WESTERN AUSTRALIAN MARINE SCIENCE INSTITUTION

SUMMARY OFFSETS PLAN

Prepared for DCCEEW in response to EPBC 2018-8236

Mardie Project

April 2024

Western Australian Marine Science Institution (WAMSI)

BCI Minerals Limited

PROJECT SUMMARY

Action: To construct and operate the Mardie salt and sulphate of potash project, 80 km south-west of Karratha, Pilbara region, Western Australia.

Mardie Project Approvals: Ministerial Statement (MS) 1211 (replaced the superseded MS1175) & EPBC 2018/8236

Proponent: Mardie Minerals Pty Ltd (ABN 50 152 574 457)

DECLARATION OF ACCURACY

In making this declaration, I am aware that sections 490 and 491 of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) make it an offence in certain circumstances to knowingly provide false or misleading information or documents. The offence is punishable on conviction by imprisonment or a fine, or both. I declare that all the information and documentation supporting this Summary Offset Plan is true and correct in every particular. I am authorised to bind the approval holder to this declaration and that I have no knowledge of that authorisation being revoked at the time of making this declaration.

Signed: 

Name: Dr Luke Twomey

Position: CEO

Organisation: Western Australian Marine Science Institution

Date: 24/04/2024

Signed: 

Name: Dr Shaun Meredith

Position: Head of Approvals & Government Relations

Organisation: BCI Minerals

Date: 24/04/2024

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1. OVERVIEW

Mardie Minerals Pty Ltd (Mardie Minerals, a wholly owned subsidiary of BCI Minerals Limited, BCI) is developing the Mardie Project in the Pilbara Region of Western Australia. Ministerial Statement 1175 (MS1175) provided conditional approval for the construction and operation of a solar salt and sulphate of potash production facility. Additionally, MS1175 provided for financial offsets for marine and intertidal research under Condition 14. The Optimised Mardie Project (significant amendment to the approved Mardie Project) was conditionally approved via MS1211 in October 2023. MS1211 supersedes MS1175 and includes condition B10 'Intertidal and Subtidal Research Offsets', with the project details and funding allocation detailed in Schedule 2 being consistent with those prescribed in Condition 14 (Marine and Intertidal Research Offsets) of MS1175. EPBC 2018-8236, published on 12 January 2022, includes condition 29 which references the projects required under the WA approvals (MS1175 and MS1211) and includes three additional projects along with conditions specific to Commonwealth approval.

A Summary Offset Plan (SOP) was approved in August 2022 by the CEO DWER, in accordance with to address the Intertidal and Subtidal Research Offsets required under MS1175. However, as progress has been made on the projects under the SOP and new projects are required, this second SOP has been prepared to meet the requirements of EPBC2018-8236. This SOP outlines the process for planning and implementing the Mardie Project Marine and Intertidal Research Offsets Program, as required under Condition 14-5 of MS1175 and two of the additional projects required under Condition 29 of EPBC 2018-8236 on migratory shorebirds and green sawfish. The following key documents will provide the framework:

- SOP – this document– overview of the process for planning and implementing the Mardie Project Marine and Intertidal Research Offsets Program and research projects on migratory shorebirds and green sawfish including: governance, project development strategy, project design, timeframe, completion criteria and communication.
- Science Program (Attachments 1 – 6)– detailed description of the Mardie Project Marine and Intertidal Research Offsets Program and research projects on migratory shorebirds and green sawfish including: project objectives, participating research institutions and scientists, methodology, milestones, deliverables, schedule and budgets.

This SOP has been written by the Western Australian Marine Science Institution (WAMSI) on advice of the Department of Primary Industries and Regional Development (DPIRD) and the Department of Biodiversity, Conservation and Attractions (DBCA) representatives from the Steering Committee. WAMSI and Mardie Minerals signed a contractual agreement on 29 July 2022 to develop and implement the Mardie Project Marine and Intertidal Research Offset Program.

The Plan:

- provides direction on how the Science Program will be designed and implemented to fill identified knowledge gaps through an open and transparent process.
- describes the processes and timing for the development and implementation of the Science Program and includes a draft Science Program.
- provides an overview of the governance and management structures that have been put in place to design an independent and transparent Science Program.
- outlines the role of the Steering Committee of key WA agencies, which will provide the overarching project direction to ensure that the research is fit-for-purpose and fulfils the commitments outlined in Condition 14 of MS1175 and EPBC 2018/8236.
- will be delivered through WAMSI and will involve key science institutions invited to participate through a transparent process.

2. MARDIE PROJECT SCIENCE PROGRAM GOVERNANCE STRUCTURE

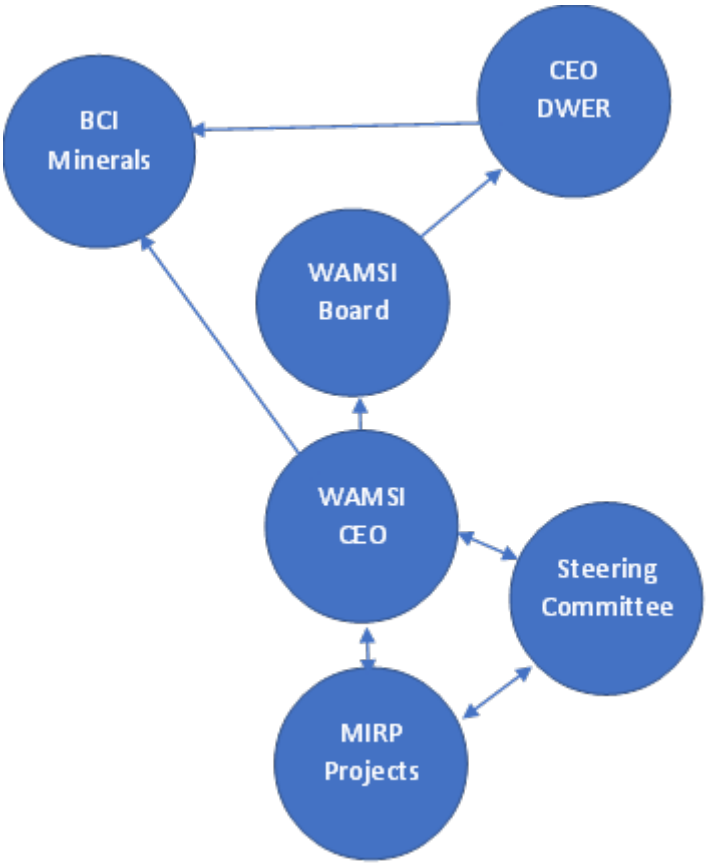

Figure 1 Mardie Project Marine Intertidal Research Offset Program Governance Structure

The Mardie Project Marine Intertidal Research Offset program is clearly defined in condition 14 of MS1175 (and subsequently as Condition B10 of Ministerial Statement 1211). The proponent was directed through MS1175 to select a third party to carry out the work. WAMSI was selected by BCI and endorsed by DWER and a contractual agreement for the Science Program to be implemented through WAMSI signed between the parties on 29 July 2022. The governance structure for oversight of the science program is in Figure 1 and highlights that WAMSI will be supported by a Steering Committee in managing the projects and will report on program development and delivery via BCI to DWER. Feedback and direction from DWER may come to WAMSI via the WAMSI Board or via BCI Minerals.

In accordance with the Commonwealth's Environmental Offsets Policy (DSEWPaC, 2012) reporting criteria, Project Reports detailing the progress and key findings of the SOP deliverables (see Section 12) will be provided to DCCEEW.

This document references the MS1175 for continuity as this Summary Offsets Plan was originally implemented under this approval.

3. MINISTERIAL STATEMENT NO. 1175 – ORIGINAL MARDIE PROJECT

Condition 14 of MS1175 (published on 24 November 2021) outlines the requirement to provide Marine and Intertidal Research Offsets. Specifically, Condition 14-5 outlines requirements to provide documentation to the CEO of DWER of an agreement between the proponent and the third parties (i.e.

WAMSI) endorsed by the CEO of DWER. Condition 14-3 to 14-5 are reproduced below for clarity, with a status update on each obligation and where that obligation is addressed in this document (Table 1.).

Table 1. Status of requirements under condition 14.

Condition number	Condition	Status
14-3	The proponent shall ensure that the financial arrangements described in schedule 2 and under condition 14-2 are maintained to achieve the outcomes of Projects A, B and C to the extent that: (1) funding between projects is transferred as agreed by the CEO; and (2) additional funds up to a maximum of 10 per cent are contributed to complete project outcomes.	WAMSI and BCI will seek approval from DWER CEO for funding transfers between Projects A, B and C through the development of the science program.
14-4	The proponent shall select a third party to carry out the work required to meet the outcomes of condition 14-1 to the satisfaction of the CEO, on advice of DPIRD and DBCA. In applying to the CEO for endorsement of the selected third parties, the proponent shall provide: (1) demonstration of the track record, experience, qualifications and competencies of the proposed third party to carry out the work and achieve the outcomes in the intertidal and marine environment.	DWER approved BCI nomination of WAMSI on 16 February 2022.
14-5	Prior to the commencement of ground disturbance, unless otherwise agreed by the CEO, the proponent shall provide to the CEO documentation of an agreement between the proponent and the third parties endorsed by the CEO under condition 14-4. This agreement shall: (1) Ensure that the funds described in schedule 2 are used to meet the outcomes of condition 14-1	On 16 February 2022, DWER granted an extension of time to 30 April 2022 for development of the agreement with WAMSI. A further extension was granted on 13 May 2022 for research funding to be paid by 1 August 2022. An agreement has been signed on 29 July 2022 between Mardie Minerals and the University of Western Australia on behalf of WAMSI, to develop a marine science program to meet the outcomes of condition 14-1. The agreement describes the contractual relationship to fund marine research to the value of $2.5M on the following three projects as described in Schedule 2 of MS1175: **Project A**. Mapping of the original and current extent of Samphire and Algal mat on the west Pilbara Coast **Project B**. Identify and quantify the potential effects of sea level rise on mangroves, samphire and algal mat on the west Pilbara Coast

Condition number	Condition	Status
		Project C. Identify the ecological roles, values and functions of algal mat on the west Pilbara coast
	(2) Provide the objectives, timing (deliver outcomes within three (3) years of issue of Ministerial Statement or as otherwise agreed with the CEO), milestones and methodology of the proposed research and management programs to meet the outcomes in Condition 14-1; (3) Include a Summary Offset Plan, on advice of DPIRD and DBCA, that provides the design for the proposed research and management programs and completion criteria for each project to meet the outcomes of Condition 14-1;	WAMSI has drafted the original Summary Offsets Plan (SOP), which outlined: • Objectives (process for development- Section 6 and Section 7; project objectives provided in Attachments 2A, 2B and 2C) • Timing, (for the program under WAMSI see Section 12; for individual project timeframes see Attachments 2A, 2B and 2C) and • Process for establishing the milestones and methodology (Section 9) for the proposed research and management programs to meet the outcomes of Condition 14-1. This SOP was reviewed and finalised on advice by a Steering Committee, comprised of representatives from DWER, DPIRD and DBCA (Section 4). The SOP provides an overview of the governance and organisation structures that have been implemented to design the proposed research and management programs and the completion criteria for each project to meet the outcomes of Condition 14-1. A guidance document was prepared by the Steering Committee to assist scientists in developing appropriate projects for the program. This document details the Research Design (Section 5) and Completion criteria (Section 6) (See Attachment 1, Guidance document prepared by the Mardie Project Offset Steering Committee). Finally, three project summaries were developed and reviewed by the Steering Committee and considered appropriate to achieve the objectives of Condition 14-1 (See Attachment 2A, 2B and 2C). It is recognised that further guidance from the Steering Committee would be used to refine these summaries as they are developed into full project plans, including confirming the indicative site selection. The SOP was approved by the CEO, DWER in August 2022 and full project plans were developed under the oversight of the Steering Committee that became the Science Program.
	(4) Set out that the Summary Offset Plan will be made available publicly, within a reasonable time period in a manner agreed by the CEO; and	Section 11 of this SOP makes it clear that the document will be made available publicly, within a reasonable time period in a manner agreed by the CEO of DWER.

Condition number	Condition	Status
	(5) Identify how outcomes of the proposed programs will be made available publicly.	The SOP identifies how the outcomes of the proposed programs will be made available publicly (Section 11).

a. MINISTERIAL STATEMENT NO. 1211 – OPTIMISED MARDIE PROJECT

The Optimised Mardie Project (significant amendment to the approved Mardie Project) was referred to the State EPA in March 2022 and approved via MS1211 in October 2023. MS1211 supersedes MS1175 and includes condition B10 'Intertidal and Subtidal Research Offsets', with the project details and funding allocation detailed in Schedule 2 of MS1211 being consistent with Condition 14 and Schedule 2 prescribed in MS1175.

4. EPBC ACT – MARDIE PROJECT

Condition 29 of EPBC 2018-8236 (published on 12 January 2022) sets out a number of additional requirements for the approval holder. These are detailed and addressed in Table 2.

Table 2. Status of requirements under condition 29 of the EPBC Act.

Condition Number	Condition	Relevant Section of Document	Summary of Commitments
29	To compensate for the residual significant impacts of clearing and directly impacting of up to 880 hectares of algal mat, 296 hectares of coastal samphire that supports migratory shorebirds habitats, 17 hectares of mangrove that supports migratory shorebirds and Green Sawfish and 79 hectares of subtidal Short-nosed Sea Snake habitat, the approval holder must commission research projects to inform the strategic protection, better management and long-term ecological functionality of migratory shorebirds, Green Sawfish and Short-nosed Sea Snake habitat (the Marine Research Objectives). The approval holder must:		
29(a)	Comply with the research objectives in condition 14-1 of the WA Approval for the contribution funding of, and responsibility for, achieving the outcomes for three separate research projects for the intertidal algal mat, coastal samphire, and mangrove habitats as outlined in Schedule 2 of the WA Approval.	Table 1, Page 7 and 8	The SOP is the relevant document that outlines how condition 14-1 of the WA Approval is met. Refer table 1 for a summary of commitments with respect to the WA Approval.
29(b)	Contribute, in addition to condition 29(a), the equivalent (by yearly adjustment by CPI) of $300,000, to research and/or management program that guides conservation efforts to maintain ecological functionality of nearshore subtidal habitats of the Pilbara region that support Short-nosed Sea Snake, which are increasingly at threat from development and climate change impacts.	Not Applicable	This condition is met under the separate Sea Snake Research proposal.
29(c)	within six (6) months of the commencement of the action, submit a detailed Research Project Proposal for the intertidal (condition 29(a)) and subtidal (condition 29(b)) research requirements that will meet the Marine Research Objectives, to the Department for approval by the Minister. The Research Project Proposal must include:		This condition is met in relation to 29(a) only with further detail provided below relevant to teach sub condition.
29(c)(i)	The information required under condition 14-1 of the WA Approval;	This document	The SOP is the relevant document that outlines how condition 14-1 of the WA Approval is met. Refer table 1 for a summary of commitments with respect to the WA Approval.

Condition Number	Condition	Relevant Section of Document	Summary of Commitments
29(c)(ii)	Details of how the proposed research projects will achieve the Marine Research Objectives;	Addendum A and B	The following conditions relate only to the two additional projects required under Condition 29 on Migratory Shorebirds and Green Sawfish. Section 2 of the Green Sawfish Marine Research proposal (Attachment 5) states: The proposed research program aims to contribute to the marine research objectives by addressing important knowledge gaps concerning the: • abundance and distribution of Green Sawfish along the Pilbara Coast; • Green Sawfish habitat use, residency and migration patterns in key nurseries; • Green Sawfish population genetics and kinship; and • trophic interactions with sympatric predators and prey. Section 2 of the Migratory Shorebird Research proposal (Attachment 6) states: the proposed research program aims to contribute to the marine research objectives by addressing important knowledge gaps concerning the: • Presence, abundance and migratory patterns of Migratory Shorebirds along the Pilbara Coast • knowledge on individual species visiting specific habitat types along the Pilbara coast • information on migratory shorebird foraging behaviour, inter- and intra-specific interactions, diet and prey selection
29(c)(iii)	Details (including relevant capacity and expertise) of the party/ies proposed to undertake the research projects, and the proposed project governance, and roles and responsibilities of the approval holder and any other party,	Addendum A and B	Section 9 of the Green Sawfish Marine Research proposal (Attachment 5) proposal outlines the Project Team responsible for delivering the proposal. Section 7 of the Migratory Shorebird Research proposal (Attachment 6) outlines the Project Team responsible for delivering the proposal.

Condition Number	Condition	Relevant Section of Document	Summary of Commitments
29(c)(iv)	A risk assessment of the third party/ies not being able to achieve the Marine Research Objectives;	Section 21	Section 21 of this document outlines the risk assessment process implemented by WAMSI with respect to the delivery of the proposals.
29(c)(v)	Details of the research methodologies, proposed project timelines, progress and completion criteria, schedule of progress monitoring and reporting to the Department, for each proposed research project;	Section 16 Section 18 Addendum A and B	Section 16 of this document provides the overarching project management for the research program. Section 18 outlines the project reporting requirements. Section 6 of the Sawfish Marine Research proposal (Attachment 5) outlines the study methods for the proposal, including sampling effort and locations; Section 10 include the project milestones for the proposal. Section 4 of the Migratory Shorebird Research proposal (Attachment 6) outlines the study methods proposed.; section 6 includes the project deliverables.
29(c)(vi)	Details of the funding arrangements and schedule of payments including an initial 10% contribution of the overall funding to be made within two (2) months of the Research Project Proposal being approved by the Minister;	Section 13 Section 14	Section 13 includes the offset payments criteria for the implementation of the research. Section 14 includes the contingency payment arrangement.
29(c)(vii)	Details of how the Research Project Proposal takes into consideration relevant conservation advices, recovery plans and threat abatement plans for the relevant species;	Section 17, Table 3 Section 5, Attachment 2C Addendum A and B	Section 17, table 3 outlines how the project meets the conservation advice requirements. Section 5 of Attachment 4 includes a commitment that recovery plans and threat abatement plans will be considered by WAMSI researchers in development of proposals and projects. Section 3 of the Sawfish Marine Research proposal (Addendum A) details current recovery plans and how these align to the Marine Research Objectives. Section 3 of the Migratory Shorebird Research proposal (Attachment 6) details current recovery plans and how these align to the Marine Research Objectives.
29(c)(viii)	Details of how the Research Project Proposal is consistent with the criteria for research programs specified in Appendix A of the Environmental Offsets Policy;	Section 17, Table 3 Addendum A and B	Table 3 of this document outlines how the proposals align to the criteria.

Condition Number	Condition	Relevant Section of Document	Summary of Commitments
			Table 1, Section 4 of the Sawfish Marine Research proposal (Attachment 5) details current recovery plans and how these align to the Marine Research Objectives. Table 2, Section 3 of the Migratory Shorebird Research proposal (Attachment 6) details current recovery plans and how these align to the Marine Research Objectives.
29(c)(ix)	Details of how the research projects will take into consideration and utilise the following monitoring and management plans: 1. Mardie Dredge Management Plan 2. Marine Environmental Quality Monitoring and Management Plan 3. Long-term migratory shorebird monitoring program 4. Groundwater Monitoring and Management Plan (GMMP). 5. Benthic Community Habitat Monitoring and Management Plan (BCHMMP). 6. Marine Turtle Monitoring Program. 7. Illumination Plan.	Section 17	Section 17 of this document provides a commitment to incorporate the information developed from the monitoring and management plans.
29(c)(x)	Details of permissions and permits that will need to be obtained (or have already been obtained) to conduct the research projects;	Section 17, Table 4	Table 4 includes the relevant permits required.
29(c)(xi)	Assurances that the research will be conducted to a standard that would allow the findings to be published in a peer-reviewed scientific journal or report and provide sound recommendations and information for management and conservation for migratory shorebirds, Green Sawfish and Short-nosed Sea Snake and their habitats;	Section 17, Table 3 Section 18	Table 3 provides a summary of how the research proposals meet the research commitments. Section 18 includes a commitment "All findings will be made available for publication in an appropriate peer-reviewed scientific journal or report."
29(c)(xii)	Commitments that, within 6 months of completion of any research project, all reports, publications and supporting data will be provided to the Department, Birdlife Australia Shorebird Program, DBCA, and Department of Water and Environmental Regulation (DWER) and published, or the existence and locations of the reports and publications detailed, on the website for the remainder of the life of the project; and	Section 18	Section 18 of this proposal includes this commitment.
29(c)(xiii)	Details of a communication and engagement program to promote the achievement of the research outcomes.	Section 22	Section 22 provides a summary of the commitments regarding community and education programs.

5. MARDIE PROJECT STEERING COMMITTEE

A Steering Committee comprised of relevant government agencies has been established to provide overarching project direction. The Steering Committee is chaired by WAMSI and includes representatives from:

- Department of Water and Environmental Regulation (DWER) – Marine Ecosystems Branch: Hans Kemps, Fiona Webster.
- Department of Biodiversity, Conservation and Attractions (DBCA) – Marine Science Program: Dr Tom Holmes.
- Department of Primary Industries and Regional Development (DPIRD) – Aquatic Science and Assessment Branch: Dr Stephen Newman.
- Others, on recommendation of other agencies.

The agreed roles and responsibilities of the Steering Committee include:

- Provide advice to WAMSI on the scope, objectives, timing, milestones and methods of the science program. This includes advice on project funding allocation to meet outcomes of Condition 14-5 of MS1175.
- Provide advice on allocation of contingency project funding to meet requirements of Condition 14-1(4) and 14-1(5) and Schedule 2 of MS1175.
- Review the Science Program for compliance against EPA Report 1704, Section 14, Marine and Intertidal Offsets, including:
    - mapping the original and current extent of Samphire and Algal mat on the west Pilbara coast.
    - identifying and quantifying the potential effects of sea level rise on the values of mangroves, samphire, and algal mat on the west Pilbara coast, and identifying the significance of salt projects in preventing the adaptation of intertidal BCH to sea-level rise; and
    - identifying ecological roles, values and functions of algal mat on the west Pilbara coast.
- Provide advice on additional project funding allocation to meet the Marine Research Objectives of EPBC Approval 2018-8236 Condition 29.
- Advise WAMSI on project methods, deliverables and timing.
- Endorse the Science Program.
- Review science progress against the milestones and schedule.

Meeting frequency – Over the first six months regular meetings will be required while the SOP and science program are established. Once the science program is endorsed and project agreements are in place, meetings will become biannual to monitor project progress. All meetings will be accessible via MS Teams.

Meetings in the early stages of program development have included:

- First meeting – 2 June 2022 to discuss Terms of Reference and to review the schedule (refer to Table 2).
- Several meetings from June through July 2022 for the Steering Committee to nominate interim project leaders and prepare guidance advice on the development of the research projects that will comprise the Science Program (Attachment 1).

- Additional meetings in early August 2022 to review the Expressions of Interest prepared by the project teams and endorse project summaries to include in this Plan.
- Meetings in October 2022 and February 2023 with the Project Teams to discuss final field site selection, field logistics and project integration.

6. ONGOING PROGRESS UPDATES

Project Managers will provide ongoing progress updates on a quarterly basis through to the end of the research program. Ongoing Progress updates - project managers are required to report on progress quarterly so that risks of projects not meeting their objectives are identified and communicated in a timely manner."

7. PROJECT AMENDMENTS / VARIATIONS

Mardie Minerals understands that while the Western Australian Marine Science Institute (WAMSI) has been contracted to deliver the SOP, under the EPBC Approval (as prescribed by condition 29(a) of 2018/8236), it is Mardie Minerals responsibility to ensure the delivery of the Research Project Proposal(s) for the intertidal research meets the Marine Research Objectives. Should the SOP and/or new Green Sawfish and Migratory Shorebird research proposals fail to meet the Marine Research Objectives, further research may need to be commissioned by BCI Minerals to meet the Marine Research Objectives of EPBC Approval 2018-8236.

8. RESEARCH DESIGN

The Steering Committee met several times in June 2022 to discuss the requirements of MS1175 and in particular the knowledge gaps identified by DWER that were sought to be informed by Condition 14-5. The Committee prepared a guidance document which more clearly spelled out the key objectives and information needs to guide the design and development of the 3 projects (Attachment 1). The Steering Committee also met with the project leaders several times between October 2022 and February 2023 as they developed the project plans and sampling design to ensure project design and delivery would meet the needs and deliver the outcomes required.

9. CONSERVATION ADVICE, RECOVERY PLANS, THREAT ABATEMENT PLANS

Conservation advice will be provided by the Steering Committee (refer to section 4). Recovery plans (http://www.environment.gov.au/cgi-bin/sprat/public/publicshowallrps.pl) and threat abatement plans (https://www.dcceew.gov.au/environment/biodiversity/threatened/threat-abatement-plans/approved) will be considered by WAMSI researchers in development of proposals and projects. Information relevant to the aforementioned plans derived from the Mardie Marine and Intertidal Research Program will be provided to DCCEEW.

10. COMPLETION CRITERIA

As noted above, a guidance document was prepared by the Steering Committee with very clear knowledge gaps and deliverables expected for the three projects under MS1175. These deliverables will be required as per the completion criteria.

11. WAMSI SCIENCE WORKSHOP

WAMSI convened a science workshop on 1 July 2022 with partners that have the capability and capacity to undertake the Science Program as outlined in MS1175 Condition 14, and as further directed by the Steering Committee. The science workshop included invitees from: Curtin University, Edith Cowan University, Murdoch University, The University of Western Australia, Australian Institute of Marine Sciences, DPIRD, DWER, and DBCA.

The workshop was formally convened by WAMSI and addressed the following topics/items:

- Overview of offset requirements.
- Overview of Steering Committee recommendations.
- Discussion on present scientific understanding of the region/themes; including existing literature and data availability.
- Nomination of interim project area leaders and process for Science Program development.
- Timeframe for Science Program development including:
    a. Identification of project teams
    b. Expression of Interest
    c. Development of full proposals
    d. Collaboration agreement with WAMSI

12. SCIENCE PROGRAM

Interim project leaders were asked to develop, with their project teams, an Expression of Interest (EOI) that would meet the objectives outlined in the guidance document and submit this to WAMSI for review by the Steering Committee. The three EOIs were submitted on 29 July 2022 and reviewed by the Steering Committee with feedback provided to the project leaders. Final EOIs were submitted on 15 August 2022 and were reviewed by the Steering Committee. These EOIs were endorsed by the Steering Committee and were assessed by the DWER CEO as suitable to meet Condition 14-1The Science Program was then fully developed by the project teams with fuller detail on project methodology, budgets, refined milestones and timeframes in consultation with the Steering Committee. The full project proposals were completed in November 2022, with the endorsement of the Steering Committee and form the basis of the contractual arrangements with WAMSI. These project plans comprise the Science Program for Projects A, B and C under MS1175 and are at Attachments 2, 3 and 4 respectively.

Research proposals have been requested from project leaders, selected for their expertise and pre-existing research, to meet the requirements for the Green Sawfish and Migratory Shorebird projects (Attachments 5 and 6 respectively) required under EPBC2018-8236. These have been reviewed and accepted by WAMSI and by DCCEEW and will be developed into project plans under the oversight of the Steering Committee.

13. COLLABORATIVE RESEARCH AGREEMENTS

Collaborative Research Agreements (CRA) will be established between participating WAMSI partners and will be considered formal and legally binding contracts to undertake each research project. The head agreement of each contract will be based on the agreement between Mardie Minerals and WAMSI and will be negotiated with the participating research partners at the time of proposal development.

Each CRA will incorporate the details from the relevant final proposal, including the budget, research methods, timing of milestones and deliverables.

There will be a separate CRA for each project and it may include one or more WAMSI partners.

14. OFFSET PAYMENTS

Mardie Minerals is providing funding for Research Projects to provide new knowledge on the intertidal areas of the project location, focusing on mangroves, algal mat and coastal samphire that will inform the strategic protection and management of the ecological values of these habitats on the west Pilbara coast, which include migratory bird habitat and ecological maintenance of marine fauna habitat.

Funding will also be provided for projects that will inform the strategic protection and better management of Green Sawfish and migratory shorebirds. Funding was provided for the former in full on execution of the contract between Mardie Minerals and UWA (on behalf of WAMSI) on the 29th of August 2022. Funding will be provided for the latter on the execution of a Variation to the contract between Mardie Minerals and UWA (on behalf of WAMSI).

15. CONTINGENCY OFFSET PAYMENT

Mardie Minerals is required to provide additional funds as prescribed in Schedule 2 of MS1175 for Projects C (ii) and C (iii), should additional impacts be identified. As outlined in the Benthic Communities and Habitats Monitoring and Management Plan (BCHMMP), BCH monitoring data will be assessed against the trigger and threshold criteria and reported in an annual report. These reports will include an assessment of cumulative spatial impacts to BCH. In the event an impact to BCH is detected through the BCHMMP, the value ($/ha) and timing of the required offset payments (into Project C(ii) or C(iii)) are as stipulated in Schedule 2 of Ministerial Statement 1175).

The Mardie Project Steering Committee will provide advice on the allocation of contingency project funding for Projects C (ii) and (iii) to meet the requirements of Condition 14-1(4) and 14-1(5) of MS1175, and Condition 29 of EPBC 2018/8236.

DCCEEW will be consulted during the development of Projects C (ii) and (iii).

16. PROJECT AWARD

Projects will be awarded on execution of the CRA by each participating collaborative research institution, WAMSI, Mardie Minerals. A copy of each executed CRA will be provided to CEO of DWER.

The date of Project initiation is the date of award.

17. PROJECT MANAGEMENT

Projects will be managed by WAMSI. Biannual (or more regular if required) Project Reports will be developed to track project progress against the schedule, budget, milestones and deliverables. All reporting will be reviewed by the Steering Committee, who will be responsible for providing advice via the CEO WAMSI on project progress. The Steering Committee will also be responsible for issues resolution and providing endorsement for milestone payments.

The CEO WAMSI will provide these Project Reports, once finalised and approved, to DCCEEW and the CEO of DWER, BCI and the WAMSI Board.

18. PROJECT CRITERIA

Research Projects will take into consideration and utilise the following monitoring and management plans for the Mardie Project, as relevant:

- Mardie Dredge Management Plan;
- Marine Environmental Quality Monitoring and Management Plan;
- Long-term migratory shorebird monitoring program;
- Groundwater Monitoring and Management Plan (GMMP);
- Benthic Community Habitat Monitoring and Management Plan (BCHMMP);
- Marine Turtle Monitoring Program; and
- Illumination Plan.

BCI shall ensure that any information from the implementation of the EMPs is provided to WAMSI researchers on a regular basis, through steering committee or research updates.

Field studies completed under any EMP will ensure that opportunistic sightings are collected and reported to researchers to assist in data gathering. BCI is required to ensure that all contractors are aware of the requirement to maintain opportunistic sighting registers whilst operating on the Project.

Ongoing monitoring of habitat health/condition at Mardie (i.e. under the BCHMMP), including following the commencement of operations, in parallel to detailed monitoring of groundwater and surface water (i.e. under the GMMP), will assist in informing WAMSI of the tolerances and responses of the different communities and EPBC Act listed species present across the intertidal and shallow subtidal zones. These learnings from Mardie will be directly relevant to the equivalent habitats and EPBC Act listed species at the WAMSI study sites.

Furthermore, sharing of data collected under these plans will support broader regional research projects currently being undertaken by WAMSI and other research institutions, and will advance the understanding against the Commonwealth's Marine Research Objectives. Mardie Minerals will provide reports from the monitoring programs to WAMSI for distribution to Project leaders and will provide data on request as needed to support the WAMSI led research projects.

Details of how the Research Projects will be consistent with the criteria for research programs specified in the EPBC Act Environmental Offsets Policy (DSEWPaC, 2012) are detailed in Table 3.

Table 3: DCCEEW Criteria for research programs (DSEWPaC, 2012)

No.	Criteria	Project Suitability
A suitable research or education program must:		
1	Endeavour to improve the viability of the impacted protected matter, for example: – signage in key areas to educate the public regarding the risks to a threatened animal, or – research into effective re-vegetation techniques for a threatened ecological community.	The research project(s) will fill major gaps in the understanding of nutrient sources and flows in the region and connectivity between key ecological elements. The research will provide new information to help meet the objectives of the relevant species recovery/management plans.
2	Be targeted toward key research/education activities as identified in the relevant Commonwealth approved recovery plan, threat abatement plan, conservation advice, ecological character description, management plan or listing document. Where Commonwealth approved guidance documents are not available or are insufficient in detail, the department will consider additional information sources such as state and territory management plans or peer reviewed scientific literature to inform priority offset activities.	The research program was developed in consultation between WAMSI and key WA management agencies including DPIRD, DBCA and DWER, and took into account commonwealth-approved recovery plans and conservation advice for the relevant species. The major objectives of the research are to provide new information on important components of the ecology of the region to assist future management, planning and decision making. Refer to Section 4.
3	Be undertaken in a transparent, scientifically robust and timely manner.	Research Projects will be developed by WAMSI and: – include detailed information about timeframes and transparency of information; and – involve consultation with relevant stakeholders to ensure that they are

No.	Criteria	Project Suitability
		effective, scientifically robust and reasonable.
4	Be undertaken by a suitably qualified individual or organisation in a manner approved by the department.	WAMSI will be responsible for the development and implementation of Offset Research Projects. WAMSI is an independent, leading Australian marine research organisation. WAMSI is a collaboration of state, federal and academic entities that deliver large-scale, long-term and world-class research.
5	Consider best practice research approaches.	WAMSI is interested in developing a strategic research program for the Pilbara coast region. It is envisaged that the Mardie Project will provide the catalyst for WAMSI to pursue a larger program focused on filling knowledge gaps. WAMSI would approach other Pilbara coast stakeholders to better understand the science needs in the region and expand the scope and funding and develop Research Programs though best practice approaches. The best-practice research approach will consider: - ethics and informed consent - scientific validity - safety and other risks - data and records management - bias, conflicts of interest and other probity matters WAMSI works under a charter to implement best practice approach to research.
Research programs:		
1	Will be tailored to at least a postgraduate education level; however, there will be scope to engage other educational levels in educational programs (see below).	All research projects in this program involve postgraduate level scientists or higher. A Postdoctoral Fellow will be required to coordinate the extensive field campaigns, undertake key aspects of Project laboratory work, and undertake writing of Project reporting. Recruitment of high-quality Postdoctoral Fellow(s) to conduct the Research Programs in addition to Research Assistant(s) has been factored into Project funding and timelines.
2	Will present findings that can be peer-reviewed.	Project research reports shall be developed by the relevant project manager and approved by the Steering Committee. The intent of the research proposals shall be such that the works can be published in an
3	Will publish findings in an internationally recognised peer-reviewed scientific journal or be of a standard that would be acceptable for publication in such a journal. Publications should be submitted to free open access journals.	

No.	Criteria	Project Suitability
	Data and information collected should have creative commons licensing and be free and accessible.	internationally recognised peer reviewed journal. Data and information from the Mardie research projects shall be free and accessible. As outlined in Section 20.
4	Research outputs should inform future management decisions on the protected matter and, where possible, be readily applicable to other similar matters (species groupings etc).	Project environmental management plans should be updated based on research findings. Project findings should also be considered by regulators when assessing future projects, research for similar matters, and reflected in updates to conservation and recovery plans.

The research projects will need to obtain permissions and permits, which may include those detailed in Table 4.

Table 4: Permits required for research programs

Permit type	Approval authority	Notes
Drone flying	CASA, Military, private, DBCA	Depending on land/airspace
Flora/fauna collection	DBCA and DPIRD	
Fish collection ethics	UWA and ECU	
Land access: - Mineral tenements - Indigenous land use agreements	Department of Planning, Lands and Heritage Rio Tinto; Sino Iron; Onslow Salt; Mardie Salt Kuruma Marthudunera and Yaburara and Coastal Mardudhunera ILUA Thalanyji and Minderoo Pastoral ILUA Macedon ILUA	 Mardie to Cape Preston SW Pilbara coast near Onslow SW of Onslow
Traditional Owners	Wirrawandi Aboriginal Corporation Buurabalayji Thalanyji Aboriginal Corporation Nganhurra Thanaardi Garru Aboriginal Corporation	

19. PROJECT REPORTING

The final reports for the three individual Project Reports will be provided to DWER on completion of the program for endorsement by the CEO of DWER. The Program is completed when endorsement of the Final Report/s by the CEO of DWER is received, and all milestone payments have been made to the project participants.

Final Project Reports will be provided to the DCCEEW. The reports for the migratory shorebird and Green sawfish projects will include a discussion on how the project findings contribute to informing the strategic protection, better management and long-term ecological functionality of migratory shorebird and Green Sawfish habitat, and provide recommendations for potential future research programs that advance the understanding against the Commonwealth's Marine Research Objectives.

All findings will be made available for publication in an appropriate peer-reviewed scientific journal or report. Publications and reports will include recommendations and information for the management and conservation of migratory shorebirds and green sawfish, and their habitats.

Within 6 months of completion of the research projects, all reports, publications and supporting data will also be provided to DCCEEW, the Birdlife Australia Shorebird Program, DBCA, Department of Water and DWER, and published on the WAMSI website for the remainder of the life of the Mardie Project.

20. PROJECT AMENDMENTS / VARIATIONS

Mardie Minerals understands that while the Western Australian Marine Science Institute (WAMSI) has been contracted to deliver the SOP under the EPBC Approval (as prescribed by condition 29(a) of 2018/8236), it is Mardie Minerals responsibility to ensure the delivery of the Research Project Proposal for the intertidal research meets the Marine Research Objectives. Should the SOP and/or new Green Sawfish and Migratory Shorebird research proposal fail to meet the Marine Research Objectives, further research may need to be undertaken.

21. CORRECTIVE ACTIONS

Internal monitoring of the environmental aspects outlined in this offset Research Proposal will occur during proposal construction and implementation. Any non-conformances or incidents within this Proposal will be investigated, rectified or mitigated to ensure minimal ongoing environmental harm. Where relevant, the research program may be amended to ensure that the Marine Research Objectives are to be met. Any amendments will be through the Steering Committee in consultation with BCI, DCCEEW and EPA.

22. SCHEDULE

The table below sets out the indicative timing for development and implementation of the Science Program.

Table 5. Indicative schedule for Mardie Marine and Intertidal Research

Milestone	Description	Indicative Timing
Draft SOP submitted to DWER	SOP provides an overview of the governance structure and the process required to design and operationalise the science program.	29 April 2022
Steering Committee meeting 1	Meeting 1 to set the objectives and expectations of the science program.	2 June 2022
WAMSI science workshop(s)	Workshop with science experts from the WAMSI partnership to determine the high-level methods, appropriate participating research institutions to develop the draft science program plan.	1 & 6 July 2022
WAMSI draft science program plan	EOIs submitted with project objectives, methods, deliverables, schedule and budget to form the framework for the science program.	29 July 2022
Steering Committee meeting(s)	Review of the EOIs with feedback provided to project leaders and discussed further to refine the EOIs into a plan for the science program.	2 & 10 August 2022
WAMSI draft Science Program	Revised EOIs submitted and reviewed by Steering Committee, compiled into draft Science Program.	17 August 2022
SOP submitted	SOP submitted to the CEO DWER with draft Science Program.	22 August 2022

Milestone	Description	Indicative Timing
WAMSI draft full project proposals	Detailed project proposals developed with detailed project objectives, methodology, resourcing, deliverables, schedule and budgets	1 November 2022
Steering Committee review	Steering committee review of project proposals.	15 November 2022
Finalise Science Program	Response to Steering Committee comments and finalisation of the Science Program	1 December 2022
Publish Science Program	Within 4 weeks of Science Program being finalised by the Steering Committee.	29 December 2022
Collaborative Project Agreements	Contractual agreement between collaborating science organisations and WAMSI to deliver each Science Project – including the Final Science Program Plan	31 December 2022
Program Start		1 January 2023
New project development	Addition of new projects on migratory shorebirds and Green sawfish	April 2024
DCCEEW Submission	Submission of approved research plans to DCCEEW prior to Program Start	
Program Finish	Within 3 years of issue of MS1175. While the projects will endeavour to finish by 23 November 2024, at least one project will require additional time based on the breadth and complexity of objectives and on administrative timeframes. The indicative finish date reflects the completion date for the final project, noting that all projects will provide annual reports and can provide interim results in report or presentation format to DWER as required throughout the project.	January 2026[1]

Note: Schedule is subject to change based on advice from the Steering Committee.

23. PUBLIC AVAILABILITY OF THE SUMMARY OFFSETS PLAN

WAMSI intend to make this SOP publicly available within four weeks of it being endorsed by the DWER CEO as fulfilling the requirements of MS1175 Condition 14-5.

WAMSI intend to make the Science Plan publicly available within four weeks of it being finalised by the Steering Committee.

WAMSI will develop a webpage dedicated to the Mardie Project Science Program, from which it is intended to make the SOP and Science Program (and projects) publicly available within the timeframes stated above upon agreement by the DWER CEO. Further, WAMSI has a strict requirement that all research products and data are made publicly available, unless the material can be demonstrated to be Commercially Sensitive and In Confidence. WAMSI does not expect the results from the Mardie Project Science Program to be commercially sensitive, but rather there is an expectation that the results from the science program will be used to inform public decision making for the Pilbara coast for the near future.

[1] This date being the completion of the Migratory Shorebird and Sawfish research projects.

24. RISK ASSESSMENT

WAMSI has reviewed the risk identified in the EPBC environmental approval (EPBC 2018/8236) Condition 29iv: *A risk assessment of the third party/ies not being able to achieve the Marine Research Objectives,* and has provided the response below:

WAMSI is an unincorporated Joint Venture between 10 partners that encompasses and represents the capability of marine research in Western Australia. The risk of WAMSI not fulfilling the Marine Research Objectives is negligible. WAMSI has existed for 16 years and has completed >$185M of strategic marine research programs encompassing the extent of the WA coastline. Specifically, WAMSI has operated programs in the Pilbara region previously as part of the Dredging Science Node, which was a $19.5M research offset funded program to investigate the impacts of dredging on the marine environment. WAMSI is funded by the WA Government, is managed by the University of Western Australia, and is governed by an independent board. The WAMSI CEO will have the ultimate responsibility to ensure that the program is managed appropriately. Should issues need to be resolved, or additional research capacity be required, WAMSI will use the established governance structure to resolve those issues. A full description of WAMSI can be found at wamsi.org.au.

25. COMMUNICATION AND ENGAGEMENT

WAMSI intends to use several mechanisms to communicate the outcomes of the Mardie Project Science Program to Government, industry, Traditional Owners, and the wider community. WAMSI will employ standard newsletter, bulletin and social media platforms to provide dynamic information throughout the program. Further, it is intended that industry workshops will be conducted to expand the program scope and to access and make use of existing industry data from the region. Finally, it is expected that a final workshop would be convened to communicate the program results to the scientific community, government agency representatives, industry sector and general community.

Publications are to be provided to DCCEEW as soon as possible and at least five working days before public release.

Mardie Project Summary Offset Plan

ATTACHMENT 1 – WAMSI GUIDANCE DOCUMENT

Guidance for the Development of the Mardie Project Marine and Intertidal Offsets Research Program

Provided by the Mardie Project Offset Steering Committee

1. Mardie Salt Offset Program

Mardie Minerals Pty Ltd (a wholly owned subsidiary of BCI Minerals Limited) is developing the Mardie Project, a solar salt and sulphate of pot ash production facility in the Pilbara region of Western Australia. Ministerial Statement 1175 (MS1175), which was superseded with Ministerial Statement 1211, provided conditional approval for the Project that includes requirement for financial offsets for marine and intertidal research. The offsets are based on the significant residual impacts and risks of the proposal to intertidal benthic communities and habitat (BCH) namely mangroves, algal mat and coastal samphire and were put in place for the purpose of guiding the strategic protection and management of the ecological values of these habitats on the west Pilbara coast. Values associated with BCH include primary productivity, ecosystem maintenance, nutrient cycling, carbon storage and habitat values such as foraging, breeding or nursery habitat.

