Project Plan SP 2018-136

Understanding the key ecosystem services provided by the seagrass meadows of Western Australia

Marine Science

Project Core Team

Supervising Scientist	Simone Strydom
Data Custodian	Simone Strydom
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Project status as of Jan. 7, 2020, 3:51 p.m.

Approved and active

Document endorsements and approvals as of Jan. 7, 2020, 3:51 p.m.

Project Team	granted
Program Leader	granted
Directorate	granted
Biometrician	granted
Herbarium Curator	not required
Animal Ethics Committee	granted

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Biodiversity and Conservation Science Program

Marine Science

Departmental Service

Service 7: Research and Conservation Partnerships

Project Staff

Role	Person	Time allocation (FTE)
Supervising Scientist	Simone Strydom	0.5
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Research Scientist	Alan Kendrick	0.05
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Related Science Projects

Marine Monitoring Program (SPP 2012-008)

Proposed period of the project

Nov. 21, 2018 – Nov. 21, 2023

Relevance and Outcomes

Background

Seagrasses are foundation species that support important ecosystem services and processes (Ellison et al., 2005; Nordlund et al., 2017; Orth et al., 2006). For example, seagrasses provide food and habitat for fauna that support tourism and fisheries, detritus and nutrient subsidies, water quality maintenance, storing of organic carbon, and sediment accretion and stabilization (York et al. 2018; Unsworth, Nordlund, and Cullen-Unsworth 2018). Some of the largest and most diverse seagrass meadows in the world occur in Western Australia (WA); the warm south-flowing Leeuwin current amplifies the distribution of tropical genera (e.g. *Halophila* and *Halodule*) to intermix with temperate genera (e.g. *Posidonia* and *Amphibolis*). These meadows support many commercially, recreationally and culturally important fauna, such as blue swimmer crabs, dugong, herring, King George whiting, tailor, tarwhine, tiger prawns, snapper, sea turtles, western blue groper, western rock lobster and various cephalopods (Cappo, Alongi, Williams, & Duke, 1998; Heck, Hays, & Orth, 2003; Heithaus, 2004; Jernakoff, 1987; Kenyon, Loneragan, & Hughes, 1995).

Seagrass meadows are however declining globally (~110 km^2 yr^{-1}), and anthropogenic related pressures such as terrestrial run-off, anchor damage, eutrophication and dredging are threatening the ecological, economic and social services that seagrass meadows provide (Waycott et al. 2009). For example, poor water quality caused by discharge of industrial waste, combined with harbour construction, resulted in the loss of approximately 1587 ha of seagrass in Cockburn Sound from 1967-1972 (Cambridge and McComb 1984; Kendrick et al. 2002), which is yet to fully recover even though water quality has since improved (Mohring and Rule 2013). Another key pressure globally and across WA is climate change; increased sea water temperature and extreme events (e.g. marine heat waves) have induced significant declines in seagrass cover in the Shark Bay World Heritage Area (Nowicki et al. 2017). An estimated 90% reduction in *A. antarctica* meadows occurred around the Peron Peninsula in response to the marine heat wave of 2010/11 (Thomson et al. 2015). The full extent of seagrass loss in WA's largest World Heritage Area since this marine heat wave is unknown. However, current estimates for seagrass loss for 68% of the Shark Bay Marine Park area between 2002-2014 are equivalent to approximately 60,000 ha (Holmes et al., 2019). Seagrass loss associated with the marine heat wave coincided with sea turtle starvation (Thomson et al. 2015), a collapse in the Shark Bay scallop (*Amusium balloti*) fishery (Caputi et al. 2016) and an estimated release of 9 million metric tons of CO_2 from the sediment (Arias-Ortiz et al. 2018).

As the condition of seagrass meadows respond readily to environmental and anthropogenic pressure, they are used as indicators for the overall effectiveness of management (Key Performance Indicators) across several WA marine reserves managed by the Department of Biodiversity of Conservation and Attractions (DBCA). The long-term monitoring of seagrasses by the Marine Science Program (MSP) and Region staff helps to provide a greater understanding of changes in seagrass condition in response to pressure within each marine reserve. However, across-region comparisons and thorough temporal assessments of seagrass condition need to be compiled and assessed to gain a broader appreciation of seagrass health among the state's network of marine reserves.

