural Monitoring Report

Southwest Recreational Fishing Artificial Reef Trial, Geographe Bay, Western Australia

P. Lewis & M. Pagano

May 2019

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Executive Summary

Monitoring of the Southwest Artificial Reef Trial is documented in two reports: The Biological, Ecological and Structural monitoring conducted by the Department of Primary Industries and Regional Development (previously Department of Fisheries) (this report) and the Socio-Economic assessment, conducted by Recfishwest (FRDC Project 2014-005).

The overall findings of the Southwest Artificial Reef Trial were that Bunbury and Dunsborough Reefs have both been successful in their key objective of providing additional recreational fishing opportunities in the Geographe Bay area through;

1) the suitability of the design for the WA environment and chosen target species,
2) the limited impact detected on the surrounding area,
3) high usage by recreational fishers (FRDC Project 2014-005 report),
4) high knowledge and community support for their existence (FRDC Project 2014-005 report), and
5) benefits they provide to the whole community (FRDC Project 2014-005 report).

This report details the key findings from the Biological and Ecological monitoring of the Southwest Artificial Reef Trial over the first four years after they were deployed in autumn of 2013.

The key findings were;

- During the 4-year trial a total of 603 Baited Remote Underwater Video (BRUV) drops, 93 Diver Operated Video (DOV) surveys and 36 sidescan sonar transects were conducted on the artificial reefs and natural sites in the surrounding area,
- The BRUV, DOV and sidescan sonar methods proved complimentary in detecting significantly different fish communities and contributing to the different Priority 1 monitoring requirements,
- The number of fish species recorded on the Bunbury and Dunsborough Reef sites increased from 10 and 12, respectively, before deployment to 63 and 70 recorded by baited remote underwater video and diver operated video surveys over the four-year trial,
- The overall abundance of fish has continued to increase at the Dunsborough Reef, due primarily to species such as slender bullseyes, rough bullseyes, western king wrasse and footballer sweep, but has been stable on the last two surveys at the Bunbury Reef after increasing for the first three years,
- The fish species composition and abundance were significantly different between the Bunbury and Dunsborough Reefs but also between the surrounding natural reefs in

each area which is likely due to the differences in environmental conditions such as depth, 17 m compared to 27 m, wave climate and proximity to estuarine outflow between the two areas resulting in different fish communities for each area and hence on the Reefs,

- The three chosen target species (Samson fish, silver trevally and snapper) for which the 3x3x3 m "Fishbox" reef module design was expected to suit were all recorded on both Reefs and in most surveys over the four-year trial, for the first two species,
- The three target species are utilising the Reefs at different sizes and life history stages,
- The Dunsborough Reef consistently supported relatively high numbers of Samson fish, at the size of maturity, and small/juvenile trevally, neither of which were not recorded in the surrounding area or on Bunbury Reef so possibly enhancing their local biomass,
- The abundance of recreationally targeted demersal species recorded on the Southwest Artificial Reefs were low at 1-4 per BRUV, for Dunsborough Reef this was consistently lower than recorded on the surrounding natural area but at the Bunbury Reef these were equivalent in the final, fourth-year survey,
- Different fish species were recorded to utilise the Reefs in different ways with;
    - both Samson fish and trevally occurring in higher abundance on the two clusters of modules on the upcurrent side of the Dunsborough Reef than on the other module clusters,
    - Long snout boarfish occurring in much higher numbers on both Reefs than recorded in surveys of the surrounding natural low profile reef areas,
    - Western Australian dhufish (WA dhufish), only occurring on the cluster of modules closest to natural low profile reef at both Bunbury and Dunsborough,
- The fish species community composition on both Reefs changed significantly over the four-year trial but are still significantly different to the communities recorded on the nearby natural reefs and on nearby established artificial structures, such as *MV Lena* dive wreck and Quindalup Tyre Reef, due primarily to the absence of cryptic reef associated species,
- Over the four years of monitoring there have been no significant changes in the fish community composition at the 1 and 5 km distant natural reef monitoring sites for both Bunbury and Dunsborough Reefs,
- There was an initial decline in the abundance and sizes of snapper and WA dhufish at the 1 km monitoring site near Dunsborough Reef, suggesting a possible initial impact due to attraction to the artificial reef and increased fishing effort,

- There have been no issues detected with structural integrity of the modules by regular visual inspection by divers over the first four years, after the replacement of a module at Dunsborough Reef site that was damaged on deployment,

- There has been no detected change in the positioning of the modules by sidescan sonar, even after a storm event approaching the 1/100 year level that occurred within the first six months of deployment,

- The modules bedded down into the sediment to a depth of approximately 30 cm by the first survey, after 3 months, and visual inspection did not detect scouring at the site or impacts on seagrass beds in the vicinity, at either Reef,

- The amount of fishing debris such as fishing line, tackle and lost anchors detected accumulating annually on the Reefs has been low over the first four years,

- There were zero Threatened, Endangered or Protected Species (TEPS) recorded or reported on either of the Reefs during the four-year trial but Humpback whales and Bottlenose dolphins were observed in the vicinity of the Dunsborough Reef,

- The introduced marine pest species of colonial ascidian *Didenium sp.* was confirmed to occur on the Bunbury Reef by genetic sampling in 2016. The species is already established in the area and surveys showed percent coverage on modules varied annually with low coverage recorded in the final survey in 2017.

The final recommendations from the monitoring of the Southwest Artificial Reef Trial are;

- The “fish cube” module design has proved suitable to Western Australian conditions and for the chosen target species, particularly Samson fish,

- The placement of future artificial reefs should consider the results of the current study which showed differences in fish communities between the Bunbury and Dunsborough areas, likely due to the influence of differing environmental conditions, which will influence the results for any artificial reef so highlighting the need to conduct surveys prior to deployment to assess the local abundance of target species,

- The modules and layout of future deployments would likely suit more species and various life history stages by having a wider variety of structure types to give a range of habitat types similar to natural reef areas, particularly ledges and caves, which would allow more refuge from large predators, such as Samson fish, and suit cryptic reef associated species,

- Further studies to discern the diet, reproduction and movement of target fish species could determine the degree to which they are resident upon the reefs, spawning at the reefs, utilising the reefs for resources compared to surrounding areas, and impacts they could be having upon other species, both on the artificial reef and surrounding area,

- The limited accumulation of fishing debris means ongoing diver surveys for removal could be conducted every three- five years, along with a sidescan sonar survey to confirm module positioning,
- The initial monitoring of an artificial reef should be conducted for a minimum of four years by both remote and diver surveys as results obtained by only one method within the first two years will not meet all of the monitoring requirements and only provide part of the picture on the effectiveness and possible impacts of the artificial reef.

1. Introduction

In 2012, the then Western Australian Department of Fisheries – now called Department of Primary Industries and Regional Development (Department) commenced a trial project to construct, deploy and monitor two purpose-built artificial reefs in Geographe Bay. This trial, the first of its kind in Western Australia, evaluated the effectiveness of the two artificial reefs and the social benefits of providing alternative recreational fishing opportunities in the Geographe Bay area in the south west of Western Australia.

A comprehensive consultation process with local government and community, coupled with comprehensive constraints mapping, clearances from a range of State and Commonwealth authorities and agencies resulted in the selected sites for the two artificial reefs.

In February 2013, the Department was granted Artificial Reef Permits, issued under Section 19 of the *Environment Protection (Sea Dumping) Act 1981*, to deploy two artificial reefs in Geographe Bay off the coast of Dunsborough and Bunbury (Figure 1).

A State government tender process was undertaken through the Department of Finance, Building Management and Works Division for the design, construction and deployment component of the project. The successful tenderer (Haejoo Pty Ltd) was required to comply with the Departments' 'Habitat Enhancement Structures Policy' and 'Guidelines for Risk Management of Vessel Biofouling', 'Long Term Monitoring and Management Plan (LTMMP) for the Recreational Fishing Artificial Reef Trial in Geographe Bay', and conditions as set out in the *Environment Protection (Sea Dumping) Act 1981* Artificial Reef Permits.

Project Objectives:

- To enhance the local recreational fishing opportunities and values in the south west of the state for nearshore fish species;
- Engage with experts to identify appropriate sites for deploying fishing enhancement structures, based on local fishing species, access, navigation issues and other considerations; and
- Design, install and monitor the effectiveness of two purpose-built artificial reefs in Geographe Bay.

This Report Outlines:

- the monitoring conducted prior to and following the deployment of the artificial reefs in Geographe Bay;
- the findings of the priority one Biological, Ecological and Structural monitoring and some priority two objectives for the trial (see below); and
- any incidents or management actions undertaken.

2. Deployment

The artificial reef modules were deployed at the Dunsborough and Bunbury sites (Figure 1) between the 18-21st of March and 2-4th April 2013, respectively. The fabrication and deployment was conducted and overseen by the contractor Haejoo Pty Ltd, a specialist artificial reef design, manufacturer and deployment company.

Once all 30 of the artificial reef modules were deployed at each site their positioning was confirmed using sidescan sonar survey (Figure 2). Sidescan and depth soundings were also used with tide height to calculate the minimum water depth over the modules at Lowest Astronomical Tide (LAT) for each site. The LAT depth and extent of the modules was provided to the Department of Transport and the Royal Australian Navy (Hydrographic Office) for inclusion on nautical charts. The artificial reef sites were officially named as the "Bunbury Reef" and the "Dunsborough Reef" by the Minister for Lands on the 12th April 2013.

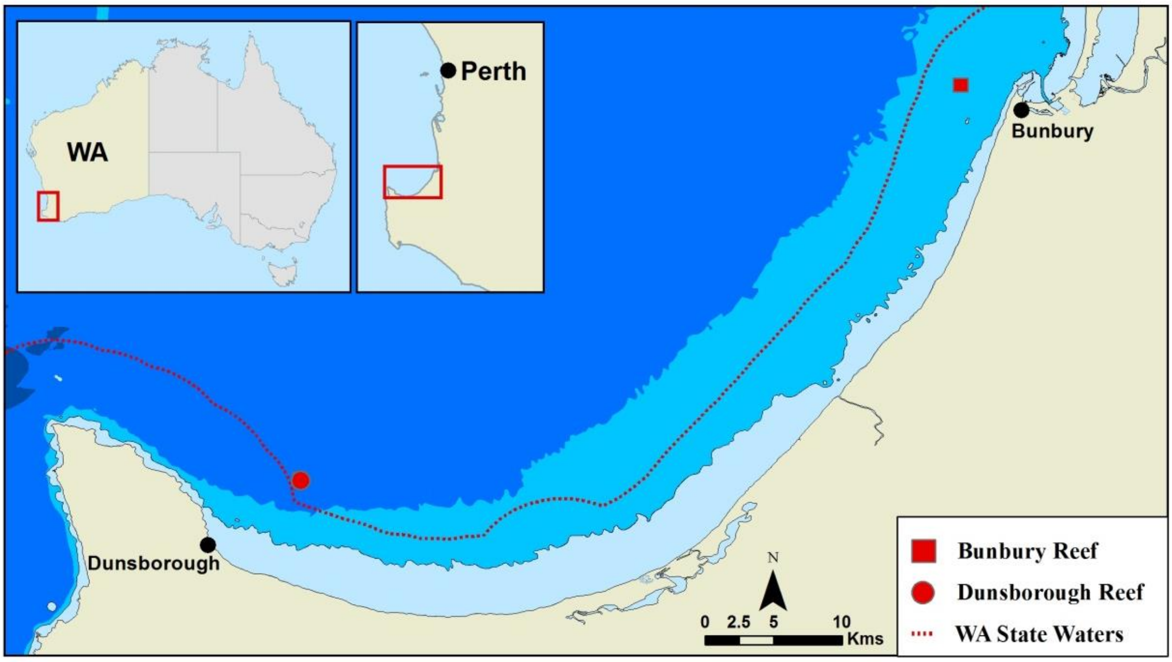


Figure 1. Map showing locations of Bunbury and Dunsborough Reefs.

2.1 Bunbury site details

- Located 3.4 km from the closest point on shore;
- Water depth at the artificial reef site ranges between 16.7 and 17.8 m;
- The site is predominantly sand with a small percentage of patchy seagrass <25% with further seagrass and exposed limestone reefs in the surrounding area.

The centre of the Bunbury site is located at 33° 18.500 S latitude and 115° 35.900 E longitude (Datum; WGS 1984) and the extent of the site is:

Corner	Latitude	Longitude
Northwest	33° 18.447 S	115° 35.846 E
Northeast	33° 18.447 S	115° 35.951 E
Southeast	33° 18.553 S	115° 35.951 E
Southwest	33° 18.553 S	115° 35.846 E

2.2 Dunsborough site details

- Located 6.3 km from the closest point on shore.
- Water depth at the artificial reef site ranges between 26.8 and 27.7m.
- The site is mainly sand with a small percentage of patchy seagrass <10% with further seagrass and exposed limestone reefs in the surrounding area.

The centre of the Dunsborough site is located at 33° 33.962 S latitude and 115° 9.980 E longitude (Datum; WGS 1984) and the extent of the site is:

Corner	Latitude	Longitude
Northwest	33° 33.909 S	115° 9.919 E
Northeast	33° 33.909 S	115° 10.035 E
Southeast	33° 34.007 S	115° 10.035 E
Southwest	33° 34.007 S	115° 9.919 E

3. Layout

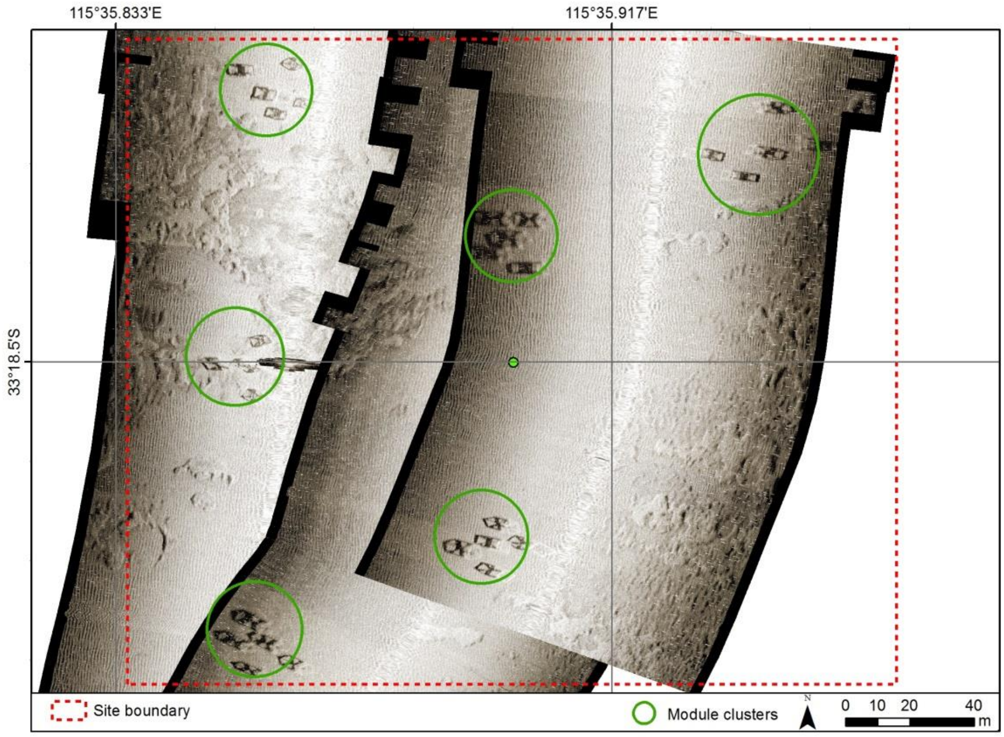
The artificial reefs were deployed in an arrangement of six clusters at each of the two sites with a spacing of between 50 m and 70 m between each cluster. Each cluster comprises five modules arranged with a central module and the other four spaced around in an approximate compass pattern, to the north, south, east and west, with spacing between individual modules

of between 1 and 7 m (Figure 2). Each cluster was identified based on its location within the site *i.e.* northwestern corner (NW), northeastern (NE), western (W), southwestern (SW), southeastern (SE) and closest to centre point of the site (CENT).

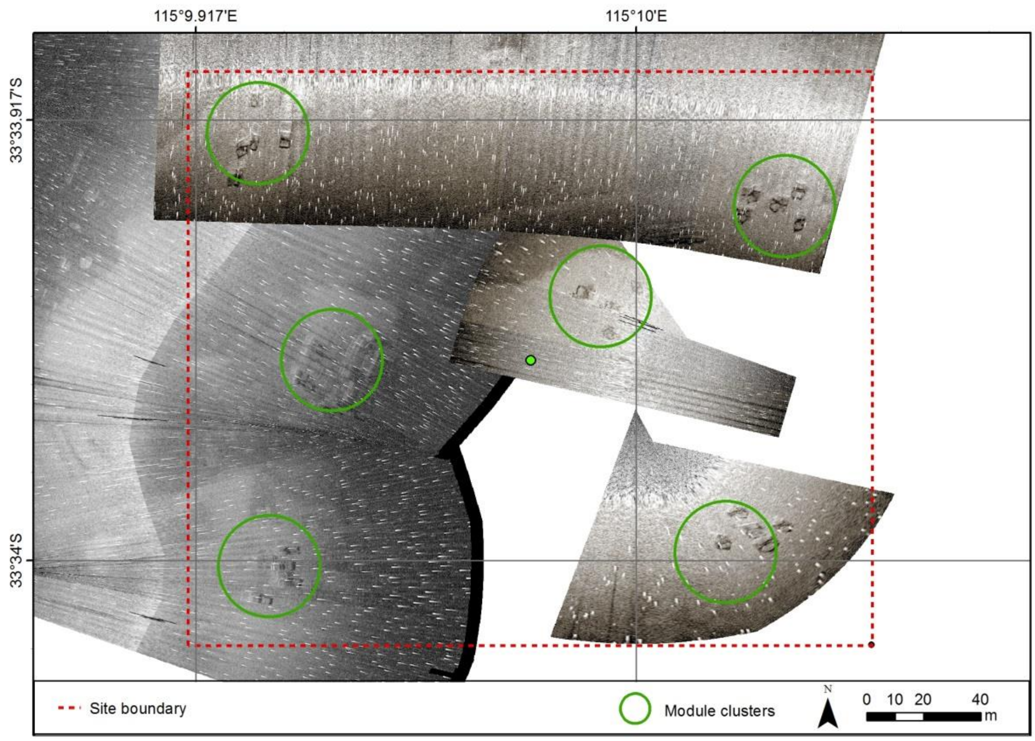
Each module is constructed of steel reinforced concrete to basic structural code AS3600 – 2009 for concrete structures (minimum 28 mpa, 20 aggregate and 120 slump), cured for at least 28 days prior to deployment to ensure full structural strength is achieved, and concrete pH has stabilized. The modules are approximately 3.0 x 3.0 x 3.0 m open cube shapes with a surface area of between 25 m^2 and 30 m^2 and an internal volume of between 20 m^3 and 25m^3. The modules weigh approximately 10 tonnes of which 700 kg is steel reinforcing. The completed artificial reef consisted of 30 modules placed in several clusters making up a minimum internal volume of 800 m^3 at each reef location.

The modules were placed in their respective layouts (Figure 2) to;

1) avoid areas of seagrass;
2) increase the volume of each reef;
3) maximise possible recreational boat fishing access to each site; and
4) ensure that most clusters were facing the predominant current direction.



a)



b)

Figure 2. Sidescan sonar survey of artificial reef modules recorded in February 2017 at a) Bunbury and b) Dunsborough Reefs with red line indicating site boundary (200 x 200 m) and green circles indicate each cluster of five modules.

4. Monitoring

4.1 Plan development

The Department established the Habitat Enhancement Structures Scientific Reference Group (SRG) to provide advice and input on the proposed locations, monitoring and assessment programs related to applications to deploy artificial reefs in Western Australia.

The SRG consisted of representatives from the main universities and environmental agencies including the Department, the University of Western Australia's Oceans Institute, Murdoch University, Curtin University, Challenger Institute of Technology, the WA Museum and the then Department of Environment and Conservation -now Department of Biodiversity, Conservation and Attractions (DBCA).

Initial discussions by the SRG in February and March 2012 developed an initial monitoring and assessment plan to investigate all aspects of the artificial reef trial. This monitoring plan for the artificial reefs incorporated the requirements of the Department's Environmental Protection (Sea Dumping Act) artificial reef permit (obtained for both reefs) to determine whether:

1) The project goals and objectives are being met,

2) The reef is remaining stable and retaining its structural integrity, and

3) Any other conditions required under the permit.

A subsequent meeting in March 2013 of the SRG revised the monitoring plan to focus on the key objectives of the artificial reef trial *i.e.* their effectiveness as recreational fishing sites and impacts on surrounding natural reefs. Items identified in the previous monitoring plan were retained as secondary objectives subject to additional funding and/or collaborative student projects.

At the March 2013 meeting of the SRG a number of issues with the monitoring plan were discussed, including,

1) the difficulties in testing the attraction Vs production in a fished system,

2) that it was unlikely to see increased production during the initial years until the modules had become sufficiently colonised by primary producers,

3) it was considered that results were likely to vary between species with some transient sp. unlikely to increase production while resident species may through increased refuge, food resources and recruitment,

4) the need to examine the species occurring and being caught at the artificial reef sites particularly if recruitment of recreationally important species is occurring at the site,

5) the funding was not sufficient to gather information from the benthic surveys of sessile invertebrates and was not deemed critical to answering the key question of their effectiveness of the sites for recreationally important species,

6) it was determined that it was more feasible to examine the impacts of artificial reefs upon the fish abundances on surrounding reefs and infer possible processes from these results than assess the inputs or extraction on the artificial reefs themselves, ie.

positive impact – increased abundance through reduced fishing pressure and increased local recruitment/production or

negative impact– attraction of fish from surrounding reefs to artificial reefs and subsequent extraction by increased fishing pressure.