This offset package covers three specific areas of research for a total cost of $2.5M. The research program to meet this condition will be undertaken through an independent body, the Western Australian Marine Science Institution (WAMSI), with the guidance and support of a Steering Committee comprising members from DWER, DBCA and DPIRD to ensure the research program, funding allocation and delivery meet the conditions of MS1175 and fit into the above needs highlighted for regional understanding of the Pilbara coastal environments to inform future decision-making, management and conservation.

The project areas as defined in MS1175 Condition 14 (now Condition B10 of are noted below with the scope and research priorities for each. Proposed projects area summarised in the following tables:

Project A. Mapping of the original and current extent of Samphire and Algal mat on the west Pilbara Coast

The aim of this project is to complete mapping of the extent of algal mat and samphire on the west Pilbara coast to provide an understanding of the regional extent and distribution of these habitats to complement the existing mangrove mapping. While a complete map of the current distribution of these habitats is the priority, having an understanding of how these habitats have changed over time will also inform their response to anthropogenic and natural events.

Priority research areas are:

- What is the current spatial extent of mangrove, algal mat and samphire habitat in the west Pilbara?
- What is the historic spatial extent of algal mat, mangrove and samphire habitat in the west Pilbara based on Landsat imagery (where applicable)? [Note: historical mapping of mangrove may be available]
- Has this distribution changed in the west Pilbara over the past 60 years in response to natural events (storm/cyclonic activity, heat waves) or anthropogenic pressures (coastal development)?

Project B. Identifying and quantifying the potential effects of sea-level rise on mangroves, samphire and algal mat on the west Pilbara Coast and identifying the significance of salt projects in preventing the adaptation of intertidal BCH to sea-level rise

The aim of this project is to improve the management of intertidal BCH in the region in the event of sea-level rise given the potential for the Mardie Project (or other salt proposals) to reduce the capacity of some intertidal BCH to adapt to climate change. The priority for this project will be on understanding how BCH may respond to sea-level rise and limitations created by the presence of salt projects in terms of BCH spatial extent and capacity to function.

Priority research areas are:

- Understanding the influence of sea-level rise on BCH extent and migration including environmental and physical parameters.
- Predicting BCH response to climate change scenarios in particular to sea-level rise.
- What role will salt projects play in reducing BCH adaptation to sea-level rise and how will this affect the ecological services provided by these habitats.

The research will focus on predicted impacts to all intertidal BCH which includes mangroves, samphire and algal mats. The spatial emphasis will be on the footprint area of the Mardie Project, but will extend across the west Pilbara, particularly considering the potential for additional proposals. This project will rely on information from projects A and C to be complete.

Project C. Identifying the ecological roles, values and functions of intertidal benthic communities and habitat

The aim of this project is to provide information on the ecological role and values of key BCH that will inform future decision making on development across the Pilbara region. The highest priority habitat is algal mat as it is the least understood of the intertidal benthic coastal habitats. In particular, very little is known about its contribution to nutrient and energy flow in the intertidal to subtidal system and how this varies spatially and temporally. The second priority will be samphire habitat, followed by mangrove. While there is an expected emphasis on the Mardie Project site footprint, research in this project area may extend to the west Pilbara coast, e.g. from the SE corner of Exmouth Gulf to Karratha.

Priority research areas are**:**

- Estimate primary productivity in space and time for algal mat and other BCH.
- Identify the pathway for transfer of nutrients and energy from BCH to other communities and habitats (e.g. from the intertidal mosaics to the subtidal).
- Describe the role of BCH as habitat, assess community composition, biodiversity constituents, trophic transfer (flow of energy), nutrient transfer to understand ecosystem function.
- Identify the key physical drivers such as the response to the wetting and drying associated tidal movement, rainfall, episodic events (storms and cyclones), evaporation etc.

The above questions will need to take into account both spatial and temporal considerations including:

- Identifying a spatial gradient of productivity and energy flow for the west Pilbara coast and extending into subtidal areas.

- Intra-annual to understand the response to the wetting and drying associated with key physical drivers such as: tidal movement, rainfall, episodic events (storms and cyclones), evaporation etc.
- Inter-annual variability, however, it is noted that this will be limited as it is likely that a maximum of two years of data would be collected in the short timeframe.

Project A: Mapping of coastal and intertidal habitats with a priority focus on samphire and algal mat on the west Pilbara coast.

Aim: To produce habitat maps of algal mat and samphire habitat across the west Pilbara coast comparable to those for mangrove habitat and compare these to historic records to better understand natural variability and the response of these habitats to natural events and anthropogenic pressures

Theme Leaders: Ben Radford (AIMS), Sharyn Hickey (UWA) **Nominal funding:** $650,000

Project 1.1 Mapping of the original and current extent of Samphire and Algal mat on the west Pilbara Coast		
Knowledge gap	**Project deliverables**	**Project leader/s**
Current extent of mangrove, samphire and algal mats in the west Pilbara	• Map of current distribution of mangrove, samphire and algal mats from SE corner of Exmouth Gulf to Karratha.	
Project 1.2		
Knowledge gap	**Project deliverables**	**Project leader/s**
Historic extent of algal mats, mangrove and samphire in the west Pilbara	• Prediction of mangrove, samphire and algal mats from SE corner of Exmouth Gulf to Karratha prior to European habitation.	
Project 1.3		
Knowledge gap	**Deliverables**	**Project leader/s**
Temporal stability of mangrove, samphire and algal mats in the west Pilbara	• Investigate and identify methods for assessing changes in the temporal and spatial extent of algal mat and samphire. • Map and describe temporal differences in the extent of mangrove, samphire and algal mats in the west Pilbara, investigating the effect of season and disturbance (natural and anthropogenic). This may include assessing changes in inundation patterns as some of these habitats are difficult to see on Landsat imagery.	

Project B: Identifying and quantifying the potential effects of sea-level rise on intertidal habits of the west Pilbara coast with a focus on mangroves, samphire and algal mat:

Aim: To provide a better understanding of the potential impacts of sea-level rise on intertidal habitats of the west Pilbara coast and how coastal infrastructure such as that by salt works may influence adaptation to sea-level rise.

Theme Leaders: Matt Hipsey (UWA) **Nominal funding:** $650,000

Project 2.1		
Knowledge gap	**Project deliverables**	**Project Leader/s**
To what extent do environmental and physical conditions inhibit migration of intertidal habitats with rising sea-level?	• Models projecting SLR impacts along the coast and associated redistribution of intertidal habitats (mangroves, samphire and algal mats). This will need consideration of sedimentary processes that may influence the distribution of the communities (e.g. erosion, sedimentation under existing mangrove forests, etc).	
Project 2.2		
Knowledge gaps	**Project deliverables**	**Project Leader/s**
How may projected climate changes effect intertidal habitat's ability to migrate?	• Models that consider how increasing temperature (sea and land), changes to rainfall and cyclone activity influence capacity of intertidal habitats to redistribute with SLR.	
Project 2.3		
Knowledge gap	**Project deliverables**	**Project Leader/s**
What is the significance of the proposed salt works in preventing adaption of BCH to sea-level rise?	• Models projecting SLR impacts along the coast, particularly at sites where there are existing or proposed salt works and how this infrastructure and sedimentary processes may influence the potential for redistribution of intertidal habitats.	

Project C: Identifying the ecological roles, values and functions of intertidal benthic communities and habitats of the west Pilbara:

Aim: The priority for this project will be understanding the role of algal mats including their value and function through nutrient flows and energy budgets and where this productivity goes in the system, including a spatial and temporal gradient.

Theme Leaders: Kath McMahon, Glenn Hyndes and Paul Lavery (ECU) **Nominal funding**: $1,000,000

Project 3.1		
Knowledge gap	**Project deliverables**	**Project Leader/s**
What is the primary productivity (including nitrogen fixation) in space and time for algal mat and other BCH in the west Pilbara?	• Estimation of primary productivity nitrogen fixation across a spatial gradient for algal mat, samphire and mangroves. • Estimation of the relative productivity for the whole West Pilbara Coast for mangroves, samphire and algal mats. • Estimation of nitrogen flux (temporal and spatial) to the marine environments from all sources (e.g., algal mats and terrestrial flows). • Estimation of the relative importance of nitrogen flux from algal mat communities to the marine environment compared to other sources of nitrogen (temporal and spatial).	
Project 3.2		
Knowledge gaps	**Project deliverables**	**Project Leader/s**
Identify the pathway for transfer of nutrients and primary productivity from intertidal BCH to subtidal communities and habitat	• Identification of pathways for transfer of nutrients and primary productivity from intertidal to subtidal areas. • Estimation of the proportion of primary productivity and nitrogen which is exported from each intertidal habitat type to subtidal areas.	
Project 3.3		
Knowledge gaps	**Project deliverables**	**Project Leader/s**
Describe the role of BCH as habitat, assess community composition, biodiversity constituents, trophic transfer (flow of energy,	• Identification of the role of algal mats in terms of composition, biodiversity, trophic transfer and habitat across a spatial gradient.	

nutrients) etc. The primary focus is algal mat communities, but other BCH should be considered		
Project 3.4		
Knowledge gaps	**Project deliverables**	**Project Leader/s**
Identify the key physical drivers of spatial and temporal variability in primary productivity and N fixation, such as the response to wetting and drying associated tidal movement, rainfall, episodic events (storms and cyclones), evaporation etc.	• Identification of key physical drivers of spatial and temporal variability in primary productivity and nitrogen fixation. • Identification of key processes which transfer the carbon and nitrogen to the subtidal environment.	

2. Linkages to other programs

There are a number of research programs currently underway or in development through research institutions and government departments in WA and nationally that will be producing deliverables relevant to this strategy. Links will be established with other organisations and programs to build upon, complement and leverage other local, regional and national initiatives and activities. Some current initiatives include:

Department of Transport initiative to develop topographical and habitat mapping based on lidar and digital elevation for priority coastal areas. This is part of a national project that is being led by DoT for WA. There is scope to support the Pilbara as a priority area for this project.

CSIRO has a project planned that will compile existing habitat mapping products to assess Australia's 'blue carbon' potential.

DBCA is leading research evaluating primary productivity, energy transfer and connectivity among marine habitats in the Dampier Archipelago.

Commonwealth required offset for research that guides conservation efforts to maintain ecological functionality of nearshore subtidal habitats of the Pilbara region that support the short-nosed sea snake.

3. Governance

A governance structure has been agreed with BCI Minerals, WAMSI and DWER to manage the Mardie Salt Marine and Intertidal Offset program. This will involve a Steering Committee to provide guidance on the projects comprising the offset program and their delivery. The Steering Committee will operate under agreed Terms of Reference that set out the membership, roles and responsibilities of the Committee, membership and meeting frequency. The overall role of the Steering Committee is to provide overarching program direction and coordination, issues resolution, and oversee project delivery. The Steering Committee reports to the WAMSI CEO.

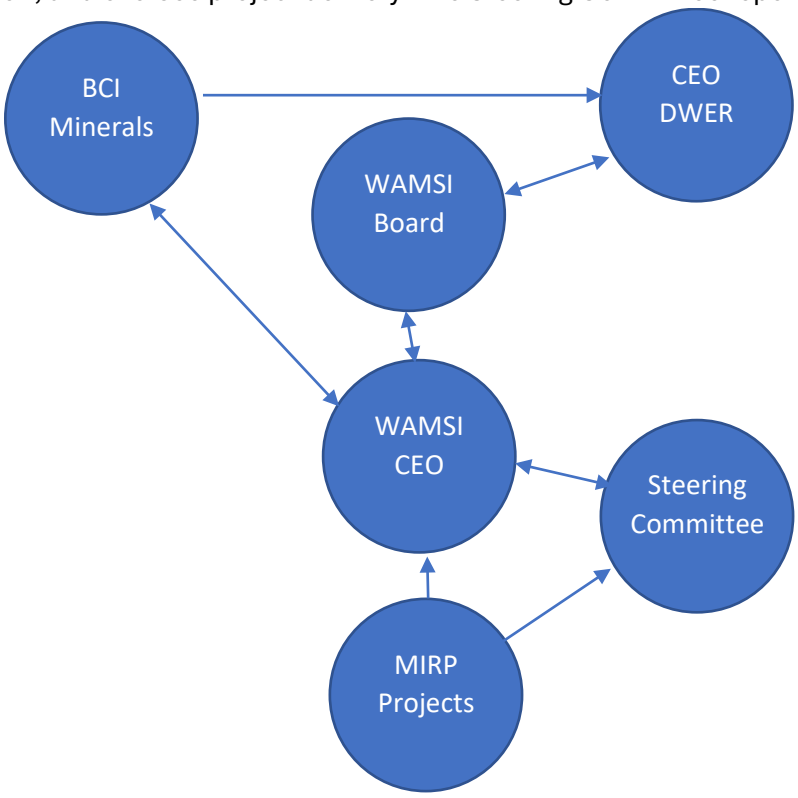

Figure 2. Governance Structure for delivery of the Mardie Salt Marine and Intertidal Offset program through WAMSI.

4. Data Management

A Data Management Plan and Technical Standard Data and Analytics Deliverables, in recognition that effective and efficient data management will underpin the Program.

ATTACHMENT 2 –PROJECT SUMMARY MARDIE PROJECT MARINE AND INTERTIDAL RESEARCH OFFSET PROGRAM – PROJECT A

WAMSI project plan for the Collaborative Project Agreement

Mardie Project Marine and Intertidal Research Offsets Program

Project details

Project Title.
Mapping of the original and current extent of samphire and cyanobacterial mat on the west Pilbara Coast

Start Date/End Date.
15-01-2023 to 15-12-2024

Project Leader.

Sharyn Hickey	Mick O'Leary

WAMSI Partner Organisation:
The University of Western Australia

Contact details:
School of Agriculture and Environment, and School of Earth Sciences, The University of Western Australia, 35 Stirling Hwy, Crawley, WA, Australia
sharyn.hickey@uwa.edu.au
mick.oleary@uwa.edu.au

All project collaborators must submit proof of insurances to WAMSI.

- Public liability
- Product liability
- Professional indemnity
- Property insurance over assets purchased with this funding
- Worker's compensation
- Marine liability.

Scope of the project.

Project summary

Need
The Pilbara coast hosts a unique arid zone mangrove environment recognised as one of only six across the globe (Adame *et al.*, 2020). Broad flat inter/supratidal flats combined with a hot dry climate has resulted in a distinctive habitat zonation. The Pilbara coast tends to be fringed by mangrove communities that transition to samphire and salt tolerant vegetation in the lower intertidal zone. The higher intertidal zone and lower supratidal zones tend to be covered by cyanobacterial mats (referred to as 'algal mats' in the Ministerial Statement) . These organic mats comprise microbial cyanobacterial communities, and are considered be highly productive primary producers, fixating carbon and nitrogen (Stal, 1995; Lovelock *et al.*, 2010; Adame *et al.*, 2012) and are thought to contribute to primary and secondary productivity in the nearby coastal waters (Penrose; Lovelock *et al.*, 2010; Adame *et al.*, 2012).

However, information on these habitats, particularly in the Pilbara coastal region is limited and has largely been focussed on mangroves (Hickey and Radford, 2022), or focussed on particular sites (Lovelock *et al.*, 2010; Adame *et al.*, 2012). Similar areas, further north, which contain overlapping habitats, including mangrove, tidal flats and samphire vegetation, such as Eighty Mile Beach have been recognised as RAMSAR sites of significance under The Convention on Wetlands of International Importance, demonstrating the significance of these environments. There remains a knowledge gap in the functional role of mangrove, samphire and cyanobacterial mat habitats play in the Pilbara's dryland coastal ecosystems. The vast size, remote location, terrain and tide has possibly hindered research in this area, however advancement in remote sensing techniques alongside field observations can provide valuable insight to map these habitat communities, and explore the natural dynamics, threats and responses.

Regional climatology (e.g., El Nino Southern Oscillation), sea level, precipitation, and temperature have been demonstrated to affect these coastal habitats. For instance, a 20 cm decline in sea level at Mangrove Bay on the Ningaloo Coast in Western Australia coincided with porewater salinity increasing by 25% compared to the 16 year mean level, and ultimately resulted in areas of mangrove dieback (Lovelock *et al.*, 2017). While cyclones were shown to damage seaward mangroves, and provided an avenue for landward mangrove seedling recruitment and establishment in Exmouth Gulf (Lovelock, Reef and Masque, 2021). There is limited knowledge on the extent of mangrove, samphire and cyanobacterial mat communities in the Pilbara, however we first need to know their extent to understand their vulnerability to both climate and anthropogenic threats.

Understanding environmental change in the West Pilbara requires baseline information that predates ecological monitoring/mapping programs. This is because over time scales relevant to a changing climate and anthropogenic impacts we need to reduce the possibility of shifting baseline syndrome (SBS; Knowlton and Jackson 2008). Developed by Pauly (1995), the concept of SBS is defined in Soga and Gaston (2018) as

“a change in the accepted norms for the condition of the natural environment due to lack of past information or lack of experience of past conditions”.

As suggested here, acceptance of an already changed coastal ecosystem’s baseline as “healthy” may lead to the use of inappropriate baselines for habitat conservation (Thurstan et al. 2015; Soga and Gaston 2018;). As such, there is a need to both identify the limitations of relatively recent ecological monitoring data in capturing the full impact of anthropogenic pressures over multiple decades (Mihoub et al. 2017) and identify novel methods to capture and record environmental data that can extend our understanding beyond the observational/instrumental record.

Aims

The project proposes to use a unique combination of (1) satellite and aerial remote sensing techniques, (2) Indigenous knowledge to map habitat extent and track environment change across space and time (i.e., seasonal to multidecadal timescales). The Pilbara’s coastal environments host a unique sedimentary and geomorphic archive that may contain palaeo-ecological records of habitat distribution and zonation during periods of high sea levels spanning the last several thousand years. Though not a focus for this investigation we flag the potential utility of these archives in predicting habitat response to future predicted changes in sea level along the Pilbara coast.

(1) The first approach uses satellite remote sensing datasets which will provide up to 35 years of data and represent the most recent period of coastal industrialisation and climate change along the Pilbara coast. The approach will also benefit from the recent availability in higher spatial and temporal resolution satellite, airborne and drone remote sensing datasets, and the coincident increases in cloud processing and advances in machine learning. This advances in automated mapping and processing capability have provided an avenue to link fine-scale field measurements with broader-scale remote sensing data, across spatial scales, with associated uncertainty models. Using these methods, recent historical records, an understanding of space-time dynamics of coastal habitats can be made to help inform

ecological drivers of change, and habitat contribution to the ecosystem values and functions. We will also use historical air photo imagery to establish the historical loss of mangrove-samphire-cyanomats that resulted from the development of the Onslow and Dampier solar ponds and crystallisers (e.g., SI1 and SI2) prior to satellite imagery, where aerial imagery is available (see appendix).

(2) The second approach will make use of Indigenous knowledge and living memory to identify areas, specific locations or patterns of habitat change that will both overlap and extend beyond the satellite instrumental record. With collective knowledge of the land, sea, and sky, Indigenous peoples are excellent observers and interpreters of the natural environment and have experienced climate driven environmental change through deep time, adapting to changes in sea levels, precipitation regimes, evolving seasonal variability, and the resultant impact on their immediate environments. This knowledge can complement scientific data by providing environmental baselines (that can extend beyond the observational and instrumental timeseries) in which to measure change. Particularly we see indigenous knowledge providing reconstructions on environments that were impacted by the development of the Onslow and Dampier Salt developments.

Methods & sampling design

To address the priority research areas as identified by the Steering Committee to meet the Ministerial Statement we have developed two approaches (see below), related to the priority research areas identified with sub-questions and objectives within each, as outlined in Table 1 in Outcomes section. Here we define the Pilbara coast as the coastline from Exmouth Gulf to Karratha in Figure 1. A total of 3 field sites (Figure 1) have been identified and selected based on the representative nature of the three key habitats (mangrove, samphire, cyanobacterial mats) and represent a gradient in tidal amplitude (1.8 m in the south to 3.7 m in the north), All projects will align their field research efforts to these indicative field sites, project A will also provide a remote sensing habitat model for the Pilbara coast.

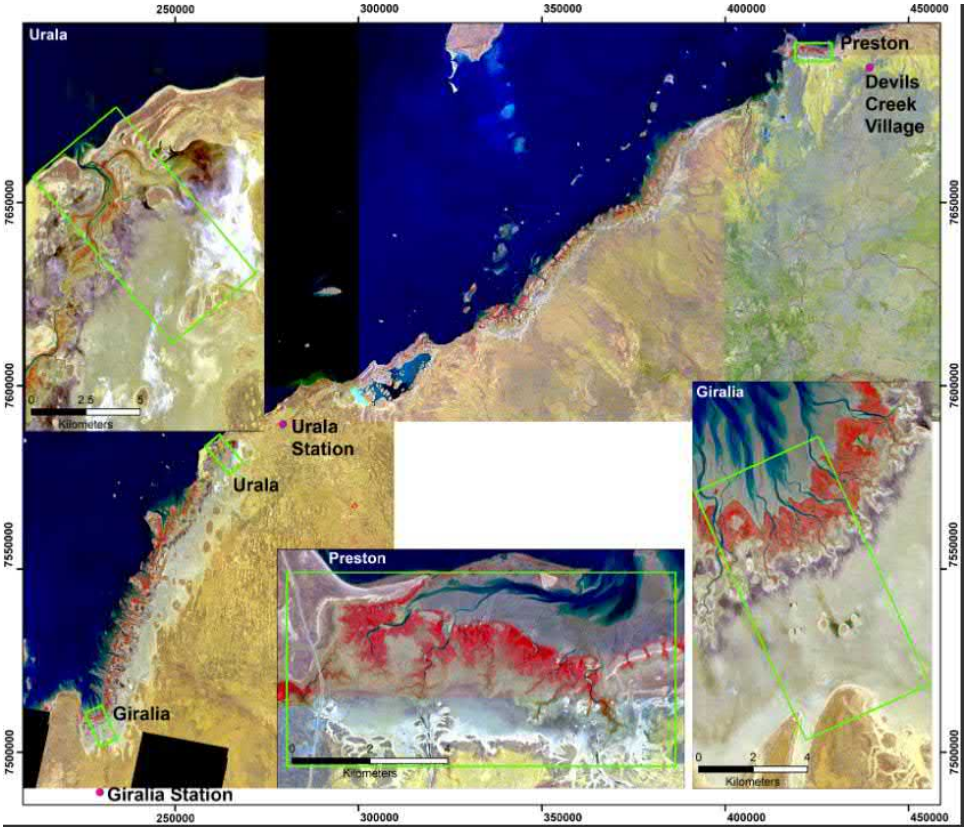

Figure 1: Study location with proposed focus study sites along the Pilbara coast. Project A will provide a remote sensing model at broadscale for Pilbara coast extent (as identified above).

1.1.1 Approach A > Remote Sensing

This approach will utilise a combination of broadscale (satellite multispectral) and fine scale (airborne LiDAR-hyperspectral) remote sensing data to develop both predictive and actual habitat maps for the Pilbara coast respectively (Figure 1 and 2). Although not ideal, the use of broadscale (satellite multispectral) imagery is justified on the basis of limited budget and the requirement to produce a contiguous coastal habitat map (mangrove, samphire [habitat zone], cyanobacterial mats) for the entire Pilbara coast.

We will also develop a series of temporal change maps at set time points .Higher resolution airborne topo-LiDAR and hyperspectral imagery will be collected across the defined study sites in Figure 2, with the aim to provide information on species level distribution across the various coastal habitats. Higher spatial resolution satellite imagery will be purchased in order to expand the coverage beyond the study sites and improve the uncertainty in the regional scale predictive habitat map.

At a smaller number of locations we will purchase higher resolution satellite imagery (aerial footprint to be determined) to cover timepoints (seasonal/interannual) in order to provide information on the dynamic response of habitats to events like ENSO and past extent of coastal communities.

On ground mapping of habitat will be essential to validate both the airborne hyperspectral remote sensing data within the field study areas, and broadscale remote sensing satellite data outside the field study areas. This will require extensive field mapping across the entire Pilbara coastal study area with traverses covering as many habitat and community types as possible. Ground based fieldwork will also provide the ground control points which are required to validate the Topo LiDAR datasets.

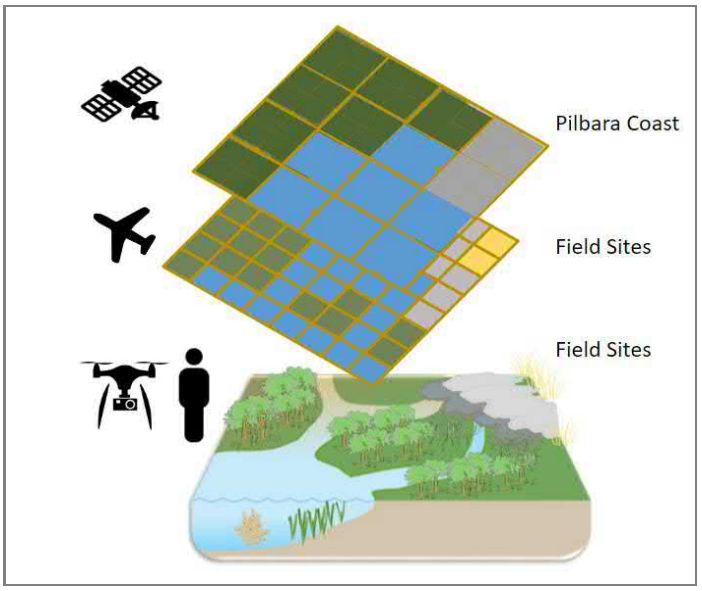

Figure 2: Conceptual overview of Approaches A1 and A3 illustrating the different scales and indicative methods data will be collected and habitat modelled at. See Supplementary Information for imagery examples.

A1. Broadscale habitat models for Pilbara coast

Landsat and/or Sentinel satellite imagery will provide the multi-decadal scale time series of environmental change along the Pilbara coast, as well as provide information on the regional scale spatial extent of key habitats in order to define areas for more focused (higher resolution) investigations. Modelling will follow the techniques of Hickey et al. (2021), Hickey and Radford (2022), and Chamberlain et al. (2021). Samphire has traditionally been difficult to map with multispectral imagery due to its similar spectral scale with the surrounding environment and low height, however it may be possible to map out the representative extent of samphire based on the landward and seaward boundaries of mangrove and cyanobacterial mats respectively, this is similar to techniques by Murray *et al.*, 2019.

Cyanobacterial mat detection via broadscale remote sensing will be attempted following techniques by Murray *et al.*, 2019 and Hickey and Radford, 2022. A range of remotely sensed indices will also be established including greenness (e.g., NDVI for mangroves), and water (e.g., NDWI). Model validation will be undertaken where validation data is available (e.g., high resolution imagery, previous available field data). We will also use historical air photo imagery to establish the historical loss of mangrove-samphire-cyanomats that resulted from the development of the Onslow and Dampier solar ponds and crystallisers (Figure 3).

Deliverable A1.2 is to provide validation data for habitat models. Validation data refers to uncertainty mapping. We are mapping 3 focus sites with high resolution LiDAR and hyperspectral imagery as well as field data (A3). We have allocated a budget to purchase available historical high resolution satellite data to supplement current information for these sites, listed in the budget as Remote Sensing Data. All maps will have uncertainty information. Also, we are mapping the entire Pilbara coast study region from Giralia to Karratha as identified in Figure 1 at a broader scale due to project budget limitations in collecting high resolution data over wider areas. We will use the overlap of the focus sites to help develop and validate models to inform the uncertainty of the mapping. However, it is important to note that if there is no high-resolution data or field data at sites there is no way to validate the model with certainty at these sites, a global (e.g., regional) validation will be provided.

NDVI and water indices are provided as examples of common spectral indices. Everything on the Earth's surface reflects and absorbs wavelengths (spectra) uniquely. We will be utilising this with other ecological information to develop a model to predict these habitats. For instance, Lovelock et al. 2009 has shown that at least for Giralia, cyanobacterial mats, samphire and mangrove exist in specific tidal envelopes, characterised by the location relative to lowest astronomical tide and sea level. Field data and hyperspectral information, along with LiDAR will be collected at the 3 field focus sites, with this information we will be able to explore what specific spectral indices, along with what other information (e.g., water inundation) are useful for predicting samphire and cyanobacterial mat presence or absence.

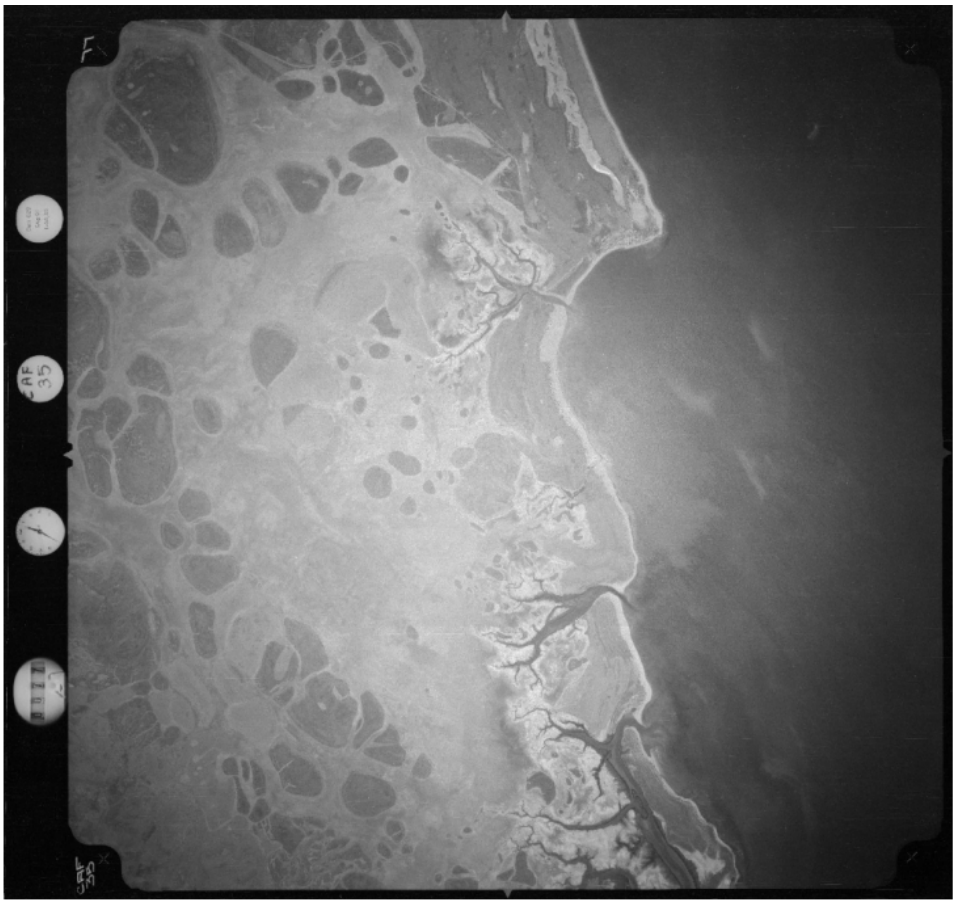

Figure 3: Black and white non georeferenced image of Onslow solar salt ponds area, flown 1967, source: Geoscience Australia (Historical Aerial Photography)

A2. Investigate space-time dynamics of habitat for Pilbara coast

Spatial-temporal analysis will be used to investigate changes in key habitats (interannual through to multidecadal) following the methods of Hickey et al. (2018); Hickey and Radford (2022). This will be key in establishing the response of these habitats to climate driven changes in sea surface height, precipitation and atmospheric temperatures. It will also establish those habitat areas which 1) experience a more ephemeral existence, 2) have experienced a transition in habitat type, or (3) those areas where indicative habitat is more stable or persistent though time. It is these areas of more stable habitat that could become the focus of long-term monitoring (e.g., TERN).

A3. For field sites provide finescale models of current habitat extent

Due to the limitations in spatial/spectral resolution when mapping at the regional scale, three locations within the border study area are selected for higher (spectral and spatial) resolution investigation. Following the techniques of Hickey et al. (2018), we use airborne LiDAR and hyperspectral scanners to map geomorphology and vegetation at the decimetre scale. At this level of resolution it will be possible to quantify mangrove canopy height and cover, map the distribution of samphire, examine the spectral traits of cyanobacterial mats, and detail the transition of habitat as it relates to surface elevation or tidal dynamics. Spatial modelling at this final scale will use similar techniques to the broadscale mapping approach discussed above.

Figure 4: Exemplar LiDAR data showing Urala Creek (NE Exmouth Gulf). Grid cells = 100 m and pixel resolution is 25 cm. Green is representative of mangrove canopy.

1.1.2 Approach B

B1 Provide a record of living memories that capture environmental changes on sea country

We will document cross-cultural perceptions and configurations of threat as it relates to the West Pilbara coastal environments. The cross-cultural emphasis will be on establishing the parameters and nature of Indigenous and mainstream non-Indigenous understandings of threat/risk/harm as it relates to these coastal environments (See Kearny et al., 2022). This is a crucial step in establishing the cross-cultural parameters of this project and will inform the project's 'bridging discussions' aimed at centralising Indigenous perspectives in a discussion of risk/threat/future

security, and of generating intercultural approaches to addressing the impact of change in sea country settings over the short and long term.

Key activity will be the presentation at a workshop of very large printed airphoto maps of the Pilbara coast, to Indigenous Elders, Rangers, and community participants. The maps are then annotated by the traditional custodians with their personal observations as well as contextualising change across longer timescales using intragenerational intergenerational ancestral narratives. These annotated maps can be then used to extend the deeper time understanding of environmental change along the Pilbara Coast. This will be communicated back to the community via ESRI storymap as a form of digital storytelling of Indigenous narratives of environmental change. We will also digitistise participatory mapping outputs as spatial layers and provide these to the appropriate Aboriginal corporation and their cultural custodians/managers.

Key Indigenous stakeholders within the study area are the Buurabalayji Thalanyji Aboriginal Corporation (BTAC) based in Onslow and the Murujuga Aboriginal Corporation (MAC) Based an Dampier. O'Leary has had strong engagement with MAC over the last 6 years and has engaged with BTAC on a number of project proposals. Amanda Kearny (Melb Uni) is an internationally recognised Australian anthropologist and will lead the Indigenous engagement component of this project.

Describe how data will be secured during the project.
Data for this project will be stored on the secure UWA IRDS system and will be stored according to WAMSI guidelines.

Linkages

Mardie Salt Projects.
Project A will provide initial assessment of the spatial extent of the habitats for Project B and C to inform sampling design. Project A will provide updated habitat models to Projects B and C to scale data to Pilbara coast and regions of interest. Project A will work closely with Projects B and C on ecological data and application of spatial data and temporal scales for prediction modelling. Project A will work with Project B if change analysis is shown to link to sea level, or cyclone events to explore impact on habitat here from the remotely sensed habitat data.

All projects will share data and will aim to coordinate field trips. A data management plan following WAMSI protocols will be implemented for access during and post project duration. We will liaise with DBCA, DPIRD and other relevant stakeholders.

External projects

Hickey and Lovelock are currently engaged by Minderoo Foundation to write a review of the Exmouth Gulf Salt Flats and develop a cyanobacterial habitat envelope spatial layer for the Exmouth Gulf (Giralia to south of Onslow). The review is due to be completed August 2022, and the spatial layer December 2022 (desktop study, and not representative of a single time-point - envelope of likely area). There is a further review of carbon and productivity modelling using current literature (desktop study), and potential changes (desktop study) due June 2023 and December 2023.

ICoAST

Hickey has recently published a mangrove layer as part of the IOMRC ICoAST project for northern WA which overlaps the area of interest (Hickey and Radford, 2022). This method will provide a baseline for methods.

Implications for Management

The creation of a detailed coastal habitat map will become a key management tool for assessing the cumulative impact of industrial development along the Pilbara coast. It will provide a quantitate assessment on the spatial distribution, density and ephemeral nature of a range of coastal habitats and extent to which these habitats may be impacted, either through direct habitat loss or longer-term degradation, by industrial development. It will provide the state environmental regulator, i.e., the EPA to make informed decisions though the approvals process regarding the cumulative impact of proposed developments.

Risks to delivery and how they will be managed.

Project A will be able to provide broadscale habitat models if field work is affected as these datasets are being generated though remote sensing satellite date. However, model uncertainty is based on data availability and ability to detect habitats at relevant spatial and temporal scales.

1 Staffing > The success on Project A is dependent of a skilled Remote Sensing Scientist undertaking the bulk of the hyperspectral data analysis and processing. Ideally a job search would be initiated/posted very early in the new year, and a candidate appointed and start date confirmed before the end of March 2023. For this to occur the project leads plans to write the job description and liaise with UWA HR have a the prospective staff position posted to appropriate job boards immediately after the new year.

2. The timing of fieldwork must coincide with the airborne survey. To ensure the best possible weather window both for the airborne and ground survey teams, have selected the first two weeks in May which coincide with the end of the cyclone season and low easterly winds which will minimise atmospheric dust impacting on the quality of the hyperspectral imagery. We have also purchased two all-terrain 8 wheeled amphibious vehicles which will make all weather access to all field sites possible.

3. Negotiating site access

There are three Aboriginal Corporations that cover the areas we are intending to work.

- Along the Eastern Exmouth Gulf it is the Nganhurra Thanardi Garrbu Aboriginal Corporation
- Along the SW Pilbara Coast (Onslow)t it is the Buurabalayji Thalanyji Aboriginal Corporation
- Along the NE Pilbara Coast it is the (Cape Preston area) Wirrawandi Aboriginal Corporation

An Indigenous Land Use Agreements

- Kuruma Marthudunera and Yaburara and Coastal Mardudhunera IULA, covers the Mardie to Cape Preston research area.
- Thalanyji and Minderoo Pastoral ILUA covering the SW Pilbara coast near Onslow
- Macedon ILUA covers the area SW of Onslow

There will Mineral Tenements that we will need to request access too.

- Rio Tinto – Dampier Salt
- Sino Iron
- Onslow Salt
- Mardie Salt

As well as permits for drone flying from CASA, military airspace if relevant, or private landholders.

It has not yet been agreed who will take the lead in negotiating site access, either WAMSI, DBCA or UWA/ECU. Access agreements will need to be made before the first field season commences, i.e., in the first three months of 2023. Project A does not require collection permits.

Outcomes.

Table 1: Project Outputs and sub-objectives within the 3 approaches

WAMSI and Steering Provided Deliverables	Knoweldge Gap Identified	1.1 Current extent of mangrove, samphire and algal mats in the west Pilbara	1.2 Historic extent of algal mats, mangrove and samphire in the west Pilbara	1.3 Temporal stability of mangrove, samphire and algal mats in the west Pilbara	
	Deliverable Requested	1.1 Map of current distribution of mangrove, samphire and algal mats from SE corner of Exmouth Gulf to Karratha	1.2 Prediction of mangrove, samphire and algal mats from SE corner of Exmouth Gulf to Karratha prior to European habitation	1.3.1 Investigate and identify methods for assessing changes in the temporal and spatial extent of algal mat and samphire	1.3.2 Map and describe temporal differences in the extent of mangrove, samphire and algal mats in the west Pilbara, investigating the effect of season and disturbance
Approach A	**A1 Broadscale habitat models for Pilbara coastas**				
	A1.1 Utilise remote sensing and available validation data to provide a habitat extent model for mangrove vegetation, samphire zone, and cyanobacterial mat area on the Pilbara coast at annual timescales for satellite temporal scale (e.g., Landsat 30 years)	☑		☑	☑
	A1.2 Provide validation data around habitat models.	☑		☑	☑
	A2 Investigate space-time dynamics of habitat for Pilbara coast				
	A2.1 Compare habitat extent models at temporal scales and investigate both spatial and temporal changes in mangrove, samphire zone area and cyanobacterial mat areas	☑		☑	☑
	A3 For selected field sites provide finescale models of current habitat extent				
	A3.1 Utilise remote sensing and field data to provide current habitat extent model for mangrove canopy, samphire, and cyanobacterial mat extents	☑			
	A3.2 Provide validation data around habitat models.	☑			
Approach B	**B1 Indigenous observations of environmental change**				
	B1.1 Provide a record of living memories that capture environmental changes on Sea Country		☑		
	B1.2 Creation of ESRI Story Map for digital story telling of Indigenous narratives of Environmental change		☑		
	B1.3 Delivery of digitised participatory mapping datasets to Aboriginal Corporation cultural heritage managers		☑		
Approach C	**C1 Palaeo-eco-geomorphic investigation of West Pilbara coastal environments – NOT INCLUDED IN CURRENT BUDGET AND SCOPE**				
	C1.1 Identification and characterisation of active and relic coastal landforms, establish their formation age		☐	☐	☐
	C1.2 Creation of spatially-temporally contiguous sediment facies maps and assign an depositional environment		☐	☐	☐
	C1.3 Reconstruction of high resolution palaeosea level curve spanning the late Holocene		☐	☐	☐

Project Team.

Name	Organisation	Role	• Tasks
Sharyn Hickey	UWA	Project Co-Lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at UWA. Coordinate and design spatial sampling plan and oversee remote sensing habitat models
Mick O'Leary	UWA	Project Co-Lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at UWA. Coordinate and design the Airborne surveys and ground mapping. Lidar Data processing and analysis. Report writing
Ruth Reef	Monash	Team Member	• Provide expertise on area, and habitat dynamics. Link to previous and ongoing collaborations
Peter Fearns	Curtin	Team Member	• Provide expertise on remote sensing spectral data
Shams Islam	ECU	Team Member	• Provide expertise on machine and deep learning techniques for remote sensing imagey
Catherine Lovelock	UQ	Team Member	• Provide expertise on area, and ecological relationships affecting habitat dynamics. Link to previous and ongoing collaborations
Remote Sensing and Spatial Analyst		Team Member	• Undertake analysis and collation of remote sensing data for habitat development

Post Doctoral fellow (Indigenous Engagement)		Team Member	• Undertake and lead Indigenous habitat mapping
Research Assistant		Team Member	• Assist with data collation, storage and analysis across Project A

Background IP.

See linkages to other projects section

Project Funds Requested.

The budget is based on salary and operational costs starting January 2023. Total funds requested $754,000.00 and in-kind contribution $430,205.

Salaries: Appointed positions will be required to undertake extensive remote sensing analysis, assist in field, and Indigenous engagement activities.

Operating Costs: The field work budget is based on the hire of a vessel, accommodation, vehicle travel. transport of equipment, flights for field campaigns.

Data: We have attempted to budget $300k across the 3 projects ($120k(A), ~$70k(B), $75k(C) to do this. This equates to a coverage of approximately 12% of the Pilbara coast region as identified from the Steering Committee. **Any gap in amount we ask the Steering Committee to help with allocating resources for this.**

This cost covers transfers of aircraft from Adelaide-Karratha-Adelaide, all ground logistics, plus 10 days of survey. It is possible to map approx. 50 square km per day (LiDAR/Hyperspectral/Airphoto). The Aircraft can carry the hyperspectral scanner (SPECIM EAGLE II VNIR 400-1000nm, up to 488 bands) or either a topo-bathy Lidar (RIEGL VQ820G) or topographic lidar (RIEGL Q680i-S) (there are only 2 underwing pods to house these instruments). The Topo-Bathy Lidar will capture tidal creeks, nearshore bathymetry and landforms now submerged within the solar ponds, however this is not the best instrument for capturing terrestrial vegetation and landforms, so for terrestrial mapping we would recommend the Q680i-S topo-Lidar system. To operate both LiDAR systems simultaneously. To extend LiDAR and hyperspectral imagery to the entire coastal region would equate to $1.5 million, and a minimum of 50 days of flight time.

Due to the limited area (12%) covered by the airborne survey we intend to augment this with high resolution satellite imagery, however, to cover the entire region this was quoted at $1.25 million - $4.5 million depending on satellite data available. This would be for 1 time point, which may not be the same along the entire coast as it is based on satellite capture date and it is an extensive area, so is not captured in a single scene. This is based on an academic price from Apollo Mapping at $156-.25-

$568.75 for 25km2.