Like seagrass, finfish communities have a strong economic and social value, and as such, are used as indicators of marine biodiversity and the ecosystem services they provide (Pratchett, Hoey, and Wilson 2014). While the MSP long-term monitoring program conducts an effective finfish program designed to detect impacts associated mainly with fishing pressure, surveys are focussed around high diversity rocky and coral reefs. The efficacy of these methods in WA seagrass meadows are however unknown, and as a consequence monitoring does not currently assess the condition of seagrass associated fish assemblages. Nonetheless seagrasses cover extensive areas of the states marine reserves, providing food and habitat for many fish (and other fauna). Identifying appropriate techniques to survey fish in seagrass meadows will improve understanding of the dynamics and condition of faunal assemblages associated with this habitat.

A wide range of sampling methods are used to determine faunal assemblages (Short and Coles 2001), for example, invertebrate and finfish assemblages have been surveyed using seine nets, beam and otter trawls, crab scrapes, and diver observations along transects or within randomly placed quadrats (McNeill and Bell 1992; MacArthur and Hyndes 2001). Finfish sampling methods commonly include underwater visual census (Caldwell 2011), or underwater videos (Parker et al., 1994), either operated by a diver or placed as remote videos, which can be baited (Hardinge et al. 2013) or unbaited (Watson et al. 2010). Determining the optimal technique for sampling faunal assemblages will depend on the type of data required and the habitat being surveyed.

The composition of faunal assemblages is dynamic as communities are influenced by ecological processes that vary across multiple scales. For sedentary taxa, the condition of surrounding habitat can be an important determinant of local diversity and abundance (Wilson et al. 2006). Seascape metrics such as habitat composition, patch size, edge-to-patch size ratio, depth, distance to adjacent habitats as well as level of fragmentation can have a strong influence on faunal assemblages (Connolly 1994; Hyndes et al. 2018; Travers and Potter 2002). Structurally complex habitats such as seagrass meadows often form part of a mosaic of interconnected coastal habitats (e.g. mangrove, reefs, saltmarshes), that support a range of transient and resident fauna. Studies should therefore consider the effect of both seascape and local habitat factors on fish assemblages (van Lier et al. 2018; Connolly and Hindell 2006).

Within-patch seascape metrics such as seagrass structural complexity (i.e. aboveground biomass, canopy height, leaf morphology and epiphyte abundance) also influence fish and invertebrate assemblages within meadows (Edgar & Robertson, 1992; Gartner, Tuya, Lavery, & McMahon, 2013; Orth et al., 1984). For example, both the structural complexity of different seagrass species and the presence of algal epiphytes are known to influence macro-invertebrate density (Gartner et al. 2013). The prominent type of seagrass can also influence local structural complexity with consequences for both invertebrate (Jernakoff and Nielsen 1998) and fish assemblages (Hyndes, Kendrick, MacArthur, & Stewart, 2003; Travers & Potter, 2002). While these studies demonstrate that fish and invertebrate assemblages are influenced by the structural complexity of persistent seagrass genera (e.g. *Posidonia*), assessments among meadows with different seascape metrics (i.e. patch size, edge-to-patch size ratio, distance to adjacent habitats), temperate and tropical meadows (e.g. *H. uninervis*) or macroalgae (e.g. *Sirophysalis trinodis*) are lacking in WA. However, studies elsewhere indicate that patchy meadows have lower species richness compared to non-fragmented meadows (Macreadie et al. 2009). Such comparison are critical for understanding the future of seagrass assemblages, because as tropicalization ensues, the southerly contraction of temperate *P. australis* and *A. antarctica* will likely lead to their replacement by tropical seagrasses and macroalgae from sub-tropical regions like Shark Bay (Hyndes et al. 2016). An increased prevalence of the colonizing species *H. uninervis* post marine heat wave in Shark Bay indicates that tropicalization may be underway (Nowicki et al. 2017); but how this transition will affect faunal assemblages is unknown.

Clearly the taxonomic composition and physical structure of seagrasses vary spatially and, in some places, is in a state of change. As a consequence, the ecological role and conservation value of seagrass meadows is likely to vary both spatially and temporally. Identifying the seascape and within patch characteristics of seagrass meadows important to fish, and understanding the effects of habitat loss and fragmentation to biodiversity is therefore essential for effective management of seagrass meadows and associated communities. Accordingly, the overarching aim of this project is to increase our understanding of the ecology of different types of seagrass meadows, providing insight into the effect of spatial and temporal differences, which then can lead to inferring effects of shifts in seagrass condition on ecosystem services.

Aims

Three key objectives have been identified to improve understanding of the ecology of different seagrass meadows: 1) describe seagrass distribution and condition over time across the sub-tropical/temperate WA marine reserves; 2) establish appropriate methods for surveying and monitoring faunal communities in seagrass meadows; and 3) assess faunal communities in different types of seagrass meadows across the seascape to inform how key ecosystem services are affected by pressures that impact seagrass condition.