4.2 Monitoring Objectives

The SRG ranked the monitoring objectives as Priority 1 (essential), and Priority 2 (to be addressed if and when resources become available or if priorities or risk levels change).

Priority 1 monitoring objectives listed below were fully funded. The monitoring objectives are grouped under four headings (although there may be some overlap). The biological, ecological and structural components of the monitoring plan were conducted by the Department's Research Division, the results of which are presented in this report. The social and economic components were carried out by Recfishwest and reported separately.

4.2.1 Priority 1 Objectives

The detailed priority 1 objectives are grouped under four headings, although there is overlap.

1. Biological

a. Document the use/colonisation of artificial reefs by recreationally important fish species, noting any concentration and production effects. How and why are fish using these structures?

b. Document the presence of any threatened, endangered or protected species (TEPS) in proximity with the artificial reefs,

c. Document the presence of any introduced species in proximity with the artificial reefs.

2. Ecological

a. Describe the extent of the influence of the artificial reefs on recreationally important fish species in the area.

b. Assess the impacts of artificial reefs on proximal reef communities with comparisons to (potentially) HMAS Swan, natural reefs and Busselton Jetty (NB – existing data for the HMAS Swan and Busselton Jetty already exists).

3. Artificial Reef Structures

a. Document changes to the artificial reef modules post-installation including movement, integrity (e.g. cracking and rusting).

b. Document changes to areas immediately around the artificial reefs post-installation including scouring, sedimentation, and benthic habitat types etc.

c. Document any other anthropogenic changes such as fouling of fishing gears and anchors, and remove to reduce risks.

4. **Social/ Economic** (conducted by Recfishwest in Florrisson *et al.* 2018**)**

a. Document the use of the artificial reef areas by recreational fishers.

b. Document fishing activties (effort and catch) on artificial reefs. Compare to iSurvey data (when available) to identify changes in recreational angler behaviour (catch, effort etc).

c. Document reasons why fishers use the artificial reefs.

d. Any other information available of the social/economic impacts of artificial reefs (e.g. divers/non-extractive; commercial views/displacement; non-fishery users such as tourists on beaches etc.); local knowledge of artificial reefs.

4.2.2 Priority 2 Objectives

Priority 2 objectives were to be conducted if resources become available (e.g. external funding) or if priorities or risk levels change. To encourage universities to develop student projects to meet these priorities a letter identifying potential projects was sent to the Universities in Perth. In addition, a collaborative expression of interest (EOI) project proposal and Targeted Research Fund (TRF) application were developed and submitted to the FRDC in June 2013 for additional funding. The EOI application was developed by CSIRO to collect additional information on the primary productivity at the artificial reef sites and compare with surrounding areas for differences and changes over time which may indicate increased production by the artificial reefs. The TRF aimed to gather initial benthic colonisation data and genetic samples of benthic invertebrates which could be utilised in a future dietary study. Unfortunately, none of these applications were successful and no student projects were developed. The project was however able to assess the Priority 2 objectives on fish community for the artificial reef sites and natural monitoring sites.

Biological

- Document the use/colonisation of artificial reefs by the entire fish community (Covered in Report),
- Document the colonisation of artificial reefs by the macro-invertebrate community, and
- Investigate movements of high priority species within the study area.

Ecological

- Document the colonisation and settlement of artificial reefs by the sessile community,
- Describe the extent of the influence of the artificial reefs on the entire fish community in the area (Partly covered in Report),

- Assess the impacts of the artificial reefs on surrounding benthic communities, including comparison on sand patches (controls) in proximity.
- Document changes in biodiversity associated with the artificial reefs and compare to adjacent and control sites.

4.3 Monitoring conducted

An initial pre-deployment survey of the artificial reef sites and nearby natural reef control sites within 1 km (CR1) was conducted four months before deployment in Summer 2013. Surveys of the artificial reef sites, control sites and surrounding area were conducted seasonally after deployment, in Summer (Jan/Feb), Autumn (May) and Spring (Sep/Oct) of the first two years and in Summer only for the final two years (2016 and 2017). This resulted in nine periodic surveys at 1, 6, 10 13, 18, 22, 25, 34 and 46 months after deployment. The section below gives details of the methods conducted in the vicinity of each artificial reef site in each survey.

Due to funding constraints, consistent with the Departments LTMMP, the surveys focussed on priority 1 objectives in the monitoring program, although some priority 2 objectives were also met. The timing of surveys conducted and the methods used during each survey are summarised in Table 1. At the Bunbury Reef the diving component was generally restricted to the Summer surveys due to limited visibility encountered during Autumn and Spring surveys.

Table 1. Types and amount of monitoring conducted (number of drops or transects) in each survey at each artificial reef site. (A- artificial reef site; C-control sites; All- comprehensive).

				Bunbury Reef				Dunsborough Reef			
Survey	**Month**	**Time in water**	**Sites**	**BRUV**	**Dive**	**Sonar**	**TUV**	**BRUV**	**Dive**	**Sonar**	**TUV**
Pre-Deploy	Jan	Prior	A & C	9	-	4	6	9	-	4	6
Deployment	Apr	0	A	-	-	2	2	-	-	2	2
Autumn13	May	1 mth	All	58	-	2	-	55	4	2	-
Spring13	Sep	6 mth	A & C	9	-	-	-	9	4	-	-
Summer14	Feb	10 mth	All	50	10	2	-	50	4	2	-
Autumn14	May	13 mth	A & C	9	-	-	-	9	4	-	-
Spring14	Oct	18 mth	A & C	9	-	2	8	9	-	2	8
Summer15	Feb	22 mth	All	50	10	2	-	50	12	2	-
Autumn15	May	25 mth	A & C	9	3	-	-	9	3	-	-
Summer16	Feb	34 mth	All	50	10	2	-	50	12	2	-
Summer17	Feb	46 mth	All	50	6	2	-	50	11	2	-

4.3.1 Biological and Ecological

The priority 1 biological and ecological monitoring objectives can be grouped into:

1 effectiveness of the artificial reefs sites for the three target recreationally important finfish species (Objectives 1a & 2a), namely Samson fish – *Seriola hippos*, Silver trevally - *Pseudocaranx georgianus* and Snapper - *Chrysophrys auratus*, with comparison to nearby sites and established artificial structures (Objective 2b);

2 impacts of the artificial reefs upon the relative abundance and size of recreationally important fish species at proximal natural reef sites (Objectives 2a & 2b);

3 documenting the occurrence of any threatened, endangered or protected species or introduced marine pasts in the vicinity (Objectives 1b & 1c), see management section.

4.3.1.1 Effectiveness of artificial reef sites

During the artificial reef trial the effectiveness of the artificial reef sites (ARs) for the three target species and recreationally important demersal species and their utilisation of the sites were monitored on each survey. The size and abundance of three target species and other recreationally targeted species on the artificial reef sites was assessed by the following methods:

1) stereo Baited Remote Underwater Video (sBRUVS) sets (all surveys);

2) stereo Diver Operated Video (sDOV) surveys of each cluster (as possible); and

3) stereo Towed Underwater Video (sTUV) surveys (where sDOV not possible).

4.3.1.2 Impacts of artificial reef sites

During the trial the possible impact of the artificial reef on the abundance and size of key recreational species and fish communities on surrounding natural control sites was assessed by:

1) seasonal sBRUV surveys of nearby natural control reef within 1 km (CR1) and distant natural control reef >5 km away (CR5), during each survey; and

2) additional comprehensive sBRUV surveys of surrounding natural reefs (approximately every kilometre away from AR), conducted during each Summer survey (Note: not covered in this report),

3) additional sDOV surveys of nearby (CR1 - within 1 km) and distant (CR5 >5 km away) control reefs (when possible).

At Dunsborough the CR1 and CR5 natural sites were low profile reef areas located along the 24 m depth while at Bunbury the sites were located along the 14 m and 17 m depth reef areas. These low profile natural reef areas were located initially from the Light Detection and Ranging (LIDAR) mapping (Figure 3) and finalised by sidescan sounder surveys of the areas. At the CR1 and CR5 sites there were three sBRUV replicates deployed on each survey.

The comprehensive sBRUV survey of natural reef sites was carried out at distances of approximately every kilometre up to 6 km away from each artificial reef site in replicates of three at Bunbury and five at Dunsborough. This was done due to the paucity of natural low profile reef areas near the Bunbury Reef and to allow comparison of the Dunsborough surveys with ongoing and historical BRUV survey methods in the Geographe Bay area. Similarly, the timing of the comprehensive surveys of surrounding natural reefs areas over the February-March period was to coincide with other similar surveys (not covered in this report).

4.3.1.3 Survey methods

All sBRUV sets were of at least 1-hour duration and baited with at least 0.5 kg of chopped pilchards. In most surveys six sBRUV units were used allowing three to be set at each distance initially and at Dunsborough, where each distance had five replicates, a second set of two sBRUVs at each distance to finish each group. All sBRUV sites in the surrounding area were separated by at least 300 m. This separation was not possible at the Reefs where some clusters were only 70-80 m apart, except where sets were done at three corner clusters allowing at least 150 m separation between each unit. The sBRUV sets done on the Reefs were targeted at each cluster with the sBRUV set close to the modules, usually within 3-8 m, and aligned when deployed so most likely to be facing the modules. Similarly, sBRUV sets done on natural surrounding area sites were done targeting hard benthos areas of low profile reef and changes in depth indicating ledges, where possible, so as to get as similar a structure as possible to the Reefs.

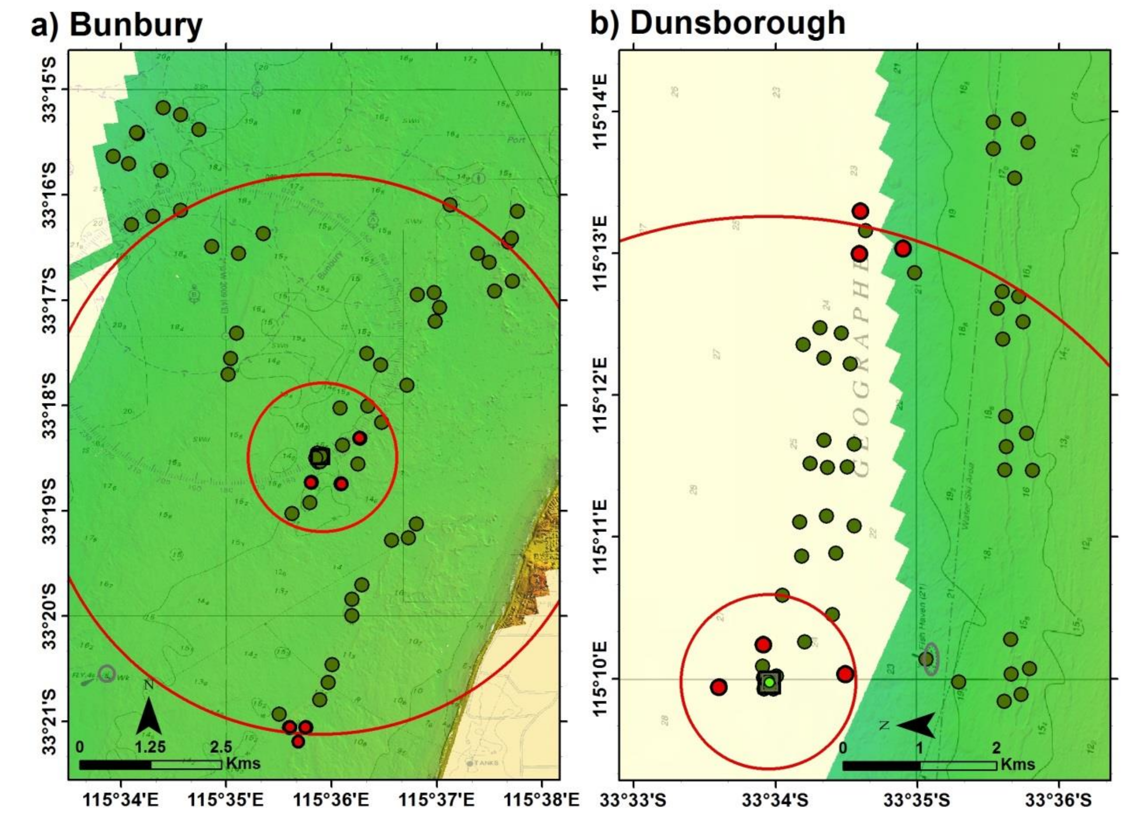


Figure 3. Map showing locations of all sBRUV sets (green) with CR1 and CR5 sites (red) at a) Bunbury and b) Dunsborough Reefs, where smaller red circle at 1km, larger at 5 km from Reef, green colouration is LIDAR mapping of area showing depth changes and RAN charts overlaid. Note: Dunsborough Reef map orientation altered to fit page.

The diver surveys of the Reefs were conducted to sequentially survey the fish in and around each module in each cluster by sDOV and underwater photography. As each cluster is set out in an approximate compass pattern around a central module a consistent survey design was utilised. Before the divers entered the water the sidescan sonar was used to locate and position the shotline as close to the central module as possible. Divers descended with sDOV recording and first surveyed fish above the cluster and in and around the central module, with the underwater photography used to capture detailed images of the structures, fish species and some of the benthic organisms on the modules. Once completed the divers located the northern module by compass and swam around the perimeter surveying fish in and around the module along with the structure of the module itself and any fishing debris. Divers then returned to the central module before next surveying the western module and again swimming around the perimeter before returning to the central module and continuing this pattern for the southern and eastern modules. Similarly, at the CR1 and CR5 sites the divers used the shotline as the central marker and surveyed to the North, West, South and East to a distance of approximately 15 m and return to simulate the area covered on the Reefs of approximately 60 m (5 modules x 4 sides x 3 m length). Where the area of natural reef did not continue in any direction the surveys were extended in the other directions to compensate and cover the overall distance. At the other artificial structures, which included the Quindalup Tyre Reef, Busselton Jetty and *HMAS Swan* near Dunsborough and the *MV Lena* at Bunbury, the surveys were varied to

include all areas of the structure for qualitative comparison of species occurring on these sites with those on the Reefs.

4.3.1.4 Processing methods

The relative abundance (MaxN) of each fish species observed and the size (TL or FL to mm) of each individual recreationally targeted species at the time of MaxN were assessed on all sBRUV and sDOV videos using the EventMeasure software (SeaGis tm). The mean MaxN and standard error for each target species in each area, at each site (AR, CR1 and CR5), on each survey was calculated from the MaxN on each sBRUV. As differentiation of the visually similar trevally species, silver and sand (*Psuedocaranx wrightii*), is not possible from video footage all trevally smaller than 250 mm, the maximum reported size of sand trevally (Hutchins and Swainston, 1986), of were grouped as small trevally sp. and any larger classified as silver trevally. To calculate the relative abundance of demersal species the combined MaxN on each sBRUV for the demersal species (Snapper, WA dhufish (*Glaucosoma hebraicum*), baldchin groper (*Choreodon rubescens*), boarfish species (Long-snouted - *Pentaceropsis recurvirostris,* Yellow-spotted - *Paristiopterus gallipavo,* and Short - *Parazanclistius hutchinsi*), breaksea cod (*Epinephilides armatus*), western foxfish (*Bodianus frenchii*), queen snapper *(Nemadactylus valenciennesi*) and blue groper (*Achoerodus gouldii*)) were added.

The overall species abundance data from the sBRUV surveys was fourth root transformed while the sDOV data was examined qualitatively by species presence or absence only. For each a Bray Curtis similarity matrix developed and examined by nMDS (non-metric multidimensional scaling). The data was then analysed by non-parametric permutational analysis of variance (PERMANOVA) in the Primer E package (ePrimer) with a three factor nested design of Area (Bunbury and Dunsborough), Site (AR, CR1, CR5), and Survey (nested in site) with replicates (n=3-6).

Each sBRUV and sDOV unit was calibrated before and after each survey using the software CAL (SeaGis Pty Ltd). To get the most accurate length estimates possible for target species and recreationally targeted species at the time of MaxN each individual of for the species was numbered and measured on a number of different occasions while in the field of view. This was achieved by stepping through the video in 5 or 1 frame steps to track the movement of each fish and numbering the measurements of each individual. For individuals with a number of length estimates the best estimate was determined as either 1) the estimate with the lowest precision or 2) if numerous measurements with a precision of less than 5 mm or 1% of the length it was determined as the longest length, to allow for swimming motion of the fish giving smaller lengths. The length frequency distribution was determined for each of the Target species at each Site in each Area over all surveys for comparison. In addition, the mean lengths and standard errors for each Target species were calculated for each Survey at each Site and were compared over the trial for differences and changes.

4.3.2 Position, structural and debris removal

During the trial the positioning of the artificial reef modules was assessed at each Reef by sidescan sonar during each of the surveys. Transects across each reef were recorded on Humminbird 1098C (2012-2016) and Helix12 (2017) sounders units. The recorded transects were processed with SonarTrX-SI software (Leraand Engineering Inc.) using the Create mosaic tool to generate georeferenced images of each sidescan transect. These images were imported into ArcGIS software to create maps with the locations of the module clusters at each reef site. The distribution of habitat types was also discerned from these images and was compared by overlaying the sidescan images of successive surveys. The areas of different habitats included seagrass beds which showed as mottled areas, sediment that showed as clear featureless areas at Dunsborough or ridges in sand at Bunbury and macroalgal reef a mottled and dark echo return area at Bunbury.

The structural integrity of the modules and the amount of fishing debris (hooks, line, anchors, rope, etc.) on the artificial reef sites was assessed during the sDOV surveys. Each aspect of each module in all six clusters at the Dunsborough Reef and Bunbury Reef were inspected in the Summer survey of each year by divers swimming around each module with sDOV recording to document that status of the modules and location of fishing debris (anchors, fishing line and other), which was removed.

4.3.3 Social/Economic

Recfishwest, the peak body for recreational fishing in Western Australia, is undertaking the socio/economic monitoring component of the SW artificial reef trial. The assessment will include information collected from recreational fishers evaluating the Priority 1 objectives relating to catch and experience fishing at the artificial reef sites. This assessment utilised a range of methods including a fishing logbook, fisher activity observations, boat ramp surveys, local business questionnaires and an electronic survey (Florisson 2017).

5. Key findings

5.1 Biological & Ecological surveys

The sBRUV and sDOV footage from all surveys of the AR, CR1, CR5 and other artificial structures (Busselton Jetty, *HMAS Swan*, *MV Lena* and Quindalup Tyre Reef) have been fully processed and undergone analysis for this report. The stereo video methods used allow the total length (TL) and/or length to caudal fork (FL) to be estimated for the target species and most other recreationally important fish observed.

5.1.1 Pre-deployment

The pre-deployment sBRUV and sTUV surveys at the Bunbury and Dunsborough reef sites recorded 10 and 12 species of finfish, respectively (see Appendix 1). Of the target species only three snapper (FL= 445-480 mm) and five small trevally (FL= 90-120 mm) were recorded by the three BRUVs at the Dunsborough Reef site and nine silver trevally (FL = 262-272 mm) at the Bunbury Reef site on these surveys.

5.1.2 Effectiveness of artificial reefs

5.1.2.1 Summary

The Bunbury and Dunsborough Reefs have both developed a diverse fish community over the first four years but remain quite distinct from each other, to nearby surrounding natural reefs and to other artificial structures surveyed, with significant differences. The fish species occurring in the areas off Bunbury and Dunsborough were found to be quite different and hence the results differ between the two Reefs. This is likely due to the areas being quite different marine environments with Dunsborough being more sheltered from oceanic conditions, having finer sediments, patchy seagrass beds, scallop shell beds and sponge garden reefs, while Bunbury is more exposed to oceanic waves and swell, having course sediments, low profile macroalgal reefs interspersed with extensive seagrass beds. In addition, the Bunbury Reef is close to a large estuary system, the Leschenault Inlet with the outflow contributing to nutrient inputs and suspended sediments which combined with the decomposition of macroalgal wrack after large storm events at times reducing visibility to less than 1 m.

Both artificial reefs show signs they are becoming established with the number of fish species and relative abundance stabilising in more recent surveys after increasing dramatically over the first two years. The relative abundance of all fish has continued to steadily increase at the Dunsborough Reef and stabilised at the Bunbury Reef after the third year. The variability in abundance recorded on some surveys are likely due to seasonal factors influencing the abundance of some species and influence of low visibility on results from video surveys. All three target species (Samson fish, snapper, and silver trevally) have been recorded on both artificial reefs to date, albeit in low numbers for snapper at both reefs and silver trevally at the

Bunbury Reef. Comparison with natural reefs and nearby artificial structures indicates many species found there are not yet occurring on the Reefs and the lack of crevices, ledges and darkened cavelike areas provided by the “fish cubes” may prevent some of these reef dwelling species from occurring on the Reefs.

The target species appear to be utilising each of the reefs differently with high numbers of Samson fish at the size of maturity occurring on the Dunsborough Reef which were not recorded consistently on the Bunbury Reef or on the nearby natural reefs, indicating a possible concentration effect for the species at the Dunsborough Reef. However, as the species are growing and occurring in schools during the spawning season there may also be some production. Similarly, high numbers of small trevally but no larger individuals have consistently been recorded on the Dunsborough Reef but not at the Bunbury Reef or on the nearby natural reefs where predominantly larger individuals occurred. As most of the small trevally are recent recruits there may be some production effect for the species by the Dunsborough Reef enhancing the local recruitment and biomass for the species in the local area but the lack of larger individuals may indicate the Dunsborough Reef does not prove suitable for them as they grow, for as yet unknown reasons. Meanwhile the numbers of snapper recorded have been low and more variable on both artificial reefs, which is also evident on the natural reefs in both areas. Although the size of snapper recorded on the Dunsborough Reef is generally larger than that recorded on the natural reefs with few of the smaller 250-400 mm FL size group recorded, which were highly abundant on the natural reefs, possibly indicating the Reefs are not yet suited to small/juvenile snapper. While at the Bunbury Reef the opposite is true with almost all snapper below the LML with some larger fish on the surrounding natural areas and this may be due to fishing pressure removing the snapper above LML from the Bunbury Reef.