Instead, to scale the data within the budget constraints we have augmented high resolution data at focus sites that overlap field data, and will use broadscale lower spectral/spatial satellite data to scale. This has limitations around sites being representative of the Pilbara coast, of being able to detect samphire or cyanobacterial mats, utilising habitat ecology with remote sensing data to build habitat prediction models. We will be required to validate these additional areas with in situ field observations and provide uncertainty models. We are also utilising in-kind high spatial resolution satellite data PlanetLabs (low spectral data) under the UWA academic licence (10,000 sqkm per month costed at $15, 0000 annual licence) to augment Landsat and Sentinel imagery for the Pilbara coast scale maps. Where there is no field data or high resolution imagery validation of habitat models is based on global values and there will be uncertainty here.

In-kind: Is based on a contribution of team members employed at UWA, ECU, CURTIN and UQ. It is anticipated that Universities will waive their University Service Charge (USC) on research grant income. Other in-kind contributions relate to use of infrastructure such as computing, imagery and LiDAR, field equipment, and lab infrastructure.

Table 1. Funds requested from WAMSI

Year	2022/23	2023/24	2024/25	TOTAL
Salaries Remote Sensing and Spatial Analyst (2 years *1.0fte)	$ 147,055.00	$ 149,996.00		$ 297,051.00
Salaries Post-doctoral fellow -Indigenous Engagement and Field (1 years *0.5fte)	$ 59,528.00			$ 59,528.00
Salaries Research Assistant (Level 4.4) (3 months)	$ 35,000.00			$ 35,000.00
Remote Sensing Data	$ 77,421.00			$ 77,421.00
Mudd-Ox all-terrain vehicles & trailer	$ 54,000.00	$ 54,000.00		$ 108,000.00
Field Costs (vehicle hire, accommodation, logistics)	$ 30,000.00			$ 30,000.00
LiDAR (Project A costs only)	$ 120,000.00			$ 120,000.00
Indigenous narrative workshop	$ 15,000.00			$ 15,000.00
Hardware/Computing	$ 6,000.00	$ 6,000.00		$ 12,000.00
Totals	$ 544,004.00	$ 209,996.00	$ -	**$ 754,000.00**

Table 2. Co-investment (staffing)

Organisation	2023		2024		2025	
	FTE	($'000)	FTE	($'000)	FTE	($'000)
Sharyn Hickey	0.2	30.174	0.2	30.174		
Mick O'Leary	0.2	39.452	0.2	39.452		
Ruth Reef	0.1	23.248	0.1	23.248		
Peter Fearns	0.1	17.000	0.1	17.000		
Shams Islam	0.2	36.283	0.2	36.283		
Catherine Lovelock	0.02	12.000	0.02	12.000		
Total						

Table 3. Co-investment (cash and in-kind)

Organisation	2022/23		2023/24		2024/25	
	Cash ($'000)	In-kind ($'000)	Cash ($'000)	In-kind ($'000)	Cash ($'000)	In-kind ($'000)
UWA		57.0000		53.000		
ECU		23.000		23.000		
Total		80.000		76.000		

Project deliverables and timing

Deliverable:	Completion date
Milestone Report	**July 2023**
Annual update Presentation	Sep/Oct 2023
Milestone Report	December 2023
Milestone Report	July 2024
Annual update Presentation	Sep/Oct 2024
Final report	December 2024

Milestones, activity, and payments

Year	Milestones / Major activities	Activity (A) or Milestone (M)	Expected Completion Date	WAMSI Funding ($'000)
2022/2023				
	Agreement Signed	M	December 2022	489.603
	MU Agreement signed	A	February 2023	
	Staff Appointments	A	March 2023	
	Ethics, Permits, Permissions	A	April 2023	
	Indigenous Engagement	A	April 2023	
	Airborne Survey	A	May 2023	
	Field Work 1	A	May 2023	
	B1 Indigenous observations of environmental change		June 2023	
	Milestone Report 1	M	July 2023	
	A1 Broadscale habitat models for Pilbara coasts	A	December 2023	
	B1.2 Creation of ESRI Story Map for digital story telling of Indigenous narratives of Environmental change	A	December 2023	
	B1.3 Delivery of digitised participatory mapping datasets to Aboriginal Corporation cultural heritage managers	A	December 2023	
	Milestone Presentation to SC	M	September/October	
	Milestone Report 2	M	December 2023	194.397
2023/2024				
	Milestone Report 3	M	July 2024	
	A2 Investigate space-time dynamics of habitat for Pilbara coast	A	31/12/2024	
	A3 For selected field sites provide finescale models of	A	30/12/2024	

	current habitat extent			
	Milestone Presentation to SC	M	September/October	
	Milestone Report 4	M	December 2024	
	Final Payment on completion and submission of reports	M	December 2024	70.00
2024/25				

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ATTACHMENT 3 –PROJECT SUMMARY MARDIE PROJECT MARINE AND INTERTIDAL RESEARCH OFFSET PROGRAM – PROJECT B

WAMSI project plan for the Collaborative Project Agreement

Mardie Project Marine and Intertidal Research Offsets Program

Project details

Project Title.
Quantifying the effects of climate change on intertidal habitats of the west Pilbara coast (Project B)

Start Date/End Date.
15/1/2023 - 15/12/2024

Project Leaders
Matthew Hipsey and Ryan Lowe

WAMSI Partner Organisation:
The University of Western Australia

Contact details:
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Scope of the project.

Project summary

This project fits into the offset research program for the conditionally approved Mardie Project (Mardie Minerals Pty Ltd), a solar salt and sulphate of potash production facility in the Pilbara region of Western Australia. Conditional approval under the Ministerial Statement 1175 (MS1175) requires research on the marine and intertidal environment in the region, based "on the significant residual impacts and risks of the proposal to intertidal benthic communities and habitat (BCH) namely mangroves, algal mat and coastal samphire". The proposed research project (Project B in MS1175) aims to quantify the nature of future risks faced by BCH, with the outcomes to be used to guide the strategic protection and management of the ecological values of these habitats into the future.

The intertidal communities and habitats across the West Pilbara Coast, where salt projects are being developed, create a unique eco-geomorphic setting with extensive tidal creeks, tidal flats and other low-lying coastal landforms (Brocx and Semeniuk 2015). Such arid zone coastal wetlands are rare globally compared to analogous temperate or tropic zone systems (Adame et al. 2020), due to how they are established by the complex zonation of salinity, sediments and habitat that are collectively shaped by tidal cycles. Episodic inputs and flooding from the terrestrial edge interact with sea level variability to create a complex inundation regime and pattern of salt, nutrient and sediment redistribution within the intertidal landscape. However, there remains limited data and gaps in our understanding how different coastal units in this region behave, making it difficult for regulators and managers to assess the risks of coastal developments and environmental change, and to support conservation efforts.

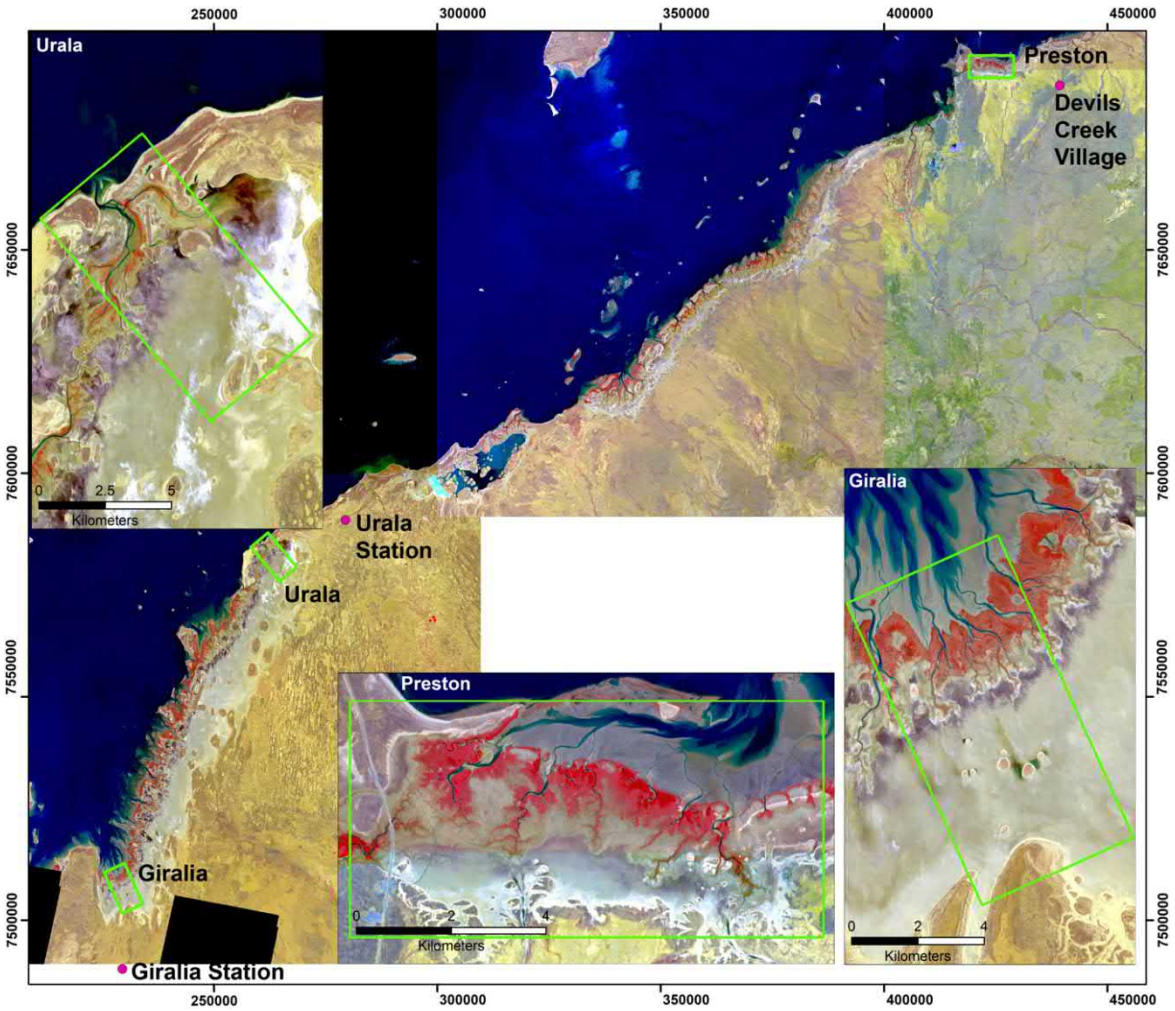

Figure 1. Indicative locations for sampling sites for Projects A, B and C. The final locations will be confirmed at the beginning of the project and after negotiations with land and facility holders and engagement with traditional owners.

The large intertidal areas along the West Pilbara Coast display a notable zonation of mangrove, samphire and algal (cyanobacterial) mat communities that span from the sub-tidal areas within the coastal embayments to the terrestrial edge (Figure 1). The broad salt-flat areas where the algal mat exists, experience a complex ecohydrological regime based on the interaction between rainfall, evaporation, surface-groundwater interaction, and flooding and inundation frequency (controlled by periodic tidal cycles and episodic extreme events such as tropical cyclones). These coastal habitats likely provide a substantial subsidy to both sub-tidal marine ecosystems and surrounding terrestrial ecosystems; however, to what extent remains unknown. In addition, given the sensitivity of many of these BCH to altered inundation and salinity regimes, any abrupt changes to conditions may trigger mortality of different species or communities and eventually alter their present distributions. For example, relatively small sea level anomalies (order 10 cm) during the 2015/16 El Nino, led to well-documented Mangrove dieback events at a number of locations across northern Australia (Lovelock et al. 2017). Furthermore, recent examples have shown that mangroves experiencing hyper-salinity may have little room to adapt when conditions become stressed, which can lead to tree mortality (Dittmann et al. 2022).

Complex feedbacks between physical and ecological processes mediate how vegetation and habitat areas adapt to sea level variability and salinity regimes (Sandi et al. 2018, Wimmler et al. 2021).

Different vegetation biomass and form has a different ability to attenuate flows (Rodriquez et al. 2017, Gelderland 2020), and flows and inundation patterns also mediate soil salinity in the root zone which can affect growth and persistence of vegetation (Wimmler et al. 2021, Dittmann et al. 2022). By modifying near-bed flows, the physical properties of coastal vegetation often have a profound influence on local sediment transport processes (including those responsible for coastal erosion and accretion), which over periods of time (e.g. years to decades) can play a major role in shaping evolution of coastal landforms (Lowe and Ghisalberti 2016). Changes to coastal vegetation can thus determine the capacity of a coastal system to mitigate and adapt to different coastal hazards (e.g., extreme storms and sea level rise) (Willemsen et al. 2021). For example, historical losses of mangroves in southern Asia have been directly attributed to large-scale erosion of deforested sections of coastlines (e.g., Mazda et al. 2002).

The potential for disruption of intertidal habitats is primarily in response to developments and operations within the intertidal zone, which are superimposed onto projected changes associated with climate change (Gordon 1998; Guo et al. 2022). Climate change effects include sea level rise (SLR), as well as changes in rainfall, cyclone intensity and temperature. Whilst there are various conceptual depictions of these environments (e.g., Semeniuk, 1994; Eliot 2013) and site-specific studies (e.g., as undertaken as part of regulatory requirements or commercial activities), their remains a fundamental lack of knowledge of how sensitive these habitats, and the ecosystem services they provide, are to proposed future developments and anticipated climate changes. It also remains unclear how sensitive habitats may be across the variety of different coastal landforms that exist within the Pilbara Coast.

As a result, there is a need to identify and quantify the potential effects of climate change (including sea level rise) on mangroves, samphire and algal mat along the West Pilbara Coast, and to be able to assess the significance of salt projects in potentially altering the capacity of intertidal BCH to move and adapt to changing future conditions. The development of conceptual and numerical models is therefore needed to provide a holistic assessment of how these ecosystems are likely to respond; however, to date there are not well accepted conceptual or numerical models able to fully resolve the interactions that are known to be important in shaping the coupled evolution of both habitats and coastal morphology under changing environmental conditions.

This project will meet the conditions of MS1175 under Condition 14-1(2) by directly aiming to improve understanding of how intertidal BCH in the region will likely respond to sea-level rise and the presence of salt project developments in terms of BCH spatial extent and capacity to function, and will be either informed by or feed into projects addressing Conditions 14-1(1) Project A and 14-1(3) Project C.

Aims

The overall aim of the project is to develop a predictive understanding of how West Pilbara BCH are likely to change in the future due to climate change and salt project developments. Specific project aims include:

1. Undertake a synthesis of our current understanding and knowledge gaps through data review, and develop conceptual models of key coastal processes in the region
2. Develop a modelling capability that will be applied to assess how intertidal BCH will respond changes in sea level, flooding and extreme events, and coastal development
3. Assess how different coastal processes determine the function and adaptive capacity (e.g., ability to migrate over time to new locations) of West Pilbara BCH
4. Assess how future changes in sea level, extreme events and salt works may impact upon the intertidal BCH distributions and function

Methods

The project proposes to include an initial data collation and conceptual modelling phase (Task 1), followed by the sequential development of a fit-for-purpose modelling capability (Task 2-4), and finally application of the models to answer the key questions related to future responses and risks faced by the intertidal BCH (Task 5). The relationship and dependencies between the major work components is shown as a summary in Figure 2, the proposed approach is expanded upon further below.

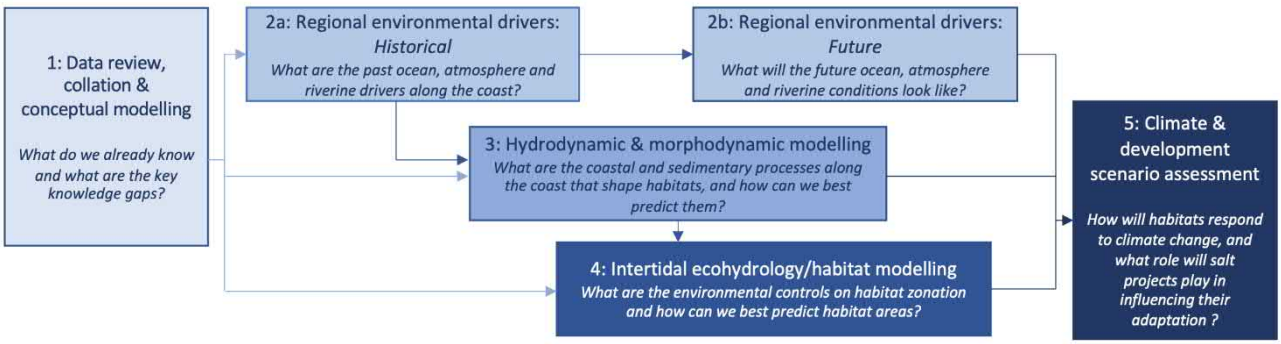

Figure 2. Overview of the five key work components proposed for the assessment and the key question(s) they seek to focus on.

The project will focus on understanding and predicting the physical, environmental and biological processes at up to three focus sites (Figure 1). These sites have been chosen to represent a range of tidal regimes, coastal morphologies and habitat landscape characteristics and also coincide with focus field study sites for Projects A and C. The development of models for each site (detailed below) will require critical field data for model input (e.g., high resolution bathymetry/topography, sediment properties, habitat properties, hydrodynamic observations, etc.) and for model calibration/validation. The exact scope of the model applications will thus likely vary among sites depending on available field data at each site (i.e., from data collected in Projects A and C and any available historical industry datasets). For example, Project C will likely collect in situ field data at 2-3 of the sites, allowing for a more detailed validation of the processes at these sites. Final site selection will occur after final agreement of the monitored sites and following a detailed data audit and review.

Task 1. Data review collation and conceptual modelling

The West Pilbara Coast is remote with patchy availability of prior environmental data. There is a range of potentially valuable data available held in unpublished studies or undertaken by consultants and industry. Similarly, there are a range of past coastal management relevant impact and assessment studies that have been undertaken.

In collaboration with Project A and C, this first task will therefore seek to:

- Catalogue and collate prior environmental data-sets relevant to the region, including seeking permission for access to datasets held in the private domain;
- Undertake a workshop including selected research and industry experts on coastal management to develop refined conceptual models of the physical and ecological processes shaping BCH distribution and adaptation pathways;
- Identify key knowledge gaps, including priority areas of model development to resolve BCH (e.g., physical controls on sediment movement, processes controlling mangrove seedling recruitment,

environmental controls on algal mat productivity, surface-groundwater interaction and salt redistribution, etc.).

Task 2. Regional environmental drivers

Available oceanic and atmospheric data for the Pilbara coastal region will be compiled for a period spanning several decades (up to 60 years) to identify how historical changes to intertidal BCH and coastal morphology (quantified in Project A) are related to key environmental drivers over a range of timescales, i.e., from long term (decadal) to extreme events (e.g., from tropical cyclones).

Data for this task will be sourced from a combination of existing hindcast regional ocean model outputs, regional weather/climate model datasets, remote sensing data and available historical *in situ* coastal observations available in the region, noting that individual datasets are available over different timeframes. Regional model output of historical ocean conditions (e.g., waves, sea level, ocean currents, temperature, salinity, etc.) will be sourced from a combination of existing high-resolution model simulations of the North West Shelf using ROMS-SWAN (Dufois et al. 2019) and using Delft3D-SWAN (Sun and Branson 2018), both of which have been extensively validated using data collected as part of the Wheatstone monitoring program. Additional ocean data will be sourced from satellite remote sensing products (e.g., for SST, turbidity, etc.), long term sea level (tide gauge) and wave records (e.g., from DoT). For atmospheric data, output from the ERA5 Reanalysis (Hersbach et al. 2020) and regional BOM weather stations will provide atmospheric forcing information (e.g., rainfall, wind, atmospheric heat fluxes, etc.).

Project A will develop maps of historical changes of key BCH in the West Pilbara (i.e., algal mat, mangrove and samphire habitat) and changes to coastal landforms. In collaboration with Project A, the analysis of data within Task 2 will be used to develop long term timeseries of the key environmental drivers in the region during overlapping periods, to quantify the influence of environmental drivers on historical changes to BCH and coastal landforms. Data from Task 2 will also be used as boundary conditions for the much-finer scale coastal models developed in Tasks 3-5.

Finally, Task 2 will develop a set of regional environmental conditions under future climate change scenarios (e.g., up to 2100) using data from CMIP6 (O'Neill et al. 2016), which will include projected changes from sea level, ocean and atmospheric warming, and wind and wave conditions. These future climate forcing scenarios available at 0.1 degree (~100 km) resolution will be used as boundary condition forcing for the high-resolution coastal modelling applied in Task 5 (i.e., via downscaling), providing the necessary inputs for future habitat predictions.

Task 3. Coastal hydrodynamic and morphodynamic assessment

A coupled high-resolution hydro-morphodynamic model will be developed using the Delft3D Flexible Mesh software suite (Delft3D-FM). Delft3D-FM is a state-of-the-art numerical modelling suite developed by Deltares and that is capable of simulation complex interactions in coastal and estuarine environments. The hydrodynamics will be simulated on unstructured 2D or 3D (or a combination thereof) domains, with high mesh resolutions designed to resolve complex intertidal zones that typify the study region, e.g., tidal creeks and other heterogeneous geomorphological features. The model will include a range of processes including resolving the effects of currents and waves, on cohesive and non-cohesive sediment transport, and the influence of different vegetation types such as mangroves, samphire, algae mats and other intertidal vegetation on hydrodynamics and sediment transport. Models will be developed for the sites shown in Figure 1, with domains focused around the areas where field work and validation measurements are planned for collection (Figure 3). Note, the final simulated sites may be subject to change depending on the final bathymetric and data collection campaigns agreed within Project A and C.

Bathymetry for the model domains will be based on the higher-resolution data that is to be obtained in collaboration with Project A using aerial LiDAR and/or photogrammetry and supplemented by merging with the existing 30-m-resolution North-West Australia Digital Elevation Model (available from Geoscience Australia) or other topographic/bathymetric products that are available (e.g., Geoscience Australia's National Intertidal Digital Elevation Model available at 25 m resolution).

Sediment model inputs will be based on analysis of sediment samples (both grab samples and sediment cores) collected opportunistically at the sites as part of Project A and C's field campaigns (i.e., grain size distributions and composition), and from other monitoring data, which will be mapped over the simulated regions. In addition, sediment cores will be returned and analysed in the UWA Coastal & Offshore Engineering Laboratory O-tube facility to obtain critical shear stress values and sediment resuspension rates that are required for the different sediment types within the model.

Vegetation model input will be derived from the validated BCH distribution maps from Project A and will impact upon water flows through water drag and by altering resuspension. The model also enables coupling with a dynamic (intertidal) vegetation module, allowing for inclusion of the parameterization of vegetation colonization, development and mortality (Willemsen et al. 2022), which will be tailored for the application based on review work undertaken in Task 1. We do not anticipate high-resolution sub-tidal vegetation data as it is beyond the scope of project A. We will compile available data in Task 1 referrign to previous studies near our focus areas, and also explore remote sensing options to get indicative estimates of bare sediment vs "vegetation" in subtidal regions adjacent to our focus areas. This will not distinguih seagrass vs macroalgae but we will undertake sensitivity scenarios with various (sub-tidal) vegetation assumptions and quantify the effect it has on sub-tidal turbidity dynamics, and other coastal processes influencing the intertidal zone.

Once the domains are setup, a range of hindcast model simulations will be undertaken, as forced by the regional ocean and atmospheric condition data from Task 2. A range of different conditions will be resolved including for key cyclone and flood events for where data is available for model comparison and validation (e.g., studies undertaken in Giralia Bay such as May et al. (2018) and Lovelock et al. (2021) showing post-cyclone shifts in sediment, mangrove dieback and recruitment; as well records of mangrove changes in response to TC Vance in the Exmouth Gulf in Paling et al. 2008). For the present study period (2023-2024), the model will additionally be assessed by comparing to available in-situ hydrodynamic and sediment data collected at a range of strategically chosen sites (collected in collaboration with Project A and C), and data from remote imagery (e.g., ponded areas, water turbidity).

The validated model will be used to improve understanding of local and larger scale flows (transport pathways) and resulting sediment dynamics, both at the scale of the focus sites. Analyses of the model results will be undertaken to develop insights into the role of the present BCH on hydro- and morphodynamic processes, as well as how current conditions influence the present BCH distributions. The results will be explored in terms of the relative contribution of long-term changes (e.g., sea level variability) and past extreme events (e.g., cyclones) to the distributions of BCH.

Task 4. Intertidal ecohydrology assessment

Beyond physical controls (e.g., water inundation regimes, and sediment supply or erosion), habitats in the broad intertidal flats are also sensitive to water and soil salinities, nutrient availability, and weather drivers such as light and temperature. In this task the hydro-morphodynamic model developed in Task 3 will be extended to include simulation of the intertidal ecohydrology, with new modules for capturing the salt dynamics, and habitat models of the algal mat and samphire regions.

Salinity within the intertidal regions of arid coastal wetlands can be complex and excessive salinities may become a barrier to the movement of habitats inland into the future. The accumulation of salt occurs as saline ocean and ground water is subject to evapo-concentration, forming areas of hyper-salinity in the root-zone and salt crusts. Salt becomes redistributed following periods of inundation, flooding and rainfall. Seeps of saline groundwater in local depressions and tidal channels can also influence local salinity regimes. Various models such as SUTRASET and OGS have recently been used resolve the tidally driven changes in groundwater levels and salinity in tidal marshes (Liu et al. 2022, Bathmann et al. 2021); however, to date coastal hydrodynamic models do not account for these dynamics, making it difficult to connect hydrodynamics, sediment transport, vegetation and habitat. Therefore, whilst coastal models like Delft3D-FM provide a base platform able to resolve evapo-concentration and hyper-salinity, further development is required to model processes necessary to resolve intertidal salinity dynamics before the controls on intertidal habitats can be fully captured.

Model tools for simulation of vegetation communities in salt-marsh and mangrove ecosystems include MANTRA (Luo and Chui 2022) and MANGA (Bathmann et al. 2021). These models resolve the groundwater flow and salinity dynamics, and by capturing the persistence of vegetation based on the underlying salinity and water constraints on growth and establishment, they have been used to show how vegetation will adapt to changes in hydrologic conditions over long time periods. Whilst some examples have been published, they have not been used as part of an integrated assessment accounting for variability in hydrodynamic and sediment transport processes which may alter the landform shape. Furthermore, models for capturing responses of cyanobacterial mats and samphire to environmental conditions also currently do not yet exist.

In this Task 4, we will therefore develop an integrated platform for resolving coastal salinity and habitat models suited for the Pilbara Coast. Model development will be undertaken with the AED aquatic ecology library (Hipsey, 2022) or through linkages with existing open-source codes where possible. These will be used linked with the hydrodynamic-sediment transport model as developed in Task 3. Samphire and algal mat model parameterization will be undertaken based on literature review (e.g., Stal 1995, Adame et al. 2012), and process data collected within Project C, assessing environmental controls on algal mat biomass and productivity.

The salinity predictions will be first validated using data from in situ soil and water salinity measurements collected within the 'natural' focus sites, and in addition we will explore salt crust quantification via remote sensing tools in collaboration with Project A. Validation of the vegetation/habitat models will be based on spatial data on vegetation extent from Project A, and local data from the focus sites collected during surveys with (or in collaboration with) Project C.

The integrated model simulations will be analysed to undertake an assessment of the water, salt and sediment budgets, habitat areas and net productivity. Model tracers of different nutrient/carbon loading sources (e.g., ocean, river, mangrove and algal mat derived) will be undertaken to elucidate the relative contribution of intertidal productivity to broader ecosystem processes.

A final application to the 'impacted' site will be undertaken to assess the ability of the approach to resolve the habitat distribution in a site with existing salt-works.

Task 5. Climate change and development trajectories

The model will be used to investigate the sensitivity of intertidal habitats to climate change and salt works developments. Priority focus areas for future scenario simulations include:

- Understanding the influence of sea level rise on BCH extent and migration including environmental and physical parameters.
- Predicting BCH response to climate change scenarios, and in particular to sea level rise.
- What role will salt projects play in reducing BCH adaptation to sea level rise and how will this affect the ecological services provided by these habitats.

The integrated model developed in Tasks 3 and 4 will be used to simulate a range of future scenarios at the focus sites which represent different coastal landforms and experience different environmental drivers (tide, waves, and riverine inputs). A scenario matrix will be assessed considering SLR, extreme event severity (including associated effects on storm surge, waves and flooding) as identified in Task 2, and vegetation and landform properties. These scenarios will be used to create an envelope of possible future trajectories for inundation, salinity, landform stability and habitat area and function.

Separate scenarios will then be undertaken to show the nature of changes that hypothetical salt works developments will have on water and sediment movement, and habitat areas. Simulations will explore the structures associated with the salt works including features such as bund walls, high saline water heads, and high salinity surface water discharges. Selected scenarios will be run with and without climate change effects included to ascertain if the presence of salt-works may reduce the future adaptation ability of intertidal BCH.

Describe how data will be secured during the project.

Data collected and generated during the project will be uploaded to secure cloud storage available to the project team members. Key project datasets will be archived on UWA's long-term Institutional Research Data Store (IRDS) facility. IRDS is provided to UWA researcher at no cost and allows secure, redundant, and easily accessible storage of research data. In addition, curated data and model files will be maintained on the GitHub platform for version control.

Linkages.

Linkage to Project A

Project A will provide a range of essential datasets that are required for model setup and validation, both at local and regional scales. These include:

- Processed topographic and bathymetric data (e.g. from LIDAR)
- Habitat/cover/biomass mapping data for present and past periods
- Assistance with logistics for collection of sediment/soil samples for analysis of particle size distributions and composition
- Ad hoc environmental data collected during their surveys (e.g. soil salinity etc)

Linkage to Project C

Project C will provide a range of essential datasets that are required for model setup and validation, both at local and regional scales. These include:

- In situ sensor deployments at focus sites – water level, salinity, current velocities, turbidity
- Algal mat density/biomass and productivity surveys at different stages of wetting
- Samphire density/biomass surveys linking cover, height and stem density
- Experimental (mesocosm) data on environmental tolerances (salinity, temperature, desiccation, etc.)
- Soil nutrient and salt fluxes, following inundation.

- Assistance with logistics for collection of sediment/soil samples for analysis of particle size distributions and composition

Linkages to external projects

The project extends or will be informed by several past and present projects:

- The offset project entitled "*Primary productivity and energy transfer between marine ecosystems*" being carried out in the Dampier Archipelago by DBCA.
- WAMSI Dredging Science Node (output from regional ocean models of the North West Shelf region)
- The project will seek to use field data and conceptual models from Prof Cath Lovelock's recent ARC projects being undertaken at the Giralia focus site.

Implications for Management.

By combining data from remote sensing, oceanographic data, coastal geomorphology and ecosystem state and function, the modelling activities will serve to build consensus on the important processes shaping coastal habitat condition and provide a tool for industry to assess how developments will the change extent and function of key habitats.

Currently no tools exist within industry or research communities to assess how Pilbara inter-tidal habitats may change in response to ongoing stressors. Widely used hydrodynamic models are applied by consultants for assessing how hard-structures or sea level rise may impact upon local inundation regimes and sediment movement, and for assessing the impacts of operational activities like discharges or dredging. However, these models do not have any proven capability to resolve the dynamics of vegetation, salinity and habitat in the inter-tidal envelope, and the associated carbon and nutrient flows. This project will identify the key environmental drivers that control inter-tidal habitats in order to allow development of a new fit-for-purpose modelling capability able to be used for regional assessments or at the scale of project specific investigations (e.g., EIAs).

Further, the project will assess future scenarios, including consideration of climate change effects, to explore the sensitivity of ecosystems to solar pond developments. This will provide an evidence base to help regulators understand the potential consequences to nearby habitat in response to specific development footprints, and the degree to which the development may restrict the ability of habitats to adapt to future oceanographic conditions.

Risks to delivery and how they will be managed.

The following outline the risks associated with the project:

1. Delays in sign-off of the agreement would lead to a delay in the start of the project, which would in turn delay recruitment of critical project staff and initial activities in Task 1 that will collate and synthesis existing data that are required for model development (High risk). This will be managed by gaining feedback on the draft agreement from UWA's legal services in advance and fast-tracking of staff recruitment to the best of our ability.
2. Resignation or personal leave (illness, carers, etc.) leading to delays in progress (Low risk). With the breadth of the project team, there is in-built capacity to generally manage individual staff losses, i.e., no project activity relies on the unique background of a single project member. In the event on of the two critical Postdoctoral Fellows resigns, recruitment for a replacement will immediately take place.

3. The project has a significant numerical modelling component that is dependent on Pawsey supercomputing centre facilities that could become unavailable for periods of time due to maintenance and upgrade of facilities and unexpected system failures (Low risk). These would be expected to only cause short-term project delays (of order a few weeks) due to measures and redundant systems in in place to maintain this critical national research infrastructure.
4. The project is dependent on several key datasets that will be collected in Projects A and C (both field and remotely-sensed data), with delays in delivery of these data having potential to delay components of this project (Medium risk). These risks and how they will managed are summarised in the Project A and C project plans and will be minimised with coordination of research activities among the three projects and the Mardi Steering Committee.

Outcomes.

Specific outcomes from the research project will include:

- The collation and analysis of available environmental data and revised conceptual models relevant for the understanding of coastal processes in the West Pilbara Coast region
- The development of high-resolution and sub-regional coastal models for the complex West Pilbara Coast, including intertidal areas.
- Improved understanding of environmental controls on intertidal BCH, and projections of future habitat areas in response to climate change
- Improved understanding of the sensitivity of intertidal BCH to salt project developments within the intertidal zone
- The establishment of fit-for-purpose coastal modelling capability for the region that will be available for future environmental assessments along the West Pilbara Coast

Overall, these project outcomes will help meet the conditions of MS1175 under Condition 14-1(2) by improving understanding of how intertidal BCH in the region may respond to sea-level rise and limitations created by the presence of salt projects in terms of BCH spatial extent and capacity to function. The outcomes will also feed directly into the EIA process for future salt production developments in the Pilbara region.

Project Team.

The project team consists of staff from the UWA Centre for Coastal & Offshore Engineering Laboratory and Centre for Water & Spatial Science, plus from Prof Cath Lovelock's team at UQ - as outlined below.

Name	Organisation	Role	Tasks
A/Prof Matt Hipsey	UWA	Project co-lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at UWA. • Leadership of the ecosystem and habitat modelling components
Prof Ryan Lowe	UWA	Project co-lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at UWA.

			• Leadership of the coastal processes modelling components
Dr Arnold van Rooijen	UWA	Team member	• Supervision and guidance related to coastal processes modelling
A/Prof Jeff Hansen	UWA	Team member	• Supervision and guidance related to coastal processes modelling
Dr Mike Cuttler	UWA	Team member	• Supervision and guidance related to coastal processes modelling
A/Prof Marco Ghisalberti	UWA	Team member	• Supervision and guidance related to coastal processes modelling
Prof Catherine Lovelock	UQ	Team member	• Provide expertise on area, and ecological relationships affecting habitat dynamics. Link to previous and ongoing collaborations and relevant datasets.
Postdoctoral Fellow – *Coastal Processes*	UWA	Team member	• Coastal model setup, validation, and reporting. Scenario assessments.
Postdoctoral Fellow – *Ecosystem Modelling*	UWA	Team member	• Water quality (temperature and turbidity) and habitat model setup, validation, and reporting. Scenario assessments.
PhD Student – *Biophysical Process Modelling*	UWA	Team member	• Fundamental research to improve understanding and predictions of coupled physical and ecological processes (for incorporation into numerical models)
Research Fellow – *Habitat Modelling*	UQ	Team member	• Conceptual model development, literature synthesis and parameterisation of key habitats

Background IP.

IP that will be brought to the project includes:

- Previous data collected by Prof Lovelock and team in the Pilbara including timeseries data on mangrove, saltmarsh and cyanobacterial mat productivity, nutrient transfer and cycling in these habitats and environmental drivers of these processes.
- Previous modelling by team members on the Pilbara coast (e.g., Delft3D and ROMS model input and output files). Data collected by the project team in nearby relevant areas (e.g., wave data)
- Prior development of the AED water quality and habitat model for coastal wetlands.

Project Funds Requested.

The budget is based on salary and operational costs starting January 2023 for 2 years. Total funds requested are $682,869, and this is complemented by a co-investment contribution of $408,900, and a 3.5yr PhD stipend (valued at $122,500).

Salaries: Appointed positions will be required to undertake extensive model development, data analysis, scenario simulation and co-ordination activities. A 2 yr 0.8 FTE position is allocated to lead the coastal modelling, and this will be supported by a fractional appointment for habitat model development and validation (0.3FTE in Yr 1 and 0.8FTE in Yr 2 as this will start after the Task 1 activities). The Task 1 (review,

data auditing and conceptual modelling) activities are costed separately as 0.2FTE, and given the extensive data sets and scripting requirements a fractional appointment for a research assistant for data management and technical support is also costed. As the project requires model software coding, funding allocation is also made for software development support.

Operating Costs: Allocation for assisting Project A and C field work is costed (field travel, sediment sampling and lab analyses), plus co-contribution to the LIDAR data collection. An allocation for support services associated software technical support and customisation is also made given the scale of modelling proposed.

Co-investment: The project team includes time allocation from existing staff members employed at UWA and UQ, which totals an approximate load of 0.8FTE/yr. Based on direct salary costs only this is estimated as $349,800 for the two-year project span. We also note that as a WAMSI member, UWA will waive their University Infrastructure Charge on research grant income, which is not costed here. Other in-kind contributions relate to use of infrastructure such as computing, field equipment, and laboratory infrastructure. UWA will allocate 1x 3.5yr PhD stipend to support a research student on the project. This student will receive training whilst working with our team on Tasks 1-5 and then continue to focus on developing and testing new refinements to the models, including beyond the 2yr project (valued at $122,500). Total co-investment = $518,300.

Table 1. Funds requested from WAMSI

Year	2023	2024	TOTAL
Salaries - Post-doctoral fellow (*Coastal processes*) 0.8 FTE (UWA)	110	118	
Salaries - Post-doctoral fellow (*Ecosystem modelling*) 0.3 - 0.8 FTE (UWA)	49	137	
Salaries - Post-doctoral fellow (*Habitat model design and development*) 0.2 FTE (UQ)	35	25	
Software engineer support (UQ)	5	5	
Software technical support (*Deltares*)	25	25	
Research assistant (data/code management)	26	26	
LIDAR data collection (see Project A)	70		
Field, lab and travel related costs	15	10	
Publication fees		2	
Total WAMSI ($'000)	**335**	**348**	**683**

Table 2. Co-investment (staffing)

Organisation	2023		2024	
	FTE	($'000)	FTE	($'000)
Hipsey (UWA)	0.2	44.3	0.2	44.3
Lowe (UWA)	0.2	51.7	0.2	51.7
van Rooijen (UWA)	0.1	17.0	0.1	17.0
Hansen (UWA)	0.1	21.0	0.1	21.0
Ghisalberti (UWA)	0.1	21.0	0.1	21.0
Cuttler (UWA)	0.1	14.4	0.1	14.4
C. Lovelock (UQ)	0.02	5.5	0.02	5.5
Total		**174.9**		**174.9**

Table 3. Co-investment (non-salary cash and in-kind)

Organisation	2023		2024	
	Cash ($'000)	In-kind ($'000)	Cash ($'000)	In-kind ($'000)
UWA	61.25	23	61.25	23
Total	**61.25**	**23**	**61.25**	**23**

Project deliverables and timing.

Timing

The project tasks are planned to span 2 years over the period Jan 2023 to December 2024, inclusive. Several dependencies exist related to data requirements for model setup and validation, that are anticipated here, and will be monitored in case of delays of critical information. An overview of the timing of the project tasks and reporting activities are shown in Table 4.

Deliverables

Project deliverables will include:

- Presentations, progress reports and a project final report covering all tasks (see below)
- Model setup files and curated data, archived on Github
- Scientific publications on the model development and scenario assessment

Deliverable:	Completion date
1. Data review and conceptual model report	July 2023
2. Presentation to the steering committee	September 2023
3. Milestone report	February 2024
4. Presentation to the steering committee	September 2024
5. Final report, and model file and data package	December 2024

Milestones, activity, and payments.

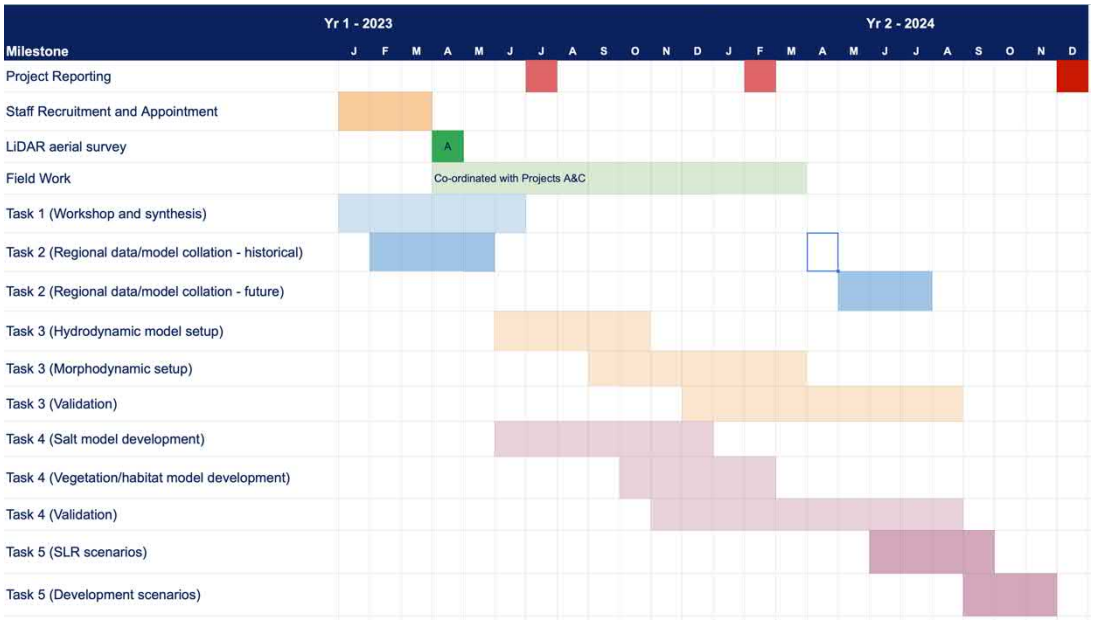

Figure 2. Project B task plan and schedule.

Task focus	Milestones / Major activities	Activity (A) or Milestone (M)	Expected Completion Date	WAMSI Funding ($'000)
2022/2023				
-	Agreement signed	**M**	December 2022	200
-	Appoint staff	A	Feb 2023	
1	Conceptual model workshop	A	March 2023	
-	Field work activities start	A	May 2023	
2	Regional ocean data/model collation	A	June 2023	
2023/2024				
1,2,3	Annual presentation to Steering Committee	**M**	September 2023	150
4	Habitat model development	A	December 2023	
3	Hydrodynamic/morphodynamic model setup	A	February 2024	
2,3,4	Annual report on activities (Tasks 2-4)	**M**	February 2024	150
4	Habitat model development	A	March 2024	
-	Field work activities end	A	April 2024	
3,4	Hydrodynamic and habitat model validation	A	June 2024	
2024/2025				
3,4,5	Annual presentation to Steering Committee	**M**	September 2024	
5	Scenario assessment (Task 5)	A	November 2024	
ALL	Deliver final report	**M**	December 2024	183

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ATTACHMENT 4 –PROJECT SUMMARY MARDIE PROJECT MARINE AND INTERTIDAL RESEARCH OFFSET PROGRAM – PROJECT C.