Expected outcome

Objective 1: The first objective will combine information collected by the DBCA marine monitoring program and external collaborators to provide an overview of seagrass condition in temperate WA marine reserves. Specifically, it will provide estimates of natural variability in seagrass condition over time, which can then be used to detect any abrupt or gradual changes outside of normal variation. The project will also specifically examine how extreme temperature in 2011 altered seagrass cover at Shark Bay, identifying resilient areas and metrics (e.g. similar to Degree Heating Weeks used in coral research) for predicting the effects of heat stress on seagrass. Useful products created out of this work include seagrass distribution maps, estimates of temporal and spatial rates of change, and digital habitat databases across the entire World Heritage Area; all of which can be used as quick reference guides on seagrass meadow condition. It is anticipated that the seagrass distribution maps and estimates of temporal and spatial rates of change in seagrass in Shark Bay following the marine heat wave (2010/11) will form the basis of publications in peer reviewed international journals.

Objective 2: The second objective will provide information regarding the diversity and abundance of invertebrate and finfish assemblages in seagrass meadows in a subset of marine reserves whilst also determining which survey techniques are most appropriate for monitoring these assemblages. This will include collaboration amongst MSP and Regional staff, both having the opportunity to be exposed to and/or become more experienced in using a range of fauna community assessment methods in addition to learning more about the general biodiversity within each region. Additionally, stable isotope and gut contents analysis will help elucidate the trophic nature of fauna and the extent to which they rely on seagrass habitats. The results from this work will also be suitable for publication, one paper comparing fauna assemblage methods, and another focussed on the food web dynamics. Results from the methodological comparison will determine which methods are most appropriate to use in the third objective.

Objective 3: Models assessing relationships between faunal communities and attributes of seagrass meadows (seascape and local), will identify which meadows are important in terms of fish biodiversity, important ecological functions and juvenile nursery grounds. By comparing faunal assemblages across impacted and stable seagrass meadows in Shark Bay, we will assess the ecological impact of meadow fragmentation and loss, potentially identifying resilient meadows. The results will also explore how ecological processes (e.g. herbivory) and ecosystem services (fisheries/ tourism) associated with fish assemblages vary among meadows of different composition. The results could be used to identify and conserve meadows with for maintaining healthy fish communities. Important seascape predictors of seagrass condition may also be used for planning in areas other than Shark Bay, to identify priority meadows for conservation. Similarly, information on seascape and local metrics can be used to refine monitoring efforts, improving our ability to evaluate management of coastal ecosystems. It is anticipated that one to two publications will be produced from this work.

Knowledge transfer

This project will predominantly benefit DBCA, especially those responsible for assessing and managing marine parks where seagrass is identified as an ecological asset in management plans. Information on important seascape predictors of seagrass condition and ecological value will be of use to park planners, and those interested in protecting seagrass from local anthropogenic impacts e.g. dredging. Information can be used to inform management decisions and feed into monitoring programs. Additionally, inclusion of regional staff in field work will facilitate knowledge transfer, and project outcomes will be transferred directly to all relevant DBCA Region/District staff in the form of information sheets and presentations. We estimate that the research findings will be published in peer reviewed journals to ensure knowledge transfer to researchers and managers nationally and internationally. The work may also be shared with the research community via conference presentations if the appropriate opportunity arises. Findings from the project will be communicated to the public in the form of newsletters (e.g. Landscope), social media (e.g. Facebook) and public lectures.

Tasks and Milestones

Project Planning	
Task 1: Science Concept Plan (SCP) written & submitted	Dec 2018
Task 2: SCP approved	Feb 2019
Task 3: Science Project Plan (SPP) written & submitted	Mar 2018
Task 4: SPP approved	Apr 2019
Objective 1	
Task 1: Complete broad-scale habitat mapping of Shark Bay seagrass	Dec 2018
Task 2: Submit Shark Bay seagrass loss paper to peer reviewed journal	Jun 2019
Task 3: Collate seagrass condition data & conduct trend analyses	Mar 2019
Task 4: Local-scale habitat mapping using high resolution imagery	Aug 2019
Task 5: Remote sensing analysis to calculate seascape statistics	Sep 2019
Objective 2	
Task 1: Field sampling for methods comparison	Completed
Task 2: Conduct lab work (fish abundance, length) & image analysis	Jan 2019
Task 3: Analyse stable isotope samples	Jun 2019
Task 4: Statistically analyse data	Jul 2019
Task 5: Write methods comparison paper	Aug 2019
Task 6: Submit paper to peer reviewed journal, inform objective 3 of outcomes	Oct 2019
Task 7: Write food web dynamics paper, write Landscope article	Nov 2019
Task 8: Submit food web dynamics paper to peer reviewed journal	Jan 2020
Objective 3	
Task 1: Pilot study field trip #1 to assess sites/ground-truthing in Shark Bay	Oct 2019
Task 2: Conduct image analysis, refine site selection, update habitat database	Nov 2019
Task 3: Conduct Shark Bay faunal assemblages field trip #2	Mar 2020
Task 4: Conduct lab work (fish abundance, length) & image analysis	May 2020
Task 5: Statistically analyse data	Jun 2020
Task 6: Write seagrass-associated faunal assemblage paper	Aug 2020