The preference for particular clusters by the target species was evident at the Dunsborough Reef where both Samson fish and trevally occurred in higher abundances on the western clusters, which are on the upcurrent side of the site and may provide some food availability and energetic advantage to these schooling species. While at Bunbury there were no clear differences in abundance of the target species between the clusters.

Although the two Reefs are quite different there were some similar results for some recreationally targeted demersal species such as WA dhufish and long-snouted boarfish. At both Bunbury and Dunsborough WA dhufish were only recorded on the cluster closest to the area of nearby natural reef, possibly indicating the species preference for suitable nearby habitat. The long-snout boarfish were recorded in much higher numbers on the Reefs than on the surrounding low profile reef areas, which indicates a clear preference and concentration effect by the Reefs. Further at the Dunsborough Reef the species showed a clear preference to the northern clusters with much higher abundances than on the other clusters. The limited observations from BRUVs and sDOVs indicated the species were sheltering among the modules and not feeding on the Reefs although further study would be required to confirm if this is the case.

5.1.2.2 Overall comparison

Although there were similar numbers of fish species recorded at both Bunbury and Dunsborough Reefs, at 63 and 70 species respectively, it was evident from the fish community composition data there were marked differences in the overall abundances between the Bunbury and Dunsborough areas. Similar numbers of BRUVs (n=42) at each Reef over all surveys recorded more than twice the number of individual fish at Dunsborough Reef of n=3440 compared to n=1655 at Bunbury Reef. Similarly, on the surrounding CR1 and CR5 natural reef areas the same number of sBRUVs (n=54) over all the surveys recorded higher numbers of fish at the sites near Dunsborough (n=3753 fish) compared to at Bunbury (n=2435).

Visualisation of the differences and similarities in the fish community composition data for all sBRUV surveys of Sites (AR, CR1 and CR5) in both Areas (Bunbury and Dunsborough) by nMDS (nonmetric Multi-Dimensional Scaling) (Figure 4) shows the clear separation between the fish communities recorded at the AR (red) and natural CR sites (blue), with little overlap. Less distinct but also evident is the separation, with some overlap, of the Bunbury (Hollow shapes) and Dunsborough (Solid) Areas for both AR and CR sites.

Analysis of the fish community data for these sites over all sBRUV surveys at both Reefs by PERMANOVA (Table 2) indicated highly significant differences (P=0.001) between Areas (Bunbury and Dunsborough), Sites (AR, CR1 and CR5), and Surveys. Further pair-wise investigation showed the Sites were all significantly different in the Dunsborough Reef area but the CR1 and CR5 sites were not significantly different at the Bunbury Reef. Between Surveys there were significant differences in fish communities recorded by sBRUVs for both the Bunbury and Dunsborough Reefs (Table 3), with the later two surveys (Summer 2016 and Summer 2017) generally significantly different to most previous surveys but also to each other.

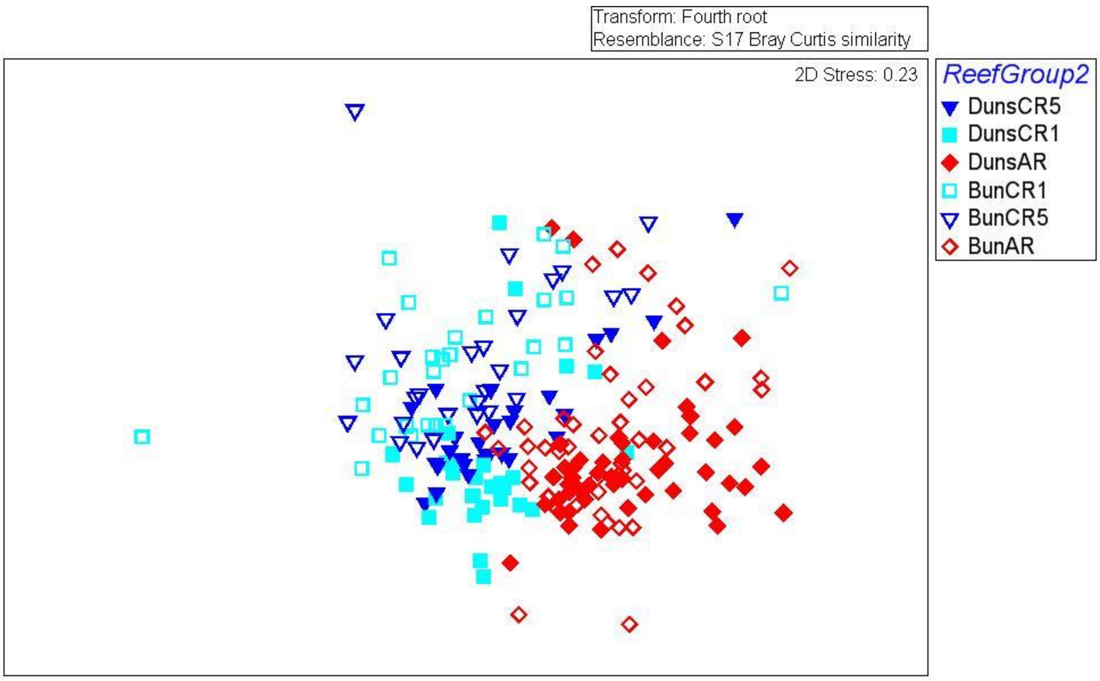


Figure 4. nMDS plot of overall fish community data from all sBRUV surveys of Southwest Artificial Reef trial.

Table 2 Results of PERMANOVA analysis of overall species data from all sBRUV surveys, with significant P values shown in **bold**.

Source	df	SS	MS	Pseudo-F	P(perm)	perms
Area	1	22235	22235	10.569	**0.001**	997
Site	2	74160	37080	10.641	**0.001**	999
Survey(Site)	24	86732	3613.8	2.0466	**0.001**	995
AreaxSite	2	20443	10222	4.851	**0.001**	998
AreaxSurvey(Site)	24	51187	2132.8	1.2078	**0.022**	995
Res	144	2.5427E5	1765.8			
Total	197	5.1568E5				

Table 3 Pair-wise results of differences between all sBRUV surveys at Bunbury and Dunsborough Reefs from PERMANOVA analysis of species abundance data, with significant P values (<0.05) shown in **bold**.

a) Bunbury	Aut13	Spr13	Sum14	Aut14	Spr14	Sum15	Aut15	Sum16
Spr13	1							
Sum14	0.601	1						
Aut14	0.497	0.213	0.084					
Spr14	0.111	0.219	0.487	0.052				
Sum15	**0.014**	**0.02**	0.086	**0.007**	0.051			
Aut15	0.101	0.291	1	0.125	0.745	0.166		
Sum16	**0.018**	**0.024**	0.155	**0.01**	0.164	0.081	0.155	
Sum17	**0.004**	**0.007**	0.053	**0.008**	**0.019**	0.076	**0.043**	**0.009**
b) Dunsborough								
Spr13	0.296							
Sum14	0.594	0.423						
Aut14	0.403	0.303	0.714					
Spr14	0.067	**0.011**	0.58	0.148				
Sum15	0.515	0.109	1	0.489	0.089			
Aut15	**0.019**	**0.006**	**0.044**	0.231	**0.002**	**0.024**		
Sum16	**0.017**	**0.019**	0.272	**0.038**	**0.041**	**0.036**	**0.024**	
Sum17	**0.007**	**0.004**	**0.004**	**0.006**	**0.003**	**0.006**	**0.001**	**0.016**

5.1.2.3 Bunbury Reef

5.1.2.3.1 Fish community

The post deployment sBRUV and sDOV surveys have recorded a total of 63 fish species at the Bunbury Reef (Appendix 1). The number of fish species recorded on each successive survey by sBRUVs has been highly variable, often due to the low visibility encountered at the site in the Spring and Autumn surveys, but continued to slowly increase for the first two years after the modules were deployed and has stabilised at 30-40 species (Figure 5).

The total number of fish species recorded on the Bunbury Reef is similar to the 67 and 75 species, respectively recorded at the CR1 and CR5 natural reef sites. However, as with the Dunsborough Reef there were 30 reef associated species, such as blue lined leatherjacket (*Meuschenia galii*), Victorian scalyfin (*Parma victoriae*) and Woodwards reef-eel (*Gymnothorax woodwardii*), which were not recorded at the Bunbury Reef.

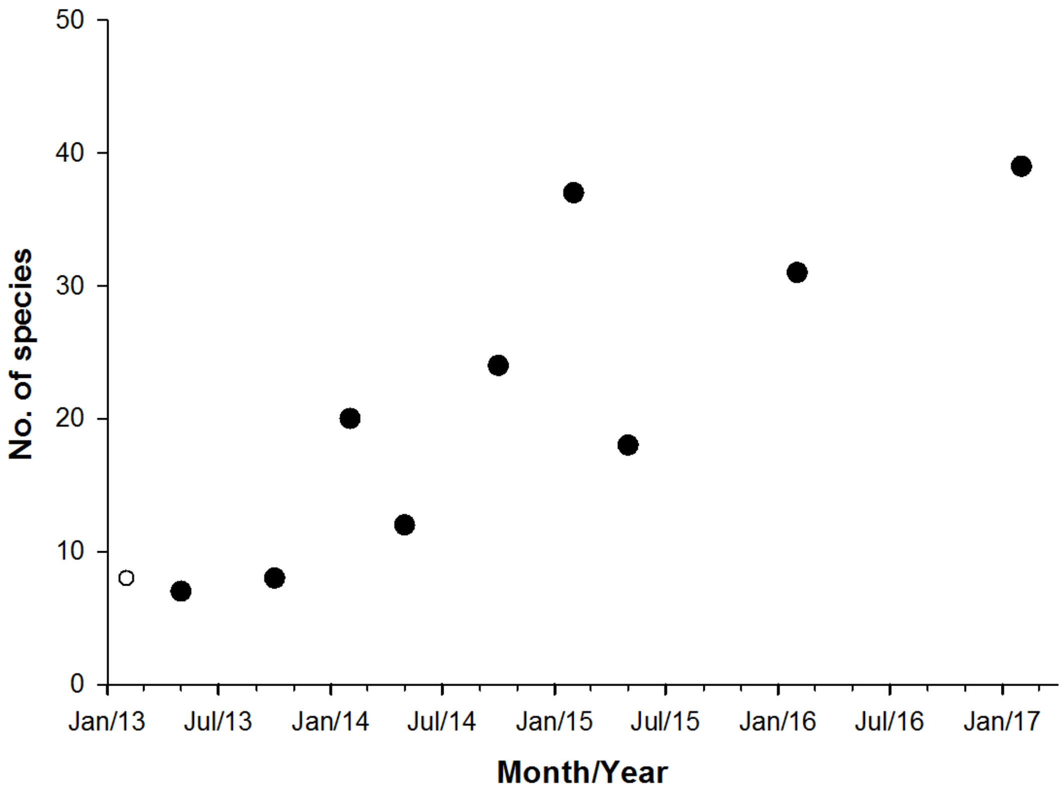


Figure 5. Number of fish species recorded by sBRUVs at the Bunbury Reef on each survey, with before deployment (hollow).

The relative total abundance of fish recorded by sBRUVs on the Bunbury Reef, as indicated by the average abundance (average combined MaxN for all species per sBRUV drop), slowly increased during initial surveys before a dramatic increase on the Summer15 survey (22 month) followed by some variability and a stabilisation in the final surveys (Figure 6). The relative abundance on these final surveys is at similar levels to that found on the natural control reef sites during the same surveys, which have also showed similar variations. Again the low

visibility influenced the results during the initial surveys and seasonal factors may have contributed to the higher abundance of some non-target species such as Western king wrasse (*Coris auricularis*), rough bullseyes (*Pempheris klunzingeri*) and black headed pullers (*Chromis klunzingeri*) on the Summer15 survey.

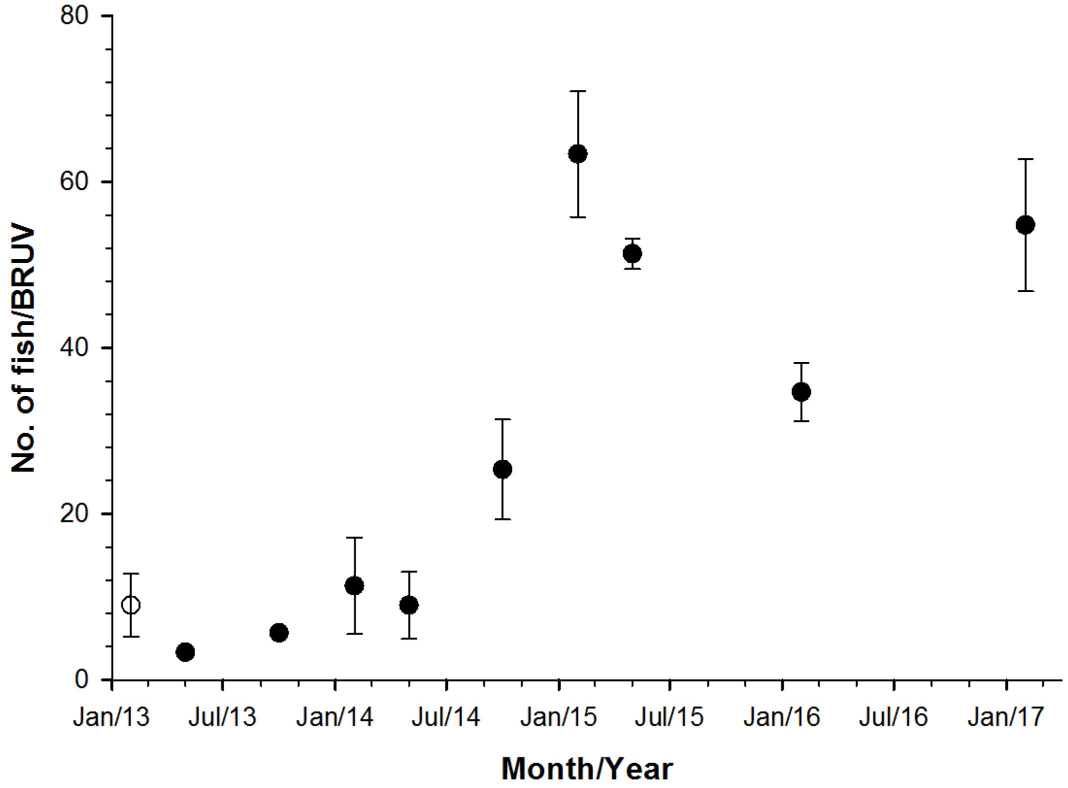


Figure 6. Relative fish abundance (Average No/BRUV drop) recorded by BRUVS on the Bunbury Reef for each survey, with before deployment (hollow) and standard errors given.

The three most abundant species recorded by sBRUV on the Bunbury Reef on the final summer 2017 survey were the footballer sweep (*Neatypus obliquus*), western king wrasse and Samson fish, with average relative abundances (MaxN/BRUV) of 18.1, 7.6, and 3.7, respectively. However, the abundance of Samson fish was primarily due to the occurrence of one large school on one BRUV, see below and not a true representation of the numbers on each cluster or BRUV. The footballer sweep were in dramatically higher abundance on the Bunbury Reef than on the natural sites in this survey where they were only recorded at an average relative abundance of 0.67 per BRUV. While the western king wrasse and Samson fish were also at considerably lower abundances on the natural sites off Bunbury of 2.5 and 1.0 per BRUV, respectively. As with the Dunsborough Reef the footballer sweep and western king wrasse are likely benefitting from not only the increased abundance of benthic invertebrates provided by the modules but also the increased supply of recreational fishing bait.

5.1.2.3.2 Comparison with nearby artificial structures

The *MV Lena* dive wreck is the only other nearby artificial structure to the Bunbury Reef and the dive surveys have consistently recorded higher numbers of species (n=42) than at the Bunbury Reef. However, the final Summer 2017 survey on the Bunbury Reef recorded 37 species when, unfortunately, a comparable survey of the *MV Lena* was not possible, due to bad weather. Comparison of the fish community data recorded by sDOV surveys through nMDS (Figure 7) indicated the fish communities on the Bunbury Reef were changing each year and becoming more similar to that recorded on the *MV Lena*. Even so there are 25 species recorded on the *MV Lena* not yet recorded on the Bunbury Reef. These included species such as the sweeps (Banded – *Scorpis aequinnus* and Sea – *Scorpis georgianus*), drummers (Silver - *Kyphosus sydneyansus* and Buffalo bream - *Kyphosus cornelii*), striped sea pike (*Sphyraena obtusata*), tarwhine (*Rhabdosargus sarba*) and Western blue devils (*Paraplesiops meleagris*). Many of these species were recorded inside the structure of the *MV Lena* wreck, along with very large numbers of rough bullseyes, in confined, darkened, cavelike areas that do not exist on the Bunbury Reef. Also as the structure of the wreck reaches to within 5 m of the surface there were other species recorded above the wreck in the surface waters which included large schools of blue sprat (*Spratelloides robustus*), southern sea garfish (*Hyporhamphus melanochir*), and on occasions skipjack tuna (*Katsuwonus pelamis*) and amberjack (*Seriola dumerelii*) which were not recorded on the Bunbury Reef. It must be recognised that there is a fishing exclusion zone around the *MV Lena* as a recreational dive site and this would likely have a bearing on some of the species recorded but the variety of structures appears to have a large influence on the diversity of species recorded.

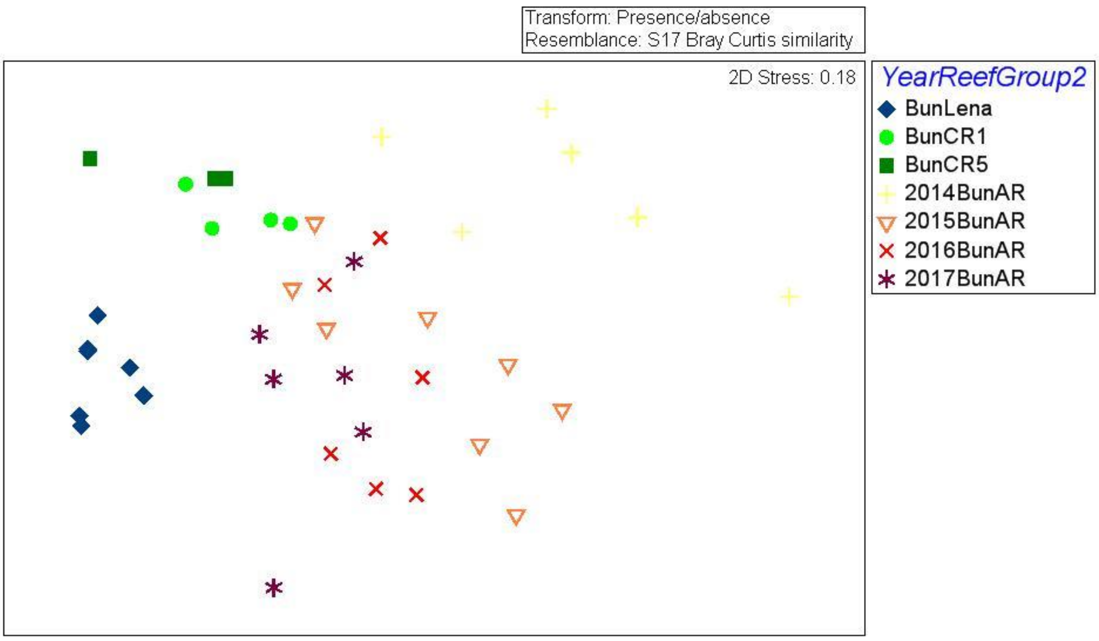


Figure 7. nMDS plot of fish community composition data from the sDOV surveys of the Bunbury Reef (by year), CR1 and CR5 natural control reefs and *MV Lena* dive site.

5.1.2.3.3 Recreational Species

All three of the target species, Samson fish, snapper and silver trevally have been recorded on the Bunbury Reef during the sBRUV and sDOV surveys but generally in low abundances (n=1 to 6). As with Dunsborough Reef only Samson fish have been recorded on all surveys of the Bunbury Reef.

The other recreationally targeted finfish species recorded on the Bunbury Reef include yellowtail kingfish (*Seriola lalandi*), baldchin groper, WA dhufish, and boarfish species, again in low abundance (n=1 to 13). Unlike the Dunsborough Reef the demersal species, particularly snapper, were recorded soon after deployment in the Autumn 2013 (1 month after deployment) survey.

Like the Dunsborough Reef the most abundant of the demersal species at Bunbury Reef was the long-snout boarfish with 13 recorded on the Summer 15 and Summer 16 sDOV surveys. The long-snout boarfish were recorded on all clusters at the Bunbury Reef in similar numbers of 1- 7 fish by the sDOV surveys, with no higher abundances on any cluster. This species was not recorded on the natural CR1 and CR5 reef sites but were recorded on the *MV Lena* dive wreck. As with the Dunsborough Reef very few species were recorded by sBRUVs and most were observed sheltering among the reef modules and not feeding. The size of the long-snouted boarfish recorded ranged from 367-580 mm in FL, indicating most were above the size at which they could be mature fish.

Also like the Dunsborough Reef the WA dhufish recorded on the Bunbury Reef (N=5) were all recorded on the same NW cluster of modules, which was closest to the area of natural low profile reef (Figure 3), and all under the LML (TL 247-440 mm in TL). Meanwhile, although the highest total number of baldchin groper (n=10) were recorded on the NW cluster over all the sBRUV surveys the species were also recorded on each of the other clusters on various surveys, in low numbers (n=1-4).