WAMSI project plan for the Collaborative Project Agreement

Mardie Project Marine and Intertidal Research Offsets Program

Project details

Project Title.
Identifying the ecological roles, values and functions of intertidal benthic communities and habitat

Start Date/End Date.

Project Leaders
Glenn Hyndes and Kathryn McMahon

WAMSI Partner Organisation:
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Scope of the project.

Project summary

Need

This project fits into the offset research program for the conditionally approved Mardie Project (Mardie Minerals Pty Ltd), a solar salt and sulphate of potash production facility in the Pilbara region of Western Australia. Conditional approval under the Ministerial Statement 1175 (MS1175) requires research on the marine and intertidal environment in the region, based "on the significant residual impacts and risks of the proposal to intertidal benthic communities and habitat (BCH) namely mangroves, algal mat and coastal samphire". This will inform future decision-making, management and conservation of the ecological values of BCH on the Pilbara coast.

A preliminary assessment of the Pilbara region indicates that mangroves, cyanobacterial mat and saltmarshes form major coastal intertidal habitats along the shores in the region. Globally, these habitats provide significant ecological functions, including primary production, nutrient cycling, carbon storage as well as foraging, breeding and/or nursery areas for a range of invertebrates, fish and birds (Adame et al. 2021). Furthermore, the immigration and emigration of fauna, as well as the outflow of dissolved nutrients and particulate material from these systems can strongly influence production and diversity in neighbouring ecosystems in the coastal seascape (Hyndes et al. 2014). Despite the recognition of the ecological values of mangroves and saltmarshes globally (Barbier et al. 2011), little is known about the relative value of these systems in arid environments like the Pilbara coast. Also, while cyanobacterial or microbial mats can be extensive and highly productive and diverse (Prieto-Barajas et al. 2018), little is known about their functional role (Penrose 2011, Adame et al. 2021). In Exmouth Gulf where some research has been carried out, cyanobacterial mats are highly productive and form an important source of carbon and nitrogen to nearshore food webs (Lovelock et al. 2010, Penrose 2011, Adame et al. 2021),

suggesting that these mats play an important function to the coastal seascape more broadly across the Pilbara region.

Mangroves, cyanobacterial mats and saltmarshes are influenced by coastal processes such as tides, waves and wind (Lovelock et al. 2011). For example, mangroves occur in wet and arid tropical regions, where they are influenced by the hydrological regime (e.g. tidal range) and evapotranspiration and rainfall that affects salinity and moisture (e.g. Santini et al. 2013, Asbridge et al. 2015). Cyanobacterial mats occur in a range of extreme environments, with coastal mats in intertidal zones subjected to large changes in salinity, temperature and moisture (Prieto-Barajas et al. 2018). The diversity and function of these systems is therefore likely to alter over daily and seasonal scales, and be impacted by climatic events such as cyclones, changes in hydrological cycles associated with coastal developments, and hydrological and atmospheric conditions associated with climate change. Understanding the environmental drivers that influence productivity and ecosystem function of these coastal systems is therefore key to future guidance on proposed coastal developments in the region.

This project will meet the conditions of MS1175 under Condition 14-1(3) by directly aiming to identify the ecological roles, values and functions of intertidal benthic communities and habitat, and will be either informed by or feed into projects addressing Conditions 14-1(1) Project A and 14-1(2) Project B.

Aims

The project will address the following priority objectives outlined in the Mardie Salt Offset Program guidelines:

1. Estimate primary productivity in space and time for algal (cyanobacterial) mat and other BCH;
2. Identify the pathway for transfer of nutrients and energy from BCH to other communities and habitats (e.g. from the intertidal mosaics to the subtidal), which includes trophic transfer (flow of energy) and nutrient transfer to understand ecosystem function; and
3. Identify the key physical drivers such as the response to the wetting and drying associated tidal movement, rainfall, episodic events (storms and cyclones), evaporation etc.

Methods & sampling design

The above objectives will be addressed through a combination of field surveys or field and/or mesocosm experiments across appropriate spatial and temporal scales to account for spatial and temporal variability and influences of hydrodynamic and atmospheric drivers. Our approach is to link field measurements with remote sensing from Project A and models from Project B at 3 sites, which will allow upscaling throughout the region using modelling. Indicative locations are Giralia in southern Exmouth Gulf, Urala and Preston (Figure 1). These sites have been chosen to represent a range of tidal regimes, coastal morphologies and habitat landscape characteristics. Moreover, Giralia has also been the focus of a number of studies led by Prof. Catherine Lovelock (team member). The intent is to focus on the same sites as Projects A and B. Sites may change if negotiations for access to sites and nearby facilities prevent use of one or more site. However, any change in site will made in consultation with WAMSI and the steering committee. Temporal sampling will vary depending on the research question (see below), but will be limited due to budgetary constraints associated with the cost of field work to two years with field trips planned twice a year. One of these trips, is planned to be opportunistic following a significant rainfall event, if it occurs over the life of the project and it is safe to access. See Figure 2 which outlines the timing of each objective and the team members working on each part of the project.

Objective 1 – Primary productivity

Net primary production (NPP) will be estimated for three habitat types: cyanobacterial mats; mangroves; and saltmarshes. For each of the three BCHs, measurements of NPP will be stratified over a gradient from the coastal to landward edge to capture different tidal inundation conditions and species composition of each BCH. The locations of sampling will depend on the landscape configuration at each site. Estimates will be made in two contrasting seasons (e.g. late wet and late dry). Due to the different growth forms and rates of productivity in these different habitat types, different methods will be used to estimate NPP. However, it will be designed in a way so that NPP (g/area/time) can be scaled up to site and regional estimates by area and with the habitat mapping outputs from Project A. This objective will be assessed in Year 1, but as some methods require tagging of plants and measurements after a period of time, the final data collection will occur in Year 2. Sampling at two times will enable an understanding of intra-annual variation, but not inter-annual variation. We acknowledge that inter-annual variation in NPP is likely to be large due to the episodic nature of rainfall events in this region, but due to the limited timeframe of this project and the cost of field campaigns in the region this is not feasible. Environmental variables such as soil salinity, surface salinity, temperature and elevation will also be collected where the NPP estimates are made. Location specific data such as rainfall and evaporation will also be extracted from data repositories for the duration of the study. This information will be used to examine the associations between NPP and these potential environmental drivers.

Cyanobacterial mats

The NPP of cyanobacterial mats will be assessed along a gradient such as distance from tidal influence or elevation to account for the potential variability in NPP due to differential wetting and drying. An "in-growth" technique will be used, where small sections of cyanobacterial mat will be removed and the amount of material that grows into the vacant space assessed over a set time period to enable an estimate of g dry weight per time. The Project Team has experience with performing these experiments and has preliminary data that can help inform the design.

In addition the photosynthetic activity of the cyanobacterial mat (active or dormant) across the spatial extent of the mat in relation to elevation and inundation gradients will be measured using pulse amplitude modulated (PAM) fluorometry to understand how the photosynthetic activity of the mat varies spatially and under different inundation frequencies. This information will assist with validating the regional estimates of cyanobacterial extent and productivity.

Saltmarsh and mangroves

The NPP of saltmarsh will be assessed by two methods, tagging of above-ground structures (e.g. leaves/stems on plants) and spatial extension of plants through markers that outline the perimeter of the plant and the extension beyond these markers is measured. This will give an estimate of new biomass produced over a set period of time (g dry weight per time). In addition, litterfall (detritus) will be estimated to contribute to the NPP estimates. To enable upscaling to site and regional estimates, plot-based measurements such as cover, height and stem density of plants will be recorded so that NPP can be scaled to area based on the cover/density of plants (Howard et al. 2014). The measurements for saltmarsh will be stratified to coastal and landward habitats.

For mangroves, NPP will be estimated through assessment of litterfall (detritus) and tree growth (leaf growth, wood growth using dendrometer bands) and scaled up using plot-based assessments of tree size

(stem diameter and tree height) and density as well as existing allometric relationships. These measurements will be stratified to two mangrove habitat types, lower intertidal fringing mangroves and higher intertidal scrub mangroves).

Objective 2 – Pathway for transfer of nutrients and energy

This objective will be split into two core research questions:

a. Do the pools and outflow of dissolved and particulate nutrients differ between algal (cyanobacterial) mats and other main BCHs?
b. What is the relative contribution of algal (cyanobacterial) mats and other main BCHs to the food web in the coastal seascape?

This objective will be addressed in two contrasting seasons (e.g. late wet and late dry) in Year 1 across the landscape of the intertidal zone and capturing the catchment inflows and outflows, and if possible over an event on at least one occasion. This event sampling will be restricted to dissolved and particulate nutrients as outlined for Objective 2a.

For Objective 2a, both dissolved and particulate nutrients will be sampled across the different habitat community types (e.g. cyanobacterial mats, saltmarsh and mangroves), and in tidal channels and creeks over a tidal cycle, and freshwater in rivers (if present) that form the downstream end of the catchments. The locations and number of samples will depend on the landscape configuration at each site. Water samples will be collected from the water column and sediment porewater and filtered where appropriate. Replicate samples will be collected within each of the key BCHs over the tidal cycle, and from key locations from the catchments. Samples will be collected and processed for concentrations of total dissolved organic and inorganic carbon, total dissolved nitrogen and inorganic nitrogen (NO_x & NH_4^+), and total dissolved phosphorus and PO_3. Suspended particulate organic matter filtered from the water column samples, as well as sedimentary particulate organic matter collected by cores, will be analysed for total organic C, N and P.

Rates of nitrogen fixation of cyanobacteria mats will be determined across three zones along a gradient of tidal influence or elevation to account for the potential variability in N fixation due to different levels of wetting and drying. Replicate samples (1 cm^2) of cyanobacteria mat will be stamped out of the mat at each tidal position and assessed for nitrogen fixation using the acetylene reduction assay (ARA, Brocke et al. 2018). The sections of mat will be taken back to the laboratory, placed in bottles and incubated in flow-through aquaria under controlled day/night and temperature conditions for 24 hours following the procedures of Brocke et al. (2018). Dry weight of the cyanobacteria samples will be determined at the end of the experiment. These data will be used to upscale rates of N fixation at the three sites, where replicate samples of cyanobacteria mat will be collected across the gradient of tidal influence or elevation, dried and weighed. Upscaling at broader spatial scales will be estimated from the habitat mapping in Project A.

To determine the role of cyanobacteria mats in the cycling of nutrients, these mats will be assessed to determine the dominant taxa, followed by metagenomics to determine their functional roles. Replicate samples will be aseptically collected within the mats and stored on ice in sterile bags for DNA extraction, avoiding contamination across samples. Samples will be collected over environmental gradients (e.g. locations exposed to desiccation for different periods over the tidal cycle). DNA extractions will be performed on samples using modified protocols for FastDNA® Spin Kit for Soil (MP Biomedicals). All DNA samples will be quantified, quality checked and sent for 16S rDNA (bacteria) 18S rDNA (eucaryotes) and ITS (fungi) diversity sequencing at Australian Genomics Research Facility (AGRF). Metagenome sequencing will be performed on samples selected based on the diversity analysis results.

The transport of particulate material can also occur through the detachment of cyanobacterial mats. As cyanobacterial mats occur over a narrow range of elevation, reflecting their inundation niche, they can be highly dynamic (Lovelock et al. 2021). When they are desiccated, they can become detached from the sediment and then transported with water flow generated from tides or surface flows. These mats can also become detached during fast surface flows associated with flooding events and transported to the coastal zone. Observations at Giralia, Exmouth Gulf, suggest that detached cyanobacterial mats are transported seaward into adjacent mangroves during ebbing tides, or with southerly winds. How often this occurs (event driven) and how much material is transported is unknown. We will qualitatively measure transport of detached mats using a combination of approaches such as digital imagery from fixed cameras or with a live feed if possible and traps to assess this transport.

For Objective 2b, the food web structure will be determined through a combination of gut content analyses (GCA) and stable isotope analyses (SIA) for the two time periods (e.g. late wet and late dry) and across the different community types (e.g. cyanobacterial mats, saltmarsh and mangroves). For SIA, replicate samples of potential sources of production, including cyanobacterial mat, mangroves, saltmarsh, phytoplankton, benthic microalgae and detritus, will be collected from the key BCHs, and detrital samples and terrestrial vegetation will be collected from the catchments. SIA for these sources and sinks (detritus) will allow the source of material contributing to the detritus across the landscape. In addition, replicate samples of key consumers in each BCH, including benthic meiofauna and macroinvertebrates, zooplankton, insects, and fish will be collected. Benthic invertebrates will be collected using a range of methods including cores and dip nets, while fish will be collected using seine, fyke, gill, scoop and/or throw nets. Species targeted will depend on the relative abundances of species during sampling. Samples will be processed for the determination of $\delta^{15}N$, $\delta^{13}C$ and $\delta^{34}S$ (and possibly $\delta^{2}H$, which has been shown to be a useful tool in mangrove systems; Then et al. 2021). The main potential sources being assimilated by different consumers will be determined using MixSIAR, a Bayesian stable isotope mixing model incorporating uncertainty and variability. Replicate samples of the same consumer species used for SIA will be used for GCA following traditional methods (e.g. Hyndes et al. 1997, Campbell et al. 2021). GCA data will be compiled and subjected to a range of multivariate statistical techniques (i.e. PERMANOVA, RELATE, ordination and shade plots) to determine the main components of the diet of each species and whether they differ spatially, temporally and with increasing size of the taxa.

Feeding ecology of shore birds will be examined using direct observations and dropping analysis from the most abundant species from different size classes (representing different feeding guilds) and when possible, listed species under the EPCA Act. Direct observations provide information on shorebird foraging behaviour, inter- and intra-specific interactions, diet and prey selection. Using video recording, collection of at least 20 to 30 observations (from different individuals) per species, per site and per period will occur prior to other sampling (droppings, invertebrate sampling). When possible, birds will be filmed using digiscoping (camera attached to a telescope) (Estrella et al. 2007, Estrella et al 2015). Where possible, droppings will be collected for shorebirds (Kuwae et al. 2012) for dropping analysis and SIA. Dropping analysis (Dekinga & Piersma 1993, Estrella and Masero 2010) will offer information about diet and prey selection. At least 20 fresh droppings per species per site per period will be collected from monospecific roosts or from areas where only one species has been observed feeding. Droppings will be preserved and analysed in the lab. Droppings will be dis-aggregated in filtered water and sieved though a 50 µm mesh. Hard parts of prey (chironomid heads, polychaete jaws, bivalve hinges, crustacean parts etc.) will be identified and measured. When possible, correlations between prey size and prey hard part size will be developed. SIA for shorebird droppings offer reliable information on short-term diets in shorebirds (Kuwae et al. 2022), and will be analysed as described above for fish samples.

Objective 3 – Key physical drivers

The key physical drivers that affect cyanobacterial mat productivity, nutrient cycling including nitrogen fixation and the flow of nutrients with events will be assessed through a combination of field and mesocosm experiments. The drivers investigated will include soil salinity, surface water salinity including addition of fresh water to simulate rainfall events, elevation, tidal inundation frequency, wetting and drying duration and frequency. These variables have been selected because inundation regimes are linked to intertidal elevation, but are modified by wind speed and direction, sea level and sea level variation, evaporative demand influencing salinity, and attenuation of tidal flows by mangroves (Lovelock et al. 2010, Prieto-Barajas et al. 2018). The field experiments will start in Year 1 and continue into Year 2 whilst preliminary mesocosm experiments will commence in Year 1, but with most focus in Year 2. Opportunistic sampling is also planned over an event such as a large rainfall event to understand how these events influence the flux of nutrients from the cyanobacterial mats to the marine environment. This event sampling requires an event to occur over the project period which is not too extreme as this will likely limit access. The data collected in Objective 1, 2 and 3 can be incorporated into Project B to model the fluxes. For example, the leaf litter production can be used to estimate particulate fluxes and the nutrient pools and flows can be used to estimate dissolved fluxes. Due to logistic reasons, all aspects of this objective will not be conducted at all three sites. For example, it would not be possible to access all sites over an event.

Field and experimental studies will be linked with mapping of cyanobacterial mats in Project A and modelling in Project B to assess how climate (e.g. wind, temperature, humidity) moderates tidal inundation over the intertidal landscapes and NPP and nutrient fluxes of cyanobacterial mats.

Field experiments

The approach for the field experiments is to assess the associations in the natural environment over gradients to understand potential drivers. As these assessments will take place in the field, it will need to take a different measurement approach to Objective 1 and 2. Firstly, productivity and nutrient fluxes will be assessed over gradients based on elevation/tidal inundation and over tidal cycles (e.g. falling vs rising tide and spring vs neap tides). These gradients will be characterised by elevation with RTK GPS, water level and inundation and salinity using loggers. The photosynthetic activity of the cyanobacterial mats will be assessed using a pulse amplitude modulated (PAM) fluorometer giving an estimate of active or dormant mats. Chamber experiments that measure oxygen evolution and nutrient fluxes will quantify the rates of productivity and nutrient fluxes along this gradient. For example, for productivity these small-scale, short-term chamber assessments will measure oxygen evolution using FireSting™ 3 mm robust REDFLASH technology sensors (Pyroscience) following a similar approach to Said et al (2021).

The second proposed approach is to place settlement structures in the field along the established gradient to identify where cyanobacteria mats develop. The colonisation and increase in biomass over time will be an estimate of NPP. The approach of gradients used by Kirwan and Guntenspergen (2015) for evaluating growth of saltmarshes over inundation gradients will be used where a series of PVC pipes of different lengths that represent different levels of elevations/inundation will be deployed in the cyanobacterial mat habitat. Sediment surfaces within the pipes that are colonised by cyanobacteria indicate inundation levels that support cyanobacterial mat development.

Laboratory experiments

The field experiments will identify potential drivers of productivity and nutrient fluxes in cyanobacterial

mats where the controlled laboratory experiments will enable testing of the drivers under controlled conditions. These results will feed into modelling and enable simulation of scenarios of rainfall or surface flows which are not possible to measure in the field. There are several potential factors that can be tested in these experiments and these will be confirmed following insight from the field work. For example, how salinity from fresh (representing rainfall) to hypersaline (representing cyanobacterial mat conditions) could be manipulated to assess the effect on productivity and nutrient fluxes. Other factors could include the duration and frequency of drying and wetting, and the response time for cyanobacterial mats to become productive. To carry out these experiments, sections of cyanobacterial mat will be removed from the site and transported to mesocosm facilities at ECU. Under controlled day/night conditions cyanobacterial mat will be exposed to a range of treatments. It is envisaged that multiple experiments will be carried out to test a range of different factors (e.g. salinity, wetting and drying duration and frequency). Like in the field experiments, O_2 production will be measured over the course of the experiment as an estimate of NPP, as well as nutrient fluxes, and the production of soluble materials (complex carbohydrate films) which is more challenging to measure in the field.

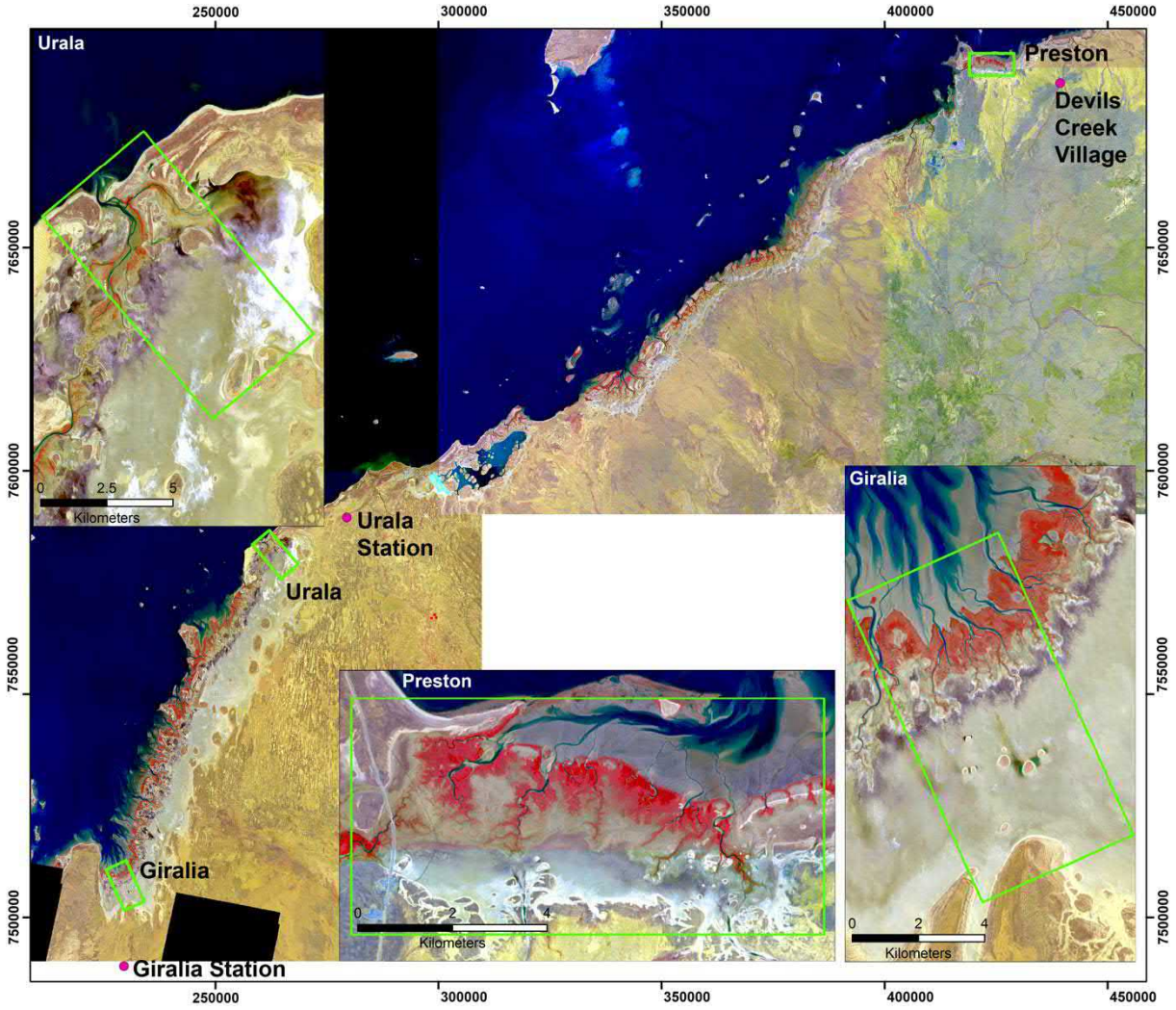


Figure 1. Indicative locations for sampling sites for Projects A, B and C. The final locations will be confirmed at the beginning of the project and after negotiations with land and facility holders and engagement with traditional owners.

Objective		Community type	Year 1	Year 2	Event	Lead
Obj. 1	Productivity	Cyanobacterial mat				McMahon & Lovelock
		Mangrove & Saltmarsh				McMahon & Lovelock
Obj. 2	Nutrient transfer & energy flows	Nutrients				Hyndes & Watkin
		Food webs				Hyndes, Marin-Estrella & Tweedley
Obj. 3	Physical Drivers	Cyanobacterial mat				McMahon

Figure 2. The timing of the four objectives in Project C.

Describe how data will be secured during the project.

Collected data will be stored on solid state drives and also uploaded to secure cloud storage available to all project investigators and research staff and students.

Linkages

Mardie Salt Projects.

Project C has strong links and co-dependence with Projects A and B. We will work closely together to ensure the required data is collected at the appropriate spatial and temporal resolution to enable integration and to maximise efficiencies. Mapping of the BCHs in Project A will allow data collected from this study to be scaled up to regional levels, while this study will also provide data for modelling of the potential effects of sea level rise on BCHs and identifying the significance of salt projects in preventing the adaptation of intertidal BCH to sea level rise in Project B.

External projects

Project C also has synergies with other external projects including:

- The offset project entitled “Primary productivity and energy transfer between marine ecosystems” being carried out in the Dampier Archipelago by DBCA.
- ARC Australian Laureate Fellowship of Prof. Lovelock on activating blue carbon for coastal restoration with sites established in the Pilbara.

Implications for Management

This project will identify and provide key data on the ecological roles, values and functions of intertidal benthic communities and habitat in the Pilbara that will feed into background information for future EIAs of proposed solar salt production developments in the region.

Risks to delivery and how they will be managed.

The following outline the risks associated with the project:

1. The delay in getting sign-off on the agreement leads to a delay in the start of the project and the ability to order equipment in advance and recruit staff to collect samples and analyse the data (High risk). This will be managed by gaining feedback on the draft agreement from ECU's legal services in advance and fast-tracking of staff recruitment to the best of our ability.
2. The delay in sign-off on the agreement leads to missing key sampling times that are restricted to climatic conditions in the Pilbara region, e.g. high temperatures and cyclone events. This would lead to delays in field sample collection and subsequent processing and data analyses (High risk). Management of this risk will depend on when the agreement is signed, staff can be recruited, and timing in relation to key sampling times.
3. Delayed or lack of access to sites and nearby facilities for field activities, leading to a need to determine and negotiate access to new field sites. This will be managed by starting negotiations on site and facility access before the agreement has been signed.
4. Mesocosm equipment failure leading to delay in cyanobacteria mat experiments (Medium risk). This will be managed by ensuring the equipment is maintained regularly.
5. Tampering, damage or loss of equipment such as temperature and depth loggers (Low risk). This will be managed by ensuring that the deployed equipment is concealed and secured as much as possible.
6. Staff and PhD student resignation/sickness leading to delays in progress (Low risk). Staff and students will be managed and mentored effectively. In the event staff member resigns, recruitment for a replacement will take place. All team members, with the exception of the two new staff to be employed, are on continuing contracts.

Outcomes.

- The outputs of this project will help meet the conditions of MS1175 under Condition 14-1(3) by identifying the ecological roles, values and functions of intertidal benthic communities and habitat.
- The outputs of this project will feed directly into the EIA process for future salt production developments in the Pilbara region.
- This project will provide baseline data on primary productivity in space and time for algal (cyanobacterial) mat and other BCH.
- This project will identify the pathways for transfer of nutrients from catchments to and between BCHs, and trophic transfer (flow of energy and food web structure) into and out of BCHs, to understand ecosystem function.
- This project will provide an understanding of the nutrient cycling, including nitrogen fixation, of algal (cyanobacterial) mats.
- This project will identify key physical drivers that influence primary productivity of cyanobacteria mats, focusing on this BCH's response to the wetting and drying associated tidal movement, and episodic events such as rainfall.

Project Team.

Name	Organisation	Role	• Tasks
Prof Glenn Hyndes	ECU	Project co-lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at ECU. Design of field and mesocosm experiments and approach. Review of analysis and report writing. Involved with other projects related to this one to facilitate the exchange of samples and data to minimize costs and duplication.
A/Prof Kathryn McMahon	ECU	Project co-lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at ECU. Design of field and mesocosm experiments and approach. Review of analysis and report writing. Involved with other projects related to this one to facilitate the exchange of samples and data to minimize costs and duplication.
Dr James Tweedley	MU	Team member	• Design of field work and approach for trophic food web studies with a particular focus on invertebrates and fish. Review of analysis and report writing.
Prof. Elizabeth Watkin	ECU	Team member	• Design of field and laboratory work for and approach for cyanobacterial mat function using genomic analyses. Review of analysis and report writing.
Dr Sora Marin-Estrella	ECU	Team member	• Design of field and laboratory work and approach for trophic food web studies with a particular focus on birds. Review of analysis and report writing.
Prof. Catherine Lovelock	UQ	Team member	• Design of field work and approach for primary productivity estimates. Review of analysis and report writing.
Postdoctoral Fellow	ECU	Team member	• Coordinating field and laboratory work, data curation, complex statistical analysis of data and report writing.
Research Assistant	MU	Team member	• Assisting fieldwork and sample processing.
2 PhD students	ECU and MU	Team member	• Develop research that complement/extend on plans. Assisting fieldwork and sample processing, statistical analysis and writing.

Data and IP Management

This project will generate the following types of data.

(i) Primary productivity data for cyanobacteria mats, mangroves and saltmarshes at different locations and times. Data will be in Excel format with associated meta-data.

(ii) Concentration data for particulate and dissolved organic and inorganic carbon and nutrients in different habitats across locations and times, as well as nitrogen fixations data for cyanobacteria mats. Data will be in Excel format and include imagery with associated meta-data.

(iii) DNA sequencing and metagenomic data for the diversity and functional groups contributing to the cyanobacterial mat communities. Data will be in Excel format with associated meta-data.

(iv) Dietary data from GCA and birds from direct observations and dropping analyses across habitats, locations and times. Data will be in Excel format and include imagery with associated meta-data.

(v) Isotopic signatures (Carbon, Nitrogen and, for some taxa, Sulphur) for a suite of biota ranging from primary producers to apex predators. Essentially an Excel spreadsheet of the sample, the signatures and associated meta-data.

(vi) Data on the key physical drivers that affect cyanobacterial mat productivity, nutrient cycling including nitrogen fixation from field and mesocosm experiments. Data will be in Excel format with associated meta-data.

These data will be stored on solid state drives and also uploaded to cloud storage available to both project leads, the post-doctoral fellow and research assistant, and PhD students.

Edith Cowan University and Murdoch University are strong supporters of open access data and have long-standing commitments to curation and storage of research data. We follow the *Responsible Conduct of Research Policy*, developed in accordance with the *Australian Code for the Responsible Conduct of Research*. This involves correct collection, storage, protection and retention of data that we gather, as part of our research. WAMSI is also committed to the management and longevity of research data, with policies on *Access, storage, management and security of data* for the purpose of preserving data from unauthorised access, loss and misuse, and to ensure fulfilment of compliance requirements, ensure privacy and to optimise storage space. Publishing our outcomes will require that data sets are submitted to curated, citable, publicly available archiving sites, such as the Dryad Digital Repository (www.dryad.org), when required for journal publication.

Background IP

IP associated with this project includes:

- Previous data collected by Prof Lovelock and team in the Pilbara including timeseries data on mangrove, saltmarsh and cyanobacterial mat productivity, nutrient transfer and cycling in these habitats and environmental drivers of these processes.
- Previous data collected by ECU in the Pilbara on groundwater discharge in nearshore coastal including nutrient and metal concentrations and surface water nutrient data and nutrient composition and isotopes of primary producers.
- Previous data collected by ECU on mangrove standing biomass and productivity as well as environmental drivers of mangrove and saltmarsh distribution and productivity in the Pilbara.
- Previous data collected by ECU stable isotopes of biota in intertidal areas of Roebuck Bay, north-western Australia.

Project Funds Requested.

The budget is based on salary and operational costs over 2.5 years, starting in April 2023. The total funds requested amounts to $1,000,000 that is to be supported by a total in-kind contribution of $1,484,030 and cash contribution of $100,000 from the partner institutes.

Salaries: A Postdoctoral Fellow will be required to coordinate the extensive field campaigns and undertake key aspects of the laboratory work, along with writing the report (Postdoctoral Fellow Level B Step 1, 1.0 FTE for 2.5 years, $385,761 including 17% oncosts for superannuation, salary tax). A Research Assistant will be required for a 2.25-year period to assist with the field work and extensive laboratory processing for core aspects of the project (HEW5 Step 1, 1.0 FTE, $228,567). A total $15,600 is allocated for consultancy services (Dr Ben Fitzpatrick) for advice on the region during a planning workshop and during the pilot field trip to finalise the field program for sampling trips.

Equipment costs: A Mudd-Ox all-terrain vehicle (and trailer to transport the vehicle) will be required to access the mud flats and other habitats with minimal damage to the habitats at a cost of $54,000 (excluding GST). Other equipment will be purchased from ECU's cash contribution (see Co-investment below).

Operating costs: The field work budget is based on accommodation ($500 per day), vehicle hire and fuel costs related to the transport of equipment and staff ($3,000 for 25 days plus fuel), and flights to transport remaining staff to Exmouth) for 4 field campaigns (2 each in Years 1 and 2). Return flights from Queensland have also been included for C. Lovelock (2 per year in Years 1 and 2, and 1 in Year 3). Budget is also allocated to a pilot field trip in Year 1 and an opportunistic sampling trip during a high flow event to sample nutrients off the catchment. Vehicle hire costs have also been included for travel requirements in the Perth metro region. Consumable costs include costs associated with items needed for fieldwork (e.g. bags, tags, ethanol, tapes, fuel for all-terrain vehicle and air freight costs for rapid transport of DNA samples for correct storage at ECU) and laboratory processing (e.g. tubes and tin cups for stable isotope samples, ethanol and other chemicals, and vehicle costs for transport between ECU, MU and UWA).

Stable isotopes analyses cost $17 per sample for δ13C and δ15N (ECU rates), and $24.50 per sample for δ34S (UC Davis rates). Nutrient analyses will include dissolved organic and inorganic carbon ($50 per sample at SCU) and dissolved inorganic N and P ($52 per sample at SCU). Costs for DNA and metagenomic sequencing are based on $300 per sample for each form of sequencing at AGRF. Budget is also allocated to an opportunistic nutrient sampling during a high flow event.

<u>Co-investment</u>

In-kind salaries (FTE) are based on the contributions of team members employed at ECU, MU and UQ. ECU and MU have waived their University Service Charge (USC) on research grant income. For consistency across universities, a 30% USC has been applied to the total funds requested for each institute as in-kind contributions. Other in-kind contributions relate to use of infrastructure such as aquarium and mesocosm facilities, as well as relevant equipment. ECU and MU will each provide a PhD scholarship (total of 2) at ~$30,000 per year, and ECU will provide a cash contribution of $100,000 to contribute towards equipment and consumable costs. Salinity and temperature loggers (4), temperature loggers (10) and FireSting probe sensors to measure O_2 production will be provided as in-kind support to measure environmental variables that are likely to form major drivers of NPP and diversity in the BCHs. Digital camera traps (7) and Zeiss binoculars will be provided by ECU, while corers and fishing nets will be provided as in-kind support from both ECU and MU. MU will also provide an Eckman grab. ECU will provide basic lab equipment for DNA extraction and preparation for sequencing of the mat samples.

Additional salinity and temperature loggers (@$1,800) and water level loggers (@$745), and replacement FireSting probes (Total $8,000) will need to be purchased from ECU's cash support. In addition, telescope attached to an SLR camera will be required for bird foraging surveys, and additional nets will need to be constructed for fish sampling.

Table 1. Funds requested from WAMSI

Year	2023	2024	2025	TOTAL
Salaries-Postdoctoral Fellow (2.5 yrs)	107.4	154.7	123.6	385.8
Salaries-Research Assistant (2.5 yrs)	55.6	97.5	55.5	228.6
Consultancy services	15.6			15.6
Mudd-Ox all-terrain vehicle & trailer	54.0			54.0
Field costs (vehicle, accommodation and food)	38.6	38,6	5.0	82.1
Perth metro travel-car hire	0.6	0.6	0.3	1.5
Consumables	10.0	10.0	4.0	24.0
Airfares	8.2	8.2	0.9	17.3
LiDAR/Hyperspectral data (shared across 3 projects)	75.0			75.0
Stable isotope analyses	15.2	15.2	5.0	35.4
DNA sequencing analyses	9.9	9.9		19.8
Nutrient analyses	20.3	20.3	20.3	60.9
Total WAMSI ($'000)	**434.3**	**355.8**	**209.9**	**1,000.0**

Table 2. Co-investment (staffing)

Organisation	2023		2024		2025	
	FTE	($'000)	FTE	($'000)	FTE	($'000)
G. Hyndes (ECU)	0.2	50	0.2	50	0.2	50
K. McMahon (ECU)	0.2	43	0.2	43	0.2	43
S. Marin-Estrella (ECU)	0.1	16	0.1	16	0.1	16
E. Watkin (ECU)	0.1	25	0.1	25	0.1	25
J. Tweedley (MU)	0.1	40	0.1	40	0.1	40
C. Lovelock (UQ)	0.05	25	0.05	25	0.05	25
Total	0.75	200	0.75	200	0.75	200

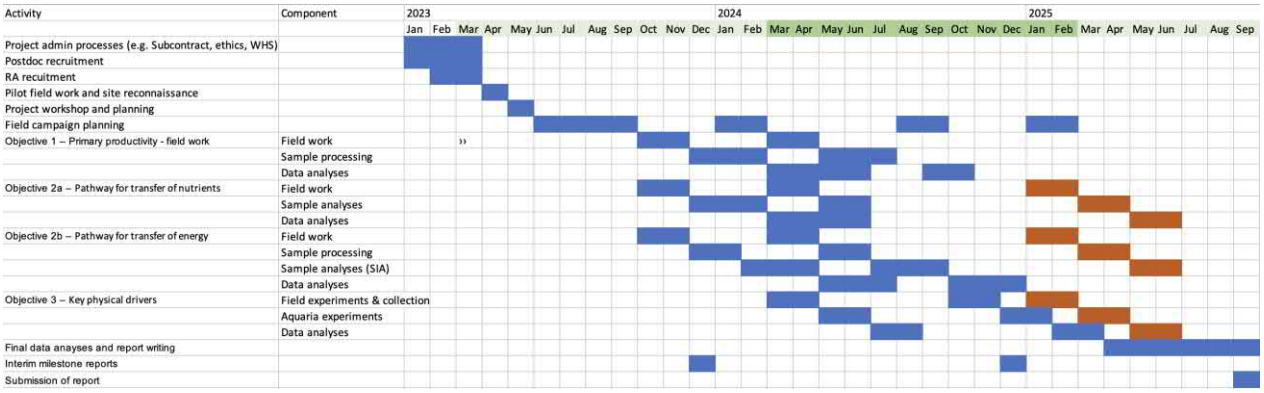
Table 3. Co-investment (cash and in-kind)

Organisation	2023		2024		2025	
	Cash ($'000)	In-kind ($'000)	Cash ($'000)	In-kind ($'000)	Cash ($'000)	In-kind ($'000)
ECU	80.0	130.9	20.0	107.3		46.8
MU		59.4		59.7		45.1
Total	**80.0**	**190.3**	**20.0**	**167.1**		**121.8**

Project deliverables and timing.

Deliverable:	Completion date
1. 1st Annual presentation	Last quarter 2023
2. Milestone report	December 2023
3. 2nd Annual presentation	Last quarter 2024
4. Milestone report	December 2024
5. 3rd Annual presentation	July 2025
6. Final report	September 2025

Table 1 – Project C schedule



Note: timing for event sampling represented in orange will depend on when or if an event occurs during the project's timeline.

Milestones, activity, and payments

Year	Milestones / Major activities	Activity (A) or Milestone (M)	Expected Completion Date	WAMSI Funding ($'000)
2023				
1.1	Agreement signed	M	December 2022	436.3
1.2	MU agreement signed	A	February 2023	
1.3	Appoint Postdoc and RA	A	April 2023	
1.4	Pilot field trip and workshop	A	May 2023	
1.5	Season 1 field trip/data collection	A	November 2023	
1.6	Annual report on activities 1.3-1.5	M	December 2023	357.8
2024				
2.1	Season 2 field trip/data collection	A	April 2024	
2.2	Mesocosm experiments		June 2024	
2.3	Sample processing & data analyses	A	September 2024	
2.3	Physical drivers field trip	A	November 2024	
2.4	Annual report on activities 2.1-2.3	M	December 2024	105.9
2024/25				
3.1	Mesocosm experiments	A	February 2025	
3.2	Seasonal event field trip/data collection	A	February 2025	
3.3	Sample processing & data analyses	A	April 2025	
3.4	Deliver final report • Primary productivity • Pathway for transfer of nutrients • Pathway for transfer of energy • Key physical drivers	M	September	100.0

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ATTACHMENT 5 – PROJECT PROPOSAL FOR MARDIE PROJECT GREEN SAWFISH

Attachment 5

WAMSI SUMMARY OFFESTS PLAN

Mardie Project – Green Sawfish (*Pristis zijsron*)

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Frontispiece: A Green Sawfish (*Pristis zijsron*) seeking refuge in a shallow Pilbara mangrove during high tide, where they seek refuge from predators whilst also hunting prey (Photograph: David Morgan).

Attachment 5

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Attachment 5

WAMSI SUMMARY OFFSETS PLAN

Mardie Project – Green Sawfish (*Pristis zijsron*)

1 Introduction

In January 2024, the Western Australian Marine Science Institution (WAMSI)/BCI Minerals Limited (BCI) *Summary Offsets Plan: Mardie Project* was revised to include, amongst other things, how the plan informed strategic protection, better management and long-term functionality of Green Sawfish habitat. Specifically, the revised offset plan included a research proposal which included a program that seeks to determine species presence, distribution and population sizes of Green Sawfish, as well as identify the trophic transfer from benthic communities and habitat (BCH) to Green Sawfish.

This Research Project is proposed as an addendum to the broader WAMSI Research Summary offsets plan (SOP) and specifically aims to address the Marine Research Objectives for Green Sawfish habitat as prescribed by condition 29 of EPBC 2018/8236, which includes the commissioning of research projects to inform better management and long-term ecological functionality of Green Sawfish habitat.

At present, there are significant knowledge gaps about the locations, extent and connectivity of biologically important habitats used for Green Sawfish along the Pilbara coast, including pupping, nursery, feeding and aggregation (DoE, 2015b, Research Objectives 8c and 9b). Quantitative information about sawfish occurrence and population trends is also lacking (DoE, 2015b, Research Objectives 3a and 8a).

The research proposal focuses on undertaking field survey work and data collection at two key sites which are currently lacking in knowledge; the Mardie Project area and Fortescue River (Study Site 1), and the Onslow/Ashburton area (Study Site 2). A key outcome of the sawfish research program will be to acquire information that will allow the identification of critical habitat across the West Pilbara Coast and quantification of threats to this habitat so as to inform the strategic protection, better management and long-term ecological functionality of Green Sawfish.

2 Objectives and scope

The overall objective of the proposed Green Sawfish research program is to advance the marine research objectives listed in EPBC approval 2018/8236 (issued on 12 January 2022). The EPBC marine research objectives stipulate that research should inform the strategic protection, better management and long-term ecological functionality of Green Sawfish. The proposed research program aims to contribute to the marine research objectives by addressing important knowledge gaps concerning the:

- abundance and distribution of Green Sawfish along the Pilbara Coast;
- Green Sawfish habitat use, residency and migration patterns in key nurseries;
- Green Sawfish population genetics and kinship; and
- trophic interactions with sympatric predators and prey.

It is proposed that this study will address knowledge gaps by undertaking the following tasks:

1. Determining the distribution, abundance and habitat value of Green Sawfish in proximity to Mardie (Fortescue River) and compare to Onslow (Ashburton River). The Fortescue and Ashburton rivers are the only two large river systems in the Southern Pilbara and each is a

known pupping site with adjacent tidal creeks potentially acting as secondary nurseries (see Morgan et al. 2015, 2017, 2023a & 2023b, Lear et al. 2023, Morgan and Lear 2023).

2. Synthesizing available data on population genetics, kinship, habitat use, and migration patterns for Green Sawfish where possible, with four additional surveys and acoustic tracking in key areas such as Mardie (Fortescue River) and Onslow (Ashburton River), aligned to time with pupping (spring) and autumn when young of the year may leave their natal habitat (see Morgan et al. 2015, 2017, Morgan and Lear 2023, Ingelbrecht in press 2024). Twice yearly sampling at these two locations will allow acoustic gear to be serviced and downloaded and recaptured sawfish to be examined for growth and body condition (girth) (see Lear et al. 2023, Morgan and Lear 2023).
3. Providing a food web analysis of Green Sawfish using the results of prey DNA analysis from cloacal swabs and data from stable isotope analyses of tissue samples.

The proposed research program will inform the marine research objectives by addressing important knowledge gaps including:

- Providing new information and data informing presence, abundance, migratory patterns and ecology of the Green Sawfish in the Pilbara region.
- Green Sawfish population genetics, kinship and population structure across the study sites.
- Trophic interactions with prey species informing an understanding of growth rate differences across Pilbara sites**.**
- Habitat connectivity, site fidelity and dispersal range of the Pilbara population
- By identifying important biological areas, such as new nursery habitats and key foraging areas.