Task 7: Write Landscope article about seagrass-associated faunal assemblages	Sep 2020
Task 8: Submit paper to peer reviewed journal, decide if #3 field trip is required to assess temporal differences in seagrass-associated faunal assemblage	Nov 2020

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Study design

Methodology

Objective 1:

To assess seagrass extent and condition in several marine reserves, a range of *in situ* and remote sensing data will be used:

(i) Seagrass habitat maps will be used to calculate change in seagrass extent in marine reserves. The priority will be to complete mapping the change in seagrass extent in the Shark Bay World Heritage Area to determine how much loss occurred in response to the 2010/11 marine heat wave. Previous assessments of seagrass loss are based on comparisons of maps of the Marine Park from 2002 and 2014. We will extend coverage of maps to include all of the World Heritage Area (including the entire Wooramel Bank) and develop maps for 2010 and 2016 to gain a better estimate of loss attributable to the 2011 heat wave. Shark Bay Sea Surface Temperature (SST) data will be used to identify which metrics of heat stress best predict seagrass change (i.e. loss and gain). To do this, daily SST (℃) data from 1985-2017 will be downloaded from NOAA (https://coralreefwatch.noaa.gov/product/5km/v3.1/) and extracted per 5x5 km pixel in order to correlate high resolution SST data to correlate spatial differences in seagrass extent across the Shark Bay region before, after and during the 2010/11 Marine Heat Wave (MHW). This will be analysed using a Generalised Additive Model (GAM) with a full subsets analysis (Fisher et al. 2018) and Akaike Information Criteria (AIC) to identify which variable (or a combination variables) of heat stress best explains changes in seagrass cover. Additionally, this approach will enable us to develop a set of SST metrics that best explains (or helps predict) change in seagrass condition in other marine reserves.

(ii) Seagrass shoot density and % cover data from insitu surveys on transects carried out as part of the DBCA marine monitoring program will be used to assess condition over time within and across Ngari Capes Marine Park, Marmion Marine Park, Shoalwater Islands Marine Park, Jurien Bay Marine Park and Shark Bay Marine Park. These data will also be combined with data from external collaborators (including data from outside of marine reserves) and be will be used as part of a latitudinal assessment of seagrass meadows across WA. For example, we will assess how seagrass variables (e.g. *Posidonia* spp. shoot density or % cover) vary spatially and temporally to determine whether seagrass density (i.e. an indicator of meadow condition) differs across WA (within, and outside of marine reserves) and which areas are likely to be experiencing declines or changes in composition (i.e. 'tropicalization'). To assess this, a statistical analysis approach might include modelling how variables such as latitude, region (marine reserve), site depth, time of year sampled, sea surface temperature etc. influence seagrass metrics.

Objective 2:

To determine appropriate methods for assessing fish in seagrass meadows, data will be collected across three locations (Ngari Capes, Shoalwater Islands and Shark Bay Marine Park), at four sites per location with five sampling replicates at each, using five different sampling techniques:

(i) Beam trawl - Beam trawls have previously been used to obtain a robust understanding of diversity and abundance of faunal assemblages in seagrass meadows (McNeill and Bell 1992, McNeill and Fairweather 1993). A beam trawl measuring 1m wide x 0.5m high with 10mm mesh will be used to collect fishes at each site. The trawl will be towed at a constant speed (~0.4 m/s) for 50m and five replicate tows will be conducted per site at five sites, ensuring no overlap of area occurs. The fauna samples will be collected, frozen and the abundance, length, and gut contents and stable isotope tissue samples will be later analysed in the laboratory.

(ii) Underwater visual census (UVC) – Divers who are knowledgeable about the fish community in each marine reserve will survey five replicate 50m belt transects at each of the five sites. Surveys will only be conducted within a minimum water visibility of 5m. Size and abundance of all species within the transect will be recorded insitu with pencil and slate and data later transferred to a database. Similar procedures have been widely used to survey finfish communities throughout Australia (Halford and Thompson 1994, Holmes et al. 2013).