5.1.2.3.4 Samson fish

Low numbers of Samson fish (n=1 to 4) were recorded at the Bunbury Reef on all of the surveys with a larger school (n=15-30) only observed on the Spring14 and Summer17 surveys. Samson fish were recorded on each of the module clusters with the schools occurring on three different clusters on the different surveys. In comparison, on the CR1 and CR5 natural reef sites only small numbers of Samson fish (n=1 to 3) were recorded on each sBRUV survey with no large schools.

The size of Samson fish measured on the Bunbury Reef ranged from 310-1310 mm in FL (Mean =741 mm), which is larger than those recorded in the surrounding area of 190-1020 mm in FL (Mean = 674 mm), Figure 8. Unlike the Dunsborough Reef there was no higher abundance of Samson fish in the 700-1000 mm FL size range at the Bunbury Reef. The occurrence of Samson fish above the size at maturity, in schools and during the Summer spawning season means the species could be possibly spawning on the Bunbury Reef. Thus,

the Bunbury Reef appears to suit immature and mature Samson fish but not the schools at the size of maturity seen at Dunsborough Reef.

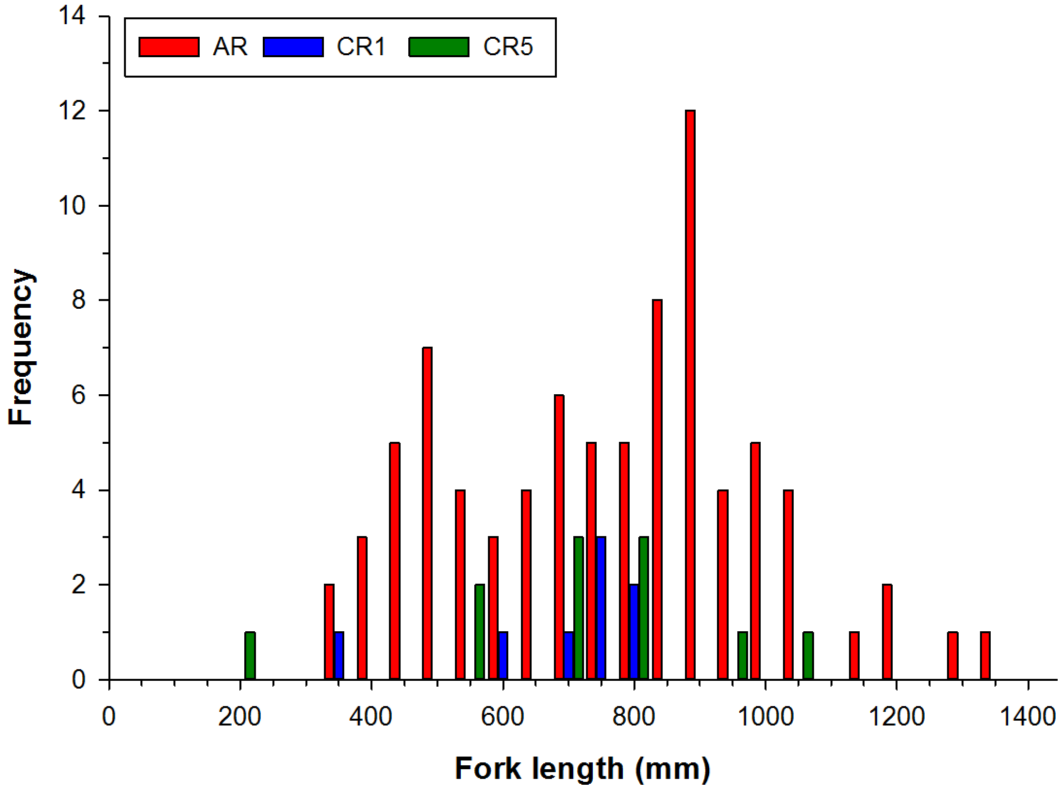


Figure 8. Length frequencies of Samson fish recorded at Bunbury Reef (red), CR1 (blue) and CR5 (green), over all surveys.

5.1.2.3.5 Snapper

Although low numbers of snapper (n= 1 to 3) were recorded on the Bunbury Reef during the initial and most recent surveys there was a period of surveys when there were no Snapper recorded on the artificial reef. Snapper were more consistently recorded on the NW and NE clusters (4 surveys each) but not recorded on the W or SE clusters. The size of snapper recorded on the Bunbury Reef has varied markedly with some very small (FL=115 mm) and very large individuals (FL=830 mm) measured but the average size was below the LML at 380 mm FL (Figure 9).

In comparison there were snapper recorded on every survey at the CR1 and CR5 natural reef sites that were generally smaller, ranging from 150-650 mm in FL (Average = 342 mm FL). Comparison of the length frequencies recorded at the sites over the trial clearly shows the lack of Snapper above the LML of 500 mm in TL or approximately 450 mm in FL at the Bunbury Reef, apart from one very large individual recorded in the early Spring 2013 survey. Only this single large snapper above the size at maturity has been recorded on the Bunbury Reef making it unlikely that the species is spawning at the site.

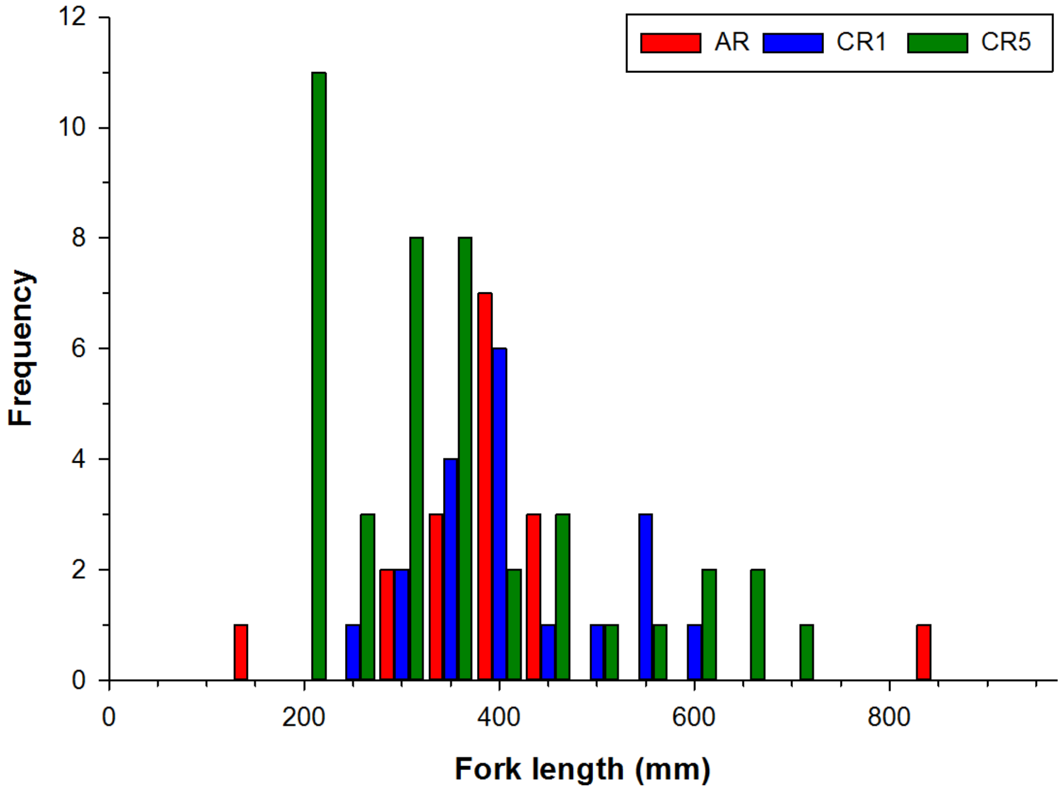


Figure 9. Length frequency (FL) of snapper recorded at the Bunbury Reef (red) and natural CR1 (blue) and CR5 (green) reefs during the SW artificial reef trial.

5.1.2.3.6 Trevally

Low numbers of trevally (n= 2 to 4) have been recorded on all surveys since Autumn 14 (18 month) at the Bunbury Reef. Over the surveys the species were recorded on all six clusters of modules with slightly lower relative abundance recorded by BRUVs on the NE cluster (mean Relative abundance = 0.83 s.e.=0.4) than at the CENT and NW clusters (mean Relative Abundances 2.75 & 3.0, se 1.0 & 1.4). The relative abundance of trevally on the natural CR1 and CR5 sites was more variable and generally higher than at the Bunbury Reef due to larger schools (n=10-30) being regularly recorded.

The length frequency data recorded for trevally over the surveys (Figure 10) shows two main size groups of 60-160 mm and 260-400 mm in FL occurring at all three sites. The individuals in the larger group can be confidently identified as silver trevally, which are above the LML. The size range recorded on the Bunbury Reef includes fewer in the smaller size group than recorded on the natural CR1 and CR5 sites in the surrounding area. This is in contrast to the Dunsborough Reef where very high numbers of smaller trevallies (FL<150 mm) were recorded. Although only low numbers of silver trevally were recorded on the Bunbury Reef there were mobile schools of up to 50 fish recorded by sBRUVs on nearby natural reef sites that only

appeared for short time periods, usually less than 5 minutes, and seemed to be constantly moving so would likely be transient through the Bunbury Reef at times.

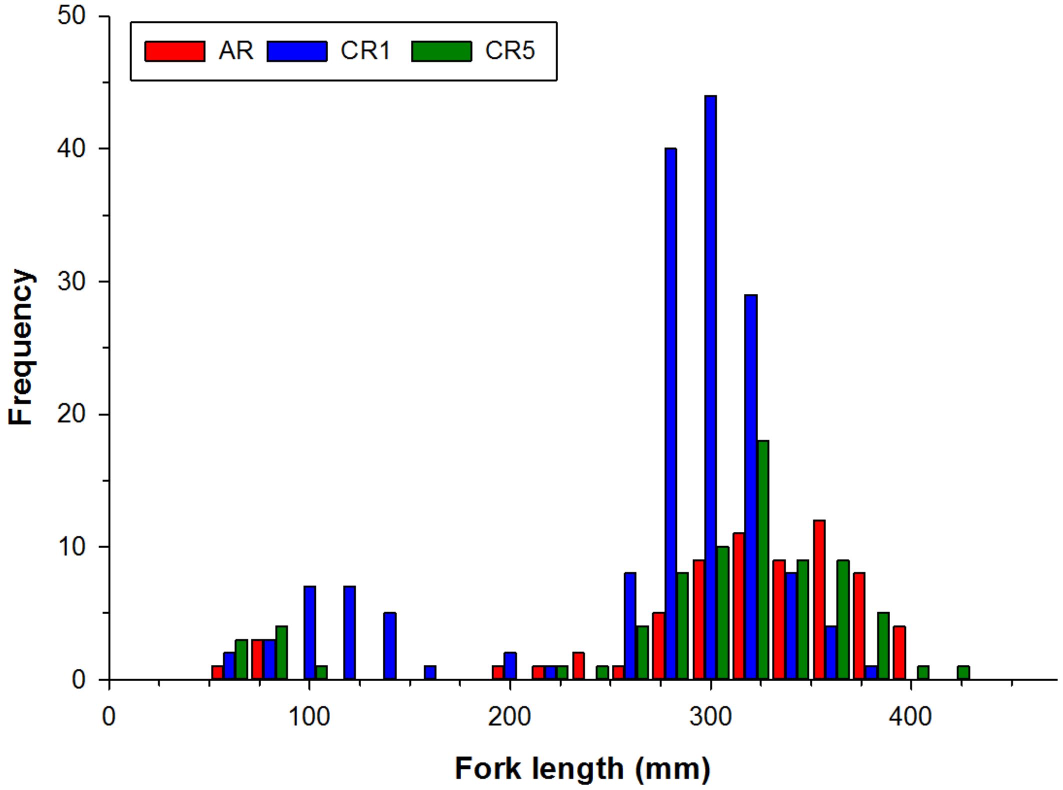


Figure 10. Length frequency (FL) of trevally sp. recorded at the Bunbury Reef (red) and natural CR1 (blue) and CR5 (green) reefs during the SW artificial reef trial.

5.1.2.4 Dunsborough Reef

5.1.2.4.1 Fish community

The post deployment sBRUV and sDOV surveys recorded a total of 70 fish species at the Dunsborough Reef, (see Appendix 1). The number of different fish species recorded on each survey by sBRUVs increased over the first two years but has stabilised at 35-37 species over the last two years. (Figure 11). The low number of species on the Summer 2015 (22 month) survey was likely due to poor visibility (only 3 m) encountered at this time.

The overall number of fish species recorded on the Dunsborough Reef is similar to the 69 and 61 species recorded at the CR1 and CR5 natural reef sites, respectively, over the same period. However, 24 of these species recorded regularly on the natural reef sites, such as breaksea cod, western blue devil and Woodwards reef-eel, were not recorded at the Dunsborough Reef. As these species were observed to utilise specific habitats such as ledges and caves, which are not found on the "fish cube" modules, they may not occur on the Dunsborough Reef without the addition of such structure.

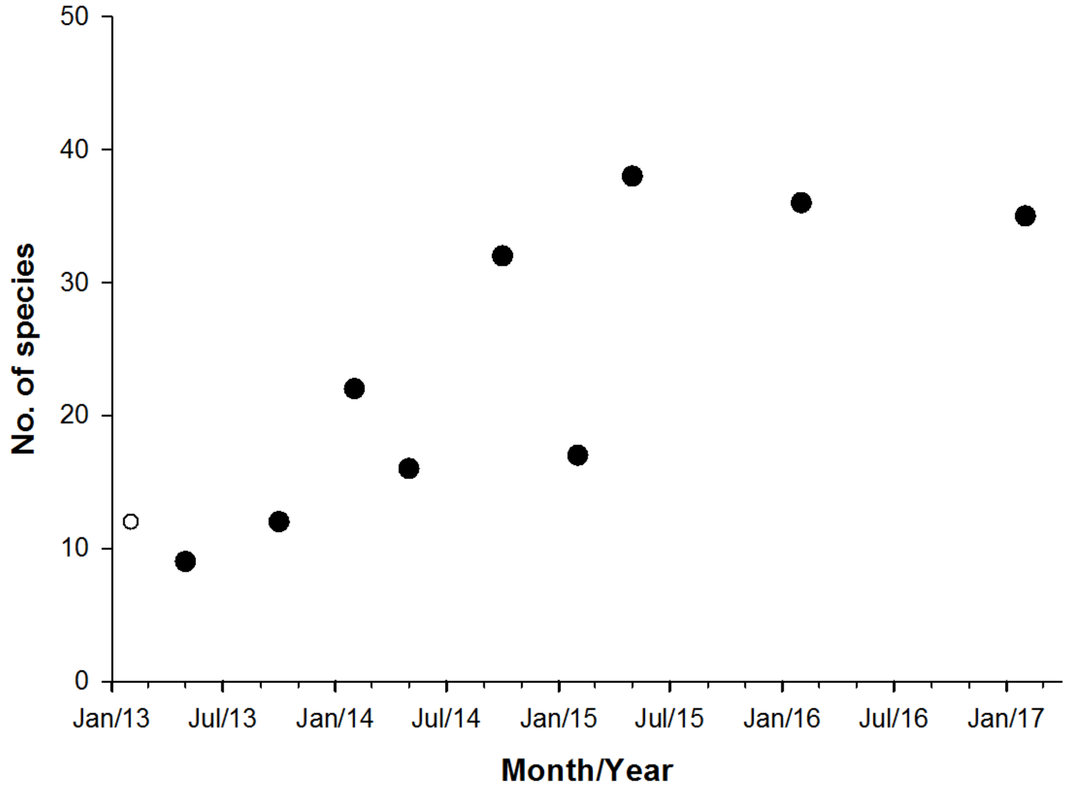


Figure 11. Number of fish species recorded by BRUVs at the Dunsborough Reef on each survey, before deployment (hollow).

The combined relative abundance of all fish recorded by sBRUVs on the Dunsborough Reef site has steadily increased since the modules were deployed, as indicated by the increase in the average abundance (average combined MaxN for all species per BRUV drop) see Figure 12. This relative abundance has increased to be only slightly below that recorded on the natural reef sites, although much is due to the increasing abundances of non-recreationally targeted species such as footballer sweep and western king wrasse, see below.

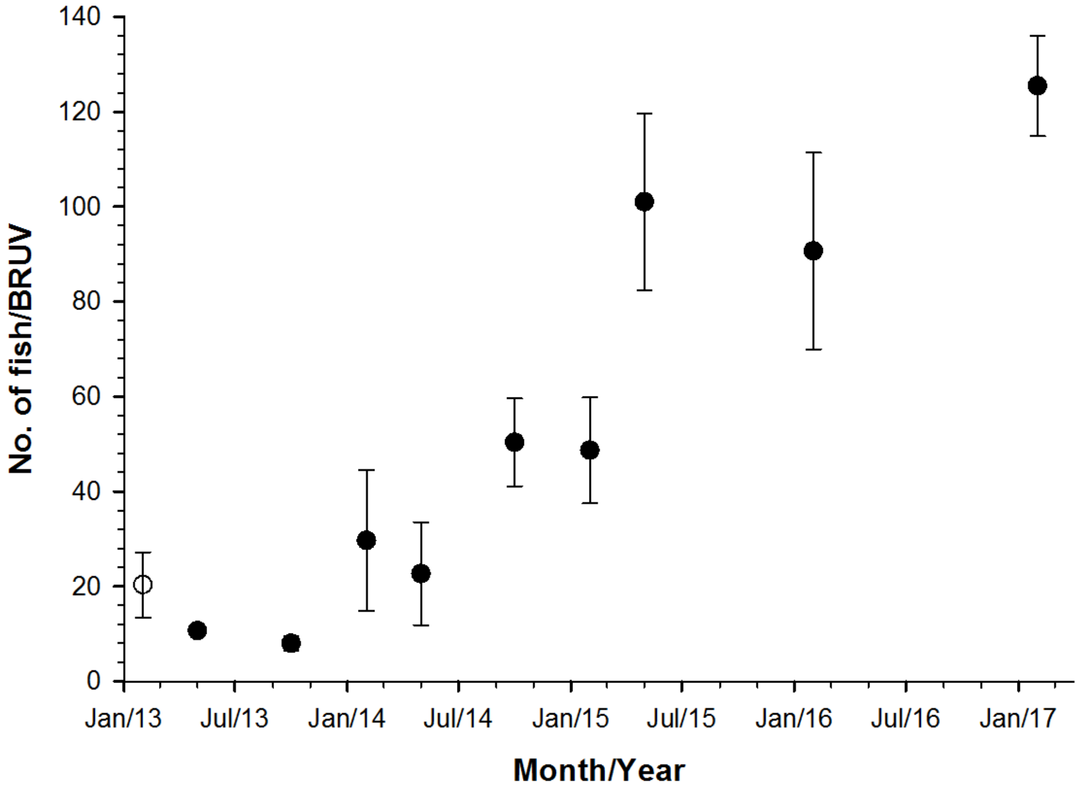


Figure 12. Relative fish abundance (Average No./BRUV drop) recorded by sBRUVs on each survey of the Dunsborough Reef, with before deployment (hollow) and standard errors given.

The three most abundant species on the final sBRUV survey of the Dunsborough Reef were the footballer sweep, small trevally (undefined species), and western king wrasse. The average relative abundances of these species at 28.3, 24.4, and 19.1 MaxN/ BRUV, respectively, recorded on the last Summer 17 survey were much higher than recorded for the same species on the natural control reefs at 15.67, 5.17 and 12.67 MaxN/ BRUV, respectively. As footballer sweep and western king wrasse are omnivorous species they are likely benefitting from not only the increased abundance of benthic invertebrates provided by the modules but also the increased supply of recreational fishing bait they are able to scavenge. The small trevally may be benefitting from the refuge and current flow disturbance provided by the modules, see more below.

5.1.2.4.2 Comparison with nearby artificial structures

The diver surveys of the Dunsborough Reef once it had become established, after Autumn 2015 (18 month), recorded similar numbers of species to the surveys of the Quindalup Tyre Reef, Busselton Jetty and *HMAS Swan* dive wreck conducted at the same time, each recording 30-35 species, except for the Summer 2016 Busselton Jetty survey which recorded a high of 51 fish species. It must be recognised that these other artificial structures are very different, have been established for many more years and that there are fishing exclusion zones around the latter

two as recreational dive sites which would influence the results. However, the similarity in number of species indicates that after the first two years the species were becoming established at the Dunsborough Reef. This is similar to the initial results on the *HMAS Swan* where the surveys recorded numbers of species stabilised and approximated those on natural reefs after the first two years but composition was still distinctly different (Morrison 2004).

A comparison of the species composition from the sDOV surveys at the Dunsborough Reef with those recorded at the other established nearby artificial structures and control reefs (CR1 and CR5) (Figure 13) indicated that the communities are still quite distinctly different. It also shows that there are significant differences between the different surveys at the Dunsborough Reef, indicating the changes in the fish community occurring at the Reef over time. Further PERMANOVA analysis confirmed this to be the case between the Sites (P=0.001) and the Surveys at the Dunsborough Reef (P=0.001). Some species recorded at the other three artificial reefs but not on the Dunsborough Reef were breaksea cod, western blue devil, black-banded seaperch (*Hypoplectrodes nigroruber*) and large numbers tarwhine. These species were often found in darkened areas, inside the structures or under the stern of the *HMAS Swan*, and such areas are not provided by the "fish cube" modules at the Dunsborough Reef.