Key outcomes informing the strategic protection, better management and long-term ecological functionality of Green Sawfish habitat include:

- Definition of critical habitat across the West Pilbara Coast, with a focus on understanding the importance of the Fortescue River (currently lacking survey data), and which is currently considered a likely key potential nursery habitat.
- Understanding the connectivity and importance of the Onslow population and its movement across the Pilbara sites through additional genetic studies.
- Inform an understanding of key threats, particularly the barrier effects of marine infrastructure on migration through examining age classes (i.e. small juveniles) found at the Cape Preston site.

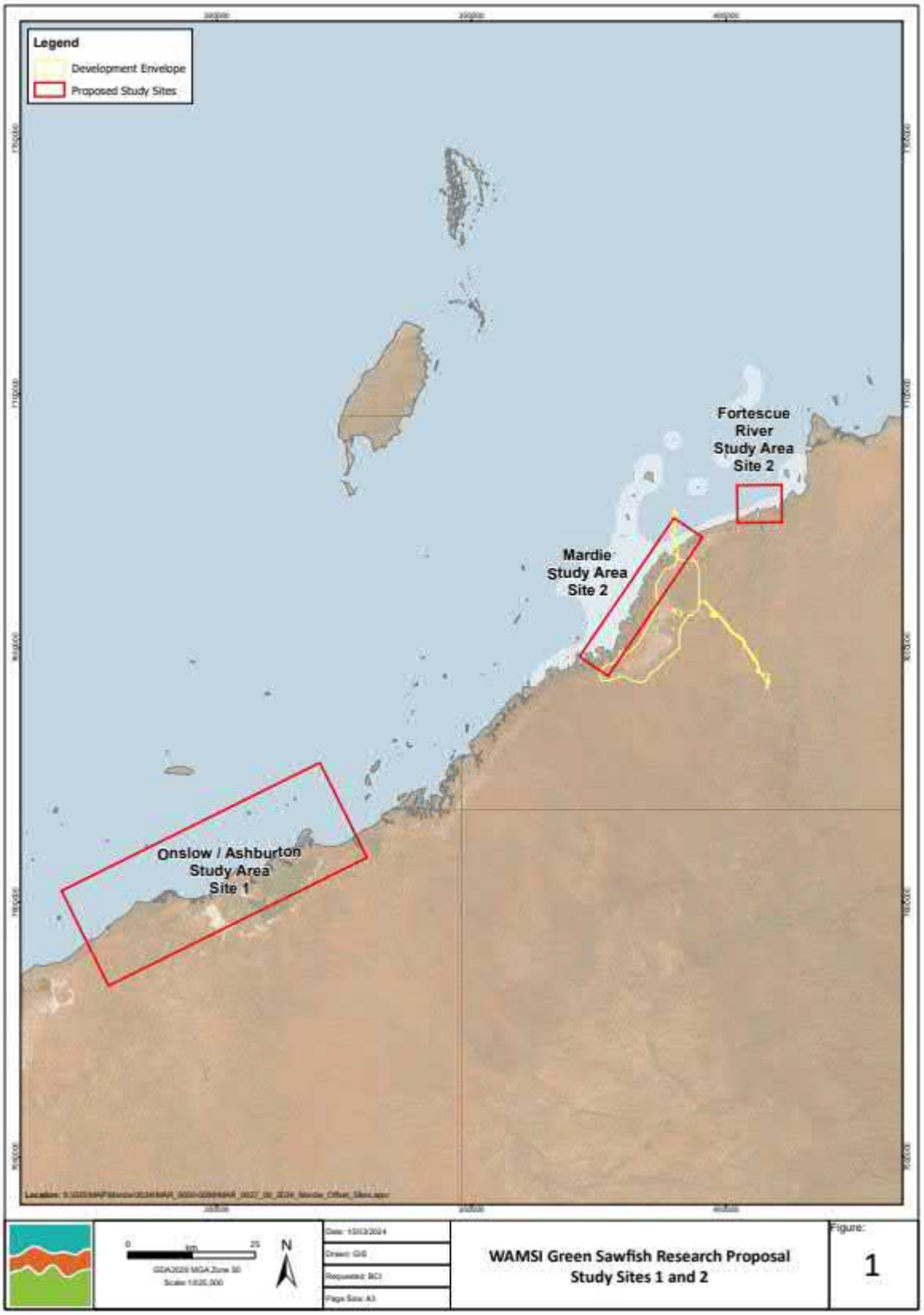

Figure 1: Proposed field study sites along the Pilbara coast

3 Recovery Plans – Meeting Marine Research Objectives

Detailed below are the key linkages between the proposal's objectives and the EPBC ACT research priorities for the species listed in the Commonwealth's *Sawfish and River Sharks Multispecies Recovery Plan* (DoE, 2015b) and *Sawfish and River Sharks Multispecies Issues Paper* (DoE, 2015a). It is noted that Murdoch University, led by Dr David Morgan (Project Leader), substantially contributed to the drafting of these plans, which relied upon the field work data collected by Murdoch University from the early 2000's, as well as technical expertise and knowledge of the species and region, developed over an academic career spanning 30 years.

- *Sawfish and River Sharks Multispecies Recovery Plan* (DoE, 2015b) – at the time that this report was published, Green Sawfish were protected in Western Australia under the *Fish Resources Management Act 1994,* the *Wildlife Conservation Act 1950*. One of the objectives of the plan is to: *Reduce and, where possible, eliminate any adverse impacts of habitat degradation and modification on sawfish and river shark species.* Another is to *Develop research programs to assist conservation of sawfish and river shark species.* This project will address these objectives by identifying important habitats to different age classes and determining extent of habitat use (residency) and relative abundance within nurseries. Under the *Recovery Plan,* the project will be deemed to be successful if habitat critical to the survival to Green Sawfish has been identified and mapped, and that appropriate measures are put in place to manage key threats.
- *Sawfish and River Sharks Multispecies Issues Paper* (DoE, 2015a) – it is only very recently that detailed biological information has been gathered for Green Sawfish, most after the publication date of the Multispecies Issues Paper. For example, none of the references cited in the paper included genetic or biological material from the southern Pilbara; the location where much of the recent research has been conducted (e.g. Morgan et al. 2015, 2017, Ingelbrecht et al. 2022, Lear et al. 2023, Morgan and Lear 2023, Bateman et al. 2024, Harry et al. 2022).
- *Listing advice - Pristis zijsron (Green Sawfish)* (Threatened Species Scientific Committee, 2008).

4 Alignment with DCCEEW criteria for Research-based offsets

4.1 EPBC Offsets Policy

Appendix A of the EPBC Act Environmental Offsets Policy provides five key criteria to be addressed by a research project:

- Criteria 1 - Improve the viability of the impacted protected matter
- Criteria 2 - Be targeted toward key research/education activities
- Criteria 3 - Be undertaken in a transparent, scientifically robust and timely manner
- Criteria 4 – Be undertaken by a suitably qualified individual or organisation in a manner approved by the Department
- Criteria 5 - Consider best practice approaches.

Details of how the research project meets these criteria are provided in Table 1. Details of how the research projects meets the requirements of EPBC 2018/8236 are provided in Table 2.

Table 1: DCCEEW Criteria for research programs

No.	Criteria	Project Suitability
A suitable research or education program must:		
• 1	Endeavour to improve the viability of the impacted protected matter, for example 1. signage in key areas to educate the public regarding the risks to a threatened animal, or 2. research into effective re-vegetation techniques for a threatened ecological community	The proposed research program will improve the viability of Green Sawfish by addressing important knowledge gaps aligned with the marine research objectives, including: • providing new information and data informing presence, abundance, migratory patterns and ecology of the Green Sawfish in the Pilbara region • Green Sawfish population genetics, kinship and population structure across the study sites • Trophic interactions with prey species informing an understanding of growth rate differences across Pilbara sites • Habitat connectivity, site fidelity and dispersal range of the Pilbara population • identifying important biological areas, such as new nursery habitats and key foraging areas Key outcomes informing the strategic protection, better management and long-term ecological functionality of Green Sawfish habitat include: • Define critical habitat across the West Pilbara Coast, with a focus on understanding the importance of the Fortescue River (currently lacking survey data), which is currently considered a key potential nursey habitat • Understanding the connectivity and importance of the Onslow population and movement across the Pilbara sites through additional genetic studies • Inform an understanding of key threats, particularly the barrier effects of marine infrastructure on migration through examining age classes (i.e. small juveniles) found at the Cape Preston site Signage has already been installed at Onslow relating to sawfish for other research projects. Signage will also be erected at the Fortescue River boat ramp as part of this project.

No.	Criteria	Project Suitability
• 2	Be targeted toward key research/ education activities as identified in the relevant Commonwealth approved recovery plan, threat abatement plan, conservation advice, ecological character description, management plan or listing document.	This project will address these objectives by identifying important habitats to different age classes and determining extent of habitat use (residency) and relative abundance within nurseries. Under the *Recovery Plan,* the project will be deemed to be successful if habitat critical to the survival to Green Sawfish has been identified and mapped, and that appropriate measures are put in place to manage key threats. Much of the published research into Green Sawfish in Western Australia has occurred since the recovery plan was published. The results of the current study will be useful when these plans are updated/reviewed – e.g. Morgan et al. 2015, 2017, 2023, Phillips et al. 2017a, b, Ingelbrecht et al., 2022, 2023, Lear et al., 2023., Bateman et al. 2024). We note that the recovery plan was due to be updated in 2020.
• 3	Be undertaken in a transparent, scientifically robust and timely manner	Each methodology in each section is scientifically robust, and contemporary to our recently evolving understanding of Green Sawfish (e.g. see Lear et al. 2023, Morgan et al., 2023, Morgan and Lear 2023).
• 4	Be undertaken by a suitably qualified individual or organisation in a manner approved by the department	The team at Murdoch University has been undertaking sawfish research in Western Australia since 2001. The team leader Associate Professor David Morgan has spent over 30 years studying threatened fishes. Please refer to Section 13 (References)
• 5	Consider best practice research approaches.	The Team has spent a great deal of time developing best practice in sawfish research, such as tagging, placing the fish in a state of tonic immobility, and developing the project with Animal Ethics Committees and Government organisations.

Table 2: Specific requirements of approval EPBC 2018/8236

No.	Criteria	Project Suitability
A suitable research program must:		
1	Will be tailored to at least a postgraduate education level; however, there will be scope to engage other educational levels in educational programs (see below).	The project will partially employ a Post-doctoral Researcher, and two PhD students will be involved in the project.

No.	Criteria	Project Suitability
A suitable research program must:		
2	Will present findings that can be peer-reviewed.	This research will be conducted to a standard that will allow the findings to be published in a peer-reviewed scientific journal. The research project report will be peer reviewed prior to publication.
3	Will publish findings in an internationally recognised peer-reviewed scientific journal or be of a standard that would be acceptable for publication in such a journal. Publications should be submitted to free open access journals. Data and information collected should have creative commons licensing and be free and accessible.	This research will be conducted to a standard that will allow the findings to be published in a peer-reviewed scientific journal. The research team will submit any published findings into open-access peer-reviewed paper in an international conservation science journal. Please refer to Section 13 (References) for evidence of this project team's strong record in publishing previous related research. Spatial data will be provided to government and non-government stakeholders for inclusion in their biodiversity databases.
4	Research outputs should inform future management decisions on the protected matter and, where possible, be readily applicable to other similar matters (species groupings etc).	All research outputs will be delivered to Approval organisations, who will be able to consider the outputs, and each should assist in the needed review of the sawfish recovery plan. As per the Environmental Offset Policy criteria for research programs, publications (including media releases, website updates, and research papers) will be provided to DCCEEW as soon as possible and at least five working days before release.

5 Current Relevant Studies / Available Information

A significant amount of scientific work has been completed since the publication in 2015 of the *Sawfish and River Sharks Recovery Plan* (DoE, 2015b).

The Harry Butler Institute notes that the highest amount of effort in targeting Green sawfish has occurred within the mangrove creeks between Onslow and the Ashburton River estuary, where the Institute has previously deployed ~900 x 20-m gill net hours as well as conducted over 150 drone surveys, some of which extended to Yammadery (see Morgan et al. 2015, 2016, 2017, Ingelbrecht et al. 2022, Lear et al. 2023, Bateman et al. 2024). Furthermore, Murdoch's team is currently tracking

Green Sawfish with an acoustic array in two of the Offset regions (Onslow and Gnoorea), although the vast majority of individuals have been tagged near Onslow.

Table 3 represents a summary of previous targeted surveys for sawfish within the four areas identified in the WAMSI Offsets Plan: Mardie Project.

Table 3: Summary of Murdoch University targeted sawfish surveys within the WAMSI Offsets Plan: Mardie Project

	YEAR							
SITE	2011	2014	2016	2019	2020	2021	2022	2023
Giralia				CPUE	CPUE			
Onslow	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE
Yammadery						DRONE	DRONE	
Gnoorea							CPUE	CPUE/DRONE

CPUE = catch per unit effort which represents gill net sets; DRONE = targeted drone surveys. Onslow includes surveying of 3-4 mangrove creeks and the Ashburton River estuary. Additional sawfish surveys have been conducted in other parts of the Exmouth Gulf, the Fortescue River estuary and mangrove creeks to the south.

Existing information from these previous sawfish studies conducted in Pilbara coastal waters, as well as external reports and citizen sightings will be available to the project reporting. Relevant data will be complied in relation to the abundance (CPUE, catch-per-unit-effort), population demographics (age/size structures), growth and morphological data between the various habitats to inform the reporting of additional catch data, acoustic data and genetic data collected during field surveys in 2024 and 2025.

To inform Green Sawfish population genetics, kinship, habitat use, migration patterns for Green Sawfish available data on concurrent (Murdoch University funded) studies examining the genetic composition of Green Sawfish in the study region will be analysed following Ingelbrecht et al. (2023) for Green Sawfish in the Onslow/Ashburton area. That study used single nucleotide polymorphisms (SNPs) to investigate kinship and philopatry of Green Sawfish, of which the project team have processed 114 individuals from the study area around Onslow (~200 in total). Additional samples collected during 2024 at Mardie, Onslow, and other opportunistic catches will be analysed according to the methods of Ingelbrecht et al. (2023).

6 Study Methods

6.1 Desktop work

Desktop study collating the distribution, abundance and habitat value of Green Sawfish in proximity to southern Pilbara. This part of the study will compile and compare all relevant data in relation to the abundance (CPUE, catch-per-unit-effort), population demographics (age/size structures), growth and morphological data between the various habitats and be used as a baseline for comparisons with fieldwork conducted in 2024 and 2025.

6.2 Field work

The proposed research program aims to collect new data from two key Study Sites (shown in Figure 2 and Figure 3), including:

- Study Site 1: North Section

    - Mardie Project area
    - Fortescue River
- Study Site 2: South Section
    - Onslow area
    - Ashburton River Delta

The purpose of the research is to collect field data that informs the EPBC Act Marine Research Objectives by addressing important knowledge gaps concerning the:

- Presence, abundance and distribution of Green Sawfish along the Pilbara Coast;
- Green Sawfish habitat use and migration patterns;
- Green Sawfish population genetics and structure; and
- Trophic interactions with prey.

The following field work methods will be used in the Green Sawfish research program to understand the distribution, abundance, habitat values, genetic composition and define critical habitat across the West Pilbara Coast:

- **Migration Patterns/Distribution:** The aim of the proposed acoustic survey and tagging work will be to report on sawfish presence / absence, depth utilisation, home range, site fidelity and movement patterns (e.g. see Morgan *et al*. 2017). Information will also be collected to assess differences between size classes, sex and season (see also Morgan and Lear 2023).
- **DNA and Isotope Collection:** Allowing for genetic and food web analysis of Green Sawfish by collection of DNA from cloacal swabs and trophic position from tissue samples at Onslow; additional sympatric predators will be similarly sampled.
- **Presence/Abundance:** Undertaking visual observational data collection across the study sites and while undertaken assessments/monitoring at the Mardie Project area. Observations will be conducted by visual sampling from the boat, walking in the shallows, and from drones.

Field methods are discussed further below, including details on proposed locations, timing of surveys aligned with the ecology of species to increase the chance of observations where possible, and proposed survey/sampling effort needed to address research objectives.

The capture of Green Sawfish will be undertaken by conventional gillnet sampling and conform to the *Protocols for surveying and tagging sawfishes and river sharks* (see Kyne and Pillans 2014). Gillnets will be deployed perpendicular to the bank in several locations within the creeks and nearby creek mouths where habitat looks suitable for sawfish (typically shallow mud or sand flats adjacent to mangroves) and will be comparable to other targeted sawfish surveys in the region (see for example, Morgan et al. 2015, 2017, 2023a, Morgan and Lear 2023, Lear et al. 2023). Gill nets will be comprised of 150 mm monofilament stretched mesh, 50 to 60 m in length with a depth of 2 m. Sawfish observations will be conducted from the bow of the boat, and from the air using a drone (DJI) following the methods of Morgan et al. (2023b).

Collection and handling of Green Sawfish will be undertaken in accordance with the relevant Commonwealth's statutory document and policies, including *Survey Guidelines for Australia's threatened fish* (Commonwealth of Australia, 2011) and *Protocols for surveying and tagging*

sawfishes and river sharks (see Kyne and Pillans 2014) and will conform to University Animal Ethics protocols and government approvals.

The project will operate in line with the following approvals:

Murdoch University Animal Ethics Permit No. R3530/24 "Habitat use and ecology of threatened sharks and rays in the Pilbara region" (Approved 8th April 2024), and

DPIRD Exemption 251203824 "Tracking and monitoring of threatened rays within the coastal Pilbara region" – Approved 29 February 2024.

6.3 Acoustic survey and tagging work

Acoustic survey and tagging are proposed at additional field survey sites at Fortescue/Mardie to complement acoustic survey and fish tagging results already being collected at Onslow, and add to the acoustically tagged fish in the Fortescue River, which were tagged during a different study. 10 acoustic tags have been budgeted for in 2024.

Murdoch University is currently tracking Green Sawfish with an acoustic array in two of the Offset regions (Onslow and Gnoorea as well as near the Fortescue River mouth, and in the Exmouth); although the vast majority of individuals have been tagged near Onslow. More than 110 individual Green Sawfish have been acoustically tagged between near Onslow since 2011; some of these fish have been detected at Urala Creek (~50 km south of Onslow). Additional tags will be deployed in areas where data is lacking, focusing on the Mardie Project area, Fortescue River, and potentially Gnoorea and Onslow, Ashburton River.

Acoustic arrays used in this program will consist of VR2W receivers attached to a standard mooring design comprising a concrete block, a 10 kg anchor and 4 to 8 metres of galvanised chain attached to a rope and buoy (see Morgan et al. 2017, Morgan and Lear 2023). This surveillance system will serve to record movements of captured sawfish fitted with acoustic tags. Acoustic receivers (VR2W) used in this study are required to be physically downloaded and re-batteried at least twice annually to ensure detection continuity in case of receiver loss or battery failure. The acoustic tracking will follow the methodologies used in Morgan et al. (2017), Whitty et al. (2017), Morgan et al. (2021) and Morgan and Lear (2023). The Approval Holder will be responsible for supplying a larger vessel for offshore deployment and retrieval of receivers at Mardie and Urala Creek.

6.4 DNA and Isotope Collection

Prey DNA and isotope sampling will occur in the Onslow study area due to the likelihood of catching Green Sawfish individuals for sampling. The Ashburton River Delta is recognised as a globally important habitat for Green Sawfish, in part because of the high abundances that have been observed. This is supported by survey work undertaken in Onslow (October 2021) where a Catch Per Unit Effort (CPUE) of 0.15 sawfish were caught per 20 m of net per hour.

The budget for data collection allows for the collection and analysis of 50 prey DNA samples that will include the previously collected Green Sawfish swabs (14) from the Onslow/Urala region and an additional 13 other sympatric elasmobranchs.

Cloacal swabs (for prey DNA analysis) and a fin clips (for isotope analysis) will be taken from target species. The total number of samples collected for the isotope analysis will depend on the number of fish captured, and will add to samples collected in April 2024 of 2 Green Sawfish, 9 Nervous Sharks, 3 Lemon Sharks, 1 Bottlenose Wedgefish, 1 Giant Guitarfish. The swabbing process involves inserting a

sterile cotton swab approximately 5 cm deep (for large animals ~2 m total length) into the animal's cloaca, and slowly rotating the swab for 10 s before removing. The swabs will immediately be stored in high-purity ethanol for later DNA barcoding analyses to identify prey items, while the fin-clip will be frozen for food web analysis. The swabbing and fin-clipping will occur while the animal is oriented on its back in tonic immobility just prior to acoustic tag implantation.

6.5 Visual Sampling

Observational data collection will be conducted by visual sampling from the boat and walking in the shallows. Drone based imagery will also be collected. Observation-based surveys are typically carried out by examining the shallow edges of the creeks for sawfish, as young juveniles often tend to swim along shorelines in very shallow water with their fins exposed. Flights will be conducted at altitudes of between 15 and 20 m to increase the likelihood of observing new born pups and as at altitudes higher than 5-10 m the sound produced by most small drones is undetectable above background levels underwater (Christiansen et al. 2016). The majority of flights will be conducted between 08:00 and 11:00 when wind speeds are predicted to be lowest based on long-term BOM data and to enhance visibility (see Butcher et al., 2019).

If a sawfish is sighted by the pilot, video will be taken at ~5 m ASL to determine if the sawfish has previously been tagged (a t-bar tag visible lateral to first dorsal fin), to record any scarring, and to allow rostral teeth counts (for comparison to those individuals previously tagged). During each flight, the following variables will be recorded: Flight start and finish time; Altitude of flight; Turbidity (at the beginning and end of each flight; the clarity of the water scored from 1-5, where 1 is very poor, 5 is extremely clear); Cloud cover (ranging from 0 to 8 oktas (measurement as to how many eighths of the sky is covered – 0 being no clouds, 8 being completely overcast)); Sea State (ranging from 0-12 on the Beaufort Scale (0 being less than 1 knot, 1 being 1-3 knots, 2 (light breeze) being 4-7 knots, 3 (gentle breeze) being 7-10 knots, 4 (moderate breeze) being 11-16 knots, 5 (fresh breeze) being 17-21 knots, 6 (strong breeze) being 22-27 knots, 7 being (near gale) 28-33 knots, and 8 (34-40 knots)); Wind direction (offshore, onshore, across-shore, E, W, N, SSE etc.); Air temperature; Number of sawfish sighted (species identification if possible); Tidal information. The total number of sawfish within each transect will be recorded by the drone pilot, and then compared by a non-drone pilot in the office using VLC media player. Sawfishes will be identified to species level and their relative abundance (number/hour of footage) for each transect calculated as per Morgan et al. (2023).

6.6 Sampling location / Sampling Effort

The two key areas to be surveyed for sawfish include the Mardie/Fortescue area and the Onslow/Ashburton area. The Fortescue and Ashburton represent the two largest river systems in the southern Pilbara and potentially are important pupping sites and nursery areas (see Morgan et al. 2015, 2017, 2022).

Survey efforts

Both sites/regions will be surveyed at least once in spring, which encompasses the main pupping period for Green Sawfish (August-December) in the southern Pilbara (Morgan et al., 2015, 2022, Lear et al. 2023), and again in autumn, which will allow growth to be recorded (from recaptures), acoustic receiver to be downloaded, and diets compared between seasons. A full outline of sampling details is in Table 4.

Table 4: Sampling details

Method	Location	Survey Effort	Timing*
Sawfish Tagging	Onslow (Ashburton River and adjacent mangrove creeks) Mardie (Fortescue River and adjacent mangrove creeks)	5-7 days (x 3 personnel) 5-7 days (x 4 personnel)	2024 – May, October 2025 – May, October 2024 – May, October 2025 – May, October
Acoustic Logger Data Collection (from existing loggers) Additional Acoustic Logger Deployment	Onslow (see Morgan and Lear 2023) -Ashburton River (5) -Adjacent mangrove creeks (11) Mardie - Fortescue River (1) Mardie (see Lear and Morgan 2022) - Mardie North 3 - Middel 1 - Mardie South 2 - Fortescue River 1	2-4 days 2-4 days 4 days 4 days	2024 – May, October 2025 – May, October 2024 – May, October 2025 – May, October
Visual Sampling - Drone Survey Work	Onslow (Ashburton River plus 3-6 mangrove creeks) Mardie (Fortescue (river plus 3-6 mangrove creeks)	4 days 4 days	2024 – May, October 2025 – May, October 2024 – May, October 2025 – May, October
DNA & Isotopic Sample Collection	As per Sawfish Tagging	As per Sawfish Tagging	As per Sawfish Tagging

**** Indicative timing for survey work is provided and dependant on climatic conditions and vessel availability***

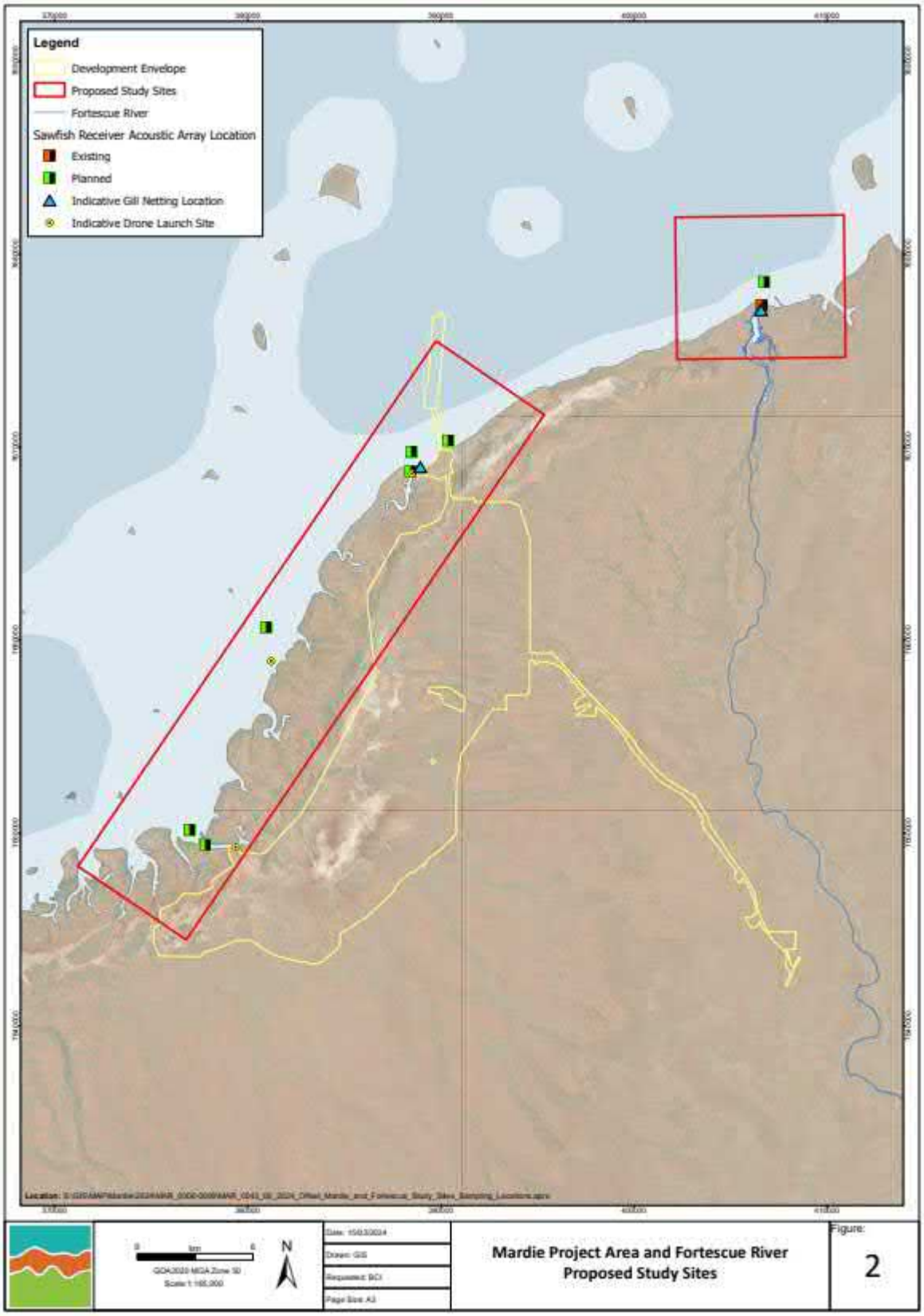

Figure 2: Study Site 1 - Mardie and Fortescue Study Sites Sampling Locations

Figure 3: Study Site 2 - Mardie and Fortescue Study Sites Sampling Location

7 Data Analysis

7.1 Data Compilation

Existing data as detailed in Section 6.1 will be compiled to support the field work data collection. This part of the study will compile and compare all relevant data in relation to the abundance (CPUE, catch-per-unit-effort), population demographics (age/size structures), growth and morphological data between the various habitats. This information will enable our understanding of the distribution, abundance and habitat value of Green Sawfish in proximity to Mardie Project area compared to the Onslow area and where other similarly collected data are available (see Morgan and Lear 2023 for example).

7.2 Migratory Patterns/Habitat use

Data will be downloaded and analysed from the acoustic array in two of the Offset regions (Onslow/Ashburton and Mardie/Fortescue) to identify tagged sawfish with each region and to determine lengths and timing of migrations for various life stages. Data will inform the migratory patterns adjacent to the Mardie Project Area, along the Pilbara coastline to the Fortescue River, and in Gnoorea and Onslow. Habitat use analysis will follow that of Morgan et al. (2017) and Lear et al. (2023).

The data collected from the acoustic monitoring of the study sites will be analysed to determine whether sawfish pupped and acoustically tagged adults in the Onslow region migrate up to the area of the Mardie Footprint.

7.3 DNA and Isotope Analysis

DNA from cotton cloacal swabs (from captured Green Sawfish) will be extracted using DNeasy Blood & Tissue extraction kits (Qiagen). Primer pairs targeting the 12S rRNA gene region and modified with Nextera XT sequencing adapters (Illumina) will be used to amplify the extracted DNA. Two distinct primer pairs will be employed to minimise primer bias and improve taxonomic coverage and sensitivity. The resulting purified amplicons will then be sent to the Australian Genome Research Facility (AGRF) for amplicon indexing, library preparation, and next-generation sequencing on the NextSeq 2000 platform. Sequences will be demultiplexed, with primer sequences removed, and then quality control and high-resolution amplicon sequence variants (ASV) inference will be inferred with DADA2. Taxonomy will be assigned with a Naïve Bayes classifier trained on sequences sourced from a custom region-specific database.

7.4 Population Genetics

To inform Green Sawfish population genetics, available data on concurrent (Murdoch University funded) studies examining the genetic composition of Green Sawfish in the study region will be analysed. It is noted that the Institute are currently using single nucleotide polymorphisms (SNPs) to investigate kinship and philopatry of Green Sawfish, of which the project team have processed 114 individuals from the study area around Onslow (~200 in total). As additional samples present, these will be analysed and allow comparisons between regions (where possible) (see for methods Ingelbrecht et al. 2023).

8 Project Deliverables

Reporting will include the following key deliverables:

Report 1 - (Habitat Use)

A report will be provided on Green Sawfish detection histories, depth utilisation, home range, site fidelity and movement patterns (e.g. see Morgan et al. 2017). Additionally, we will explore differences between size classes, sex and season. We currently have some fish fitted with tags that have a 10 year lifespan. Additional tags will be deployed in areas where data is lacking (e.g. Fortescue/Mardie).

Reporting 2 - (Diet)

Prey items will be reported for the different regions, size classes and species and this data will assist with the food web study and would represent a non-destructive method of determining the diet of sawfish.

Final Program Report (Marine Research Objectives)

The Final Program Report present the key findings, and will provide discussion and conclusion as to how the information relates to the Marine Research Objectives, including:

- report on their detection histories, depth utilisation, home range, site fidelity and movement patterns (e.g. see Morgan et al. 2017). Additionally, we will explore differences between size classes, sex and season as well as kinship analysis of all sawfish captured (see Ingelbrecht et al. 2023).
- Present the findings for presence, abundance and distribution of Green Sawfish along the Pilbara Coast;
- Discuss Green Sawfish habitat use and migration patterns;
- Provide finds on Green Sawfish population genetics and structure; and
- And discuss trophic interactions with prey based on date collected.

The Final Report will be provided to the DCCEEW and will include a discussion on how the project findings contribute to informing the strategic protection, better management and long-term ecological functionality of Green Sawfish habitat, and it will provide recommendations for potential future research programs that advance the understanding against the Commonwealth's Marine Research Objectives. Key topics will include:

- Discussion on critical habitats across the West Pilbara Coast, with a focus on understanding the importance of the Fortescue River (currently lacking survey data), which is currently considered a key potential nursery habitat
- Understanding the connectivity and importance of the Onslow population and movement across the Pilbara sites through additional genetic studies
- Commentary on key threats, particularly the barrier effects of marine infrastructure on migration through examining age classes (i.e. small juveniles) found at the Cape Preston site

9 Project Team

Refer text below and Table 5.

Project Team Leader – Dr David Morgan

Associate Professor David Morgan has been at the forefront of freshwater research in Western Australia over 30 years. Dr Morgan began his career at Murdoch University as a researcher in the Freshwater Fish Research Group (now part of the Centre for Sustainable Aquatic Ecosystems under the Harry Butler Institute). Dr Morgan's commitment to both Murdoch University and to our freshwater ecosystems has resulted in a significant expansion of our knowledge of freshwater systems and species, the on-ground application of conservation measures and the training and inspiration of the next generation of freshwater ecologists. Morgan has co-authored over 300 scientific publications, been a co-investigator on projects in excess of $10M. He is Western Australia's leading sawfish expert conducting projects on three of the species since 2001.

Table 5: Project Roles and Responsibilities

Name	Organisation	Project Role
Associate Professor David Morgan	Murdoch University	Project Direction and Oversight Research Lead
Professor Justin Brookes Tyler Doonan	University of Adelaide	Project Team Members
Travis Fazeldean Jack Ingelbrecht Rebecca Bateman Penélope Taira Dantas Suárez James Tweedley	Murdoch University	

10 Project Milestone

The project tasks are planned to span 2 years over the period April 2024 to December 2025, inclusive. An overview of the timing of the project tasks and reporting activities are outlined in Table 6.

Table 6: Project Milestones

Task	Estimated Timeframe	Party
Research Proposal Submission to DCCEWW	March 2024	BCI
Research Proposal Approval (pending feedback and finalised scope)	March 2024	Cth Minister for Environment
Kick-off Meeting	April 2024	BCI and Project Team
Apply for sampling permit extension (including under Part13 of the EPBC Act)	April 2024	Project Team
Field Trip 1	May 2024	Project Team
Field Trip 2	October 2024	Project Team
Field Trip 3	May 2025	Project Team

Task	Estimated Timeframe	Party
Field Trip 4	October 2025	Project Team
DNA extraction, amplification, primers, library prep., bioinformatics	2024 - 2025	Project Team
Reporting (diet, DNA)	2024 2025	Project Team
Reporting (habitat use)	2025	Project Team
Report (Marine Research Objectives)	2025	Project Team
Final Report (written) to BCI	2025	Project Team
All reports, publications and supporting data provided to BCI and DCCEWW, DBCA, and Department of Water and Environmental Regulation (DWER).	2025	Project Team

11 Funding Arrangement

BCI will allocate the equivalent of $200,000 to this project. These costs are indicative, based on a number of assumptions that need to be confirmed in relation to logistics (e.g., vessel cost for acoustic receiver deployment within the Mardie sites) and survey design (including logistics to support Mardie sawfish surveys). The final design will be completed after direct consultation with DCCEEW.

The budget (Table 7) includes salary for participation of key researchers, costs for logistical and governance arrangements and an allocation for the presentation/publication of project outcomes. Salary contributions for project leaders Associate Professor Morgan, Associate Professor Brookes and Dr Tweedley are in- kind.

Table 7: Budget Proposal

Item	Year 1	Year 2
Salaries-Research Assistant(s)		
Salaries (total 0.6 FTE)	38,694 (0.4 FTE)	20,051 (0.2 FTE)
Desktop Study		
Literature Review / Reporting	19,347 (0.2 FTE)	-
Field surveys		
Field costs (boat*, vehicle, accommodation (2 field trips))	20,000	20,000
Consumables (acoustic tags*, receiver batteries)	17,000	3,000

Item	Year 1	Year 2
Airfares	4,800	4,800
Analysis		
DNA extraction, amplification, primers, library prep., bioinformatics	11,000	5,000
Reporting		
Reporting (diet, DNA) (0.1 FTE)	9,637	10,026
Reporting (habitat use) (0.1 FTE)	0	9,673
Final Report (Marine Research Objectives	0	6,972
Annual sub totals	**101,131**	**98,869**
Grand total		**200,000**

* *Indicative depending on boat availability*

*** A contingency fund of $15,000 is available to the survey work should additional acoustic loggers and transmitters be required*

In-kind: Is based on a contribution of team members employed at Murdoch University and the University of Adelaide. It is anticipated that Universities will waive their University Service Charge (USC) on research grant income with WAMSI governing the project with an overhead charge of 5%. Other in-kind contributions relate to use of infrastructure such as computing, imagery and LiDAR, field equipment, and lab infrastructure.

Table 8: Co-investment for proposed sawfish research

	Co-investment (staffing)			**Co-investment (cash and in-kind), $'000**		
Task 1: Desktop study determining the distribution, abundance and habitat value of Green Sawfish	Organisation	Year 1 FTE ($'000)	Year 2 FTE ($'000)	Organisation	Year 1	Year 2
	D Morgan (Murdoch University (MU))	0.1 (22)	--	Murdoch University	Cash: Nil In-kind: 22	Cash: Nil In-kind: Nil
Task 2: Synthesis of available data on population genetics, kinship, habitat use, migration patterns AND establishment and survey at additional field sites	D. Morgan (MU)	0.2 (44)	0.1 (22)	Murdoch University	Cash: Nil In-kind:116	Cash: Nil In-kind: 37
	J. Tweedley (MU)	0.1 (15)	0.1 (15)			
	J. Ingelbrecht	0.2 (20)	--			
Task 3: Food web analysis of Green Sawfish by collection of prey DNA from cloacal swabs and	D. Morgan (MU) J. Brookes (UA) J. Tweedley (MU)	0.2 (44) 0.1 (25) 0.1 (15)	0.1 (22) 0.1 (25) 0.1 (15)	Murdoch University/The University of Adelaide	Cash: Nil In-kind:88	Cash: Nil In-kind: 62

	Co-investment (staffing)			Co-investment (cash and in-kind), $'000		
trophic position from tissue samples						

12 Dissemination of Information

Publication standard

The research outcomes will be made publicly available. This research will be conducted to a standard that will allow the findings to be published in a peer-reviewed scientific journal and will provide sound recommendations and information for the management and conservation of the Green Sawfish and habitats. The surveys, acoustic tracking, drone and diets sections are all designed to be scientifically robust and thus publishable. The team has published extensively in the field of threatened species, including recent peer-reviewed papers on sawfish (e.g. Morgan et al. 2011, 2015, 2017, 2021, Ingelbrecht et al. 2022, Lear et al. 2023, Bateman et al. 2024). See also Section 13 (References).

Data provision

Within six months of completion of any research project, all reports, publications and supporting data will be provided to the Department, DBCA, and Department of Water and Environmental Regulation (DWER) and published, or the existence and locations of the reports and publications detailed, on the website for the remainder of the life of the project. Data will be managed with best practice quality assurance and quality control measures developed for sea snake research.

All publications (including media releases, website updates, and research papers) will be provided to DCCEEW as soon as possible, and at least five working days before public release.

13 References

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ATTACHMENT 6 – PROJECT PROPOSAL FOR MARDI PROJECT- MIGRATORY BIRDS

ATTACHMENT 6

WAMSI SUMMARY OFFSETS PLAN

Mardie Project – Migratory Shorebirds

Table of Contents

1. Introduction

This Research Project is proposed as an attachment to the broader WAMSI Research SOP being undertaken using funding provided by BCI Minerals as part of its implementation of the Mardie Solar Salt project.

The work proposed under this Research Proposal will link strongly with the Objective 2b of Project C detailed in the Western Australian Marine Science Institution (WAMSI) Summary Offset Proposal (SOP), through a commitment to undertake additional fieldwork across established WAMSI research sites and proposed new sites in the Mardie Project area to obtain new habitat use and trophic ecological data.

There is a significant lack of knowledge on migratory shorebirds' habitat use and basic ecology (including diet and food webs that support migratory shorebirds) in the Pilbara region (see Estrella *et al*. 2015). New knowledge in these areas is required to meet Australian Commonwealth Government policy objectives to protect, conserve and manage migratory shorebirds in the Pilbara region (Commonwealth of Australia, 2015 and 2017).

Aligned with this, a key outcome of this research program will be to inform the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 Marine Research Objectives by undertaking on-site field work to acquire information that will allow the identification of critical habitat across the West Pilbara Coast important to Migratory bird species.

This study will be led by research members from Edith Cowan University (ECU) and Birdlife Australia, with support from WAMSI and oversight from BCI Minerals.

2. Objectives and scope

2.1. Research objectives

The overall objective of the proposed Migratory Bird research program is to meet the marine research objectives prescribed by EPBC approval 2018/8236 (issued on 12 January 2022), which are to inform the:

- strategic protection,
- better management, and
- long-term ecological functionality

of migratory shorebirds habitat.

The general objective of the proposal will be data collection which will inform presence, abundance, and identify the trophic transfer from significant habitats of the West Pilbara Coast to migratory birds.

The specific objectives of the proposal will be to:

- Evaluate migratory shorebird habitat use considering potentially significant habitats in the Pilbara coast for shorebirds such as intertidal areas, tidal channels, salt flats/cyanobacteria mats.
- Assess trophic transfer and food web structure that support migratory shorebirds in the region.

The expected research outputs will be:

- Data documenting the presence and abundance of migratory shorebirds near the SOP study sites.
- Information on habitat attributes at locations where migratory bird presence / absence and abundance data are collected, and
- Improved knowledge on trophic transfer, including identification of main primary producers that support migratory shorebirds food webs, obtained through analysis and interpretation of eDNA and stable isotope samples.

2.2. Scope

Proposed field work locations include established WAMSI research sites at Giralia in southern Exmouth Gulf, Urala Station, Gnoorea, Onslow, and the Mardie Project area (Figure 1**Error! Reference source not found.**). Not all field techniques will be used at every location.

Fieldwork will be undertaken using conventional habitat usage methods such as GPS tracking and camera traps alongside collection of biological samples for environmental DNA (eDNA) and Stable Isotope analysis (SIA).

GPS tracking and camera traps provide the opportunity to use two complementary methods, and offer a robust combination to gain knowledge on individual species visiting specific habitat types along the Pilbara coast. The combination of SIA and eDNA methods would provide a comprehensive approach to determine what prey shorebirds are feeding on, and if their diets match what is available within these intertidal areas.

Data collection from this research proposal will also document the presence and abundance of shorebirds and will contribute to an improved understanding of the food web structure and trophic transfer from intertidal zones to migratory birds.

Field surveys will include observations of species presence and abundance and will include recording information to describe habitat attributes/characteristics (e.g. tidal channel, mangrove, seagrass meadow or cyanobacteria matt presence). This information will help in defining which habitats or habitat attributes represent 'critical habitat' for the targeted species.

Field data will be considered alongside laboratory data to develop recommendations for management of key habitat(s).

Target migratory shorebird species include:

- Bar-tailed Godwit *Limosa lapponica menzbieri* – The subspecies Yakutian Bar-tailed Godwit is found on the west coast of the Australian continent. Listed Endangered/ Migratory (EPBC Act). It is an abundant medium to large migratory shorebird in the study area. Tactile feeder.

- Greater Sand Plover *Charadrius leschenaultii* – Listed Vulnerable/Migratory (EPBC Act). It is a common medium size migratory shorebird in the study area. Visual feeder.