(iii) Diver operated stereo-video (DOV) – Divers will use mounted stereo-DOV units (consisting of high definition Sony HG21 digital video cameras) to survey finfish communities along five replicate 50m belt transects at each of the five sites. Once surveys are complete, video files will be uploaded onto an external hard drive (+ back-ups) and later analysed for fish abundance and length data in SeaGIS EventMeasure software. These methods are the basis of the departments monitoring program for rocky and coral reefs and have been widely used throughout Australia (Harvey and Shortis 1996, Holmes et al. 2013).

(iv) Baited remote underwater video (BRUV) – Paired, transportable BRUV units will be used to capture underwater video footage of finfish communities at five fixed sites (mounted with GoPro HERO 4). Five replicates of paired BRUV video footage will be obtained at each site for a minimum of 60 minutes. A bait bag filled with x 600 g of pilchards will be attached within the field of view using a tube of PVC extended from the BRUV frame. Upon retrieving the cameras, each video file will be uploaded onto an external hard drive (+ back-ups) and later analysed for fish abundance. This is an established method used throughout Australia (Willis and Babcock 2000, Harvey et al. 2007, Colton and Swearer 2010).

(v) Unbaited remote underwater video (URUV) – Paired, transportable URUV units will be used in the same fashion as BRUVs to capture video footage of finfish communities. No bait will be used in the bait bags, but all other aspects of the experimental set-up will be comparable to the BRUV method.

The gut content and stable isotope analyses will improve our understanding of the trophic ecology of seagrass associated fauna assemblages in WA. To do this, stomach contents in fish (from the aforementioned trawls) will be dissected and food items identified to genera level at the MSP laboratory. From the same fish, flesh samples will be collected and analysed in a isotope-ratio mass spectrometry machine to measure carbon and nitrogen isotope content at Edith Cowan University. The subsequent nitrogen and carbon values will help to determine trophic position of consumers and carbon sources at each site. By understanding the diets of multiple co-occurring species and/or trophic groups, through a combination of stable isotopes and stomach contents analysis, we can begin to piece together a food web. This is an important management tool as it provides the ability to predict top-down and bottom-up trophic cascades, highlights keystone species and provides a benchmark for future research and monitoring.

Objective 3:

To assess faunal communities across different types of seagrass meadows with varying seascape and within patch metrics, information on finfish assemblages will be collected within Shark Bay Marine Park. Approximately 20 seagrass patches will be assessed, with 3 replicates at each (i.e. trawls or BRUVS). The factors will include landscape metrics (e.g. patch size, distance to reef) and within-patch metrics (e.g. seagrass composition, canopy height and cover) across standardized environmental variables (e.g. depth, salinity), and will be analysed together to inform how finfish communities differ among seagrass meadows. Analyses will consider the influence of these variables on abundance (# fish), diversity (# species), total weight (biomass) and size structure (total length) of fish with different functional roles and fisheries importance.

Site selection will be confirmed after the completion of objective 1, which will help outline areas that have the appropriate seagrass genera, patch dynamics, level of fragmentation and distance to adjacent habitats. Sites will be selected to create a gradient in seagrass condition, taxonomic composition, environmental and seascape variables. The exact methods used to assess the faunal assemblage will be derived from objective 2.

Multivariate data on fish communities will be analysed using analysis of variance to assess spatial differences and DistLM combined with redundancy analysis to determine whether faunal assemblages correspond with particular predictor variables. To determine which variables are important predictors of univariate measures of fish assemblages (fish abundance or diversity), GAM combined with a full subset analyses will be used (Fisher et al. 2018). Analysis will likely be conducted using the R package and PRIMER/ PERMANOVA+ software.

Biometrician's Endorsement

granted

Data management

No. specimens

Herbarium Curator's Endorsement

granted

Animal Ethics Committee's Endorsement

granted

Data management

The raw data will be stored on Biosys with a full back-up stored on an external hard drive held by each data custodian. Additionally, a page will be created on the DBCA Data Catalogue that will provide links to the data sets (csv), R scripts, and output figures as appropriate. The metadata reports for each field trip will be uploaded onto Confluence under a newly created project linked to the SPP number.

Budget

Consolidated Funds

Source	Year 1	Year 2	Year 3
FTE Scientist	1.5	1.4	1.3
FTE Technical	0.05	0.05	0.05
Equipment	1000	1000	1000
Vehicle	500	500	500
Travel	2100	2580	2580
Other	4600	4800	1800
Total	8200	8880	5880

External Funds

Source	Year 1	Year 2	Year 3
Salaries, Wages, Overtime			
Overheads			
Equipment			
Vehicle			
Travel			
Other			
Total			