Of interest for the demersal species recorded at these other artificial structures were the relatively high abundance of WA dhufish at the Busselton Jetty and the recording of three juvenile yellow-spotted boarfish at the Quindalup Tyre Reef. The Busselton Jetty is a relatively shallow site at less than 9 m depth and has little reef structure other than the upright pylons and yet the highest abundances of juvenile WA dhufish were recorded on a number surveys (n=12-18). The WA dhufish at the Busselton Jetty all ranged from 290-450 mm in TL so are yet to enter the fishery and their annual numbers at this site and others could contribute to the monitoring of the stock. The juvenile yellow-spotted boarfish recorded on the Summer 2016 survey of the Quindalup Tyre Reef are likely the smallest recorded in WA as they were measured at 140-170 mm in FL and previously only a single individual of TL<212 mm has been recorded for the species in WA by the Museum (Coulson 2016). Their discovery at the Quindalup Tyre Reef may give an important indication as to the habitat type the juveniles of yellow-spotted boarfish are likely to occur on. Small juvenile WA dhufish (TL<150mm) were also recorded on the Quindalup Tyre Reef and the low profile cave or ledge like refuge created by the tyres in a predominantly sand and seagrass habitat area appears to be an important combination for juveniles of the species as large numbers of juvenile WA dhufish were recorded previously around concrete pipes at an abalone lease in similar habitat off Augusta (Lewis 2015).

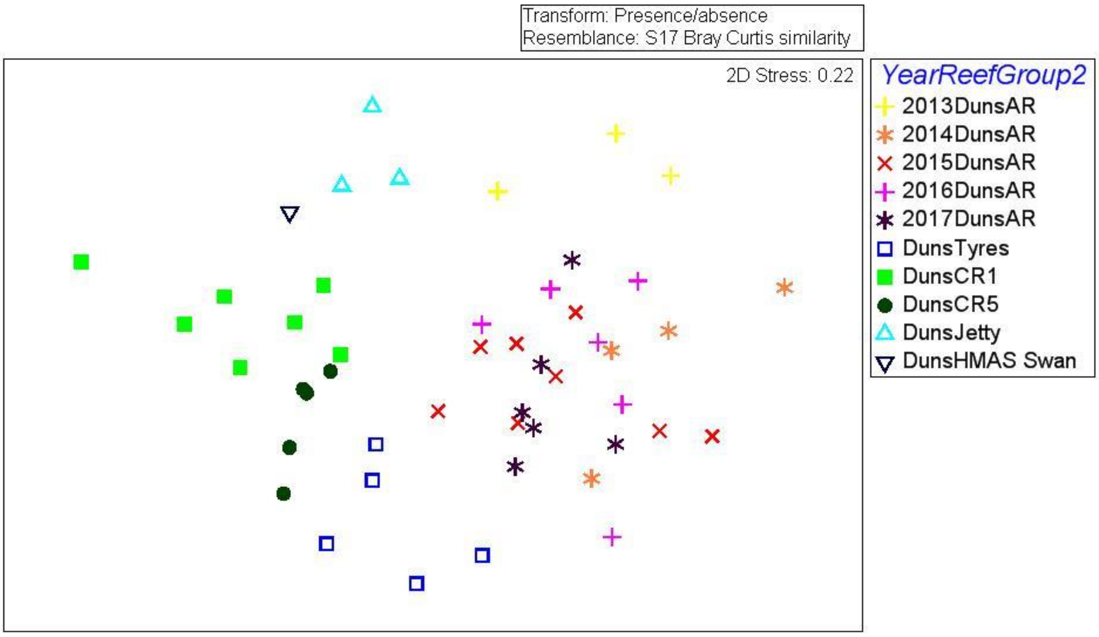


Figure 13. nMDS plot of fish community composition data from the sDOV surveys of the Dunsborough Reef, Control reefs and other artificial structures (Busselton Jetty, Tyre Reef and HMAS Swan).

5.1.2.4.3 Recreational Species

Of the three target species only Samson fish were recorded on all of the sBRUV and sDOV surveys on the Dunsborough Reef over the first three years. Reasonable numbers (n=5-40) of small trevally (FL = 60-180 mm) were also been recorded on the Dunsborough Reef in most surveys. Snapper were only recorded on three (Summer15, Autumn15 and Summer16) of the nine post deployment surveys of the Dunsborough Reef.

In addition, to all three target species further recreationally targeted demersal finfish species recorded occurring on the Dunsborough Reef include, WA dhufish, baldchin groper, blue groper and three boarfish species (Long-snouted, Yellow-spotted, and Short). Most of these were not recorded on the Dunsborough Reef until after the Spring 2014 (18 month) survey.

The most abundant of these demersal species on the Dunsborough Reef were the long-snouted boarfish with a total of 19 recorded on the Summer 2015 sDOV survey of all clusters. The species were also recorded by sBRUVs but did not respond to the bait and only recorded in low numbers passing in the background so their abundance was more reliably assessed by sDOVs. Over the last four sDOV surveys higher numbers of boarfish were recorded on the NW and NE clusters compared to the other clusters and none were observed on the CENT cluster of modules (Figure 14). The possible reasons for this are unclear but as the species were not observed feeding on the Dunsborough Reef and appeared to be sheltering within the structures the northern clusters may be closer to their suitable foraging habitat in deeper waters. While at the CENT cluster they may have been targeted by spearfishers, as only the centre coordinates are given in the current maps and information for the Dunsborough Reef. The long-snouted

boarfish recorded on the Dunsborough Reef ranged in size from 315-460 mm FL, so were mostly above the size at which females could reach maturity of 350 mm TL for the species (Coulson 2016). In comparison, this species was only recorded once by sBRUV at one of the CR1 natural reef sites so appears to have been concentrated by the Dunsborough Reef.

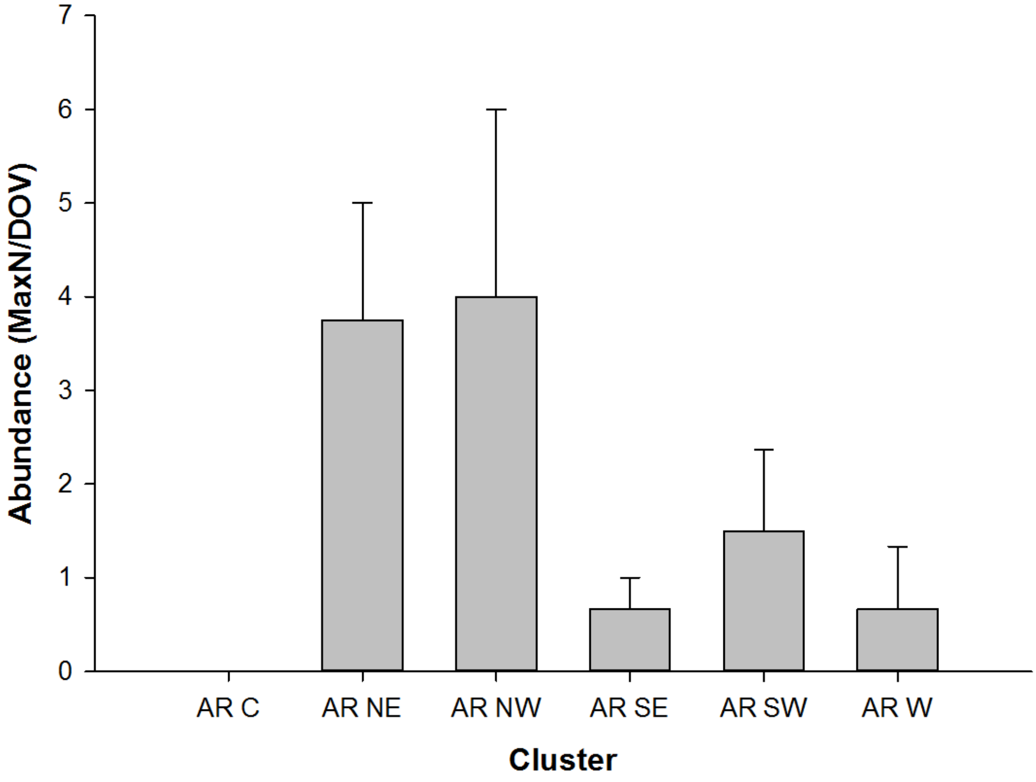


Figure 14. Mean abundance of long-snout boarfish at each cluster of modules from last four sDOV surveys at the Dunsborough Reef, with standard errors.

The WA dhufish recorded on the Dunsborough Reef (N=14) were all under the Legal Minimum Length (LML) of 500 mm for the species, at 290-400 mm in TL and, apart from two very small juveniles (TL<150 mm) recorded in the Spring14 survey, all were recorded on the NE cluster of modules. This cluster is closest to the area of natural low profile reef (Figure 3). Similarly, all of the baldchin groper recorded at the Dunsborough Reef (n=16) were only on this same NE cluster, but were recorded in larger sizes of up to 650 mm in TL. The occurrence of these two important demersal species at only this one particular cluster may indicate their reliance on the nearby natural reef habitat and their reluctance to swim the further 50-70 m across open sandy habitat to the other clusters of modules at the Dunsborough Reef.

5.1.2.4.4 Samson fish

Samson fish were not recorded at the Dunsborough Reef site prior to deployment but have occurred in reasonable numbers (n=10 - 30) on all surveys since the modules were deployed. Even though Samson fish were recorded on all clusters of modules the schools (where n>5)

were only recorded on the SW and NW clusters by sBRUVs, although the sDOV surveys recorded schools of Samson fish on all clusters, apart from the W cluster. This higher incidence of Samson fish schools recorded by the sDOV surveys could indicate they could be attracted to the activity of divers in the water. The sBRUV results clearly show the school is not travelling between modules to be recorded on each sBRUV, as three are set at the same time on the AR, even though some were <100 m apart. The possible reason for the higher occurrence of Samson fish on the two western clusters may be due to the direction of current flow at the Dunsborough Reef, which is predominantly in an easterly direction. Thus, the western clusters are facing the current direction which may provide some schooling or food provision advantage to the Samson fish.

The size of Samson fish on the Dunsborough Reef predominantly ranged from 700-1000 mm in FL, average 880 mm FL over all surveys (Figure 15). Over the trial there was a progressive increase in average size from 805 mm, on the initial survey, to 950 mm on the final survey after four years. As this growth approximates the growth curve of 800 mm TL at 5 year old and 1000 mm at 10 year old (Rowland 2009), it appears the surveys are tracking the growth of a cohort or even the same school of Samson fish through the trial. A further tagging study, acoustic or dart tag with video surveillance, on the movement and residency of Samson fish could confirm if these are indeed the same resident fish.

Like many pelagic species female Samson fish mature at a larger size than males and have a L_{50} of 831 mm and a L_{95} of 942 mm TL (Rowland 2007). Using the length equation of $FL = TL/1.09 - 16.37$ this equates to 746 and 848 mm in FL respectively. Thus, the majority of Samson fish recorded on the Dunsborough Reef, regardless of sex, are around this size of maturity or just above and as they were recorded to occur in schools during the peak spawning period of October to February the species could be spawning on the Dunsborough Reef. Although further biological study of the species at the Dunsborough Reef would be required to confirm if this is the case.

The Samson fish on the natural reefs were of a similar size range (FL= 352-1306 mm, Av 925 mm) to the Dunsborough Reef over this same period (Figure 15). However, there was no higher abundance of Samson fish in the 700-1000 mm FL size range, as seen on the Dunsborough Reef. The abundances of Samson fish at the natural CR1 and CR5 sites were very low with no large schools recorded. Thus, it appears that the “fish cube” modules are particularly suitable for the species and particularly for Samson fish of around the size at maturity. The much higher abundances indicate there is some concentration effect on the species by the Dunsborough Reef but the growth over the trial may indicate there is also some production, if the species are gaining advantage from the Dunsborough Reef and possibly spawning there.

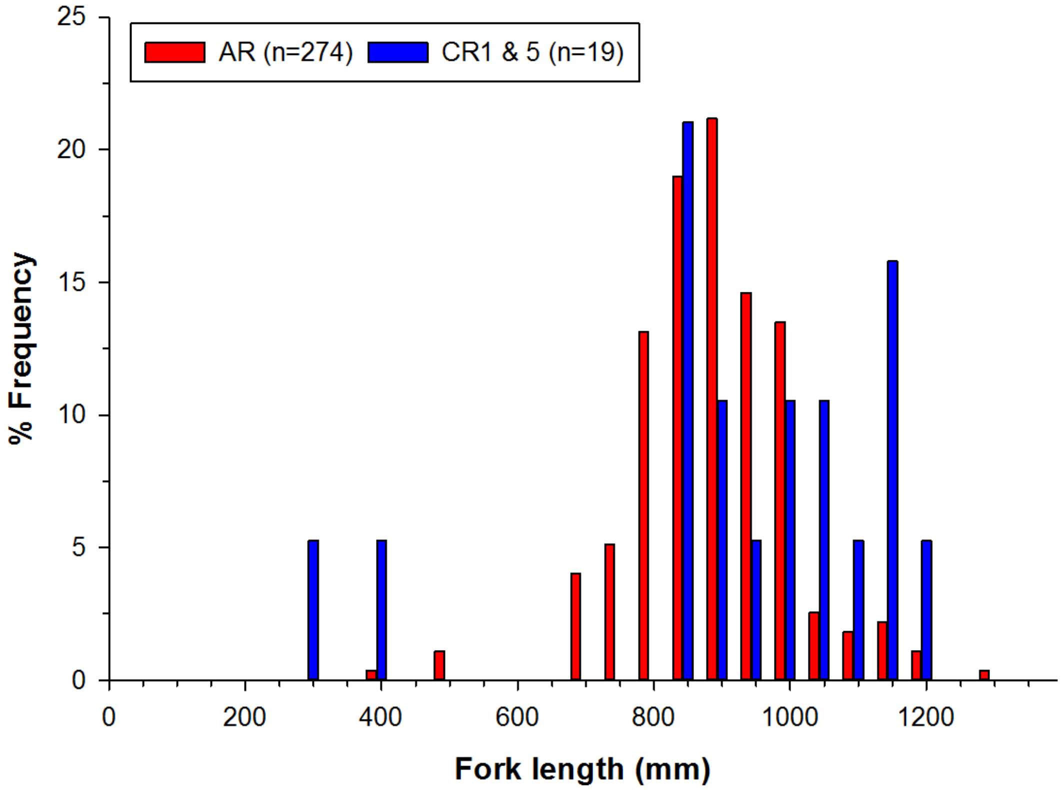


Figure 15. Length frequency (FL) percentage of Samson fish recorded at the Dunsborough Reef (red) and combined for natural CR1 and CR5 reefs (blue) during the SW artificial reef trial, with sample sizes.

5.1.2.4.5 Snapper

A few snapper (n=3) at around the LML of 500 mm in TL were recorded at the Dunsborough Reef site prior to deployment and after deployment only low numbers of snapper were recorded on three of the nine surveys at the Dunsborough Reef, with a total number of n=24 for all surveys. Snapper were only recorded on the NE and SW clusters at the Dunsborough Reef over these surveys. In comparison snapper were recorded on every survey of the CR1 and CR5 natural reef sites and at a much higher abundance with a total number of more than 80 recorded at each, with less sBRUV replicates. However, the average size of snapper recorded on the Dunsborough Reef was much higher at 511 mm in FL compared to 316 and 282 mm at the CR1 and CR5 natural reefs, respectively. Comparison of the length frequencies of snapper at each site (Figure 16) shows the highly abundant 200-300 mm size classes were only recorded on the natural reefs, and the 600-700 mm group were predominantly recorded on the artificial reef. Thus, the Dunsborough Reef may not be providing suitable habitat for this smaller size group of immature snapper and could be concentrating the larger fish.

The size at maturity for snapper on the West Coast is 585 mm in TL (L_{50} for females), (Wakefield 2006) which equates to a FL of approximately 505 mm (Length equation TL=FL, Wakefield 2006). Although the larger snapper would have been mature they were recorded on

the Dunsborough Reef in Autumn and not during the spawning season of Spring-Summer so it is unlikely they were spawning on the Dunsborough Reef.

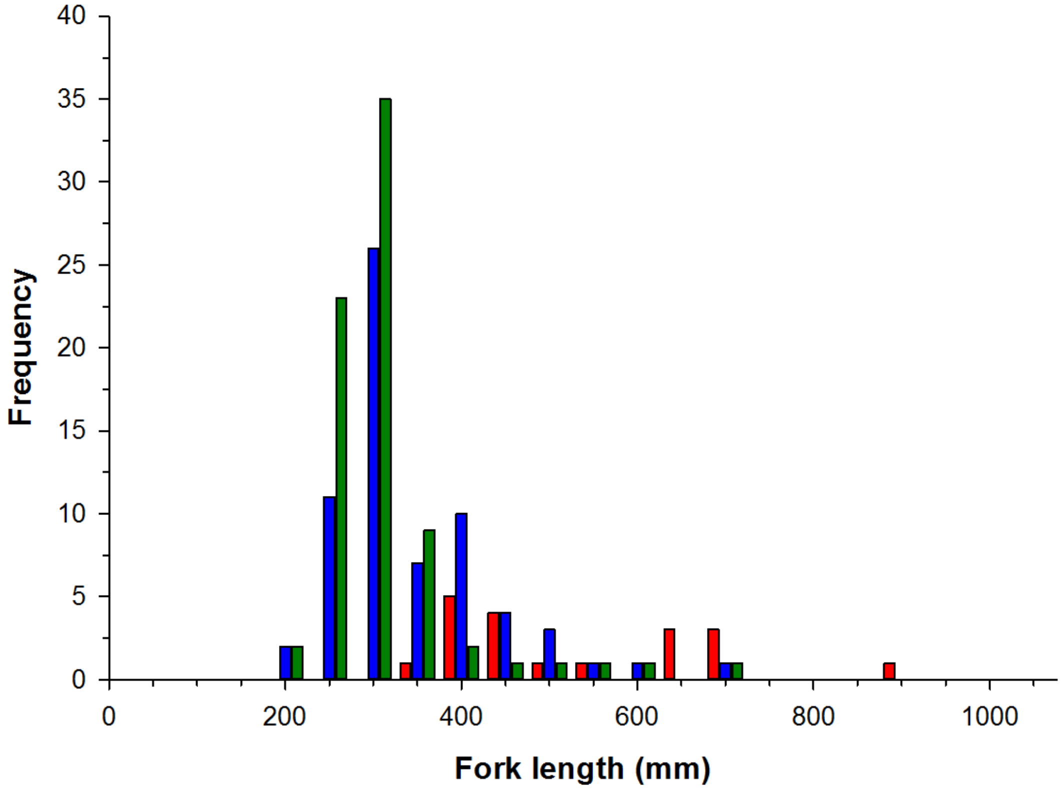


Figure 16. Length frequency (FL) of snapper recorded at the Dunsborough Reef (red) and natural CR1 (blue) and CR5 (green) reefs during the SW artificial reef trial.

5.1.2.4.6 Trevally

Reasonable numbers (n=5-220 per survey) of small trevally (FL = 60-140 mm) have been recorded on the Dunsborough Reef in all surveys. Considerably higher numbers of trevally were recorded on the NW cluster of modules and moderately higher numbers on the W cluster than the other clusters (Figure 17). As per Samson fish above this may be due to the western clusters facing into the current direction, which may suit this schooling species and be the reason for the higher abundances. Limited sampling of the small trevally on the Dunsborough Reef during surveys captured only silver trevally (*n=8*) but even so all of the those observed in the video footage cannot be confidently identified as silver trevally, as some may be the similar, smaller species of sand trevally (*P. wrightii*). Differentiation of the species diagnostic characteristics is difficult on sBRUVs but as sand trevally only reaches a maximum size of 220 mm in TL, any individuals measured larger than this can be confidently classified as silver trevally. Regardless, as only silver trevally were caught on the Dunsborough Reef a proportion can be assumed to be the target species. The lack of trevally above the L_{50} size at maturity for

silver trevally of 310 mm in TL (Farmer *et al.* 2005) means that there is no evidence that they are spawning on the Dunsborough Reef.

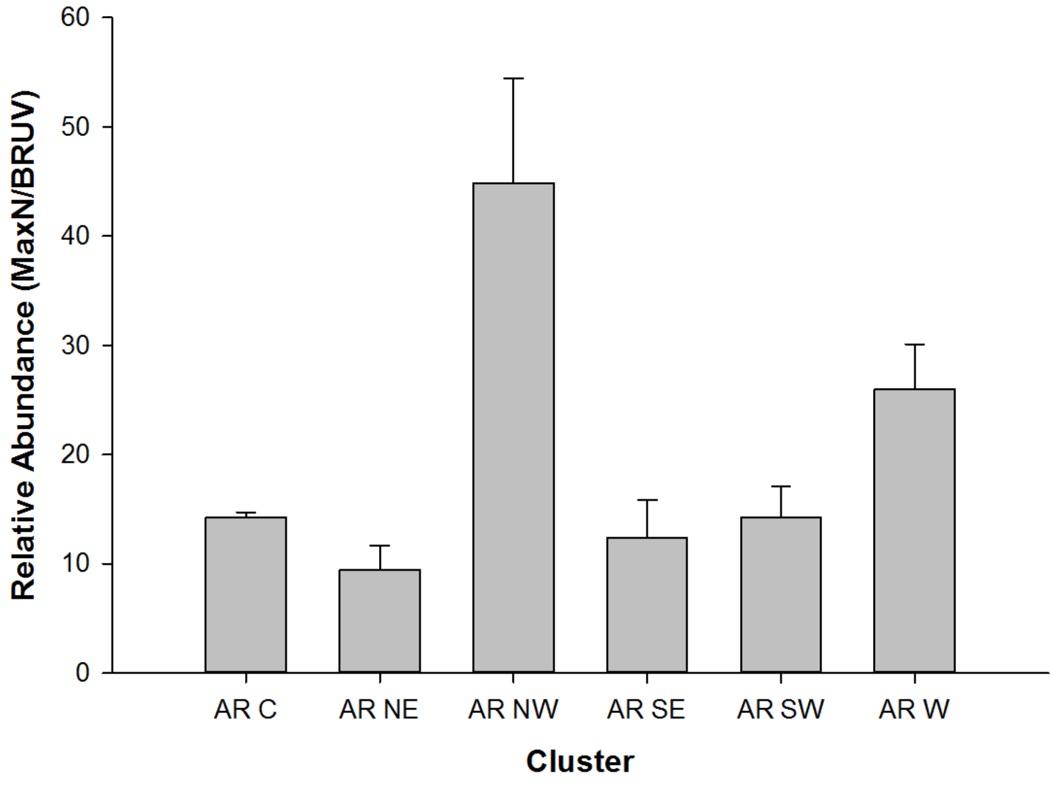


Figure 17. Mean relative abundance of small trevally at each cluster of modules from seven sBRUV surveys at the Dunsborough Reef, with standard errors.