- Far Eastern Curlew *Numenius madagascariensis* - Listed Critically Endangered/Migratory (EPBC Act). It is the largest shorebird in the world, and is relatively common in the study area, although never found in large numbers. It has been observed feeding on fiddler crabs on the saltpan areas in the region. Visual/tactile feeder.

- Red-necked Stint - Listed Migratory Species (EPBC Act). It is an abundant small-sized migratory shorebird in the study area. It has been observed feeding on the supratidal areas in the region. Visual and tactile feeder.

- The above list of species does not preclude the collection of data of other species of migratory shorebirds, particularly others listed Critically Endangered, Endangered or Vulnerable such as Curlew Sandpiper *Calidris ferruginea*, Common Greenshank *Tringa nebularia* or Great Knot *Calidris tenuirostris*.

2.3. Link to Mardie Project EMP Monitoring Provisions

The Proposal will take into consideration and utilise the following monitoring and management plans for the Mardie Project, as relevant:

- **Long-term migratory shorebird monitoring program**

The ongoing migratory bird counts (i.e. under the Long-term migratory shorebird monitoring program) will inform WAMSI Project C in its consideration of the habitat usage of different communities present across the intertidal zone. These learnings from Mardie will be directly relevant to the equivalent habitats at other WAMSI study sites.

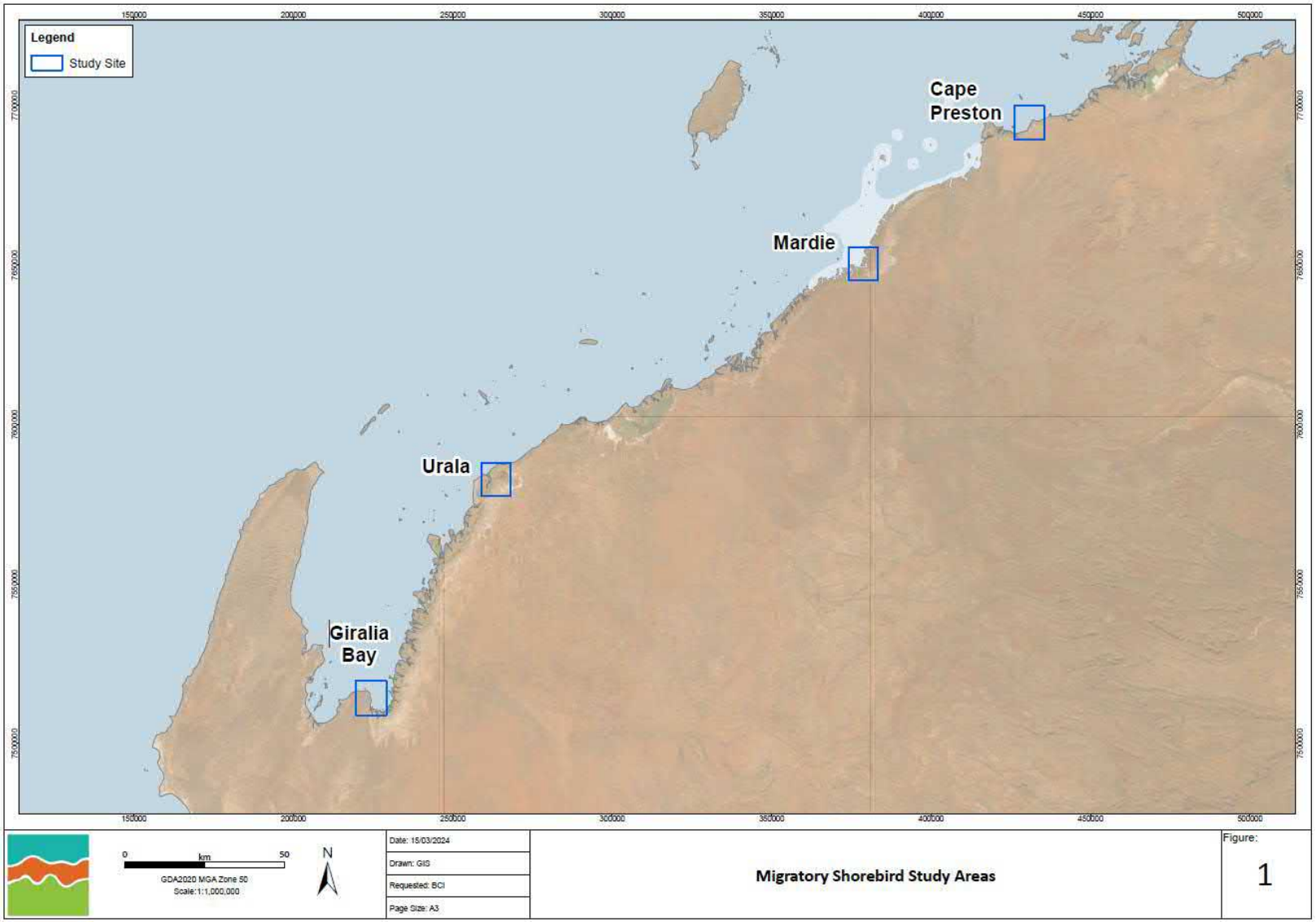

Figure 1: WAMSI field study sites along the Pilbara coast

3. Alignment with Commonwealth policy objectives

3.1. Conservation Plan for Migratory Shorebirds

Within the conservation and recovery actions stated in the Conservation Advice for *Numenius madagascariensis* (Far Eastern Curlew), one of the two primary conservation objectives is to "*minimise further loss of habitat critical to the survival of Far Eastern Curlew throughout Australia".* Exmouth Gulf, located approximately 200 km southwest of the Mardie project area, is an internationally and nationally important shorebird habitat for the species (Weller et al. 2020), and it is therefore considered critical to the survival of the species. Evaluating habitat use by Far Eastern Curlews at multiple study sites in the Pilbara coastal region will help to identify feeding and roosting areas (critical habitat) and improve site protection and management. Similarly, Exmouth Gulf is also a nationally important habitat for Yakutian Bar-tailed Godwit *Limosa lapponica menzbieri*, Great Knot *Calidris tenuirostris* and Greater Sand Plover *Charadrius leschenaultia* among other species of migratory shorebirds (Weller et al. 2020).

This research proposal aligns with several high or very high priority actions identified in the Commonwealth's *Wildlife Conservation Plan for Migratory Shorebirds* (Commonwealth of Australia, 2015). The approach adopted in the migratory bird research program is specifically relevant to Objective 4 of the Conservation Plan for Migratory Shorebirds:

Objective 4: Knowledge gaps in migratory shorebird ecology in Australia are identified and addressed to inform decision makers, land managers and the public.

Details are provided in Table 1.

Table 1: Priority conservation actions addressed in this research proposal

Reference Note 1	Action	Priority	Relevance to this research program
4a	Identify and prioritise knowledge gaps that are required to support the conservation and management of migratory shorebirds and their habitats.	High	The expected research outputs will be: • Data documenting the presence and abundance of migratory shorebirds near the SOP study sites. • Information on habitat attributes at locations where migratory bird presence / absence and abundance data are collected; • Improved knowledge on trophic transfer and the main primary producers that support migratory shorebird food webs, obtained through analysis and interpretation of eDNA and stable isotope samples.
4c	Survey northern and inland Australia for migratory shorebird populations and identify important habitats.	Very high	
4g	Promote exchange of shorebird conservation information between governments, NGOs and communities through use of networks, publications and web sites.	High	

Note 1: References relate to objectives and associated actions listed in the Commonwealth's *Wildlife Conservation Plan for Migratory Shorebirds* (Commonwealth of Australia, 2015). Priority ratings are taken from the same source.

3.2. Alignment with EPBC Act Environmental Offsets Policy

Appendix A of the EPBC Act Environmental Offsets Policy provides five key criteria to be addressed by a research project:

- Criteria 1 - Improve the viability of the impacted protected matter
- Criteria 2 - Be targeted toward key research/education activities
- Criteria 3 - Be undertaken in a transparent, scientifically robust and timely manner
- Criteria 4 – Be undertaken by a suitably qualified individual or organisation in a manner approved by the department
- Criteria 5 - Consider best practice approaches.

Details of how the proposed Mardie migratory shorebird research project meets these criteria are provided in Table 2.

Table 2: DCCEEW Criteria for research programs

No.	Criteria: A suitable research program must:	Project Suitability
1	Endeavour to improve the viability of the impacted protected matter	The information generated through this proposed research program will help to improve the viability of threatened migratory shorebird populations by addressing knowledge gaps related to critical habitat attributes and shorebird ecological requirements. Better understanding of these aspects can be used in the development of more effective policies and management strategies.
2	Be targeted toward key research activities as identified in the relevant Commonwealth approved recovery plan, threat abatement plan, conservation advice, ecological character description, management plan or listing document.	Table 1, above, explains how the proposed migratory shorebird research program is targeted toward key research activities set out in the *Wildlife Conservation Plan for Migratory Shorebirds* (Commonwealth of Australia, 2015).
3	Be undertaken in a transparent, scientifically robust and timely manner	Section 6 of this proposal describes proposed reporting arrangements and additional information on how research results will be shared. Section of this research proposal includes a summary timetable for delivery of key project milestones.

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No.	Criteria: A suitable research program must:	Project Suitability
4	Be undertaken by a suitably qualified individual or organisation in a manner approved by the department	The research will be led by researchers from Edith Cowan University (Prof Glenn Hyndes, Prof Kathryn McMahon and Dr Sora Marin Estrella) who are experts in coastal ecology including diet, food analysis and shorebird ecology with a team of researchers including a shorebird experts.
5	Consider best practice research approaches.	The proposed research program will be implemented in accordance with ECU's Research Integrity Framework, which incorporates, among other matters, best practice data and information management; peer review requirements and ethics approvals.
6	Be tailored to at least a postgraduate education level	The research will be led by researchers from Edith Cowan University (Prof Glenn Hyndes, Prof Kathryn McMahon and Dr Sora Marin Estrella) who are experts in coastal ecology including diet, food analysis and shorebird ecology with a team of researchers including a shorebird experts.
7	Present findings that can be peer-reviewed.	As this is embedded in WAMSI they will be reviewed through the standard WAMSI peer-review process.
8	Publish findings in an internationally recognised peer-reviewed scientific journal or be of a standard that would be acceptable for publication in such a journal. Publications should be submitted to free open access journals. Data and information collected should have creative commons licensing and be free and accessible.	All data accessibility will follow the WAMSI SOP that includes data to be stored on open data repositories. Findings will be published in internationally recognised peer-reviewed journals as well as reported to WAMSI.
9	Result in outputs that can inform future management decisions on the protected matter and, where possible, be readily applicable to other similar matters (species groupings etc).	The research report will directly inform future management decisions on shorebirds including listed and migratory species.

4. Study Methods

4.1. Desktop work

The areas of desktop research include broadly recognised themes such as breeding, migration, trophic ecology, predation, disturbance, parasites, physiology, pollution, habitat use, habitat destruction, and climate change. Desktop literature will be focussed on:

- relevant species of waders and/or shorebirds to the Pilbara coast
- relevant coastal habitats of the Pilbara coast (tropical and subtropical mangrove fringed coastal habitats, salt flats/marsh and cyanobacteria mats, intertidal sandflats, mudflats and seagrass meadows) as well as all important shorebird habitats in the Pilbara coast included in the "Australian National Directory of Important Migratory Shorebird Habitat" (Weller et al. 2020).
- habitat use during migratory and non-migratory periods on the Pilbara coast and relevant habitats (as described before);
- trophic ecology within these on the Pilbara coast and relevant habitats (as described before); and
- disturbance and habitat destruction on the Pilbara coast and relevant habitats (as described before).

4.2. Field work

The following field work methods will be used in the Migratory Shorebird research program across the WAMSI SOP study sites and Mardie Project area:

1. Habitat usage survey approach:
    - GPS tracking of targeted bird species
    - Camera traps at key habitat locations
2. Trophic ecological sample collection methods:
    - Sediment and scat sampling for Environmental DNA (eDNA) analysis
    - Biological sampling (incl. blood and scat sampling) for Stable Isotope Analyses (SIA)

Field methods are discussed further below, including details on proposed locations, timing of surveys to the ecology of species to increase the chance of observations where possible, and proposed survey/sampling effort needed to address research objectives.

4.2.1. Habitat use data collection

GPS tracking

Subject to additional amendment to include the additional transmitters and species to the existing animal ethics approvals, GPS tracking of targeted Migratory Bird Species will be undertaken to deliver a high spatial resolution assessment of habitat use (accuracy between 2.5 m - 5 m) (Lyu et al. 2023) during the non-breeding season. Targeted species will be fitted with solar GPS-GSM or GPS-Bluetooth trackers, where data is downloaded through Bluetooth receivers or GSM (5G) network. This work would be conducted in conjunction with BirdLife Australia and the Australasian Wader Study Group in Exmouth Gulf Station or Giralia Station between October-November 2024. Applying trackers to birds at this time of year could enable us also to track migratory birds habitat use during

the non-migratory period and throughout the Pilbara as they move north from their non-breeding habitats at the bottom of the Gulf at the start of their migration. BirdLife Australia and the Australasian Wader Study Group already hold the appropriate licences and permits to trap and fit GPS trackers to several migratory shorebirds in the Exmouth Gulf.

Camera traps

Information on migratory shorebirds' habitat use will be obtained through the deployment of camera traps in potentially significant habitats such as intertidal areas, tidal channels and salt flats/cyanobacteria mats. The use of cameras and camera traps has been proven to deliver reliable information on shorebird and other waterbirds habitat use of targeted geographical locations (Boardman et al. 2023, Jackson et al. 2022, Luy et al. 2023) for extended periods compared to abundance count.

These will be deployed across habitats at Giralia and Urala (Figure 2). Images captured from these cameras will provide information on species and individuals present through the non-breeding season and tidal phases.

Camera traps and GPS trackers offer the opportunity to achieve remote monitoring (collect data over extended time periods in remote locations without the need of researchers' presence) of shorebirds' habitat use.

4.2.2. Trophic ecological sampling

Environmental DNA (eDNA) sampling

This task will complement the existing Project C (Identify the ecological roles, values and functions of algal mat on the west Pilbara coast) Objective 2b (Identify the pathway for transfer of nutrients and primary productivity from intertidal benthic communities and habitats to subtidal communities and habitat). It is proposed to use environmental DNA (eDNA) and scats metabarcoding to identify prey consumed by migratory shorebirds. Samples will be sent to eDNA Frontiers at Curtin University for analysis using a metabarcoding approach.

Biological sampling (Blood and scat sampling).

In conjunction with GPS tracking survey work, blood samples will be collected (subject to additional amendment to include blood sampling collection for stable isotope analysis) during the November 2024 BirdLife Australia Exmouth expedition and used for stable isotope analysis (SIA) for trophic assessment. Blood will be collected from captured individuals not fitted with GPS trackers. BirdLife Australia and the Australasian Wader Study Group already hold the appropriate licenses and permits to trap, fit GPS loggers, and collect blood samples from migratory shorebirds in the Exmouth Gulf.

Blood samples allow for SIA of recently assimilated nutrients from their food sources, compared to the longer term of assimilation provided by other inert tissues (e.g. feathers) that is often used in stable isotope studies.

Additionally, selected scat samples collected as part of Project C Part 2b would be subjected to SIA. The number of scat samples collected as part of Project C Part 2b will be increased to provide a more robust data set for SIA and food web understanding. Survey methods used for the collection of biological samples and interactions with migratory birds will be undertaken in accordance with relevant Commonwealth statutory documents and policies, including *EPBC Act Policy Statement 3.21 - Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species*.

4.3. Sampling location / Sampling Effort

Proposed field work locations include established research sites at Giralia in southern Exmouth Gulf, Urala Station, Gnoorea and Onslow, along with new sites in the intertidal areas adjoining the Mardie project area (Figure 2). Not all field techniques will be used at every location. Survey efforts are detailed in Table 3 and sampling locations are shown in Figure 2.

Table 3: Sampling details

Method	Location	Survey Effort	Timing
Habitat Mapping – GPS Tracking	Conducted in conjunction with BirdLife Australia and the Australasian Wader Study Group in Exmouth Gulf Station or Giralia Station.	Data service Mini tracker x 8*	November 2024. Applying trackers to birds at this time of year will enable us to track migratory shorebirds habitat use throughout the non-breeding season (November to April) on the south section of Exmouth Gulf and potentially as they move northwards along the West Pilbara Coast at the start of their migration.
Habitat Mapping – Camera Traps	Deployed across habitats at Giralia and Urala Stations	Trap Camera x 24	Deploy in November 2024. Recovery February 2025. This will ensure that information is collected throughout most of the non-breeding period that migratory shorebirds are present in the region.
Tropic Ecological Samples 3. eDNA sampling 4. Blood and Scat collection	Exmouth Gulf Station or Giralia Station.	**WAMSI Study Area** Samples from each habitat will be collected during existing field expeditions Blood SIA x 100 Scat SIA x 100 Environmental DNA will be collected only at Giralia.	**WAMSI Study Area** Blood samples will be collected only in November 2024. Droppings and environmental DNA will be collected in November 2024 and February 2025. **Mardie Study Area**

Method	Location	Survey Effort	Timing
		<u>Mardie Project Area</u> Scat SIA x (up to) 100 Pheonix – as part of the Shorebird Migratory MMP.	December 2024 February 2025
Visual Observations	Mardie Project Area	Mardie Project area intertidal habitat will be opportunistically monitored while undertaking monitoring activities in accordance with monitoring activities undertaken while implementing the approved Environmental Management Plans.	Consultants undertaking the monitoring

*As per Lilleyman et al. 2020

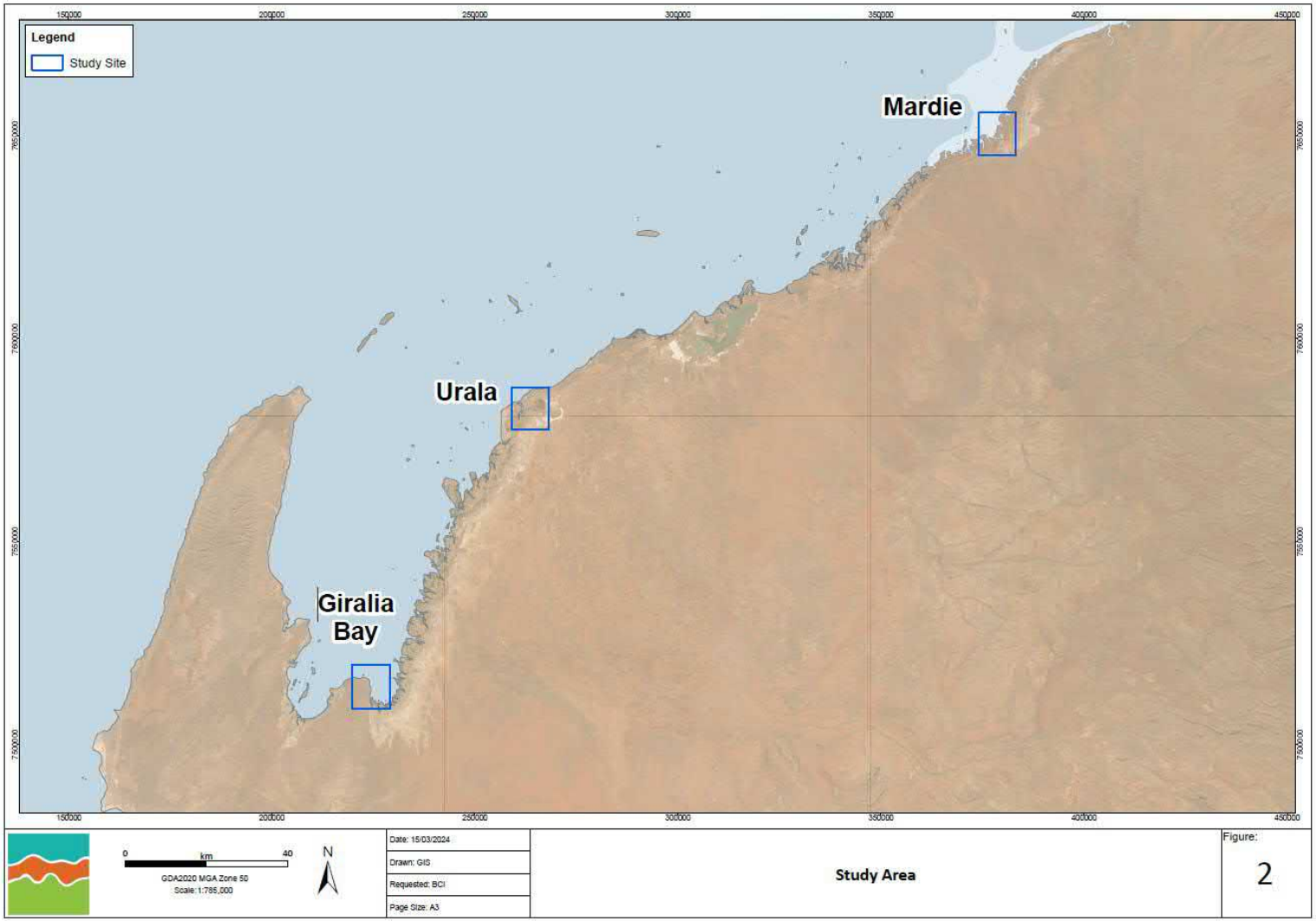

Figure 2: Proposed Study Areas

5. Data Analysis

5.1. Habitat use Data Analysis

5.1.1. GPS Tracking:

Analysing tracking data will allow for tracking migratory birds temporal habitat use throughout the non-breeding season and the tidal phases. GPS trackers could also offer information on habitat used throughout the Pilbara coast as they move northwards at the start of the migration from their non-breeding habitats at the bottom of the Gulf.

5.1.2. Camera Traps:

Images captured from the camera traps will provide spatial information on several shorebird species habitat use (present or not present and their activity, feeding and roosting) in potentially significant shorebird habitats in the Pilbara coast such as intertidal areas, tidal channels, salt flats/cyanobacteria mats.

Images captured from the camera traps will provide temporal information on several shorebird species habitat use (present or not present and their activity, feeding and roosting) in potentially significant shorebird habitats in the Pilbara coast such as intertidal areas, tidal channels, salt flats/cyanobacteria mats through time during the non-breeding season and the tidal phases.

5.2. Trophic Ecological Data Analysis

5.2.1. eDNA sample analysis

Samples of sediment from each habitat and bird scat will be collected during existing field expeditions and sent to eDNA Frontiers at Curtin University for analysis using a metabarcoding approach. Sediment samples would confirm if the prey identified within the bird scat was consumed within the intertidal habitats or other external habitats.

5.2.2. Stable Isotope analysis

Additionally, selected scat samples collected as part of Project C Part 2b would be subjected to Stable Isotope analysis (SIA), as detailed in the Project C of the WAMSI SOP, specifically to determine:

- Blood samples allow for Stable Isotope Analysis (SIA) of recently assimilated nutrients from their food sources, compared to the longer term of assimilation provided by bulk stable isotopes that is often used in stable isotope studies.
- Dropping analysis: Scat samples will be dis-aggregated in filtered water and sieved though a 50 µm mesh. Hard parts of prey (chironomid heads, polychaete jaws, bivalve hinges, crustacean parts etc.) will be identified.

This section does not include direct observations and digiscoping (videos recorded with the use of the telescope and a camera attached to it) of shorebirds feeding since information on shorebirds diet will be obtained throughout dropping analysis and previous videos from Mardie Project C Part 2b.

This information will be used to improve food web understanding.

6. Project Deliverables

Reporting will include the following key deliverables:

6.1. Report (Habitat Use):

The cameras will be collected in February 2025 and there will be a significant number of images to analyse. Tracking data for inclusion in the habitat use analysis will incorporate April 2025, therefore a final report on Habitat Use will be available in January 2026.

6.2. Reporting (Trophic ecology)

Similar to the Habitat Use report, a final report on Trophic Ecology will be available in January 2026.

6.3. Final Program Report (Marine Research Objectives)

The Final Program Report will present the key findings, discussion and conclusions including:

- Migratory shorebird presence, absence and abundance;
- Analysis of habitat attributes (e.g. tidal channel, mangrove, seagrass meadow or cyanobacteria matt presence) and habitat use;
- Interpretation of feeding ecology, based on analysis of results from eDNA and stable isotope testing.

The Final Report will be provided to the DCCEEW in January 2026 and will include a discussion on how the project findings contribute to informing the strategic protection, better management and long-term ecological functionality of migratory shorebird habitat. The final report will provide recommendations for strategic approaches to improve the viability of shorebird populations and / or to conserve habitats critical to threatened shorebird populations.

7. Project Team

7.1. ECU Project Team Leaders – Glenn Hyndes and Kathryn McMahon

Professors Glenn Hyndes and Kathryn McMahon are highly experienced coastal ecologists with 40 years experience between them. They have led multiple large research projects, and currently lead WAMSI Mardie Project C examining the ecological functions of BAHs in the Pilbara region. Dr Sora Marin Estrella is an expert in shorebird ecology with over 10 years experience working in intertidal and saltflat habitats in NW Australia. Dr Marin Estrella is also an investigator on WAMSI Mardie Project C.

The Project Team are detailed in Table 4.

Table 4: Project Roles and Responsibilities

Name	Organisation	Project Role
ECU Team Members: - Dr. Sora Marin Estrella - Prof. Glenn Hyndes - Prof. Kathryn McMahon	Edith Cowan University	Team Leaders. Experimental design and field work approach for habitat use objective (GPS trackers and camera traps) and trophic objective (stable isotopes and eDNA) for migratory shorebirds.
Bird Life Australia Team Members:	Bird Life Australia	Trapping shorebirds

- Dr. Tegan Douglas (WA Woodland Bird Program Manager National Black-cockatoo Program Manager) - Dr. Jeremy Ringma, (WA Shorebird Project Coordinator) - Dr. Roz Jessop (Australasian Wader Study Group)		and deployment GPS tracking
Mardie Project area sampling Team: - Dr Floyd Holmes - Patrick Williams - Ethan Broom	Phoenix Australia	Project data collection support – focusing on the Mardie Project area

8. Project Milestones

The project tasks are planned to span 2 years over the period April 2024 to December 2025, inclusive. An overview of the timing of the project tasks and reporting activities are outlined in Table 5.

Table 5: Project Milestones

Task	Estimated Timeframe	Party
Research Proposal Submission to DCCEWW	March 2024	BCI Minerals
Research Proposal Approval (pending feedback and finalised scope)	April 2024	Cth Minister for Environment
Kick-off Meeting	April 2024	Project Team
Apply for sampling permit extension (including under Part13 of the EPBC Act)	April 2024	Project Team
Field Trip – GPS Tracking / Blood Samples	November 2024	Project Team
Field Trip – Camera Deployment / eDNA / Scat Samples SIA	November 2024	Project Team
Mardie Project Area Field Trip 1	December 2024	Phoenix
Mardie Project Area Field Trip 2	February 2025	Phoenix
Field Trip – Camera trap collection/ Scat Samples SIA	February 2025	Project Team
Analysis	2024 - 2025	Project Team
Reporting	January 2026	Project Team

All reports, publications and supporting data provided to BCI and DCCEWW, DBCA, and Department of Water and Environmental Regulation (DWER).	January 2026	Project Team

9. Funding Arrangement

BCI will allocate the equivalent of $168,009 to this project. Project costs are currently indicative, based on a number of assumptions that need to confirmed, in relation to logistics and survey design. The final design will be completed after direct consultation with DCCEEW. The budget (Table 6) includes salary for participation of key researchers, costs for logistical and governance arrangements.

Table 6: Budget Proposal

Expense	**Price per unit (AUD)**	**Total**
Literature review		
Consultant x 80 hours	$250	$20,000
	Sub-Total	**$20,000**
Migratory shorebirds habitat use using GPS tracking		
Field expedition November 2024 (4 person airfares, accommodation, fuel, food etc)	$12,500	$12,500
Druid Mini 4G x 8	$1,672.25	$13,378
Data service for loggers	$200.67	$1,605
BirdLife Australia expedition	$22,000	$22,000
	Sub-Total	**$49,483**
Migratory shorebirds habitat use using camera traps		
Trap Camera x 24	$400	$9,600
64G SD card x 24	$128	$3,072
6-month FT RA	$52,794	$52,794
Longyard/Saxon 165-170 cm Black Steel Fence Post x 78	$95 (pack of 10)	$760
Field expedition February 2025 (4 person airfares, accommodation etc)	$12,500	$12,500
	Sub-Total	**$78,726**
Trophic ecology; diets using Environmental DNA (eDNA)		**$17,600**
eDNA analysis	$560	$16,800
Consumables	$800	$800

	Sub-Total	**$17,600**
Trophic ecology; Blood SIA		**$2,200**
SIA x 100	$14	$1400
Consumables	$800	$800
	Sub-Total	$2,200
Trophic ecology; Scatt SIA		
SIA x 100	$14	$1400
Consumables	$800	$800
	Sub-Total	$2,200
	Grand Total	**$168,009**

In-kind: Is based on a contribution of team members employed at Murdoch University and the University of Adelaide. It is anticipated that Universities will waive their University Service Charge (USC) on research grant income with WAMSI governing the project with an overhead charge of 5%. Other in-kind contributions relate to use of infrastructure such as computing, imagery and LiDAR, field equipment, and lab infrastructure.

10. References

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Guidance for the Development of the Mardie Project Marine and Intertidal Offsets Research Program

Provided by the Mardie Project Offset Steering Committee

1. Mardie Salt Offset Program

Mardie Minerals Pty Ltd (a wholly owned subsidiary of BCI Minerals Limited) is developing the Mardie Project, a solar salt and sulphate of pot ash production facility in the Pilbara region of Western Australia. Ministerial Statement 1175 (MS1175), which was superseded with Ministerial Statement 1211, provided conditional approval for the Project that includes requirement for financial offsets for marine and intertidal research. The offsets are based on the significant residual impacts and risks of the proposal to intertidal benthic communities and habitat (BCH) namely mangroves, algal mat and coastal samphire and were put in place for the purpose of guiding the strategic protection and management of the ecological values of these habitats on the west Pilbara coast. Values associated with BCH include primary productivity, ecosystem maintenance, nutrient cycling, carbon storage and habitat values such as foraging, breeding or nursery habitat.

This offset package covers three specific areas of research for a total cost of $2.5M. The research program to meet this condition will be undertaken through an independent body, the Western Australian Marine Science Institution (WAMSI), with the guidance and support of a Steering Committee comprising members from DWER, DBCA and DPIRD to ensure the research program, funding allocation and delivery meet the conditions of MS1175 and fit into the above needs highlighted for regional understanding of the Pilbara coastal environments to inform future decision-making, management and conservation.

The project areas as defined in MS1175 Condition 14 (now Condition B10 of are noted below with the scope and research priorities for each. Proposed projects area summarised in the following tables:

Project A. Mapping of the original and current extent of Samphire and Algal mat on the west Pilbara Coast

The aim of this project is to complete mapping of the extent of algal mat and samphire on the west Pilbara coast to provide an understanding of the regional extent and distribution of these habitats to complement the existing mangrove mapping. While a complete map of the current distribution of these habitats is the priority, having an understanding of how these habitats have changed over time will also inform their response to anthropogenic and natural events.

Priority research areas are:

- What is the current spatial extent of mangrove, algal mat and samphire habitat in the west Pilbara?
- What is the historic spatial extent of algal mat, mangrove and samphire habitat in the west Pilbara based on Landsat imagery (where applicable)? [Note: historical mapping of mangrove may be available]
- Has this distribution changed in the west Pilbara over the past 60 years in response to natural events (storm/cyclonic activity, heat waves) or anthropogenic pressures (coastal development)?

Project B. Identifying and quantifying the potential effects of sea-level rise on mangroves, samphire and algal mat on the west Pilbara Coast and identifying the significance of salt projects in preventing the adaptation of intertidal BCH to sea-level rise

The aim of this project is to improve the management of intertidal BCH in the region in the event of sea-level rise given the potential for the Mardie Project (or other salt proposals) to reduce the capacity of some intertidal BCH to adapt to climate change. The priority for this project will be on understanding how BCH may respond to sea-level rise and limitations created by the presence of salt projects in terms of BCH spatial extent and capacity to function.

Priority research areas are:

- Understanding the influence of sea-level rise on BCH extent and migration including environmental and physical parameters.
- Predicting BCH response to climate change scenarios in particular to sea-level rise.
- What role will salt projects play in reducing BCH adaptation to sea-level rise and how will this affect the ecological services provided by these habitats.

The research will focus on predicted impacts to all intertidal BCH which includes mangroves, samphire and algal mats. The spatial emphasis will be on the footprint area of the Mardie Project, but will extend across the west Pilbara, particularly considering the potential for additional proposals. This project will rely on information from projects A and C to be complete.

Project C. Identifying the ecological roles, values and functions of intertidal benthic communities and habitat

The aim of this project is to provide information on the ecological role and values of key BCH that will inform future decision making on development across the Pilbara region. The highest priority habitat is algal mat as it is the least understood of the intertidal benthic coastal habitats. In particular, very little is known about its contribution to nutrient and energy flow in the intertidal to subtidal system and how this varies spatially and temporally. The second priority will be samphire habitat, followed by mangrove. While there is an expected emphasis on the Mardie Project site footprint, research in this project area may extend to the west Pilbara coast, e.g. from the SE corner of Exmouth Gulf to Karratha.

Priority research areas are**:**

- Estimate primary productivity in space and time for algal mat and other BCH.
- Identify the pathway for transfer of nutrients and energy from BCH to other communities and habitats (e.g. from the intertidal mosaics to the subtidal).
- Describe the role of BCH as habitat, assess community composition, biodiversity constituents, trophic transfer (flow of energy), nutrient transfer to understand ecosystem function.
- Identify the key physical drivers such as the response to the wetting and drying associated tidal movement, rainfall, episodic events (storms and cyclones), evaporation etc.

The above questions will need to take into account both spatial and temporal considerations including:

- Identifying a spatial gradient of productivity and energy flow for the west Pilbara coast and extending into subtidal areas.

- Intra-annual to understand the response to the wetting and drying associated with key physical drivers such as: tidal movement, rainfall, episodic events (storms and cyclones), evaporation etc.
- Inter-annual variability, however, it is noted that this will be limited as it is likely that a maximum of two years of data would be collected in the short timeframe.

Project A: Mapping of coastal and intertidal habitats with a priority focus on samphire and algal mat on the west Pilbara coast.

Aim: To produce habitat maps of algal mat and samphire habitat across the west Pilbara coast comparable to those for mangrove habitat and compare these to historic records to better understand natural variability and the response of these habitats to natural events and anthropogenic pressures

Theme Leaders: Ben Radford (AIMS), Sharyn Hickey (UWA) **Nominal funding:** $650,000

Project 1.1 Mapping of the original and current extent of Samphire and Algal mat on the west Pilbara Coast		
Knowledge gap	**Project deliverables**	**Project leader/s**
Current extent of mangrove, samphire and algal mats in the west Pilbara	• Map of current distribution of mangrove, samphire and algal mats from SE corner of Exmouth Gulf to Karratha.	
Project 1.2		
Knowledge gap	**Project deliverables**	**Project leader/s**
Historic extent of algal mats, mangrove and samphire in the west Pilbara	• Prediction of mangrove, samphire and algal mats from SE corner of Exmouth Gulf to Karratha prior to European habitation.	
Project 1.3		
Knowledge gap	**Deliverables**	**Project leader/s**
Temporal stability of mangrove, samphire and algal mats in the west Pilbara	• Investigate and identify methods for assessing changes in the temporal and spatial extent of algal mat and samphire. • Map and describe temporal differences in the extent of mangrove, samphire and algal mats in the west Pilbara, investigating the effect of season and disturbance (natural and anthropogenic). This may include assessing changes in inundation patterns as some of these habitats are difficult to see on Landsat imagery.	

Project B: Identifying and quantifying the potential effects of sea-level rise on intertidal habits of the west Pilbara coast with a focus on mangroves, samphire and algal mat:

Aim: To provide a better understanding of the potential impacts of sea-level rise on intertidal habitats of the west Pilbara coast and how coastal infrastructure such as that by salt works may influence adaptation to sea-level rise.

Theme Leaders: Matt Hipsey (UWA) **Nominal funding:** $650,000

Project 2.1		
Knowledge gap	**Project deliverables**	**Project Leader/s**
To what extent do environmental and physical conditions inhibit migration of intertidal habitats with rising sea-level?	• Models projecting SLR impacts along the coast and associated redistribution of intertidal habitats (mangroves, samphire and algal mats). This will need consideration of sedimentary processes that may influence the distribution of the communities (e.g. erosion, sedimentation under existing mangrove forests, etc).	
Project 2.2		
Knowledge gaps	**Project deliverables**	**Project Leader/s**
How may projected climate changes effect intertidal habitat's ability to migrate?	• Models that consider how increasing temperature (sea and land), changes to rainfall and cyclone activity influence capacity of intertidal habitats to redistribute with SLR.	
Project 2.3		
Knowledge gap	**Project deliverables**	**Project Leader/s**
What is the significance of the proposed salt works in preventing adaption of BCH to sea-level rise?	• Models projecting SLR impacts along the coast, particularly at sites where there are existing or proposed salt works and how this infrastructure and sedimentary processes may influence the potential for redistribution of intertidal habitats.	

Project C: Identifying the ecological roles, values and functions of intertidal benthic communities and habitats of the west Pilbara:

Aim: The priority for this project will be understanding the role of algal mats including their value and function through nutrient flows and energy budgets and where this productivity goes in the system, including a spatial and temporal gradient.

Theme Leaders: Kath McMahon, Glenn Hyndes and Paul Lavery (ECU) **Nominal funding**: $1,000,000

Project 3.1		
Knowledge gap	**Project deliverables**	**Project Leader/s**
What is the primary productivity (including nitrogen fixation) in space and time for algal mat and other BCH in the west Pilbara?	• Estimation of primary productivity nitrogen fixation across a spatial gradient for algal mat, samphire and mangroves. • Estimation of the relative productivity for the whole West Pilbara Coast for mangroves, samphire and algal mats. • Estimation of nitrogen flux (temporal and spatial) to the marine environments from all sources (e.g., algal mats and terrestrial flows). • Estimation of the relative importance of nitrogen flux from algal mat communities to the marine environment compared to other sources of nitrogen (temporal and spatial).	
Project 3.2		
Knowledge gaps	**Project deliverables**	**Project Leader/s**
Identify the pathway for transfer of nutrients and primary productivity from intertidal BCH to subtidal communities and habitat	• Identification of pathways for transfer of nutrients and primary productivity from intertidal to subtidal areas. • Estimation of the proportion of primary productivity and nitrogen which is exported from each intertidal habitat type to subtidal areas.	
Project 3.3		
Knowledge gaps	**Project deliverables**	**Project Leader/s**
Describe the role of BCH as habitat, assess community composition, biodiversity constituents, trophic transfer (flow of energy,	• Identification of the role of algal mats in terms of composition, biodiversity, trophic transfer and habitat across a spatial gradient.	

nutrients) etc. The primary focus is algal mat communities, but other BCH should be considered		
Project 3.4		
Knowledge gaps	**Project deliverables**	**Project Leader/s**
Identify the key physical drivers of spatial and temporal variability in primary productivity and N fixation, such as the response to wetting and drying associated tidal movement, rainfall, episodic events (storms and cyclones), evaporation etc.	• Identification of key physical drivers of spatial and temporal variability in primary productivity and nitrogen fixation. • Identification of key processes which transfer the carbon and nitrogen to the subtidal environment.	

2. Linkages to other programs

There are a number of research programs currently underway or in development through research institutions and government departments in WA and nationally that will be producing deliverables relevant to this strategy. Links will be established with other organisations and programs to build upon, complement and leverage other local, regional and national initiatives and activities. Some current initiatives include:

Department of Transport initiative to develop topographical and habitat mapping based on lidar and digital elevation for priority coastal areas. This is part of a national project that is being led by DoT for WA. There is scope to support the Pilbara as a priority area for this project.

CSIRO has a project planned that will compile existing habitat mapping products to assess Australia's 'blue carbon' potential.

DBCA is leading research evaluating primary productivity, energy transfer and connectivity among marine habitats in the Dampier Archipelago.

Commonwealth required offset for research that guides conservation efforts to maintain ecological functionality of nearshore subtidal habitats of the Pilbara region that support the short-nosed sea snake.

3. Governance

A governance structure has been agreed with BCI Minerals, WAMSI and DWER to manage the Mardie Salt Marine and Intertidal Offset program. This will involve a Steering Committee to provide guidance on the projects comprising the offset program and their delivery. The Steering Committee will operate under agreed Terms of Reference that set out the membership, roles and responsibilities of the Committee, membership and meeting frequency. The overall role of the Steering Committee is to provide overarching program direction and coordination, issues resolution, and oversee project delivery. The Steering Committee reports to the WAMSI CEO.

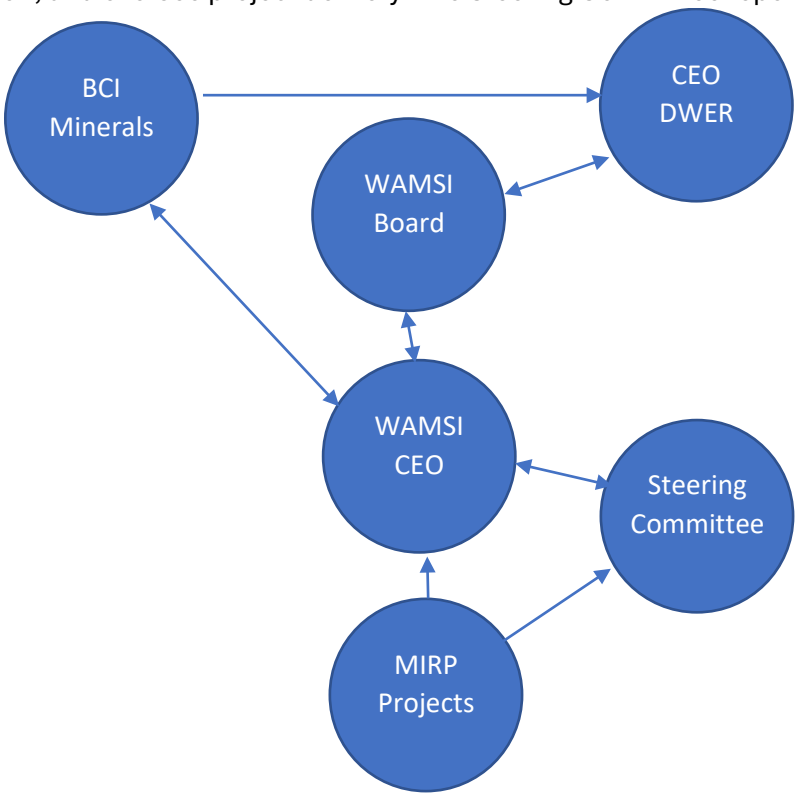

Figure 2. Governance Structure for delivery of the Mardie Salt Marine and Intertidal Offset program through WAMSI.

4. Data Management

A Data Management Plan and Technical Standard Data and Analytics Deliverables, in recognition that effective and efficient data management will underpin the Program.

WAMSI project plan for the Collaborative Project Agreement

Mardie Project Marine and Intertidal Research Offsets Program

Project details

Project Title.
Mapping of the original and current extent of samphire and cyanobacterial mat on the west Pilbara Coast

Start Date/End Date.
15-01-2023 to 15-12-2024

Project Leader.

Sharyn Hickey	Mick O'Leary

WAMSI Partner Organisation:
The University of Western Australia

Contact details:
School of Agriculture and Environment, and School of Earth Sciences, The University of Western Australia, 35 Stirling Hwy, Crawley, WA, Australia
sharyn.hickey@uwa.edu.au
mick.oleary@uwa.edu.au

All project collaborators must submit proof of insurances to WAMSI.

- Public liability
- Product liability
- Professional indemnity
- Property insurance over assets purchased with this funding
- Worker's compensation
- Marine liability.