The lack of trevally larger than 150 mm in FL until the final survey when three fish of 155-180 mm were recorded can possibly be due to a few factors such as;

1) they are emigrating from the artificial reef to the surrounding area,

2) they are mostly sand trevally (*Pseudocaranx wrightii*) so not growing any larger, or

3) they are being predated by Samson fish before reaching a larger size.

The size of 140 mm in FL equates to a TL of approximately 170 mm for the species (TL=1.203xFL-0.6185, French 2003) so it is unlikely they are being removed by recreational fishers as the LML is much larger at 250 mm in TL or approximately 210 mm in FL. Further study to help determine the species composition of the trevally on the Dunsborough Reef, plus their diet, movement and the diet of Samson fish at the Dunsborough Reef would go a long way towards answering the question on why there are no trevally larger than 200 mm in length on the Dunsborough Reef.

The trevally recorded on the CR1 and CR5 natural reefs were in lower abundances (n=1-30) but consisted of predominantly larger individuals than those recorded on the Dunsborough Reef

with average lengths of 206 and 198 mm in FL, respectively. The overall length frequency comparison (Figure 18) shows the larger size classes of trevally were only recorded on the natural CR1 and CR5 sites but also that the smaller sizes, which were highly abundant at the Dunsborough Reef, were also occurring in low numbers on the natural sites.

Silver trevally larger than 200 mm in FL were recorded on the CR1 site, less than 1 km to the north of the Dunsborough Reef, in low numbers (n=1-6) on almost every survey indicating the species are occurring in the vicinity of the Dunsborough Reef. Silver trevally were also recorded on each of the other artificial structures surveyed and were in particularly high numbers of over 100 fish on two surveys (Summer 14 and Summer 17) at the Quindalup Tyre Reef. The structures at the Tyre Reef are much lower profile, of less than 1 m in height, and more widely dispersed than at the Dunsborough Reef. Perhaps also importantly there were also no schools of Samson fish recorded at the Quindalup Tyre Reef. Thus, the modules and location of the Dunsborough Reef appears to be particularly suited to juvenile trevally but may not be suitable to larger adults. It may also be possible that the occurrence of Samson fish schools at the Dunsborough Reef site may be deterring trevally as Samson fish are known as an opportunistic predator of pelagic and demersal fishes, and silver trevally were found to occur in their diet (Rowland 2009).

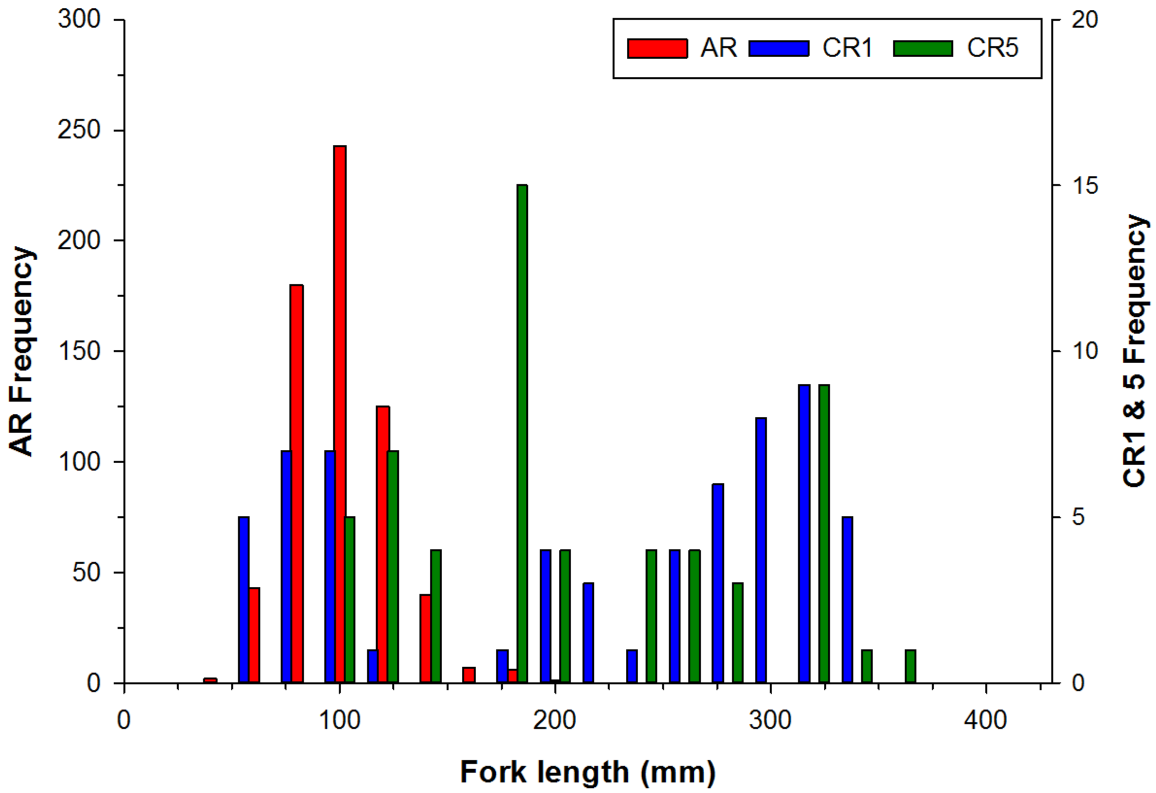


Figure 18. Length frequencies of trevally sp. recorded at Dunsborough Reef (red) and on CR1 (blue) and CR5 (green) natural reefs, on secondary axis, over all surveys.

5.1.3 Potential impacts on surrounding area

5.1.3.1 Summary

The post deployment sBRUV and sDOV surveys over the four years of the SW artificial reef trial have recorded a total of 180 different species of fish, with 122 and 117 in the area surrounding the Bunbury and Dunsborough Reefs, respectively. The surveys have recorded seasonal data on the abundance and size of the three target species (Snapper, Samson fish and Silver trevally) and other demersal finfish species targeted by recreational fishers in the surrounding area.

The pre-deployment surveys recorded low numbers of target species at the Reef sites (Dunsborough - three snapper and five small trevally, Bunbury - nine silver trevally) and these were not recorded again in the initial surveys indicating there may have been some initial impact of increased recreational fishing on the Reefs. However, as these target species were subsequently recorded regularly at both Reefs this initial impact may have been short term while the Reefs were becoming established. However, the lack of snapper above the LML at the Bunbury Reef may indicate that the increased fishing pressure is having an ongoing impact on snapper above this size at the Bunbury Reef as snapper above LML were regularly recorded at the natural sites.

The study recorded no significant changes in the fish community composition at the natural reef sites over the first four years at either Bunbury or Dunsborough Reefs, see Table 2. The size and abundance of the three target recreational species and other recreational species were generally low and variable and, apart from snapper at Dunsborough Reef, didn't change in the vicinity of either artificial reef after deployment. There was a decline in the abundance of demersal species, particularly snapper and WA dhufish, on the natural reefs in the nearby vicinity of the Dunsborough Reef after the deployment and this could indicate some initial impact on these species. However, as most of these snapper and WA dhufish were undersize and abundances were variable this decline could be due to other factors such as movement and seasonal changes in abundance but may also be due in some part to increased fishing activity at the Dunsborough Reef. Thus, the surveys suggest there was no major impact on the composition of the fish communities occurring in the nearby surrounding natural area by the deployment of the artificial reefs, over the first four years.

5.1.3.2 Bunbury Reef

5.1.3.2.1 Fish communities

The nMDS plot and PERMANOVA analysis of the overall fish community data from the sBRUV surveys show there was little change in the CR1 and CR5 sites (Figure 4) over the entire four year period. The pairwise comparison of sites at Bunbury showed there was no significant difference between the fish communities at the CR1 and CR5 sites (P=0.72). Further pair-wise analysis of the data from each of the surveys for these sites showed there were no

significant differences between any of the surveys. These results indicate that over the four years and nine surveys there has been no change in the natural fish community composition at the CR1 or CR5 distances, indicating the deployment of the artificial reef has not impacted upon the natural reefs.

To investigate the possible impacts of increased fishing pressure at the Bunbury Reef the average number of demersal species per sBRUV (combined MaxN), primarliy consisting of the abundances for snapper and baldchin groper, was investigated for change over the study at the CR1 and CR5 sites. These demersal species are potentially good indicators of increased pressure in the area as they are likely to undertake limited movement and remain relatively site attached. The results, although variable through the surveys, show a slight initial decline after deployment at the CR1 site but an overall increase in the relative abundance of the group of demersal finfish (Figure 19), indicating there is no negative impact on the demersal fish abundance since the deployment of the Bunbury Reef.

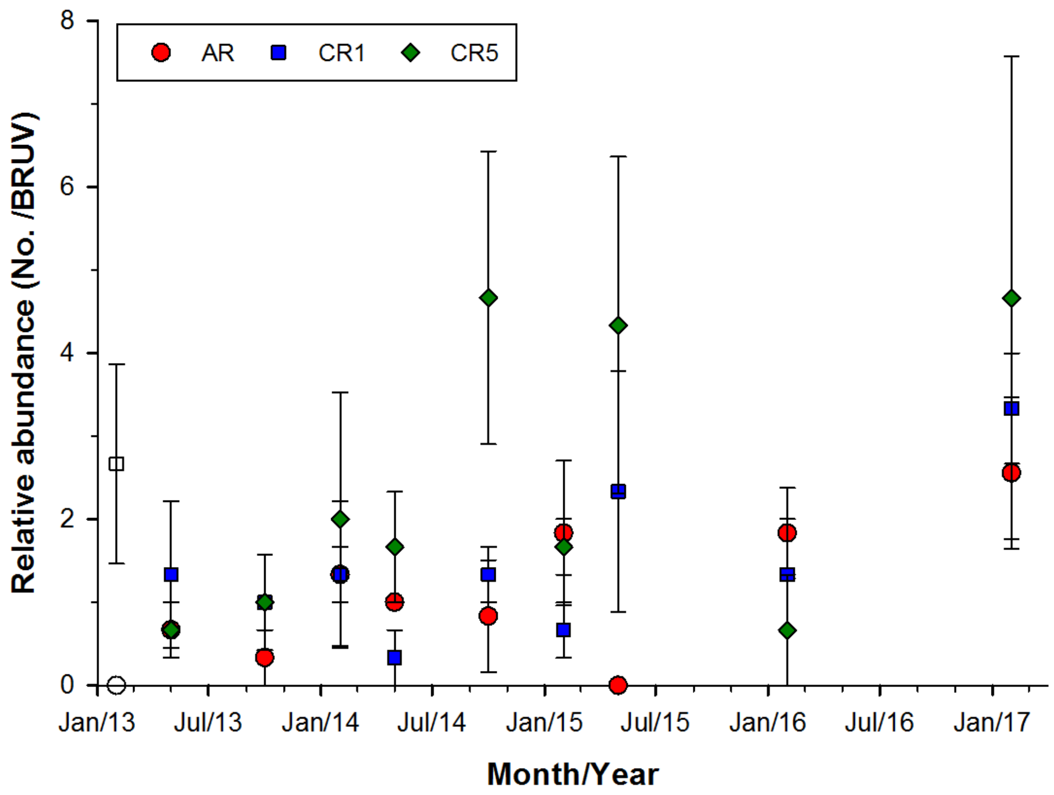


Figure 19. Mean relative abundance of demersal species (combined MaxN/BRUV) for each survey of Bunbury Reef (red circle) plus CR1 (blue square) and CR5 (green diamond) natural reefs, where hollow indicates predeployment survey and standard errors given.

5.1.3.2.2 Samson fish

Low numbers of Samson fish (n=4 to 25) were recorded by sBRUV surveys of the CR1 and CR5 natural reefs surrounding the Bunbury Reef. As no Samson fish were recorded in the pre-

deployment survey and numbers recorded through the trial were variable and low there was no discernible change in abundance of Samson fish on the natural reefs. The size range of the Samson fish on the CR1 and CR5 sites was 190-1020 mm in FL, which is slightly smaller than the size of up to 1260 mm in FL recorded on the Bunbury Reef (Figure 8). The average size of Samson fish on each survey at the CR1 and CR5 sites was variable, due to low numbers, and did not increase or decrease over the course of the trial. Thus, there was no discernible impact of the deployment of the Bunbury Reef on Samson fish in the area.

5.1.3.2.3 Snapper

The abundance of snapper on the sBRUV surveys of the CR1 and CR5 natural reefs surrounding the Bunbury Reef was also low and variable at 4 to 25 individuals per survey. Over the trial there was an initial decline over the first two years from the predeployment abundance of snapper at the CR1 site of mean 2.33 se 1.3, but after the relative abundances were variable and at similar levels in the final Summer 2017 survey of mean 1.67 se 0.9 (Figure 20). The abundance at the CR5 site was also highly variable and showed a similar initial decline in the abundance as the CR1 site followed by slightly higher but variable abundances during the trial. The size range of snapper recorded on the surrounding natural area at Bunbury was predominantly in the 200-500 mm FL size range, with most below the LML of 500 mm (Figure 9). There was no change in the average size of snapper recorded over the course of the trial at either CR1 or CR5 site, remaining at 300-350 mm in FL. Thus there appears to have been no impact on the snapper size or abundance in the surrounding area by the deployment of the Bunbury Reef.

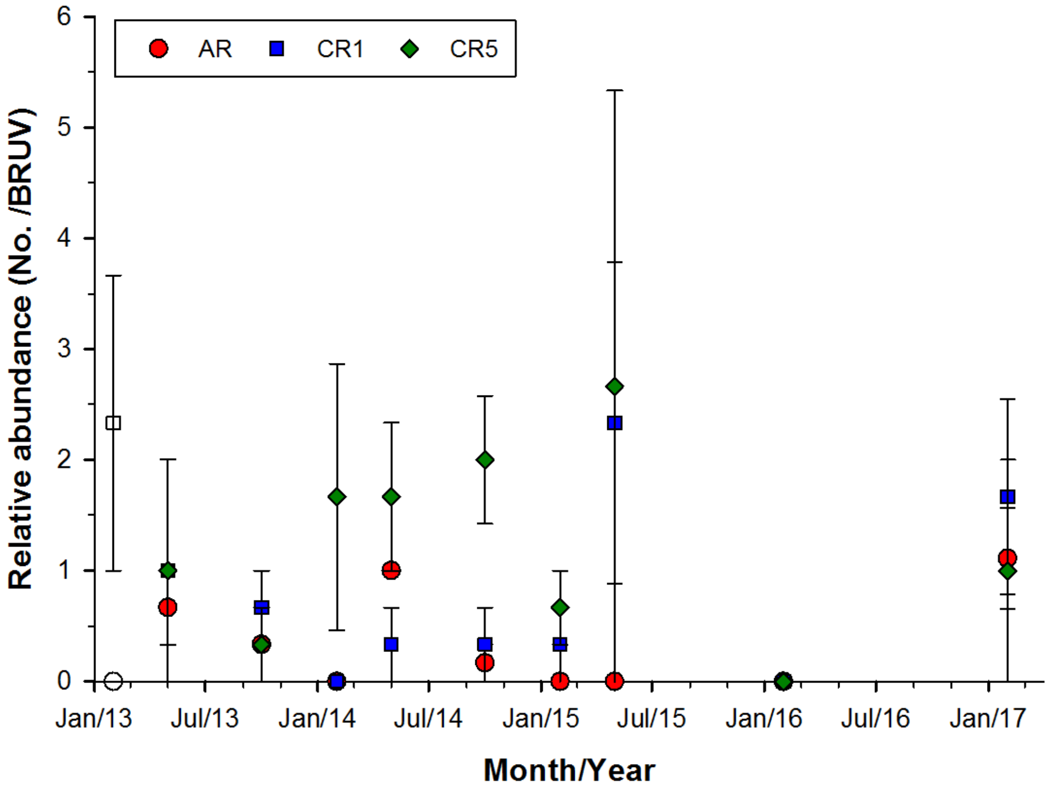


Figure 20. Mean relative abundance of snapper (average MaxN/BRUV) for each survey of Bunbury Reef (red circle) plus CR1 (blue square) and CR5 (green diamond) natural reefs, where hollow are predeployment survey and standard errors given.

5.1.3.2.4 Trevally

The relative abundances of trevally recorded by sBRUV surveys at the CR1 and CR5 sites near the Bunbury Reef were highly variable with much higher abundances when a school was observed. In addition, the poor visibility on the Autumn and Spring surveys may have contributed to the abundances for trevally recorded during these seasons over the trial. The relative abundance of silver trevally recorded on the final Summer 17 survey at the CR1 site of 3.0 (s.e.= 1.73) was similar to that recorded in the predeployment survey of 3.33 (s.e.= 1.20). The average length of trevally recorded over the trial was variable but similar for most surveys until the final two surveys when it was noticeably lower at the CR1 on both and at the CR5 on the final survey (Figure 21). This is mainly due to more trevally of the smaller size group being recorded at these natural sites during these surveys (Figure 10), which could indicate a recruitment pulse that were not recorded on the Bunbury Reef. Thus, there appears to have been no impact of the Bunbury Reef on the abundance of silver trevally in the vicinity and the overall decline in sizes in the area may be due to other factors.

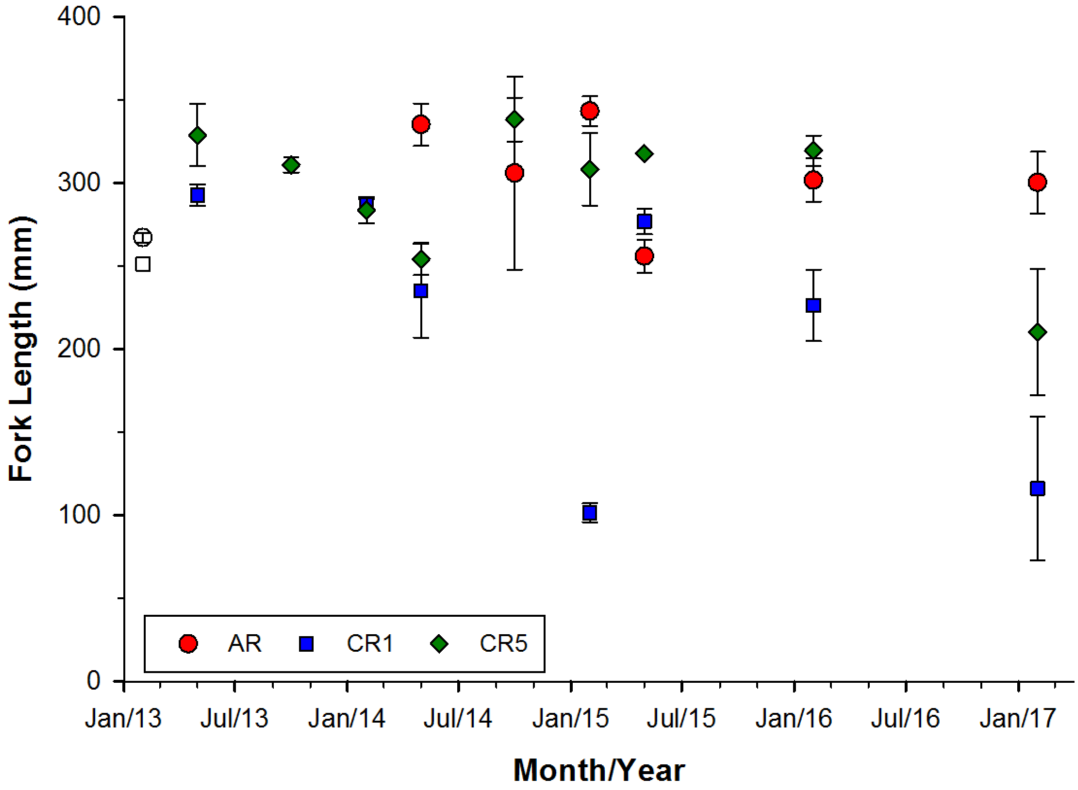


Figure 21. Mean fork length (mm) of trevally species on each survey for Bunbury Reef (red circle) plus CR1 (blue square) and CR5 (green diamond) natural reefs, where hollow indicates pre-deployment and with standard errors.

5.1.3.3 Dunsborough Reef

5.1.3.3.1 Fish communities

The nMDS plot and PERMANOVA analysis of the overall fish community data from the sBRUV surveys show there was little change in the CR1 and CR5 sites (Figure 4) over the entire four year period. The pairwise comparison of sites at Dunsborough showed there was a significant difference between the fish communities at the CR1 and CR5 sites (P=0.001). Further pair-wise analysis of the data from each survey for these sites showed there were no significant differences between surveys at each site. These results indicate that over the course of the trial there has been no discernible change in the fish community composition, indicating the deployment of the artificial reef has not impacted upon the natural reefs at the CR1 or CR5 distances.

To investigate the possible impacts of increased fishing at the Dunsborough Reef the average number of demersal species (combined MaxN) per sBRUV, primarliy consisting of the abundances for snapper, baldchin groper and WA dhufish, was investigated for change over the study for the CR1 and CR5 sites (Figure 22). These demersal species are potentially good

indicators of impacts that increased recreational fishing pressure may have in the area as they are likely to remain relatively site attached.