Scope of the project.

Project summary

Need
The Pilbara coast hosts a unique arid zone mangrove environment recognised as one of only six across the globe (Adame *et al.*, 2020). Broad flat inter/supratidal flats combined with a hot dry climate has resulted in a distinctive habitat zonation. The Pilbara coast tends to be fringed by mangrove communities that transition to samphire and salt tolerant vegetation in the lower intertidal zone. The higher intertidal zone and lower supratidal zones tend to be covered by cyanobacterial mats (referred to as 'algal mats' in the Ministerial Statement) . These organic mats comprise microbial cyanobacterial communities, and are considered be highly productive primary producers, fixating carbon and nitrogen (Stal, 1995; Lovelock *et al.*, 2010; Adame *et al.*, 2012) and are thought to contribute to primary and secondary productivity in the nearby coastal waters (Penrose; Lovelock *et al.*, 2010; Adame *et al.*, 2012).

However, information on these habitats, particularly in the Pilbara coastal region is limited and has largely been focussed on mangroves (Hickey and Radford, 2022), or focussed on particular sites (Lovelock *et al.*, 2010; Adame *et al.*, 2012). Similar areas, further north, which contain overlapping habitats, including mangrove, tidal flats and samphire vegetation, such as Eighty Mile Beach have been recognised as RAMSAR sites of significance under The Convention on Wetlands of International Importance, demonstrating the significance of these environments. There remains a knowledge gap in the functional role of mangrove, samphire and cyanobacterial mat habitats play in the Pilbara's dryland coastal ecosystems. The vast size, remote location, terrain and tide has possibly hindered research in this area, however advancement in remote sensing techniques alongside field observations can provide valuable insight to map these habitat communities, and explore the natural dynamics, threats and responses.

Regional climatology (e.g., El Nino Southern Oscillation), sea level, precipitation, and temperature have been demonstrated to affect these coastal habitats. For instance, a 20 cm decline in sea level at Mangrove Bay on the Ningaloo Coast in Western Australia coincided with porewater salinity increasing by 25% compared to the 16 year mean level, and ultimately resulted in areas of mangrove dieback (Lovelock *et al.*, 2017). While cyclones were shown to damage seaward mangroves, and provided an avenue for landward mangrove seedling recruitment and establishment in Exmouth Gulf (Lovelock, Reef and Masque, 2021). There is limited knowledge on the extent of mangrove, samphire and cyanobacterial mat communities in the Pilbara, however we first need to know their extent to understand their vulnerability to both climate and anthropogenic threats.

Understanding environmental change in the West Pilbara requires baseline information that predates ecological monitoring/mapping programs. This is because over time scales relevant to a changing climate and anthropogenic impacts we need to reduce the possibility of shifting baseline syndrome (SBS; Knowlton and Jackson 2008). Developed by Pauly (1995), the concept of SBS is defined in Soga and Gaston (2018) as

“a change in the accepted norms for the condition of the natural environment due to lack of past information or lack of experience of past conditions”.

As suggested here, acceptance of an already changed coastal ecosystem’s baseline as “healthy” may lead to the use of inappropriate baselines for habitat conservation (Thurstan et al. 2015; Soga and Gaston 2018;). As such, there is a need to both identify the limitations of relatively recent ecological monitoring data in capturing the full impact of anthropogenic pressures over multiple decades (Mihoub et al. 2017) and identify novel methods to capture and record environmental data that can extend our understanding beyond the observational/instrumental record.

Aims

The project proposes to use a unique combination of (1) satellite and aerial remote sensing techniques, (2) Indigenous knowledge to map habitat extent and track environment change across space and time (i.e., seasonal to multidecadal timescales). The Pilbara’s coastal environments host a unique sedimentary and geomorphic archive that may contain palaeo-ecological records of habitat distribution and zonation during periods of high sea levels spanning the last several thousand years. Though not a focus for this investigation we flag the potential utility of these archives in predicting habitat response to future predicted changes in sea level along the Pilbara coast.

(1) The first approach uses satellite remote sensing datasets which will provide up to 35 years of data and represent the most recent period of coastal industrialisation and climate change along the Pilbara coast. The approach will also benefit from the recent availability in higher spatial and temporal resolution satellite, airborne and drone remote sensing datasets, and the coincident increases in cloud processing and advances in machine learning. This advances in automated mapping and processing capability have provided an avenue to link fine-scale field measurements with broader-scale remote sensing data, across spatial scales, with associated uncertainty models. Using these methods, recent historical records, an understanding of space-time dynamics of coastal habitats can be made to help inform

ecological drivers of change, and habitat contribution to the ecosystem values and functions. We will also use historical air photo imagery to establish the historical loss of mangrove-samphire-cyanomats that resulted from the development of the Onslow and Dampier solar ponds and crystallisers (e.g., SI1 and SI2) prior to satellite imagery, where aerial imagery is available (see appendix).

(2) The second approach will make use of Indigenous knowledge and living memory to identify areas, specific locations or patterns of habitat change that will both overlap and extend beyond the satellite instrumental record. With collective knowledge of the land, sea, and sky, Indigenous peoples are excellent observers and interpreters of the natural environment and have experienced climate driven environmental change through deep time, adapting to changes in sea levels, precipitation regimes, evolving seasonal variability, and the resultant impact on their immediate environments. This knowledge can complement scientific data by providing environmental baselines (that can extend beyond the observational and instrumental timeseries) in which to measure change. Particularly we see indigenous knowledge providing reconstructions on environments that were impacted by the development of the Onslow and Dampier Salt developments.

Methods & sampling design

To address the priority research areas as identified by the Steering Committee to meet the Ministerial Statement we have developed two approaches (see below), related to the priority research areas identified with sub-questions and objectives within each, as outlined in Table 1 in Outcomes section. Here we define the Pilbara coast as the coastline from Exmouth Gulf to Karratha in Figure 1. A total of 3 field sites (Figure 1) have been identified and selected based on the representative nature of the three key habitats (mangrove, samphire, cyanobacterial mats) and represent a gradient in tidal amplitude (1.8 m in the south to 3.7 m in the north), All projects will align their field research efforts to these indicative field sites, project A will also provide a remote sensing habitat model for the Pilbara coast.

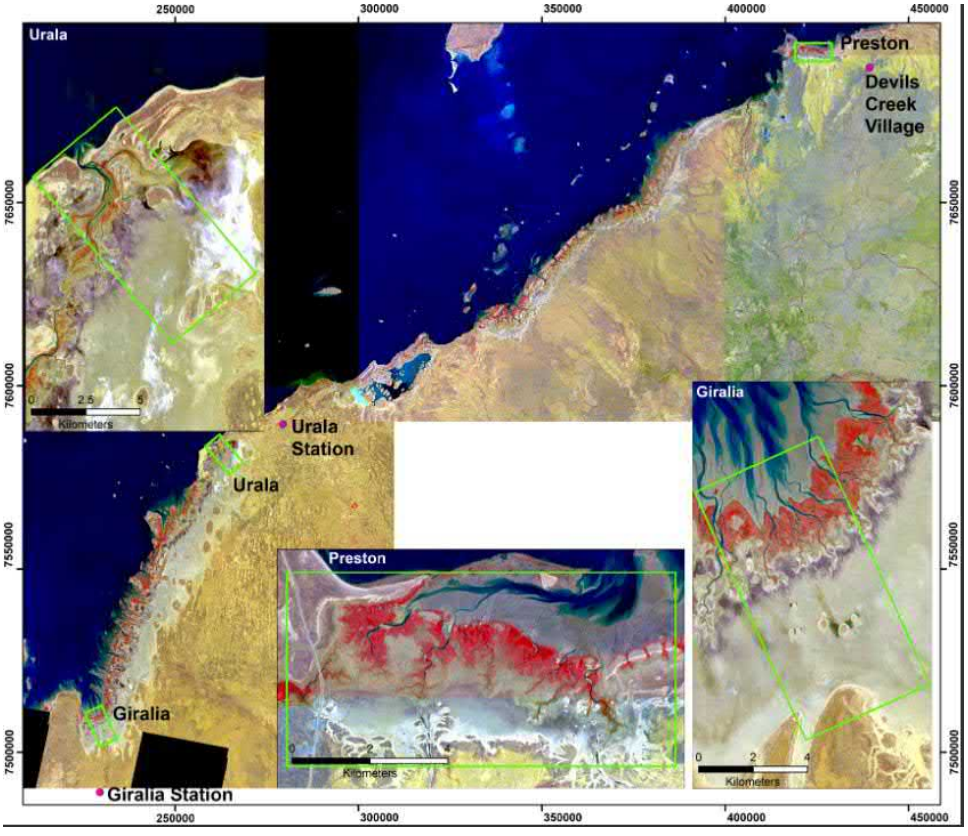

Figure 1: Study location with proposed focus study sites along the Pilbara coast. Project A will provide a remote sensing model at broadscale for Pilbara coast extent (as identified above).

1.1.1 Approach A > Remote Sensing

This approach will utilise a combination of broadscale (satellite multispectral) and fine scale (airborne LiDAR-hyperspectral) remote sensing data to develop both predictive and actual habitat maps for the Pilbara coast respectively (Figure 1 and 2). Although not ideal, the use of broadscale (satellite multispectral) imagery is justified on the basis of limited budget and the requirement to produce a contiguous coastal habitat map (mangrove, samphire [habitat zone], cyanobacterial mats) for the entire Pilbara coast.

We will also develop a series of temporal change maps at set time points .Higher resolution airborne topo-LiDAR and hyperspectral imagery will be collected across the defined study sites in Figure 2, with the aim to provide information on species level distribution across the various coastal habitats. Higher spatial resolution satellite imagery will be purchased in order to expand the coverage beyond the study sites and improve the uncertainty in the regional scale predictive habitat map.

At a smaller number of locations we will purchase higher resolution satellite imagery (aerial footprint to be determined) to cover timepoints (seasonal/interannual) in order to provide information on the dynamic response of habitats to events like ENSO and past extent of coastal communities.

On ground mapping of habitat will be essential to validate both the airborne hyperspectral remote sensing data within the field study areas, and broadscale remote sensing satellite data outside the field study areas. This will require extensive field mapping across the entire Pilbara coastal study area with traverses covering as many habitat and community types as possible. Ground based fieldwork will also provide the ground control points which are required to validate the Topo LiDAR datasets.

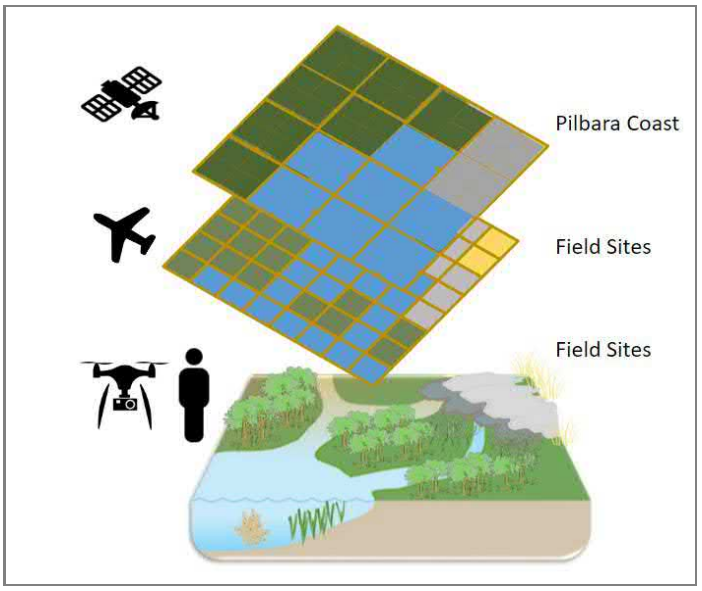

Figure 2: Conceptual overview of Approaches A1 and A3 illustrating the different scales and indicative methods data will be collected and habitat modelled at. See Supplementary Information for imagery examples.

A1. Broadscale habitat models for Pilbara coast

Landsat and/or Sentinel satellite imagery will provide the multi-decadal scale time series of environmental change along the Pilbara coast, as well as provide information on the regional scale spatial extent of key habitats in order to define areas for more focused (higher resolution) investigations. Modelling will follow the techniques of Hickey et al. (2021), Hickey and Radford (2022), and Chamberlain et al. (2021). Samphire has traditionally been difficult to map with multispectral imagery due to its similar spectral scale with the surrounding environment and low height, however it may be possible to map out the representative extent of samphire based on the landward and seaward boundaries of mangrove and cyanobacterial mats respectively, this is similar to techniques by Murray *et al.*, 2019.

Cyanobacterial mat detection via broadscale remote sensing will be attempted following techniques by Murray *et al.*, 2019 and Hickey and Radford, 2022. A range of remotely sensed indices will also be established including greenness (e.g., NDVI for mangroves), and water (e.g., NDWI). Model validation will be undertaken where validation data is available (e.g., high resolution imagery, previous available field data). We will also use historical air photo imagery to establish the historical loss of mangrove-samphire-cyanomats that resulted from the development of the Onslow and Dampier solar ponds and crystallisers (Figure 3).

Deliverable A1.2 is to provide validation data for habitat models. Validation data refers to uncertainty mapping. We are mapping 3 focus sites with high resolution LiDAR and hyperspectral imagery as well as field data (A3). We have allocated a budget to purchase available historical high resolution satellite data to supplement current information for these sites, listed in the budget as Remote Sensing Data. All maps will have uncertainty information. Also, we are mapping the entire Pilbara coast study region from Giralia to Karratha as identified in Figure 1 at a broader scale due to project budget limitations in collecting high resolution data over wider areas. We will use the overlap of the focus sites to help develop and validate models to inform the uncertainty of the mapping. However, it is important to note that if there is no high-resolution data or field data at sites there is no way to validate the model with certainty at these sites, a global (e.g., regional) validation will be provided.

NDVI and water indices are provided as examples of common spectral indices. Everything on the Earth's surface reflects and absorbs wavelengths (spectra) uniquely. We will be utilising this with other ecological information to develop a model to predict these habitats. For instance, Lovelock et al. 2009 has shown that at least for Giralia, cyanobacterial mats, samphire and mangrove exist in specific tidal envelopes, characterised by the location relative to lowest astronomical tide and sea level. Field data and hyperspectral information, along with LiDAR will be collected at the 3 field focus sites, with this information we will be able to explore what specific spectral indices, along with what other information (e.g., water inundation) are useful for predicting samphire and cyanobacterial mat presence or absence.

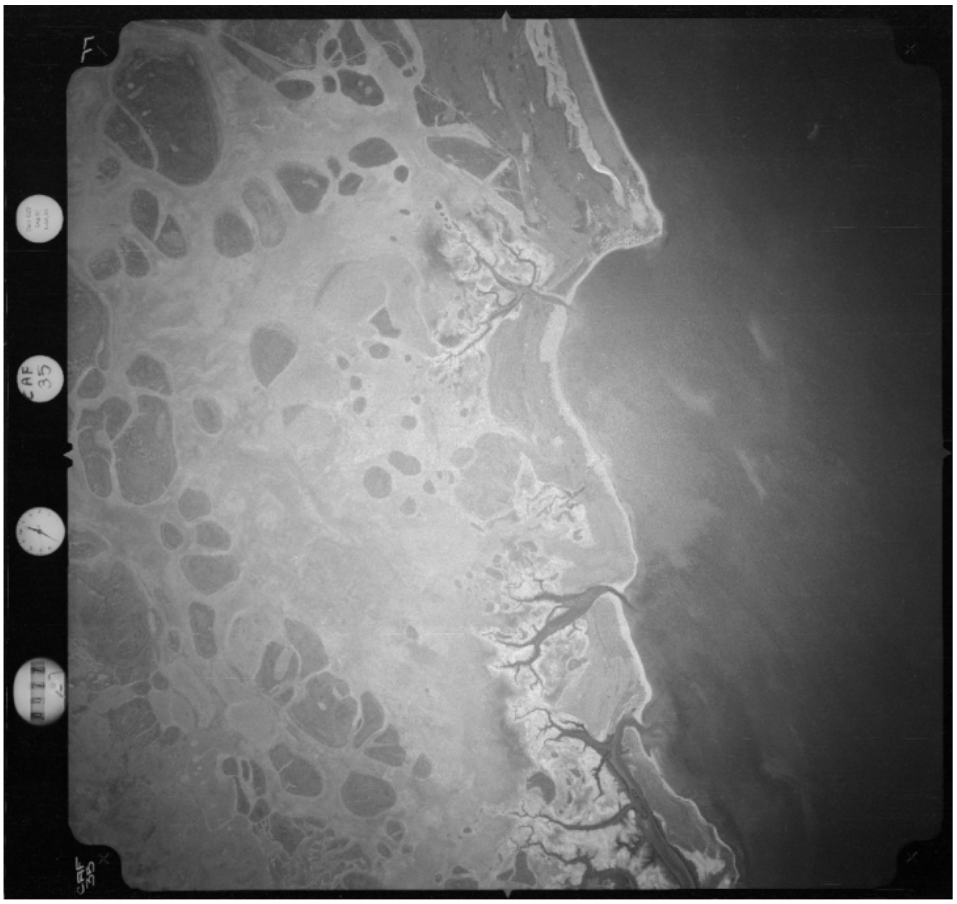

Figure 3: Black and white non georeferenced image of Onslow solar salt ponds area, flown 1967, source: Geoscience Australia (Historical Aerial Photography)

A2. Investigate space-time dynamics of habitat for Pilbara coast

Spatial-temporal analysis will be used to investigate changes in key habitats (interannual through to multidecadal) following the methods of Hickey et al. (2018); Hickey and Radford (2022). This will be key in establishing the response of these habitats to climate driven changes in sea surface height, precipitation and atmospheric temperatures. It will also establish those habitat areas which 1) experience a more ephemeral existence, 2) have experienced a transition in habitat type, or (3) those areas where indicative habitat is more stable or persistent though time. It is these areas of more stable habitat that could become the focus of long-term monitoring (e.g., TERN).

A3. For field sites provide finescale models of current habitat extent

Due to the limitations in spatial/spectral resolution when mapping at the regional scale, three locations within the border study area are selected for higher (spectral and spatial) resolution investigation. Following the techniques of Hickey et al. (2018), we use airborne LiDAR and hyperspectral scanners to map geomorphology and vegetation at the decimetre scale. At this level of resolution it will be possible to quantify mangrove canopy height and cover, map the distribution of samphire, examine the spectral traits of cyanobacterial mats, and detail the transition of habitat as it relates to surface elevation or tidal dynamics. Spatial modelling at this final scale will use similar techniques to the broadscale mapping approach discussed above.

Figure 4: Exemplar LiDAR data showing Urala Creek (NE Exmouth Gulf). Grid cells = 100 m and pixel resolution is 25 cm. Green is representative of mangrove canopy.

1.1.2 Approach B

B1 Provide a record of living memories that capture environmental changes on sea country

We will document cross-cultural perceptions and configurations of threat as it relates to the West Pilbara coastal environments. The cross-cultural emphasis will be on establishing the parameters and nature of Indigenous and mainstream non-Indigenous understandings of threat/risk/harm as it relates to these coastal environments (See Kearny et al., 2022). This is a crucial step in establishing the cross-cultural parameters of this project and will inform the project's 'bridging discussions' aimed at centralising Indigenous perspectives in a discussion of risk/threat/future

security, and of generating intercultural approaches to addressing the impact of change in sea country settings over the short and long term.

Key activity will be the presentation at a workshop of very large printed airphoto maps of the Pilbara coast, to Indigenous Elders, Rangers, and community participants. The maps are then annotated by the traditional custodians with their personal observations as well as contextualising change across longer timescales using intragenerational intergenerational ancestral narratives. These annotated maps can be then used to extend the deeper time understanding of environmental change along the Pilbara Coast. This will be communicated back to the community via ESRI storymap as a form of digital storytelling of Indigenous narratives of environmental change. We will also digitistise participatory mapping outputs as spatial layers and provide these to the appropriate Aboriginal corporation and their cultural custodians/managers.

Key Indigenous stakeholders within the study area are the Buurabalayji Thalanyji Aboriginal Corporation (BTAC) based in Onslow and the Murujuga Aboriginal Corporation (MAC) Based an Dampier. O'Leary has had strong engagement with MAC over the last 6 years and has engaged with BTAC on a number of project proposals. Amanda Kearny (Melb Uni) is an internationally recognised Australian anthropologist and will lead the Indigenous engagement component of this project.

Describe how data will be secured during the project.
Data for this project will be stored on the secure UWA IRDS system and will be stored according to WAMSI guidelines.

Linkages

Mardie Salt Projects.
Project A will provide initial assessment of the spatial extent of the habitats for Project B and C to inform sampling design. Project A will provide updated habitat models to Projects B and C to scale data to Pilbara coast and regions of interest. Project A will work closely with Projects B and C on ecological data and application of spatial data and temporal scales for prediction modelling. Project A will work with Project B if change analysis is shown to link to sea level, or cyclone events to explore impact on habitat here from the remotely sensed habitat data.

All projects will share data and will aim to coordinate field trips. A data management plan following WAMSI protocols will be implemented for access during and post project duration. We will liaise with DBCA, DPIRD and other relevant stakeholders.

External projects

Hickey and Lovelock are currently engaged by Minderoo Foundation to write a review of the Exmouth Gulf Salt Flats and develop a cyanobacterial habitat envelope spatial layer for the Exmouth Gulf (Giralia to south of Onslow). The review is due to be completed August 2022, and the spatial layer December 2022 (desktop study, and not representative of a single time-point - envelope of likely area). There is a further review of carbon and productivity modelling using current literature (desktop study), and potential changes (desktop study) due June 2023 and December 2023.

ICoAST

Hickey has recently published a mangrove layer as part of the IOMRC ICoAST project for northern WA which overlaps the area of interest (Hickey and Radford, 2022). This method will provide a baseline for methods.

Implications for Management

The creation of a detailed coastal habitat map will become a key management tool for assessing the cumulative impact of industrial development along the Pilbara coast. It will provide a quantitate assessment on the spatial distribution, density and ephemeral nature of a range of coastal habitats and extent to which these habitats may be impacted, either through direct habitat loss or longer-term degradation, by industrial development. It will provide the state environmental regulator, i.e., the EPA to make informed decisions though the approvals process regarding the cumulative impact of proposed developments.

Risks to delivery and how they will be managed.

Project A will be able to provide broadscale habitat models if field work is affected as these datasets are being generated though remote sensing satellite date. However, model uncertainty is based on data availability and ability to detect habitats at relevant spatial and temporal scales.

1 Staffing > The success on Project A is dependent of a skilled Remote Sensing Scientist undertaking the bulk of the hyperspectral data analysis and processing. Ideally a job search would be initiated/posted very early in the new year, and a candidate appointed and start date confirmed before the end of March 2023. For this to occur the project leads plans to write the job description and liaise with UWA HR have a the prospective staff position posted to appropriate job boards immediately after the new year.

2. The timing of fieldwork must coincide with the airborne survey. To ensure the best possible weather window both for the airborne and ground survey teams, have selected the first two weeks in May which coincide with the end of the cyclone season and low easterly winds which will minimise atmospheric dust impacting on the quality of the hyperspectral imagery. We have also purchased two all-terrain 8 wheeled amphibious vehicles which will make all weather access to all field sites possible.

3. Negotiating site access

There are three Aboriginal Corporations that cover the areas we are intending to work.

- Along the Eastern Exmouth Gulf it is the Nganhurra Thanardi Garrbu Aboriginal Corporation
- Along the SW Pilbara Coast (Onslow)t it is the Buurabalayji Thalanyji Aboriginal Corporation
- Along the NE Pilbara Coast it is the (Cape Preston area) Wirrawandi Aboriginal Corporation

An Indigenous Land Use Agreements

- Kuruma Marthudunera and Yaburara and Coastal Mardudhunera IULA, covers the Mardie to Cape Preston research area.
- Thalanyji and Minderoo Pastoral ILUA covering the SW Pilbara coast near Onslow
- Macedon ILUA covers the area SW of Onslow

There will Mineral Tenements that we will need to request access too.

- Rio Tinto – Dampier Salt
- Sino Iron
- Onslow Salt
- Mardie Salt

As well as permits for drone flying from CASA, military airspace if relevant, or private landholders.

It has not yet been agreed who will take the lead in negotiating site access, either WAMSI, DBCA or UWA/ECU. Access agreements will need to be made before the first field season commences, i.e., in the first three months of 2023. Project A does not require collection permits.

Outcomes.

Table 1: Project Outputs and sub-objectives within the 3 approaches

WAMSI and Steering Provided Deliverables	Knoweldge Gap Identified	1.1 Current extent of mangrove, samphire and algal mats in the west Pilbara	1.2 Historic extent of algal mats, mangrove and samphire in the west Pilbara	1.3 Temporal stability of mangrove, samphire and algal mats in the west Pilbara	
	Deliverable Requested	1.1 Map of current distribution of mangrove, samphire and algal mats from SE corner of Exmouth Gulf to Karratha	1.2 Prediction of mangrove, samphire and algal mats from SE corner of Exmouth Gulf to Karratha prior to European habitation	1.3.1 Investigate and identify methods for assessing changes in the temporal and spatial extent of algal mat and samphire	1.3.2 Map and describe temporal differences in the extent of mangrove, samphire and algal mats in the west Pilbara, investigating the effect of season and disturbance
Approach A	**A1 Broadscale habitat models for Pilbara coastas**				
	A1.1 Utilise remote sensing and available validation data to provide a habitat extent model for mangrove vegetation, samphire zone, and cyanobacterial mat area on the Pilbara coast at annual timescales for satellite temporal scale (e.g., Landsat 30 years)	☑		☑	☑
	A1.2 Provide validation data around habitat models.	☑		☑	☑
	A2 Investigate space-time dynamics of habitat for Pilbara coast				
	A2.1 Compare habitat extent models at temporal scales and investigate both spatial and temporal changes in mangrove, samphire zone area and cyanobacterial mat areas	☑		☑	☑
	A3 For selected field sites provide finescale models of current habitat extent				
	A3.1 Utilise remote sensing and field data to provide current habitat extent model for mangrove canopy, samphire, and cyanobacterial mat extents	☑			
	A3.2 Provide validation data around habitat models.	☑			
Approach B	**B1 Indigenous observations of environmental change**				
	B1.1 Provide a record of living memories that capture environmental changes on Sea Country		☑		
	B1.2 Creation of ESRI Story Map for digital story telling of Indigenous narratives of Environmental change		☑		
	B1.3 Delivery of digitised participatory mapping datasets to Aboriginal Corporation cultural heritage managers		☑		
Approach C	**C1 Palaeo-eco-geomorphic investigation of West Pilbara coastal environments – NOT INCLUDED IN CURRENT BUDGET AND SCOPE**				
	C1.1 Identification and characterisation of active and relic coastal landforms, establish their formation age		☐	☐	☐
	C1.2 Creation of spatially-temporally contiguous sediment facies maps and assign an depositional environment		☐	☐	☐
	C1.3 Reconstruction of high resolution palaeosea level curve spanning the late Holocene		☐	☐	☐

Project Team.

Name	Organisation	Role	• Tasks
Sharyn Hickey	UWA	Project Co-Lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at UWA. Coordinate and design spatial sampling plan and oversee remote sensing habitat models
Mick O'Leary	UWA	Project Co-Lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at UWA. Coordinate and design the Airborne surveys and ground mapping. Lidar Data processing and analysis. Report writing
Ruth Reef	Monash	Team Member	• Provide expertise on area, and habitat dynamics. Link to previous and ongoing collaborations
Peter Fearns	Curtin	Team Member	• Provide expertise on remote sensing spectral data
Shams Islam	ECU	Team Member	• Provide expertise on machine and deep learning techniques for remote sensing imagey
Catherine Lovelock	UQ	Team Member	• Provide expertise on area, and ecological relationships affecting habitat dynamics. Link to previous and ongoing collaborations
Remote Sensing and Spatial Analyst		Team Member	• Undertake analysis and collation of remote sensing data for habitat development

Post Doctoral fellow (Indigenous Engagement)		Team Member	• Undertake and lead Indigenous habitat mapping
Research Assistant		Team Member	• Assist with data collation, storage and analysis across Project A

Background IP.

See linkages to other projects section

Project Funds Requested.

The budget is based on salary and operational costs starting January 2023. Total funds requested $754,000.00 and in-kind contribution $430,205.

Salaries: Appointed positions will be required to undertake extensive remote sensing analysis, assist in field, and Indigenous engagement activities.

Operating Costs: The field work budget is based on the hire of a vessel, accommodation, vehicle travel. transport of equipment, flights for field campaigns.

Data: We have attempted to budget $300k across the 3 projects ($120k(A), ~$70k(B), $75k(C) to do this. This equates to a coverage of approximately 12% of the Pilbara coast region as identified from the Steering Committee. **Any gap in amount we ask the Steering Committee to help with allocating resources for this.**

This cost covers transfers of aircraft from Adelaide-Karratha-Adelaide, all ground logistics, plus 10 days of survey. It is possible to map approx. 50 square km per day (LiDAR/Hyperspectral/Airphoto). The Aircraft can carry the hyperspectral scanner (SPECIM EAGLE II VNIR 400-1000nm, up to 488 bands) or either a topo-bathy Lidar (RIEGL VQ820G) or topographic lidar (RIEGL Q680i-S) (there are only 2 underwing pods to house these instruments). The Topo-Bathy Lidar will capture tidal creeks, nearshore bathymetry and landforms now submerged within the solar ponds, however this is not the best instrument for capturing terrestrial vegetation and landforms, so for terrestrial mapping we would recommend the Q680i-S topo-Lidar system. To operate both LiDAR systems simultaneously. To extend LiDAR and hyperspectral imagery to the entire coastal region would equate to $1.5 million, and a minimum of 50 days of flight time.

Due to the limited area (12%) covered by the airborne survey we intend to augment this with high resolution satellite imagery, however, to cover the entire region this was quoted at $1.25 million - $4.5 million depending on satellite data available. This would be for 1 time point, which may not be the same along the entire coast as it is based on satellite capture date and it is an extensive area, so is not captured in a single scene. This is based on an academic price from Apollo Mapping at $156-.25-

$568.75 for 25km2.

Instead, to scale the data within the budget constraints we have augmented high resolution data at focus sites that overlap field data, and will use broadscale lower spectral/spatial satellite data to scale. This has limitations around sites being representative of the Pilbara coast, of being able to detect samphire or cyanobacterial mats, utilising habitat ecology with remote sensing data to build habitat prediction models. We will be required to validate these additional areas with in situ field observations and provide uncertainty models. We are also utilising in-kind high spatial resolution satellite data PlanetLabs (low spectral data) under the UWA academic licence (10,000 sqkm per month costed at $15, 0000 annual licence) to augment Landsat and Sentinel imagery for the Pilbara coast scale maps. Where there is no field data or high resolution imagery validation of habitat models is based on global values and there will be uncertainty here.

In-kind: Is based on a contribution of team members employed at UWA, ECU, CURTIN and UQ. It is anticipated that Universities will waive their University Service Charge (USC) on research grant income. Other in-kind contributions relate to use of infrastructure such as computing, imagery and LiDAR, field equipment, and lab infrastructure.

Table 1. Funds requested from WAMSI

Year	2022/23	2023/24	2024/25	TOTAL
Salaries Remote Sensing and Spatial Analyst (2 years *1.0fte)	$ 147,055.00	$ 149,996.00		$ 297,051.00
Salaries Post-doctoral fellow -Indigenous Engagement and Field (1 years *0.5fte)	$ 59,528.00			$ 59,528.00
Salaries Research Assistant (Level 4.4) (3 months)	$ 35,000.00			$ 35,000.00
Remote Sensing Data	$ 77,421.00			$ 77,421.00
Mudd-Ox all-terrain vehicles & trailer	$ 54,000.00	$ 54,000.00		$ 108,000.00
Field Costs (vehicle hire, accommodation, logistics)	$ 30,000.00			$ 30,000.00
LiDAR (Project A costs only)	$ 120,000.00			$ 120,000.00
Indigenous narrative workshop	$ 15,000.00			$ 15,000.00
Hardware/Computing	$ 6,000.00	$ 6,000.00		$ 12,000.00
Totals	$ 544,004.00	$ 209,996.00	$ -	**$ 754,000.00**

Table 2. Co-investment (staffing)

Organisation	2023		2024		2025	
	FTE	($'000)	FTE	($'000)	FTE	($'000)
Sharyn Hickey	0.2	30.174	0.2	30.174		
Mick O'Leary	0.2	39.452	0.2	39.452		
Ruth Reef	0.1	23.248	0.1	23.248		
Peter Fearns	0.1	17.000	0.1	17.000		
Shams Islam	0.2	36.283	0.2	36.283		
Catherine Lovelock	0.02	12.000	0.02	12.000		
Total						

Table 3. Co-investment (cash and in-kind)

Organisation	2022/23		2023/24		2024/25	
	Cash ($'000)	In-kind ($'000)	Cash ($'000)	In-kind ($'000)	Cash ($'000)	In-kind ($'000)
UWA		57.0000		53.000		
ECU		23.000		23.000		
Total		80.000		76.000		

Project deliverables and timing

Deliverable:	Completion date
Milestone Report	**July 2023**
Annual update Presentation	Sep/Oct 2023
Milestone Report	December 2023
Milestone Report	July 2024
Annual update Presentation	Sep/Oct 2024
Final report	December 2024

Milestones, activity, and payments

Year	Milestones / Major activities	Activity (A) or Milestone (M)	Expected Completion Date	WAMSI Funding ($'000)
2022/2023				
	Agreement Signed	M	December 2022	489.603
	MU Agreement signed	A	February 2023	
	Staff Appointments	A	March 2023	
	Ethics, Permits, Permissions	A	April 2023	
	Indigenous Engagement	A	April 2023	
	Airborne Survey	A	May 2023	
	Field Work 1	A	May 2023	
	B1 Indigenous observations of environmental change		June 2023	
	Milestone Report 1	M	July 2023	
	A1 Broadscale habitat models for Pilbara coasts	A	December 2023	
	B1.2 Creation of ESRI Story Map for digital story telling of Indigenous narratives of Environmental change	A	December 2023	
	B1.3 Delivery of digitised participatory mapping datasets to Aboriginal Corporation cultural heritage managers	A	December 2023	
	Milestone Presentation to SC	M	September/October	
	Milestone Report 2	M	December 2023	194.397
2023/2024				
	Milestone Report 3	M	July 2024	
	A2 Investigate space-time dynamics of habitat for Pilbara coast	A	31/12/2024	
	A3 For selected field sites provide finescale models of	A	30/12/2024	

	current habitat extent			
	Milestone Presentation to SC	M	September/October	
	Milestone Report 4	M	December 2024	
	Final Payment on completion and submission of reports	M	December 2024	70.00
2024/25				

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Attachment 5

WAMSI SUMMARY OFFESTS PLAN

Mardie Project – Green Sawfish (*Pristis zijsron*)

Prepared by: David Morgan

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Frontispiece: A Green Sawfish (*Pristis zijsron*) seeking refuge in a shallow Pilbara mangrove during high tide, where they seek refuge from predators whilst also hunting prey (Photograph: David Morgan).

Attachment 5

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WAMSI SUMMARY OFFSETS PLAN

Mardie Project – Green Sawfish (*Pristis zijsron*)

1 Introduction

In January 2024, the Western Australian Marine Science Institution (WAMSI)/BCI Minerals Limited (BCI) *Summary Offsets Plan: Mardie Project* was revised to include, amongst other things, how the plan informed strategic protection, better management and long-term functionality of Green Sawfish habitat. Specifically, the revised offset plan included a research proposal which included a program that seeks to determine species presence, distribution and population sizes of Green Sawfish, as well as identify the trophic transfer from benthic communities and habitat (BCH) to Green Sawfish.

This Research Project is proposed as an addendum to the broader WAMSI Research Summary offsets plan (SOP) and specifically aims to address the Marine Research Objectives for Green Sawfish habitat as prescribed by condition 29 of EPBC 2018/8236, which includes the commissioning of research projects to inform better management and long-term ecological functionality of Green Sawfish habitat.

At present, there are significant knowledge gaps about the locations, extent and connectivity of biologically important habitats used for Green Sawfish along the Pilbara coast, including pupping, nursery, feeding and aggregation (DoE, 2015b, Research Objectives 8c and 9b). Quantitative information about sawfish occurrence and population trends is also lacking (DoE, 2015b, Research Objectives 3a and 8a).

The research proposal focuses on undertaking field survey work and data collection at two key sites which are currently lacking in knowledge; the Mardie Project area and Fortescue River (Study Site 1), and the Onslow/Ashburton area (Study Site 2). A key outcome of the sawfish research program will be to acquire information that will allow the identification of critical habitat across the West Pilbara Coast and quantification of threats to this habitat so as to inform the strategic protection, better management and long-term ecological functionality of Green Sawfish.

2 Objectives and scope

The overall objective of the proposed Green Sawfish research program is to advance the marine research objectives listed in EPBC approval 2018/8236 (issued on 12 January 2022). The EPBC marine research objectives stipulate that research should inform the strategic protection, better management and long-term ecological functionality of Green Sawfish. The proposed research program aims to contribute to the marine research objectives by addressing important knowledge gaps concerning the:

- abundance and distribution of Green Sawfish along the Pilbara Coast;
- Green Sawfish habitat use, residency and migration patterns in key nurseries;
- Green Sawfish population genetics and kinship; and
- trophic interactions with sympatric predators and prey.

It is proposed that this study will address knowledge gaps by undertaking the following tasks:

1. Determining the distribution, abundance and habitat value of Green Sawfish in proximity to Mardie (Fortescue River) and compare to Onslow (Ashburton River). The Fortescue and Ashburton rivers are the only two large river systems in the Southern Pilbara and each is a

known pupping site with adjacent tidal creeks potentially acting as secondary nurseries (see Morgan et al. 2015, 2017, 2023a & 2023b, Lear et al. 2023, Morgan and Lear 2023).

2. Synthesizing available data on population genetics, kinship, habitat use, and migration patterns for Green Sawfish where possible, with four additional surveys and acoustic tracking in key areas such as Mardie (Fortescue River) and Onslow (Ashburton River), aligned to time with pupping (spring) and autumn when young of the year may leave their natal habitat (see Morgan et al. 2015, 2017, Morgan and Lear 2023, Ingelbrecht in press 2024). Twice yearly sampling at these two locations will allow acoustic gear to be serviced and downloaded and recaptured sawfish to be examined for growth and body condition (girth) (see Lear et al. 2023, Morgan and Lear 2023).
3. Providing a food web analysis of Green Sawfish using the results of prey DNA analysis from cloacal swabs and data from stable isotope analyses of tissue samples.

The proposed research program will inform the marine research objectives by addressing important knowledge gaps including:

- Providing new information and data informing presence, abundance, migratory patterns and ecology of the Green Sawfish in the Pilbara region.
- Green Sawfish population genetics, kinship and population structure across the study sites.
- Trophic interactions with prey species informing an understanding of growth rate differences across Pilbara sites**.**
- Habitat connectivity, site fidelity and dispersal range of the Pilbara population
- By identifying important biological areas, such as new nursery habitats and key foraging areas.

Key outcomes informing the strategic protection, better management and long-term ecological functionality of Green Sawfish habitat include:

- Definition of critical habitat across the West Pilbara Coast, with a focus on understanding the importance of the Fortescue River (currently lacking survey data), and which is currently considered a likely key potential nursery habitat.
- Understanding the connectivity and importance of the Onslow population and its movement across the Pilbara sites through additional genetic studies.
- Inform an understanding of key threats, particularly the barrier effects of marine infrastructure on migration through examining age classes (i.e. small juveniles) found at the Cape Preston site.

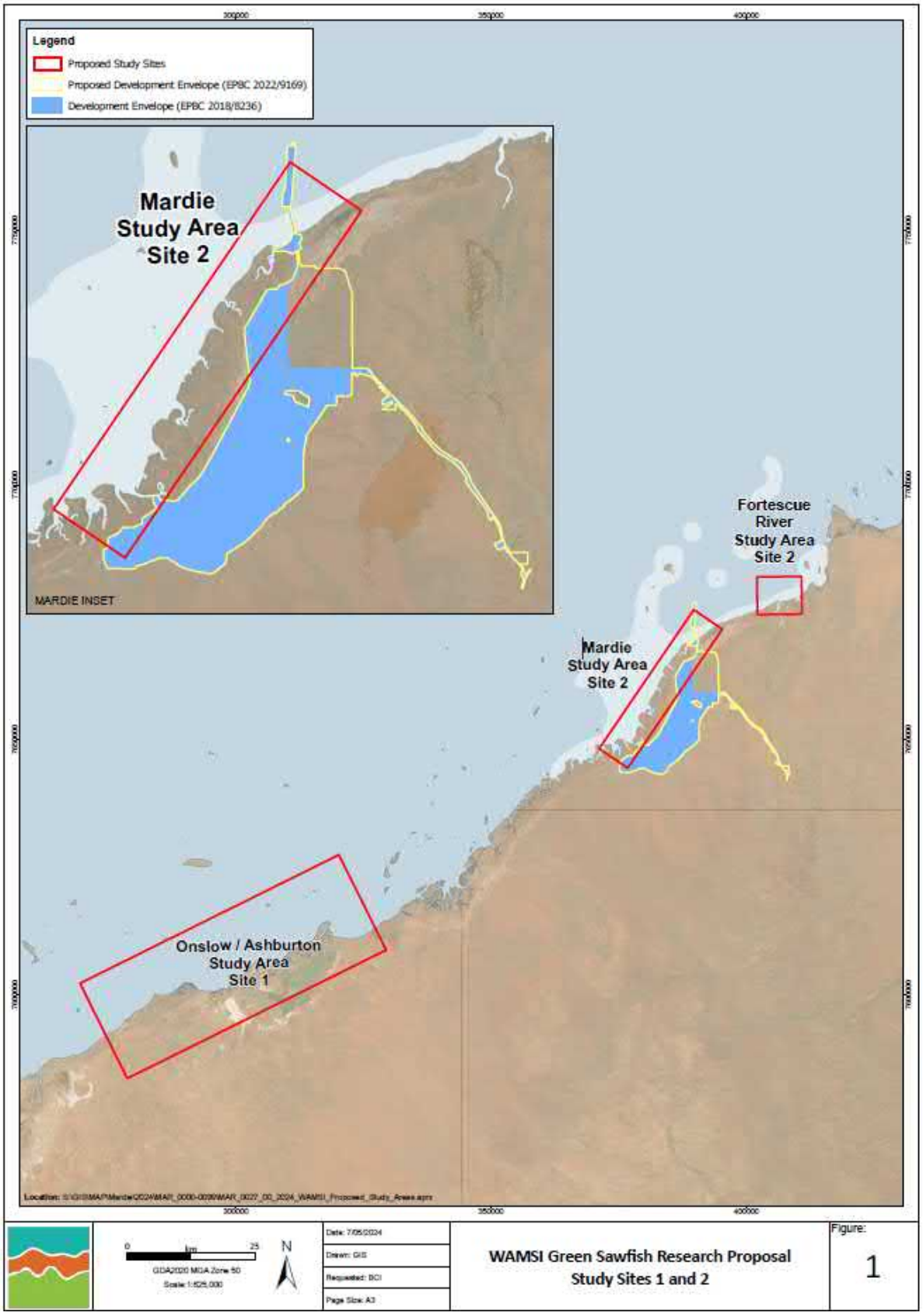

Figure 1: Proposed field study sites along the Pilbara coast

3 Recovery Plans – Meeting Marine Research Objectives

Detailed below are the key linkages between the proposal's objectives and the EPBC ACT research priorities for the species listed in the Commonwealth's *Sawfish and River Sharks Multispecies Recovery Plan* (DoE, 2015b) and *Sawfish and River Sharks Multispecies Issues Paper* (DoE, 2015a). It is noted that Murdoch University, led by Dr David Morgan (Project Leader), substantially contributed to the drafting of these plans, which relied upon the field work data collected by Murdoch University from the early 2000's, as well as technical expertise and knowledge of the species and region, developed over an academic career spanning 30 years.