The results, although variable through the surveys, show an initial decline in the relative abundance of this group of demersal finfish at the CR1 site immediately after the deployment of the Dunsborough Reef (Figure 22). The higher abundance in this initial survey at this site was due primarily to juvenile snapper (FL<320 mm), see Figure 23, and small WA dhufish (FL<420 mm). It may be possible that some of these fish were attracted to the Dunsborough Reef and removed by recreational fishing but as abundance was highly variable it may also be due to a seasonal movement of these fish around the size at maturity away from the CR1 site. From the sBRUV surveys on the Dunsborough Reef there was evidence that some of the undersized WA dhufish observed had been caught and suffered barotrauma as a result of capture from 27 m depth. Three of the five WA dhufish recorded had evidence of hook damage to the mouth, appearing as a darkened patch, and one individual had an eye completely missing, which could have been the result of capture and barotrauma. Such signs of capture were not observed on the WA dhufish at the natural reef sites.

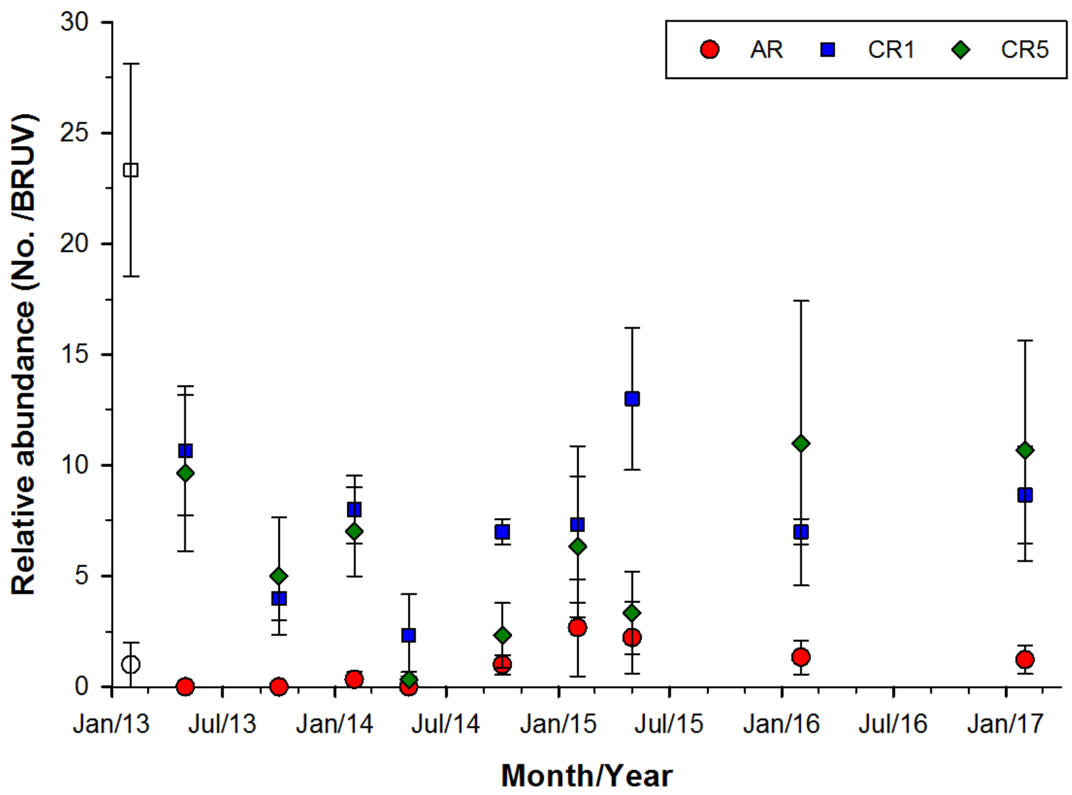


Figure 22. Mean relative abundance of demersal species (combined MaxN/BRUV) for each survey of Dunsborough Reef (red circle) plus CR1 (blue square) and CR5 (green diamond) natural reefs, with shaded area indicating pre deployment survey and standard errors given.

5.1.3.3.2 Samson fish

On the pre-deployment surveys only three small Samson fish (FL- 380 mm) were recorded at the CR1 site. The abundance of Samson fish recorded on the CR1 and CR5 natural reefs over all nine surveys was very low with a total of only 17 and 9 individuals respectively for the sites. No large schools, as occur on the Dunsborough Reef, were recorded at the CR1 and CR5 sites. The size of Samson fish recorded at the natural reef sites ranged from 400-1300 mm in FL with no higher abundance of individuals in the 700-1000 mm size range (Figure 15), which are the predominant size recorded on the Dunsborough Reef. As numbers recorded over all the surveys at both sites were low there was no discernible change in abundance or size of Samson fish on the CR1 or CR5 natural areas over the course of the trial near the Dunsborough Reef.

5.1.3.3.3 Snapper

The relative abundance of snapper recorded by sBRUVs at the CR1 and CR5 sites has been highly variable over the trial and comparison of the surveys shows a similar pattern in the abundance at the sites over the surveys, with a marked increase over early 2015. However, there was a noticeable initial decline in the abundance recorded at the CR1 site after deployment compared to before the reef was deployed (Figure 23), which contributed to the initial decline in demersal species (see above). The size ranges of Snapper recorded on the surveys at the CR1 and CR5 sites has not changed dramatically, consistently averaging between 280 to 400 mm in FL (Figure 16) making most immature and below the LML. Thus, while there may have been some initial impact by the deployment of the Dunsborough Reef on the snapper abundance at the nearby natural reefs the abundances are variable and sizes are small so other factors such as movement may also be influencing results as well. Comparison with results for the species from other wider scale surveys would help determine if the patterns are likely due to the AR.

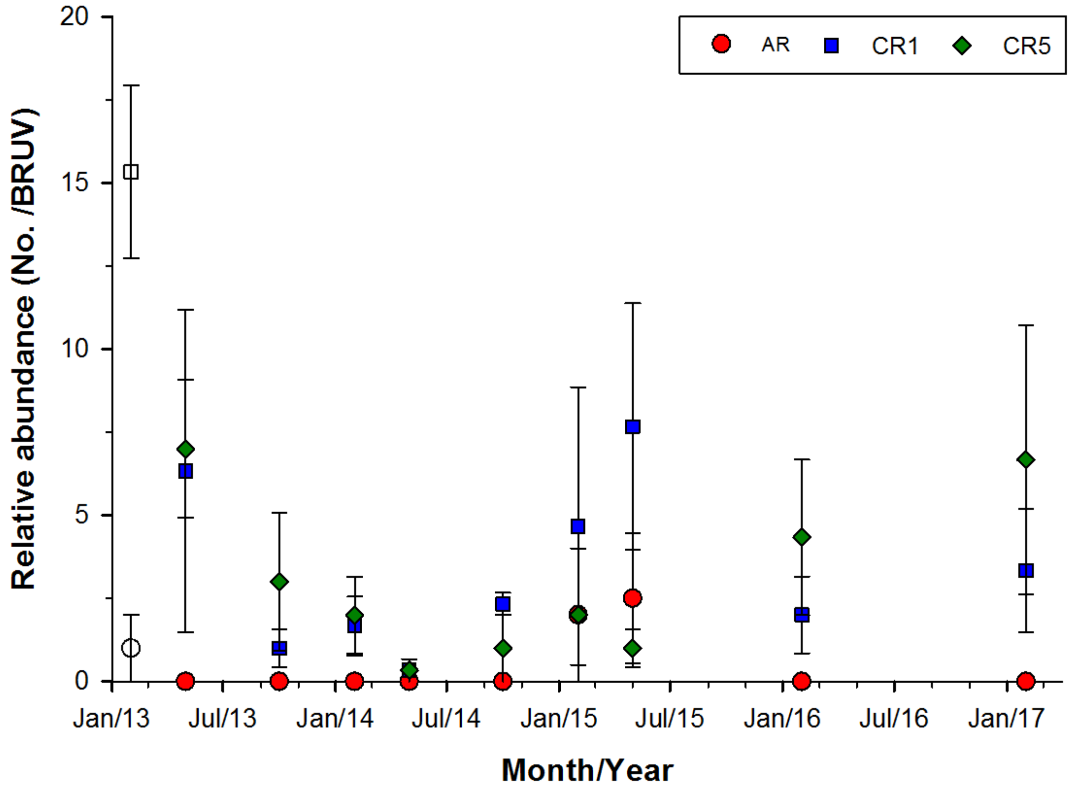


Figure 23. Mean relative abundance (MaxN/BRUV) of snapper on each survey for Dunsborough Reef (red circle) plus CR1 (blue square) and CR5 (green diamond) natural reefs, where shaded area is predeployment survey and standard errors given.

5.1.3.3.4 Trevally

The relative abundance of trevally on the CR1 or CR5 reef sites was generally variable (n=0-30) and low (mean 0-11). The predeployment Summmer 2013 survey at the CR1 site recorded a mean relative abundance of 4.3 (se 1.2) and results for each survey were above and below this. There appears to be a seasonal pattern to the abundances of silver trevally at the natural sites, which were generally higher in Summer surveys and very low in the Autumn and Spring surveys. The final Summer 2017 survey recorded a mean relative abundance of 9.33/BRUV, (se 4.8) more than twice that recorded on the predeployment survey. Thus, there appears to have been no decline in the abundances of silver trevally in the surrounding area over the trial and may have been an increase although this could be due to seasonal factors.

The size of trevally on the CR1 and CR5 sites was generally 200-400 mm in FL with very few less than 150 mm, indicating they are mostly silver trevally (Figure 17). The average size of trevally at the CR1 and CR5 sites was also variable over the trial but did not change dramatically. Thus, there appears to have been no impact of the Dunsborough Reef deployment on the abundance or size of silver trevally on the natural reefs in the areas at the 1 or 5 km distances, with their abundance showing a higher seasonal variation.

5.2 Positioning

The sidescan sonar mapping conducted on the post deployment surveys detected no movement of the modules at the Bunbury or Dunsborough Reefs (Figure 2).

During the winter of 2013 the modules were exposed to maximum winter wave conditions approaching that of a 1 in 100-year storm event. The wave conditions recorded at Cape Naturaliste of height (Hs =9.47m) and period (Tp= 16.67s) on the 1st of September 2013 (DOT 2013) were approaching the intensity of the 1/100yr storm calculated as Hs = 10-11 m, Tp = 16-20 s for a location offshore of Busselton in 50 m water depth (Calculation based on extreme analyses of NOAA Wave Watch 3 model). Thus, the modules withstood a significant storm event in their first 10 months with no signs of movement.

5.3 Structural

The diver inspections of all 60 modules at the Dunsborough and Bunbury Reefs were generally completed during each annual Summer survey. During the initial 6 month survey (18 October 2013) of the Dunsborough Reef a damaged module was detected in the north-west cluster. The corners of one module appeared to have chipped off and the steel reinforcing was exposed (Figure 24). In February 2014, the damaged module was removed and replaced, see 6.4 Management actions. A follow-up sidescan sonar survey was used to assess the positioning of the replacement module at the Dunsborough Reef. The mapping confirmed the removal of the damaged module and the correct placement of the replacement module in the NW cluster at the Dunsborough Reef.

The subsequent surveys detected no further damaged modules even after the extreme storm event in September 2013 (see Section 5.2).

Figure 24. Damaged artificial reef module being removed at Dunsborough Reef in February 2014.

5.4 Benthic habitat

The sidescan surveys of the site before deployment (Summer 2013) and on the final survey in Summer 2017 at the end of the trial, nearly four years after deployment, were overlaid to investigate any changes in benthic habitat within the Bunbury and Dunsborough Reef sites.

Both reef sites had some evidence of minor changes in seagrass beds over the four years with some areas establishing near modules at both sites. Neither site had any evidence of scouring from the sidescan or diver surveys. At the Dunsborough Reef considerably more filamentous algae was recorded in the final Summer 2017 survey growing on the shells and sloughed macroinvertebrate structures in the immediate vicinity of the modules than in the initial surveys. It appears the modules are providing more surfaces for this filamentous algae to grow at the site but the key influence may be seasonal factors such as warmer water temperatures and calm conditions as the filamentous algae was recorded elsewhere.

5.4.1 Bunbury Reef

The overlaid sidescan surveys of benthic habitat in the Bunbury Reef area show some minor differences between 2013 and 2017 (Figure 25) with some patchy beds of seagrass evident in the 2017 survey which were not clear in the Summer 2013 survey, before the deployment. The diver surveys detected no declines in the areas of seagrass in the vicinity of the modules (Figure 26).

The diver surveys detected some bedding down of the modules into the sediment at Bunbury Reef, with the top of the bottom cross bar just showing on some modules (Figure 26). There was also an accumulation of sediment in the centre of the modules. There was no evidence of sediment scouring around the modules at the Bunbury Reef with the ridges of sand still evident in the sDOV surveys and on the sidescan mapping around the modules (Figure 25). It was also evident that the diversity of benthic organisms colonising the modules had increased over the three years (Figure 27).

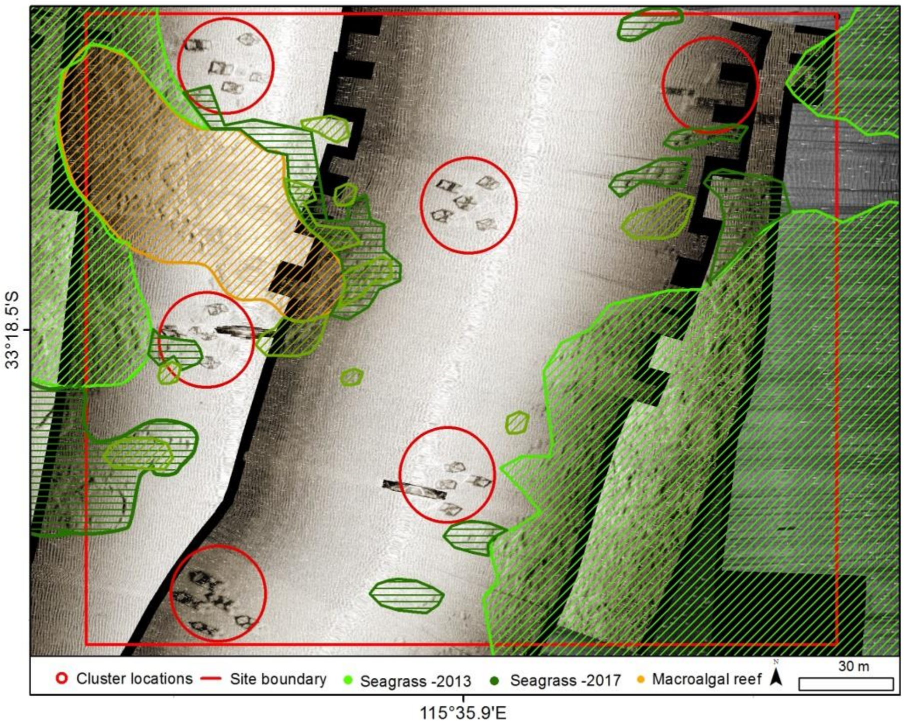


Figure 25. Habitat map from sidescan transects at Bunbury Reef indicating areas of seagrass in 2013 (light green) and in 2017 (dark green), with cluster locations (red circles) and site boundary (red square).

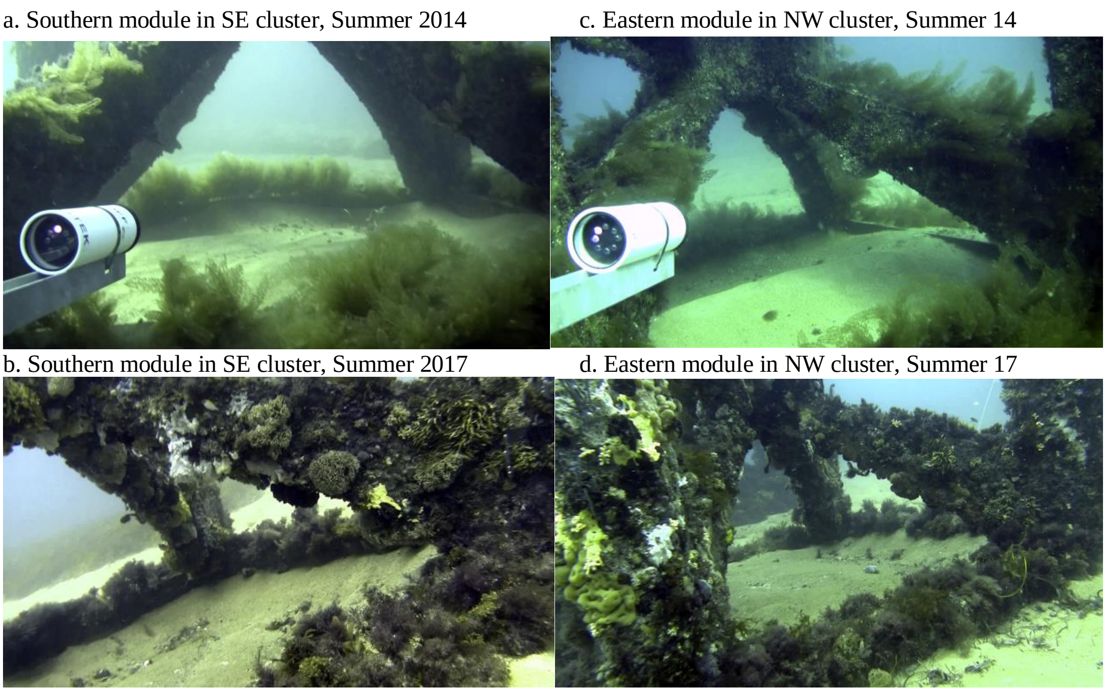


Figure 26. Underwater images from Bunbury Reef showing a) module in SE cluster on initial survey in Summer 2014 with algae on module, ridges in sand and seagrass in background, b) same module in SE cluster on Summer 17 survey with benthic colonisation, ridges in sand and seagrass bed in

background, c) module in NW cluster on initial Summer 2014 survey showing some bedding down into the sediment and accumulation of sand and d) same module in NW cluster on final Summer 2017 survey showing similar sediment accumulation and developed benthic coverage.

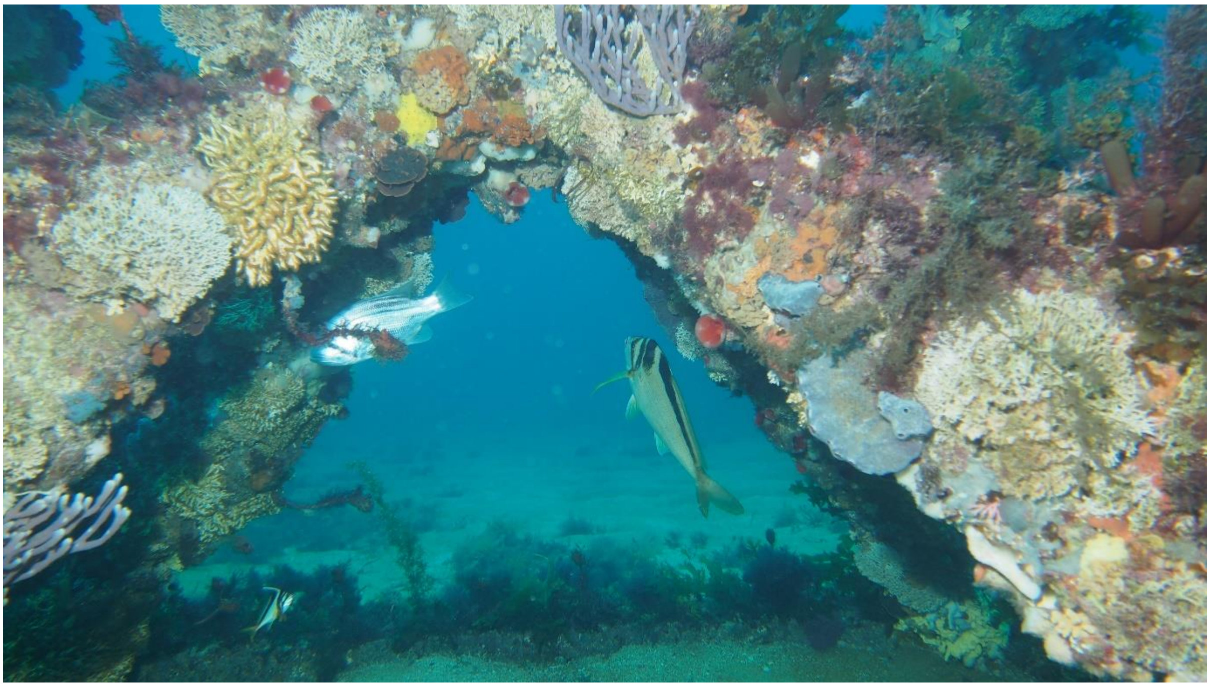


Figure 27. Underwater image from Feb 2017 diver survey of Bunbury Reef showing development of benthic community.

5.4.2 Dunsborough Reef

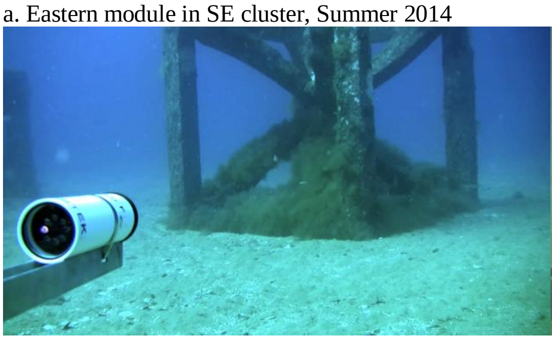
The sidescan mapping of the Dunsborough site indicates more patches of seagrass within the site in 2017 than was recorded before the deployment of the modules (Figure 28). At some clusters such as the SW there were patches of seagrass growing up to the modules. However, the initial diver surveys recorded some small and patchy segrass beds near some modules, which were not detected by the sidescan mapping with the older sidescan unit in the predeployment surveys at this deeper site and would likely have been missed in the initial limited towed video transects done.

The diver surveys showed little bedding down of the modules due to the shallow sediment depth at the site, except in the NW cluster where sediments were deeper and the lower cross bars on two modules were almost buried by the initial Spring 2013 survey (Figure 29c). The final Summer 2017 survey of the same modules showed a similar level of bedding into the sediment (Figure 29d). There was little evidence of scouring at the site but there were changes to the benthos surrounding most of the clusters at Dunsborough Reef. The final Summer 2017 survey showed an area around each cluster and inside the modules with filamentous algae growing on the exposed shell and benthic organisms such as tubeworm colonies which had sloughed off the modules on the benthos, see Figure 29. The initial 2013 surveys of this site showed some shell evident in the sediment. Some filamentous algae was also present on the modules but not the benthos during the initial Summer 2014 surveys. Some of the inshore reefs surveyed in the Summer 2017 also had high coverage of

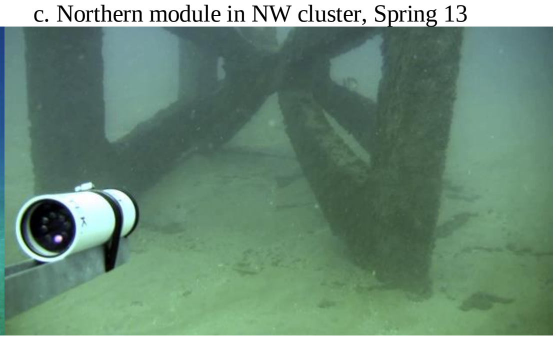
filamentous algae which may be a seasonal occurrence as a result of higher water temperatures and low water movement.

Figure 28. Habitat map from sidescan transects at Dunsborough Reef indicating areas of seagrass in 2013 (light green) and in 2017 (dark green), with cluster locations (red circles) and site boundary (red square).

a. Eastern module in SE cluster, Summer 2014



c. Northern module in NW cluster, Spring 13



b. Eastern module in SE cluster, Summer 2017

d. Northern module in NW cluster, Summer 17

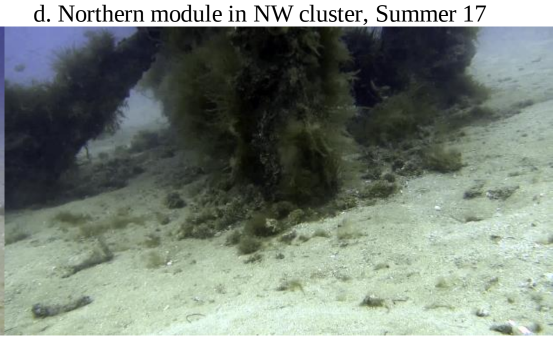


Figure 29. Underwater images from Dunsborough Reef showing a) module in SE cluster on Summer 2014 survey with filamentous algae on module, b) same module in SE cluster on Summer 17 survey

where scallop shell evident around module with filamentous algae, c) module in NW cluster on initial Spring 2013 survey showing some bedding down into the sediment and d) same module in NW cluster on final Summer 2017 survey showing similar sediment cover and sloughed macroinvertebrates with filamentous algae.

5.5 Debris removal

The diver surveys of the Reefs removed a number of anchors and numerous fishing rigs of fishing line with terminal tackle (hooks, sinkers, lures etc.) wrapped around modules (Table 4). The amount of fishing debris accumulation on the modules at each Reef is quite low considering it is spread over the 6 clusters and 30 modules. It is likely that further fishing debris is lost but if not tangled on a module will fall off and become buried in the surrounding sediment.

Of the eight anchors recovered three were inside the modules and appeared to be stuck and broken off, two had long lengths of rope and chain attached with the rope frayed where it appeared to have chaffed through on the edge of a module or been cut at the surface when stuck and the remaining four anchors recovered had no rope or chain attached at all. It is likely the shackle on these latter anchors had worked loose, which could have occurred anywhere and was not due to anchoring on the artificial reef modules. Other debris removed included a length of rope found tied to one of the modules at the Bunbury Reef on the Summer 2015 survey, which presumably had been used as a mooring line, and six fishing rods and reels, in various sizes and states of corrosion, that had been lost overboard by recreational fishers on the Reefs.

Table 4. Type and amount of fishing debris removed from each reef on each diver survey.

Reef	Type	Summer 14	Summer 15	Summer 16	Summer 17
Bunbury	Fishing line/rig	3	9	8	3
	Anchor	1	0	2	0
	Other		Rope on module	2 rod/reel	
Dunsborough	Fishing line/rig	2	9	9	9
	Anchor	0	2	2	1
	Other		1 rod/reel	2 rod/reel	1 rod/reel

6. Management of Artificial Reefs

6.1 Incidents

The only incident at the Bunbury or Dunsborough Reefs during the first four years was the discovery of a module that had been damaged during the deployment process, see Section 5.3. Note that the damage was not visible at the time of deployment. The diver surveys recorded images of the damaged module in the north-west cluster at the Dunsborough Reef showing the exposed reinforcing steel. Action was taken to ensure the damaged module was removed and replaced, see 6:4 Management actions.

6.2 Threatened, Endangered, Protected or Migratory Species

No interactions with threatened, endangered, protected or migratory species were reported at the Bunbury or Dunsborough Reefs. The sBRUV and sDOV surveys did not record any of these species but crew did visually document Humpback Whales (Spring 2013) and Bottlenose Dolphins (Summer 2017) in the vicinity of the Dunsborough Reef.

6.3 Introduced species

The widespread colonisation of some modules in the Bunbury Reef, particularly NE cluster, by a white colonial ascidian was confirmed to be the introduced *Didemnum perlucidum* after NextGen DNA testing of samples collected during the Summer 2016 survey. The species is confirmed to be widespread in WA and has been found on a vessel in Port Geographe (DoF 2015) and likely occurs in Bunbury making its occurrence at the Reefs not unexpected. The species is not regarded as a noxious pest and due to its widespread distribution the Department is now managing this pest species only in high value asset areas, *i.e.* State marine parks, A-class reserves, lands and waters adjacent to A-class reserves and pearling and aquaculture facilities, and no further action is anticipated. However, since testing was done the coverage of the white ascidian had declined dramatically in the final Summer 2017 survey (Figure 29). The images from each sDOV survey of the same modules where the initial colonisations were detected (eastern side of the Western module and the eastern side of the Southern module) in the NE cluster at Bunbury Reef show the changes through time in the coverage of the ascidian (Figure 29). The reduced coverage in the final survey is likely due to lower than average water temperatures experienced during 2016/2017 compared to higher than average in previous years as the species is tropical and cooler winter months generally reduces its colony size (Munoz & McDonald 2014).

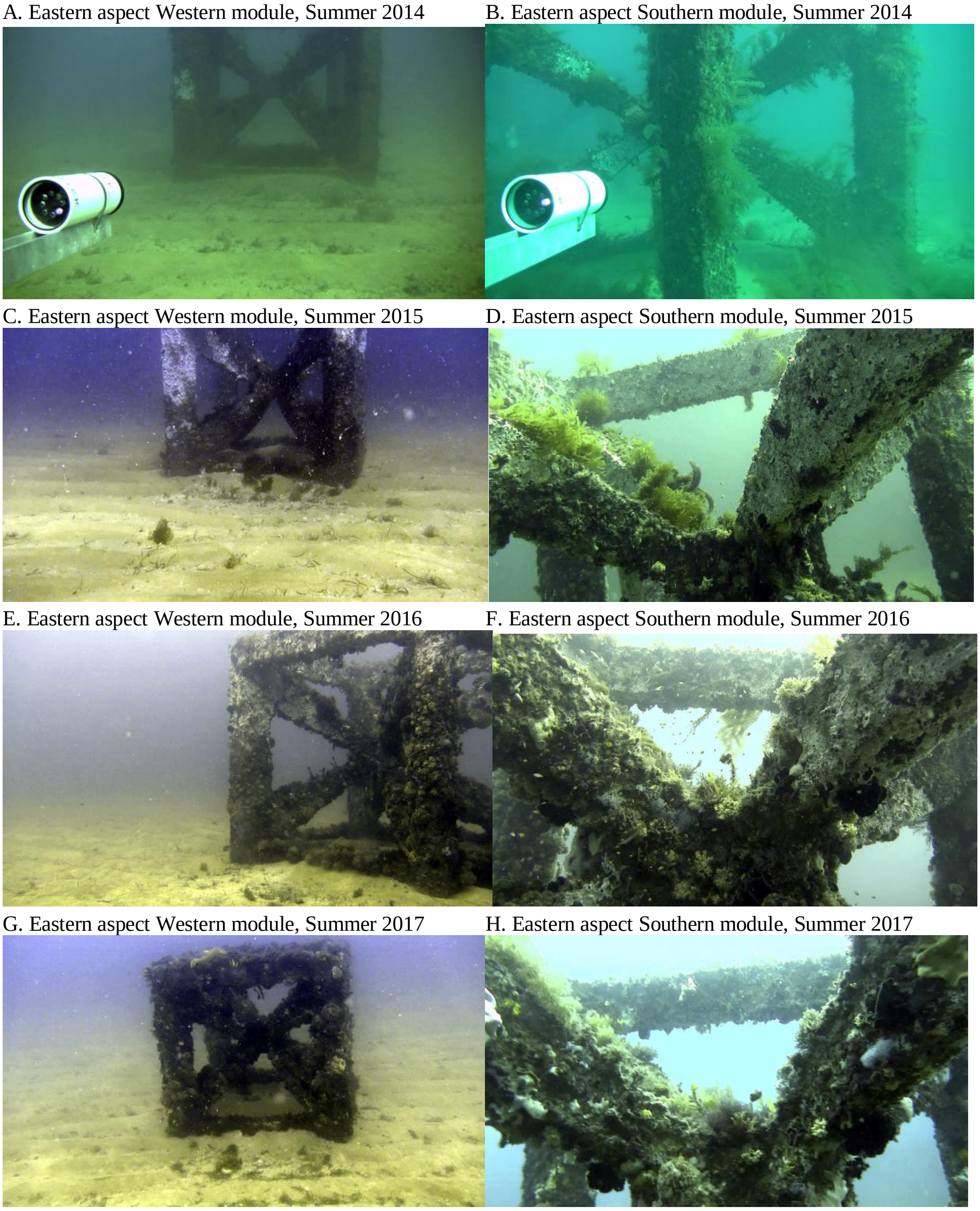


Figure 30. Images of same modules in NE cluster at Bunbury Reef from each sDOV survey showing coverage of white colonial ascidian.

6.4 Management actions

The detection of a damaged module (Section 5.3) required management action to be undertaken.

The contractor responsible for construction and deployment of the reefs was contacted and following discussions regarding possible causes of the damage it was revealed that the

module in question was repositioned during the deployment process. The repositioning occurred due to the proximity of the module in question to an adjacent module. The most likely cause of the damage was that the module in question was initially lowered onto a previously deployed module causing a compromise in the structural integrity of the module which was not evident at the time of deployment but became apparent 6 months post deployment.

On the 5th of February 2014, the contractor put in place measures (consistent with approved procedures outlined in the LTMMP) to remove the damaged module (Figure 24) and replace it with a new (identical) module. Note that several back up modules were made during the construction phase of the project both for public display purposes (Figure 31) or in the event that one or more of the modules were damaged during transport and deployment. Subsequent sidescan sonar surveys (Section 5.2) confirmed the replacement module was correctly positioned and the damaged module removed. None of the remaining modules at both Dunsborough and Bunbury Reefs show any signs of damage.

Figure 31. Image of display module and information sign at Quindalup boat ramp.

7. Extension activities

The data, images and video collected on the research surveys has been incorporated into the artificial reef information page on the Department's website (http://www.fish.wa.gov.au/Fishing-and-Aquaculture/Recreational-Fishing/Pages/Artificial-Reefs.aspx), including links to video footage from the surveys of the artificial reefs.

To promote the progress and the diversity of fish occurring at the artificial reefs ministerial media releases with associated pictures and video have been produced for the 1, 2 and 3 year anniversaries. These were widely received and resulted in numerous articles on the artificial reefs in the media, particularly in south west of Western Australia.

The project has produced a number of articles and presented a number of seminars on the South West artificial reef trial project including:

- presentation of results to date to recreational fishers at Dunsborough (May&Sept 2013, May 2015, May 2016) and Bunbury (May&Sept 2013, May 2016);
- presentation of initial results at Australian Society of Fish Biologists (ASFB) conference, Sydney (Oct 2015);
- presentation to a visiting delegation from China (30th of August, 2013),
- media releases and newspaper articles on progress of reefs at 1, 2 and 3 year anniversaries of deployment;
- articles on SW artificial reefs in Research Angler programme newsletter (Aug13), Catch e-newsletter (May 14) and Coastlines newsletter (March 2015); and
- display with video footage at the Hillarys and Mandurah Boat Shows (2013 & 2014).

Additional activities included meeting with three honours students, regular meetings with Recfishwest, involvement in a collaborative FRDC project (2014/005) on habitat enhancement structures in WA involving the citizen science project "ReefVision".

8. Acknowledgements

The Southwest Artificial Reef Trial was funded by Royalties for Regions and Recreational Fishing Initiatives Fund. The authors would like to thank the Scientific Reference Group members for the initial project design and particularly Brett Molony for his ongoing support and guidance with the project and review of report. The authors would like to acknowledge the essential support from staff of the Finfish Branch at the WA Marine Research Laboratories, particularly Brett Crisafulli, Dion Boddington and Chris Dowling. Finally, the authors would like to thank Andrew Roland and staff at Recfishwest for their support and input to the project.

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10. Appendix 1

Fish species recorded on the Bunbury and Dunsborough Reefs in the 8 surveys to Summer16 by method. Where target species in bold, # indicates species present in pre-deployment surveys, * recreationally targeted species and ^ species only recorded by night-time BRUV set in Autumn2015 at Dunsborough.

	Species	Common name	Dunsborough		Bunbury	
1*	***Seriola hippos***	**Samson fish**		**BRUV & DOV**		**BRUV & DOV**
2*	***Chyrosophyrs auratus***	**Snapper**	**#**	**BRUV**		**BRUV**
3*	***Pseudocaranx georgianus***	**Silver trevally**		**BRUV & DOV**		**BRUV & DOV**
4	*Ammotretis elongatus*	Elongate flounder				BRUV
5	*Anoplocapros robustus*	Western smooth boxfish	#	BRUV & DOV	#	BRUV & DOV
6	*Anoplocapros lenticularus*	White-barred boxfish		BRUV & DOV		BRUV & DOV
7	*Apogon victoriae*	Red striped cardinalfish		DOV		BRUV & DOV
8	*Aptychotrema vincentiana*	Shovelnose ray		BRUV		
9	*Arcana aurita*	Shaw's cowfish		BRUV & DOV		BRUV & DOV
*10**	*Achoerodus gouldii*	Blue groper		BRUV & DOV		
11	*Aulohalaelurus labiosus*	Blackspot catshark				BRUV
12	*Austrolabrus maculatus*	Black spotted wrasse		BRUV&DOV		BRUV & DOV
13	*Carcharhinus sp.*	Whaler shark sp.				BRUV
14	*Caesioscorpis theagenes*	Fusilier sweep		BRUV & DOV		DOV
15	*Chaetodermis penicilligera*	Tasselled leatherjacket	#			
16	*Chaetodon assarius*	Western butterflyfish		DOV		BRUV & DOV
17	*Cheilodactylus gibbosus*	Crested morwong		BRUV & DOV		BRUV & DOV
18	*Chelmolops curiosus*	Western talma		BRUV & DOV		BRUV & DOV
*19**	*Choerodon rubescens*	Baldchin groper		DOV		BRUV & DOV
20	*Chromis klunzingeri*	Blackheaded puller		BRUV & DOV		DOV
21	*Cleidopus gloriamaris*	Pineapple fish		BRUV & DOV		
22	*Coris auricularis*	Western king wrasse		BRUV & DOV		BRUV & DOV
23	*Dactylophora nigricans*	Dusky morwong		BRUV		
24	*Dasyatis brevicaudata*	Smooth stingray		BRUV		BRUV & DOV
25	*Diodon nicthemerus*	Globefish		BRUV & DOV		BRUV & DOV
26	*Enneapterygius larsonae*	Black head triplefin				DOV
27	*Enoplos armatus*	Old wife		DOV		DOV
28	*Epinephiledes armatus*	Breaksea cod				DOV
29	*Eubalichthys mosaicus*	Mosaic leatherjacket		BRUV		BRUV
30	*Eupetrichthys angustipes*	Snakeskin wrasse		DOV	#	BRUV & DOV
*31**	*Glaucosoma hebraicum*	WA dhufish		BRUV & DOV		DOV
32	*Halichoeres brownfieldii*	Brownfields wrasse		BRUV		DOV
33	*Helcogramma decurrens*	Blackthroated threefin				DOV
34	*Heniochus acuminatus*	Longfin bannerfish		DOV		
35	*Hypoplectrodes nigroruber*	Black-banded seaperch				DOV
36	*Hypoplectrodes cardinalis*	Red seaperch		DOV		

	Species	Common name	Dunsborough		Bunbury	
37	*Lagocephelus sceleratus*	Silver toadfish		BRUV		
38	*Meuschenia flavolineata*	Yellow striped leatherjacket		BRUV & DOV		BRUV & DOV
39	*Meuschenia freycineti*	Sixspine leatherjacket	#	BRUV		BRUV
40*	*Mustelus antarcticus*	Gummy shark		BRUV		
41	*Myliobatus australis*	Eagle ray	#	BRUV	#	BRUV
42	*Neatypus obliquus*	Footballer sweep		BRUV & DOV		BRUV & DOV
43*	*Nemadactylus valenciennesi*	Queen snapper		BRUV		
44	*Neosebastes pandus*	Gurnard perch		BRUV	#	
45	*Notolabrus parilus*	Brownspot wrasse		BRUV & DOV		BRUV & DOV
46	*Omegophora armilla*	Ringed toadfish		DOV		DOV
47	*Ophthalmolepis lineolatus*	Maori wrasse				BRUV
48	*Oplegnathus woodwardii*	Knifejaw		BRUV^		
49	*Orectolobus sp.*	Wobbegong shark		DOV		
50	*Parapercis haackei*	Wavy grubfish		BRUV & DOV		BRUV & DOV
51	*Parapercis ramsayii*	Spotted grubfish		BRUV		
52	*Paraplotosus albilabris*	Cobbler		BRUV		DOV
53	*Parapriacanthus elongatus*	Slender bullseye		BRUV & DOV		
54*	*Parazanclistius hutchinsi*	Short boarfish		DOV		
55	*Parequula melbournensis*	Silverbelly	#	BRUV	#	BRUV& DOV
56*	*Paristiopterus gallipavo*	Yellow spot boarfish		BRUV&DOV		BRUV & DOV
57	*Parma mccullochi*	McCullochs scalyfin		DOV		BRUV
58	*Parupeneus crysopleuron*	Yellow strip goatfish		BRUV		BRUV
59	*Pentapodus vittae*	Western butterfish				BRUV
60	*Pempheris klunzingeri*	Rough bullseye		BRUV & DOV		BRUV & DOV
61	*Pictilabrus laticlavius*	Senator wrasse				BRUV
62	*Platax tiera*	Roundface batfish				TUV
63	*Plotosus lineatus*	White striped catfish		DOV		
64*	*Platycephelus sp.*	Flathead sp.		BRUV		BRUV
65*	*Platycephelus speculator*	Bluespot flathead	#	BRUV	#	BRUV
66*	*Platycephelus longispinis*	Longspine flathead	#	BRUV	#	BRUV
67*	*Pentaceropsis recurvirostris*	Longsnout boarfish		BRUV & DOV		BRUV & DOV
68	*Pseudocaranx sp.*	Trevally (Sand & Silver)	#	BRUV & DOV	#	BRUV & DOV
69	*Pseudolabrus biserialis*	Red-banded wrasse		BRUV & DOV		
70	*Pseudorhombus jenynsii*	Small tooth flounder				BRUV
71	*Scobinichthys granulatus*	Rough leatherjacket		BRUV		BRUV
72*	*Scomberomorus sp.*	Mackerel sp.	#			
73	*Scorpis georgianus*	Banded sweep		BRUV		BRUV
74*	*Seriola lalandi*	Yellowtail kingfish				BRUV & DOV
75	*Siganus sp.*	Spinefoot sp.				BRUV & DOV
76*	*Sillago sp.*	Whiting sp.		BRUV^		
77	*Siphonognathus sp.*	Weed whiting sp.		DOV		DOV

	Species	Common name	Dunsborough		Bunbury	
78	*Sphyrena obtusata*	Striped seapike		BRUV		
79	*Suezichthys cyanolaemus*	Bluethroat rainbow wrasse		BRUV		
80	*Tilodon sexfasciatus*	Moonlighter		BRUV & DOV		BRUV & DOV
81	*Trachinops noarlungae*	Yellow-headed hulafish		DOV		BRUV & DOV
82	*Trachurus novaezelandiae*	Yellowtail scad		BRUV & DOV		
83	*Trygonoptera personata*	Masked stingaree	#	BRUV & DOV	#	BRUV & DOV
84	*Trygonorrhina dumerilii*	Southern fiddler ray	#	BRUV	#	BRUV & DOV
85	*Upeneichthys vlamingii*	Blue spotted goatfish		BRUV & DOV		BRUV & DOV
86	*Urolophus sp.*	Stingaree sp.		BRUV		BRUV & DOV
		Count of sp.	**12**	**70**	**10**	**63**