- *Sawfish and River Sharks Multispecies Recovery Plan* (DoE, 2015b) – at the time that this report was published, Green Sawfish were protected in Western Australia under the *Fish Resources Management Act 1994,* the *Wildlife Conservation Act 1950*. One of the objectives of the plan is to: *Reduce and, where possible, eliminate any adverse impacts of habitat degradation and modification on sawfish and river shark species.* Another is to *Develop research programs to assist conservation of sawfish and river shark species.* This project will address these objectives by identifying important habitats to different age classes and determining extent of habitat use (residency) and relative abundance within nurseries. Under the *Recovery Plan,* the project will be deemed to be successful if habitat critical to the survival to Green Sawfish has been identified and mapped, and that appropriate measures are put in place to manage key threats.
- *Sawfish and River Sharks Multispecies Issues Paper* (DoE, 2015a) – it is only very recently that detailed biological information has been gathered for Green Sawfish, most after the publication date of the Multispecies Issues Paper. For example, none of the references cited in the paper included genetic or biological material from the southern Pilbara; the location where much of the recent research has been conducted (e.g. Morgan et al. 2015, 2017, Ingelbrecht et al. 2022, Lear et al. 2023, Morgan and Lear 2023, Bateman et al. 2024, Harry et al. 2022).
- *Listing advice - Pristis zijsron (Green Sawfish)* (Threatened Species Scientific Committee, 2008).

4 Alignment with DCCEEW criteria for Research-based offsets

4.1 EPBC Offsets Policy

Appendix A of the EPBC Act Environmental Offsets Policy provides five key criteria to be addressed by a research project:

- Criteria 1 - Improve the viability of the impacted protected matter
- Criteria 2 - Be targeted toward key research/education activities
- Criteria 3 - Be undertaken in a transparent, scientifically robust and timely manner
- Criteria 4 – Be undertaken by a suitably qualified individual or organisation in a manner approved by the Department
- Criteria 5 - Consider best practice approaches.

Details of how the research project meets these criteria are provided in Table 1. Details of how the research projects meets the requirements of EPBC 2018/8236 are provided in Table 2.

Table 1: DCCEEW Criteria for research programs

No.	Criteria	Project Suitability
A suitable research or education program must:		
• 1	Endeavour to improve the viability of the impacted protected matter, for example 1. signage in key areas to educate the public regarding the risks to a threatened animal, or 2. research into effective re-vegetation techniques for a threatened ecological community	The proposed research program will improve the viability of Green Sawfish by addressing important knowledge gaps aligned with the marine research objectives, including: • providing new information and data informing presence, abundance, migratory patterns and ecology of the Green Sawfish in the Pilbara region • Green Sawfish population genetics, kinship and population structure across the study sites • Trophic interactions with prey species informing an understanding of growth rate differences across Pilbara sites • Habitat connectivity, site fidelity and dispersal range of the Pilbara population • identifying important biological areas, such as new nursery habitats and key foraging areas Key outcomes informing the strategic protection, better management and long-term ecological functionality of Green Sawfish habitat include: • Define critical habitat across the West Pilbara Coast, with a focus on understanding the importance of the Fortescue River (currently lacking survey data), which is currently considered a key potential nursey habitat • Understanding the connectivity and importance of the Onslow population and movement across the Pilbara sites through additional genetic studies • Inform an understanding of key threats, particularly the barrier effects of marine infrastructure on migration through examining age classes (i.e. small juveniles) found at the Cape Preston site Signage has already been installed at Onslow relating to sawfish for other research projects. Signage will also be erected at the Fortescue River boat ramp as part of this project.

No.	Criteria	Project Suitability
• 2	Be targeted toward key research/ education activities as identified in the relevant Commonwealth approved recovery plan, threat abatement plan, conservation advice, ecological character description, management plan or listing document.	This project will address these objectives by identifying important habitats to different age classes and determining extent of habitat use (residency) and relative abundance within nurseries. Under the *Recovery Plan,* the project will be deemed to be successful if habitat critical to the survival to Green Sawfish has been identified and mapped, and that appropriate measures are put in place to manage key threats. Much of the published research into Green Sawfish in Western Australia has occurred since the recovery plan was published. The results of the current study will be useful when these plans are updated/reviewed – e.g. Morgan et al. 2015, 2017, 2023, Phillips et al. 2017a, b, Ingelbrecht et al., 2022, 2023, Lear et al., 2023., Bateman et al. 2024). We note that the recovery plan was due to be updated in 2020.
• 3	Be undertaken in a transparent, scientifically robust and timely manner	Each methodology in each section is scientifically robust, and contemporary to our recently evolving understanding of Green Sawfish (e.g. see Lear et al. 2023, Morgan et al., 2023, Morgan and Lear 2023).
• 4	Be undertaken by a suitably qualified individual or organisation in a manner approved by the department	The team at Murdoch University has been undertaking sawfish research in Western Australia since 2001. The team leader Associate Professor David Morgan has spent over 30 years studying threatened fishes. Please refer to Section 13 (References)
• 5	Consider best practice research approaches.	The Team has spent a great deal of time developing best practice in sawfish research, such as tagging, placing the fish in a state of tonic immobility, and developing the project with Animal Ethics Committees and Government organisations.

Table 2: Environmental Offset Policy (2012) Research Program Criteria continued

No.	Criteria	Project Suitability
A suitable research program must:		
1	Will be tailored to at least a postgraduate education level; however, there will be scope to engage other educational levels in educational programs (see below).	The project will partially employ a Post-doctoral Researcher, and two PhD students will be involved in the project.

No.	Criteria	Project Suitability
A suitable research program must:		
2	Will present findings that can be peer-reviewed.	This research will be conducted to a standard that will allow the findings to be published in a peer-reviewed scientific journal. The research project report will be peer reviewed prior to publication.
3	Will publish findings in an internationally recognised peer-reviewed scientific journal or be of a standard that would be acceptable for publication in such a journal. Publications should be submitted to free open access journals. Data and information collected should have creative commons licensing and be free and accessible.	This research will be conducted to a standard that will allow the findings to be published in a peer-reviewed scientific journal. The research team will submit any published findings into open-access peer-reviewed paper in an international conservation science journal. Please refer to Section 13 (References) for evidence of this project team's strong record in publishing previous related research. Spatial data will be provided to government and non-government stakeholders for inclusion in their biodiversity databases.
4	Research outputs should inform future management decisions on the protected matter and, where possible, be readily applicable to other similar matters (species groupings etc).	All research outputs will be delivered to Approval organisations, who will be able to consider the outputs, and each should assist in the needed review of the sawfish recovery plan. As per the Environmental Offset Policy criteria for research programs, publications (including media releases, website updates, and research papers) will be provided to DCCEEW as soon as possible and at least five working days before release.

5 Current Relevant Studies / Available Information

A significant amount of scientific work has been completed since the publication in 2015 of the *Sawfish and River Sharks Recovery Plan* (DoE, 2015b).

The Harry Butler Institute notes that the highest amount of effort in targeting Green sawfish has occurred within the mangrove creeks between Onslow and the Ashburton River estuary, where the Institute has previously deployed ~900 x 20-m gill net hours as well as conducted over 150 drone surveys, some of which extended to Yammadery (see Morgan et al. 2015, 2016, 2017, Ingelbrecht et al. 2022, Lear et al. 2023, Bateman et al. 2024). Furthermore, Murdoch's team is currently tracking

Green Sawfish with an acoustic array in two of the Offset regions (Onslow and Gnoorea), although the vast majority of individuals have been tagged near Onslow.

Table 3 represents a summary of previous targeted surveys for sawfish within the four areas identified in the WAMSI Offsets Plan: Mardie Project.

Table 3: Summary of Murdoch University targeted sawfish surveys within the WAMSI Offsets Plan: Mardie Project

	YEAR							
SITE	2011	2014	2016	2019	2020	2021	2022	2023
Giralia				CPUE	CPUE			
Onslow	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE	CPUE/DRONE
Yammadery						DRONE	DRONE	
Gnoorea							CPUE	CPUE/DRONE

CPUE = catch per unit effort which represents gill net sets; DRONE = targeted drone surveys. Onslow includes surveying of 3-4 mangrove creeks and the Ashburton River estuary. Additional sawfish surveys have been conducted in other parts of the Exmouth Gulf, the Fortescue River estuary and mangrove creeks to the south.

Existing information from these previous sawfish studies conducted in Pilbara coastal waters, as well as external reports and citizen sightings will be available to the project reporting. Relevant data will be complied in relation to the abundance (CPUE, catch-per-unit-effort), population demographics (age/size structures), growth and morphological data between the various habitats to inform the reporting of additional catch data, acoustic data and genetic data collected during field surveys in 2024 and 2025.

To inform Green Sawfish population genetics, kinship, habitat use, migration patterns for Green Sawfish available data on concurrent (Murdoch University funded) studies examining the genetic composition of Green Sawfish in the study region will be analysed following Ingelbrecht et al. (2023) for Green Sawfish in the Onslow/Ashburton area. That study used single nucleotide polymorphisms (SNPs) to investigate kinship and philopatry of Green Sawfish, of which the project team have processed 114 individuals from the study area around Onslow (~200 in total). Additional samples collected during 2024 at Mardie, Onslow, and other opportunistic catches will be analysed according to the methods of Ingelbrecht et al. (2023).

6 Study Methods

6.1 Desktop work

Desktop study collating the distribution, abundance and habitat value of Green Sawfish in proximity to southern Pilbara. This part of the study will compile and compare all relevant data in relation to the abundance (CPUE, catch-per-unit-effort), population demographics (age/size structures), growth and morphological data between the various habitats and be used as a baseline for comparisons with fieldwork conducted in 2024 and 2025.

6.2 Field work

The proposed research program aims to collect new data from two key Study Sites (shown in Figure 2 and Figure 3), including:

- Study Site 1: North Section

    - Mardie Project area
    - Fortescue River
- Study Site 2: South Section
    - Onslow area
    - Ashburton River Delta

The purpose of the research is to collect field data that informs the EPBC Act Marine Research Objectives by addressing important knowledge gaps concerning the:

- Presence, abundance and distribution of Green Sawfish along the Pilbara Coast;
- Green Sawfish habitat use and migration patterns;
- Green Sawfish population genetics and structure; and
- Trophic interactions with prey.

The following field work methods will be used in the Green Sawfish research program to understand the distribution, abundance, habitat values, genetic composition and define critical habitat across the West Pilbara Coast:

- **Migration Patterns/Distribution:** The aim of the proposed acoustic survey and tagging work will be to report on sawfish presence / absence, depth utilisation, home range, site fidelity and movement patterns (e.g. see Morgan *et al*. 2017). Information will also be collected to assess differences between size classes, sex and season (see also Morgan and Lear 2023).
- **DNA and Isotope Collection:** Allowing for genetic and food web analysis of Green Sawfish by collection of DNA from cloacal swabs and trophic position from tissue samples at Onslow; additional sympatric predators will be similarly sampled.
- **Presence/Abundance:** Undertaking visual observational data collection across the study sites and while undertaken assessments/monitoring at the Mardie Project area. Observations will be conducted by visual sampling from the boat, walking in the shallows, and from drones.

Field methods are discussed further below, including details on proposed locations, timing of surveys aligned with the ecology of species to increase the chance of observations where possible, and proposed survey/sampling effort needed to address research objectives.

The capture of Green Sawfish will be undertaken by conventional gillnet sampling and conform to the *Protocols for surveying and tagging sawfishes and river sharks* (see Kyne and Pillans 2014). Gillnets will be deployed perpendicular to the bank in several locations within the creeks and nearby creek mouths where habitat looks suitable for sawfish (typically shallow mud or sand flats adjacent to mangroves) and will be comparable to other targeted sawfish surveys in the region (see for example, Morgan et al. 2015, 2017, 2023a, Morgan and Lear 2023, Lear et al. 2023). Gill nets will be comprised of 150 mm monofilament stretched mesh, 50 to 60 m in length with a depth of 2 m. Sawfish observations will be conducted from the bow of the boat, and from the air using a drone (DJI) following the methods of Morgan et al. (2023b).

Collection and handling of Green Sawfish will be undertaken in accordance with the relevant Commonwealth's statutory document and policies, including *Survey Guidelines for Australia's threatened fish* (Commonwealth of Australia, 2011) and *Protocols for surveying and tagging*

sawfishes and river sharks (see Kyne and Pillans 2014) and will conform to University Animal Ethics protocols and government approvals.

The project will operate in line with the following approvals:

Murdoch University Animal Ethics Permit No. R3530/24 "Habitat use and ecology of threatened sharks and rays in the Pilbara region" (Approved 8th April 2024), and

DPIRD Exemption 251203824 "Tracking and monitoring of threatened rays within the coastal Pilbara region" – Approved 29 February 2024.

6.3 Acoustic survey and tagging work

Acoustic survey and tagging are proposed at additional field survey sites at Fortescue/Mardie to complement acoustic survey and fish tagging results already being collected at Onslow, and add to the acoustically tagged fish in the Fortescue River, which were tagged during a different study. 10 acoustic tags have been budgeted for in 2024.

Murdoch University is currently tracking Green Sawfish with an acoustic array in two of the Offset regions (Onslow and Gnoorea as well as near the Fortescue River mouth, and in the Exmouth); although the vast majority of individuals have been tagged near Onslow. More than 110 individual Green Sawfish have been acoustically tagged between near Onslow since 2011; some of these fish have been detected at Urala Creek (~50 km south of Onslow). Additional tags will be deployed in areas where data is lacking, focusing on the Mardie Project area, Fortescue River, and potentially Gnoorea and Onslow, Ashburton River.

Acoustic arrays used in this program will consist of VR2W receivers attached to a standard mooring design comprising a concrete block, a 10 kg anchor and 4 to 8 metres of galvanised chain attached to a rope and buoy (see Morgan et al. 2017, Morgan and Lear 2023). This surveillance system will serve to record movements of captured sawfish fitted with acoustic tags. Acoustic receivers (VR2W) used in this study are required to be physically downloaded and re-batteried at least twice annually to ensure detection continuity in case of receiver loss or battery failure. The acoustic tracking will follow the methodologies used in Morgan et al. (2017), Whitty et al. (2017), Morgan et al. (2021) and Morgan and Lear (2023). The Approval Holder will be responsible for supplying a larger vessel for offshore deployment and retrieval of receivers at Mardie and Urala Creek.

6.4 DNA and Isotope Collection

Prey DNA and isotope sampling will occur in the Onslow study area due to the likelihood of catching Green Sawfish individuals for sampling. The Ashburton River Delta is recognised as a globally important habitat for Green Sawfish, in part because of the high abundances that have been observed. This is supported by survey work undertaken in Onslow (October 2021) where a Catch Per Unit Effort (CPUE) of 0.15 sawfish were caught per 20 m of net per hour.

The budget for data collection allows for the collection and analysis of 50 prey DNA samples that will include the previously collected Green Sawfish swabs (14) from the Onslow/Urala region and an additional 13 other sympatric elasmobranchs.

Cloacal swabs (for prey DNA analysis) and a fin clips (for isotope analysis) will be taken from target species. The total number of samples collected for the isotope analysis will depend on the number of fish captured, and will add to samples collected in April 2024 of 2 Green Sawfish, 9 Nervous Sharks, 3 Lemon Sharks, 1 Bottlenose Wedgefish, 1 Giant Guitarfish. The swabbing process involves inserting a

sterile cotton swab approximately 5 cm deep (for large animals ~2 m total length) into the animal's cloaca, and slowly rotating the swab for 10 s before removing. The swabs will immediately be stored in high-purity ethanol for later DNA barcoding analyses to identify prey items, while the fin-clip will be frozen for food web analysis. The swabbing and fin-clipping will occur while the animal is oriented on its back in tonic immobility just prior to acoustic tag implantation.

6.5 Visual Sampling

Observational data collection will be conducted by visual sampling from the boat and walking in the shallows. Drone based imagery will also be collected. Observation-based surveys are typically carried out by examining the shallow edges of the creeks for sawfish, as young juveniles often tend to swim along shorelines in very shallow water with their fins exposed. Flights will be conducted at altitudes of between 15 and 20 m to increase the likelihood of observing new born pups and as at altitudes higher than 5-10 m the sound produced by most small drones is undetectable above background levels underwater (Christiansen et al. 2016). The majority of flights will be conducted between 08:00 and 11:00 when wind speeds are predicted to be lowest based on long-term BOM data and to enhance visibility (see Butcher et al., 2019).

If a sawfish is sighted by the pilot, video will be taken at ~5 m ASL to determine if the sawfish has previously been tagged (a t-bar tag visible lateral to first dorsal fin), to record any scarring, and to allow rostral teeth counts (for comparison to those individuals previously tagged). During each flight, the following variables will be recorded: Flight start and finish time; Altitude of flight; Turbidity (at the beginning and end of each flight; the clarity of the water scored from 1-5, where 1 is very poor, 5 is extremely clear); Cloud cover (ranging from 0 to 8 oktas (measurement as to how many eighths of the sky is covered – 0 being no clouds, 8 being completely overcast)); Sea State (ranging from 0-12 on the Beaufort Scale (0 being less than 1 knot, 1 being 1-3 knots, 2 (light breeze) being 4-7 knots, 3 (gentle breeze) being 7-10 knots, 4 (moderate breeze) being 11-16 knots, 5 (fresh breeze) being 17-21 knots, 6 (strong breeze) being 22-27 knots, 7 being (near gale) 28-33 knots, and 8 (34-40 knots)); Wind direction (offshore, onshore, across-shore, E, W, N, SSE etc.); Air temperature; Number of sawfish sighted (species identification if possible); Tidal information. The total number of sawfish within each transect will be recorded by the drone pilot, and then compared by a non-drone pilot in the office using VLC media player. Sawfishes will be identified to species level and their relative abundance (number/hour of footage) for each transect calculated as per Morgan et al. (2023).

6.6 Sampling location / Sampling Effort

The two key areas to be surveyed for sawfish include the Mardie/Fortescue area and the Onslow/Ashburton area. The Fortescue and Ashburton represent the two largest river systems in the southern Pilbara and potentially are important pupping sites and nursery areas (see Morgan et al. 2015, 2017, 2022).

Survey efforts

Both sites/regions will be surveyed at least once in spring, which encompasses the main pupping period for Green Sawfish (August-December) in the southern Pilbara (Morgan et al., 2015, 2022, Lear et al. 2023), and again in autumn, which will allow growth to be recorded (from recaptures), acoustic receiver to be downloaded, and diets compared between seasons. A full outline of sampling details is in Table 4.

Table 4: Sampling details

Method	Location	Survey Effort	Timing*
Sawfish Tagging	Onslow (Ashburton River and adjacent mangrove creeks) Mardie (Fortescue River and adjacent mangrove creeks)	5-7 days (x 3 personnel) 5-7 days (x 4 personnel)	2024 – May, October 2025 – May, October 2024 – May, October 2025 – May, October
Acoustic Logger Data Collection (from existing loggers) Additional Acoustic Logger Deployment	Onslow (see Morgan and Lear 2023) -Ashburton River (5) -Adjacent mangrove creeks (11) Mardie - Fortescue River (1) Mardie (see Lear and Morgan 2022) - Mardie North 3 - Middel 1 - Mardie South 2 - Fortescue River 1	2-4 days 2-4 days 4 days 4 days	2024 – May, October 2025 – May, October 2024 – May, October 2025 – May, October
Visual Sampling - Drone Survey Work	Onslow (Ashburton River plus 3-6 mangrove creeks) Mardie (Fortescue (river plus 3-6 mangrove creeks)	4 days 4 days	2024 – May, October 2025 – May, October 2024 – May, October 2025 – May, October
DNA & Isotopic Sample Collection	As per Sawfish Tagging	As per Sawfish Tagging	As per Sawfish Tagging

**** Indicative timing for survey work is provided and dependant on climatic conditions and vessel availability***

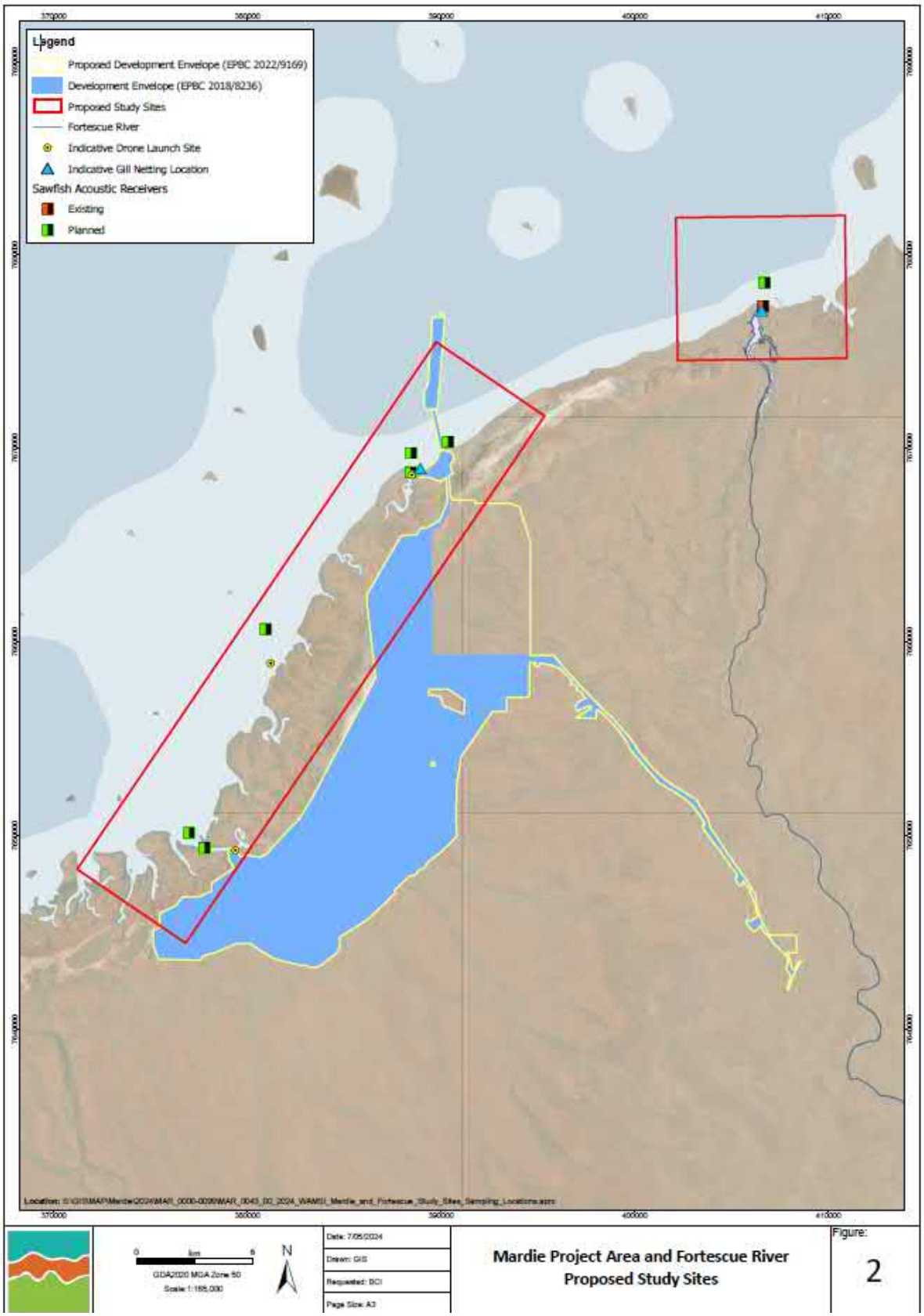

Figure 2: Study Site 1 - Mardie and Fortescue Study Sites Sampling Locations

Figure 3: Study Site 2 - Mardie and Fortescue Study Sites Sampling Location

7 Data Analysis

7.1 Data Compilation

Existing data as detailed in Section 6.1 will be compiled to support the field work data collection. This part of the study will compile and compare all relevant data in relation to the abundance (CPUE, catch-per-unit-effort), population demographics (age/size structures), growth and morphological data between the various habitats. This information will enable our understanding of the distribution, abundance and habitat value of Green Sawfish in proximity to Mardie Project area compared to the Onslow area and where other similarly collected data are available (see Morgan and Lear 2023 for example).

7.2 Migratory Patterns/Habitat use

Data will be downloaded and analysed from the acoustic array in two of the Offset regions (Onslow/Ashburton and Mardie/Fortescue) to identify tagged sawfish with each region and to determine lengths and timing of migrations for various life stages. Data will inform the migratory patterns adjacent to the Mardie Project Area, along the Pilbara coastline to the Fortescue River, and in Gnoorea and Onslow. Habitat use analysis will follow that of Morgan et al. (2017) and Lear et al. (2023).

The data collected from the acoustic monitoring of the study sites will be analysed to determine whether sawfish pupped and acoustically tagged adults in the Onslow region migrate up to the area of the Mardie Footprint.

7.3 DNA and Isotope Analysis

DNA from cotton cloacal swabs (from captured Green Sawfish) will be extracted using DNeasy Blood & Tissue extraction kits (Qiagen). Primer pairs targeting the 12S rRNA gene region and modified with Nextera XT sequencing adapters (Illumina) will be used to amplify the extracted DNA. Two distinct primer pairs will be employed to minimise primer bias and improve taxonomic coverage and sensitivity. The resulting purified amplicons will then be sent to the Australian Genome Research Facility (AGRF) for amplicon indexing, library preparation, and next-generation sequencing on the NextSeq 2000 platform. Sequences will be demultiplexed, with primer sequences removed, and then quality control and high-resolution amplicon sequence variants (ASV) inference will be inferred with DADA2. Taxonomy will be assigned with a Naïve Bayes classifier trained on sequences sourced from a custom region-specific database.

7.4 Population Genetics

To inform Green Sawfish population genetics, available data on concurrent (Murdoch University funded) studies examining the genetic composition of Green Sawfish in the study region will be analysed. It is noted that the Institute are currently using single nucleotide polymorphisms (SNPs) to investigate kinship and philopatry of Green Sawfish, of which the project team have processed 114 individuals from the study area around Onslow (~200 in total). As additional samples present, these will be analysed and allow comparisons between regions (where possible) (see for methods Ingelbrecht et al. 2023).

8 Project Deliverables

Reporting will include the following key deliverables:

Report 1 - (Habitat Use)

A report will be provided on Green Sawfish detection histories, depth utilisation, home range, site fidelity and movement patterns (e.g. see Morgan et al. 2017). Additionally, we will explore differences between size classes, sex and season. We currently have some fish fitted with tags that have a 10 year lifespan. Additional tags will be deployed in areas where data is lacking (e.g. Fortescue/Mardie).

Reporting 2 - (Diet)

Prey items will be reported for the different regions, size classes and species and this data will assist with the food web study and would represent a non-destructive method of determining the diet of sawfish.

Final Program Report (Marine Research Objectives)

The Final Program Report present the key findings, and will provide discussion and conclusion as to how the information relates to the Marine Research Objectives, including:

- report on their detection histories, depth utilisation, home range, site fidelity and movement patterns (e.g. see Morgan et al. 2017). Additionally, we will explore differences between size classes, sex and season as well as kinship analysis of all sawfish captured (see Ingelbrecht et al. 2023).
- Present the findings for presence, abundance and distribution of Green Sawfish along the Pilbara Coast;
- Discuss Green Sawfish habitat use and migration patterns;
- Provide finds on Green Sawfish population genetics and structure; and
- And discuss trophic interactions with prey based on date collected.

The Final Report will be provided to the DCCEEW and will include a discussion on how the project findings contribute to informing the strategic protection, better management and long-term ecological functionality of Green Sawfish habitat, and it will provide recommendations for potential future research programs that advance the understanding against the Commonwealth's Marine Research Objectives. Key topics will include:

- Discussion on critical habitats across the West Pilbara Coast, with a focus on understanding the importance of the Fortescue River (currently lacking survey data), which is currently considered a key potential nursery habitat
- Understanding the connectivity and importance of the Onslow population and movement across the Pilbara sites through additional genetic studies
- Commentary on key threats, particularly the barrier effects of marine infrastructure on migration through examining age classes (i.e. small juveniles) found at the Cape Preston site

9 Project Team

Refer text below and Table 5.

Project Team Leader – Dr David Morgan

Associate Professor David Morgan has been at the forefront of freshwater research in Western Australia over 30 years. Dr Morgan began his career at Murdoch University as a researcher in the Freshwater Fish Research Group (now part of the Centre for Sustainable Aquatic Ecosystems under the Harry Butler Institute). Dr Morgan's commitment to both Murdoch University and to our freshwater ecosystems has resulted in a significant expansion of our knowledge of freshwater systems and species, the on-ground application of conservation measures and the training and inspiration of the next generation of freshwater ecologists. Morgan has co-authored over 300 scientific publications, been a co-investigator on projects in excess of $10M. He is Western Australia's leading sawfish expert conducting projects on three of the species since 2001.

Table 5: Project Roles and Responsibilities

Name	Organisation	Project Role
Associate Professor David Morgan	Murdoch University	Project Direction and Oversight Research Lead
Professor Justin Brookes Tyler Doonan	University of Adelaide	Project Team Members
Travis Fazeldean Jack Ingelbrecht Rebecca Bateman Penélope Taira Dantas Suárez James Tweedley	Murdoch University	

10 Project Milestone

The project tasks are planned to span 2 years over the period April 2024 to December 2025, inclusive. An overview of the timing of the project tasks and reporting activities are outlined in Table 6.

Table 6: Project Milestones

Task	Estimated Timeframe	Party
Research Proposal Submission to DCCEWW	March 2024	BCI
Research Proposal Approval (pending feedback and finalised scope)	March 2024	Cth Minister for Environment
Kick-off Meeting	April 2024	BCI and Project Team
Apply for sampling permit extension (including under Part13 of the EPBC Act)	April 2024	Project Team
Field Trip 1	May 2024	Project Team
Field Trip 2	October 2024	Project Team
Field Trip 3	May 2025	Project Team

Task	Estimated Timeframe	Party
Field Trip 4	October 2025	Project Team
DNA extraction, amplification, primers, library prep., bioinformatics	2024 - 2025	Project Team
Reporting (diet, DNA)	2024 2025	Project Team
Reporting (habitat use)	2025	Project Team
Report (Marine Research Objectives)	2025	Project Team
Final Report (written) to BCI	2025	Project Team
All reports, publications and supporting data provided to BCI and DCCEWW, DBCA, and Department of Water and Environmental Regulation (DWER).	2025	Project Team

11 Funding Arrangement

BCI will allocate the equivalent of $200,000 to this project. These costs are indicative, based on a number of assumptions that need to be confirmed in relation to logistics (e.g., vessel cost for acoustic receiver deployment within the Mardie sites) and survey design (including logistics to support Mardie sawfish surveys). The final design will be completed after direct consultation with DCCEEW.

The budget (Table 7) includes salary for participation of key researchers, costs for logistical and governance arrangements and an allocation for the presentation/publication of project outcomes. Salary contributions for project leaders Associate Professor Morgan, Associate Professor Brookes and Dr Tweedley are in- kind.

Table 7: Budget Proposal

Item	Year 1	Year 2
Salaries-Research Assistant(s)		
Salaries (total 0.6 FTE)	38,694 (0.4 FTE)	20,051 (0.2 FTE)
Desktop Study		
Literature Review / Reporting	19,347 (0.2 FTE)	-
Field surveys		
Field costs (boat*, vehicle, accommodation (2 field trips))	20,000	20,000
Consumables (acoustic tags*, receiver batteries)	17,000	3,000

Item	Year 1	Year 2
Airfares	4,800	4,800
Analysis		
DNA extraction, amplification, primers, library prep., bioinformatics	11,000	5,000
Reporting		
Reporting (diet, DNA) (0.1 FTE)	9,637	10,026
Reporting (habitat use) (0.1 FTE)	0	9,673
Final Report (Marine Research Objectives	0	6,972
Annual sub totals	**101,131**	**98,869**
Grand total		**200,000**

* *Indicative depending on boat availability*

*** A contingency fund of $15,000 is available to the survey work should additional acoustic loggers and transmitters be required*

In-kind: Is based on a contribution of team members employed at Murdoch University and the University of Adelaide. It is anticipated that Universities will waive their University Service Charge (USC) on research grant income with WAMSI governing the project with an overhead charge of 5%. Other in-kind contributions relate to use of infrastructure such as computing, imagery and LiDAR, field equipment, and lab infrastructure.

Table 8: Co-investment for proposed sawfish research

	Co-investment (staffing)			**Co-investment (cash and in-kind), $'000**		
Task 1: Desktop study determining the distribution, abundance and habitat value of Green Sawfish	Organisation	Year 1 FTE ($'000)	Year 2 FTE ($'000)	Organisation	Year 1	Year 2
	D Morgan (Murdoch University (MU))	0.1 (22)	--	Murdoch University	Cash: Nil In-kind: 22	Cash: Nil In-kind: Nil
Task 2: Synthesis of available data on population genetics, kinship, habitat use, migration patterns AND establishment and survey at additional field sites	D. Morgan (MU)	0.2 (44)	0.1 (22)	Murdoch University	Cash: Nil In-kind:116	Cash: Nil In-kind: 37
	J. Tweedley (MU)	0.1 (15)	0.1 (15)			
	J. Ingelbrecht	0.2 (20)	--			
Task 3: Food web analysis of Green Sawfish by collection of prey DNA from cloacal swabs and	D. Morgan (MU) J. Brookes (UA) J. Tweedley (MU)	0.2 (44) 0.1 (25) 0.1 (15)	0.1 (22) 0.1 (25) 0.1 (15)	Murdoch University/The University of Adelaide	Cash: Nil In-kind:88	Cash: Nil In-kind: 62

	Co-investment (staffing)			Co-investment (cash and in-kind), $'000		
trophic position from tissue samples						

12 Dissemination of Information

Publication standard

The research outcomes will be made publicly available. This research will be conducted to a standard that will allow the findings to be published in a peer-reviewed scientific journal and will provide sound recommendations and information for the management and conservation of the Green Sawfish and habitats. The surveys, acoustic tracking, drone and diets sections are all designed to be scientifically robust and thus publishable. The team has published extensively in the field of threatened species, including recent peer-reviewed papers on sawfish (e.g. Morgan et al. 2011, 2015, 2017, 2021, Ingelbrecht et al. 2022, Lear et al. 2023, Bateman et al. 2024). See also Section 13 (References).

Data provision

Within six months of completion of any research project, all reports, publications and supporting data will be provided to the Department, DBCA, and Department of Water and Environmental Regulation (DWER) and published, or the existence and locations of the reports and publications detailed, on the website for the remainder of the life of the project. Data will be managed with best practice quality assurance and quality control measures developed for sea snake research.

All publications (including media releases, website updates, and research papers) will be provided to DCCEEW as soon as possible, and at least five working days before public release.

13 References

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WAMSI project plan for the Collaborative Project Agreement

Mardie Project Marine and Intertidal Research Offsets Program

Project details

Project Title.
Identifying the ecological roles, values and functions of intertidal benthic communities and habitat

Start Date/End Date.

Project Leaders
Glenn Hyndes and Kathryn McMahon

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Scope of the project.

Project summary

Need

This project fits into the offset research program for the conditionally approved Mardie Project (Mardie Minerals Pty Ltd), a solar salt and sulphate of potash production facility in the Pilbara region of Western Australia. Conditional approval under the Ministerial Statement 1175 (MS1175) requires research on the marine and intertidal environment in the region, based "on the significant residual impacts and risks of the proposal to intertidal benthic communities and habitat (BCH) namely mangroves, algal mat and coastal samphire". This will inform future decision-making, management and conservation of the ecological values of BCH on the Pilbara coast.

A preliminary assessment of the Pilbara region indicates that mangroves, cyanobacterial mat and saltmarshes form major coastal intertidal habitats along the shores in the region. Globally, these habitats provide significant ecological functions, including primary production, nutrient cycling, carbon storage as well as foraging, breeding and/or nursery areas for a range of invertebrates, fish and birds (Adame et al. 2021). Furthermore, the immigration and emigration of fauna, as well as the outflow of dissolved nutrients and particulate material from these systems can strongly influence production and diversity in neighbouring ecosystems in the coastal seascape (Hyndes et al. 2014). Despite the recognition of the ecological values of mangroves and saltmarshes globally (Barbier et al. 2011), little is known about the relative value of these systems in arid environments like the Pilbara coast. Also, while cyanobacterial or microbial mats can be extensive and highly productive and diverse (Prieto-Barajas et al. 2018), little is known about their functional role (Penrose 2011, Adame et al. 2021). In Exmouth Gulf where some research has been carried out, cyanobacterial mats are highly productive and form an important source of carbon and nitrogen to nearshore food webs (Lovelock et al. 2010, Penrose 2011, Adame et al. 2021),

suggesting that these mats play an important function to the coastal seascape more broadly across the Pilbara region.

Mangroves, cyanobacterial mats and saltmarshes are influenced by coastal processes such as tides, waves and wind (Lovelock et al. 2011). For example, mangroves occur in wet and arid tropical regions, where they are influenced by the hydrological regime (e.g. tidal range) and evapotranspiration and rainfall that affects salinity and moisture (e.g. Santini et al. 2013, Asbridge et al. 2015). Cyanobacterial mats occur in a range of extreme environments, with coastal mats in intertidal zones subjected to large changes in salinity, temperature and moisture (Prieto-Barajas et al. 2018). The diversity and function of these systems is therefore likely to alter over daily and seasonal scales, and be impacted by climatic events such as cyclones, changes in hydrological cycles associated with coastal developments, and hydrological and atmospheric conditions associated with climate change. Understanding the environmental drivers that influence productivity and ecosystem function of these coastal systems is therefore key to future guidance on proposed coastal developments in the region.

This project will meet the conditions of MS1175 under Condition 14-1(3) by directly aiming to identify the ecological roles, values and functions of intertidal benthic communities and habitat, and will be either informed by or feed into projects addressing Conditions 14-1(1) Project A and 14-1(2) Project B.

Aims

The project will address the following priority objectives outlined in the Mardie Salt Offset Program guidelines:

1. Estimate primary productivity in space and time for algal (cyanobacterial) mat and other BCH;
2. Identify the pathway for transfer of nutrients and energy from BCH to other communities and habitats (e.g. from the intertidal mosaics to the subtidal), which includes trophic transfer (flow of energy) and nutrient transfer to understand ecosystem function; and
3. Identify the key physical drivers such as the response to the wetting and drying associated tidal movement, rainfall, episodic events (storms and cyclones), evaporation etc.

Methods & sampling design

The above objectives will be addressed through a combination of field surveys or field and/or mesocosm experiments across appropriate spatial and temporal scales to account for spatial and temporal variability and influences of hydrodynamic and atmospheric drivers. Our approach is to link field measurements with remote sensing from Project A and models from Project B at 3 sites, which will allow upscaling throughout the region using modelling. Indicative locations are Giralia in southern Exmouth Gulf, Urala and Preston (Figure 1). These sites have been chosen to represent a range of tidal regimes, coastal morphologies and habitat landscape characteristics. Moreover, Giralia has also been the focus of a number of studies led by Prof. Catherine Lovelock (team member). The intent is to focus on the same sites as Projects A and B. Sites may change if negotiations for access to sites and nearby facilities prevent use of one or more site. However, any change in site will made in consultation with WAMSI and the steering committee. Temporal sampling will vary depending on the research question (see below), but will be limited due to budgetary constraints associated with the cost of field work to two years with field trips planned twice a year. One of these trips, is planned to be opportunistic following a significant rainfall event, if it occurs over the life of the project and it is safe to access. See Figure 2 which outlines the timing of each objective and the team members working on each part of the project.

Objective 1 – Primary productivity

Net primary production (NPP) will be estimated for three habitat types: cyanobacterial mats; mangroves; and saltmarshes. For each of the three BCHs, measurements of NPP will be stratified over a gradient from the coastal to landward edge to capture different tidal inundation conditions and species composition of each BCH. The locations of sampling will depend on the landscape configuration at each site. Estimates will be made in two contrasting seasons (e.g. late wet and late dry). Due to the different growth forms and rates of productivity in these different habitat types, different methods will be used to estimate NPP. However, it will be designed in a way so that NPP (g/area/time) can be scaled up to site and regional estimates by area and with the habitat mapping outputs from Project A. This objective will be assessed in Year 1, but as some methods require tagging of plants and measurements after a period of time, the final data collection will occur in Year 2. Sampling at two times will enable an understanding of intra-annual variation, but not inter-annual variation. We acknowledge that inter-annual variation in NPP is likely to be large due to the episodic nature of rainfall events in this region, but due to the limited timeframe of this project and the cost of field campaigns in the region this is not feasible. Environmental variables such as soil salinity, surface salinity, temperature and elevation will also be collected where the NPP estimates are made. Location specific data such as rainfall and evaporation will also be extracted from data repositories for the duration of the study. This information will be used to examine the associations between NPP and these potential environmental drivers.

Cyanobacterial mats

The NPP of cyanobacterial mats will be assessed along a gradient such as distance from tidal influence or elevation to account for the potential variability in NPP due to differential wetting and drying. An "in-growth" technique will be used, where small sections of cyanobacterial mat will be removed and the amount of material that grows into the vacant space assessed over a set time period to enable an estimate of g dry weight per time. The Project Team has experience with performing these experiments and has preliminary data that can help inform the design.

In addition the photosynthetic activity of the cyanobacterial mat (active or dormant) across the spatial extent of the mat in relation to elevation and inundation gradients will be measured using pulse amplitude modulated (PAM) fluorometry to understand how the photosynthetic activity of the mat varies spatially and under different inundation frequencies. This information will assist with validating the regional estimates of cyanobacterial extent and productivity.

Saltmarsh and mangroves

The NPP of saltmarsh will be assessed by two methods, tagging of above-ground structures (e.g. leaves/stems on plants) and spatial extension of plants through markers that outline the perimeter of the plant and the extension beyond these markers is measured. This will give an estimate of new biomass produced over a set period of time (g dry weight per time). In addition, litterfall (detritus) will be estimated to contribute to the NPP estimates. To enable upscaling to site and regional estimates, plot-based measurements such as cover, height and stem density of plants will be recorded so that NPP can be scaled to area based on the cover/density of plants (Howard et al. 2014). The measurements for saltmarsh will be stratified to coastal and landward habitats.

For mangroves, NPP will be estimated through assessment of litterfall (detritus) and tree growth (leaf growth, wood growth using dendrometer bands) and scaled up using plot-based assessments of tree size

(stem diameter and tree height) and density as well as existing allometric relationships. These measurements will be stratified to two mangrove habitat types, lower intertidal fringing mangroves and higher intertidal scrub mangroves).

Objective 2 – Pathway for transfer of nutrients and energy

This objective will be split into two core research questions:

a. Do the pools and outflow of dissolved and particulate nutrients differ between algal (cyanobacterial) mats and other main BCHs?
b. What is the relative contribution of algal (cyanobacterial) mats and other main BCHs to the food web in the coastal seascape?

This objective will be addressed in two contrasting seasons (e.g. late wet and late dry) in Year 1 across the landscape of the intertidal zone and capturing the catchment inflows and outflows, and if possible over an event on at least one occasion. This event sampling will be restricted to dissolved and particulate nutrients as outlined for Objective 2a.

For Objective 2a, both dissolved and particulate nutrients will be sampled across the different habitat community types (e.g. cyanobacterial mats, saltmarsh and mangroves), and in tidal channels and creeks over a tidal cycle, and freshwater in rivers (if present) that form the downstream end of the catchments. The locations and number of samples will depend on the landscape configuration at each site. Water samples will be collected from the water column and sediment porewater and filtered where appropriate. Replicate samples will be collected within each of the key BCHs over the tidal cycle, and from key locations from the catchments. Samples will be collected and processed for concentrations of total dissolved organic and inorganic carbon, total dissolved nitrogen and inorganic nitrogen (NO_x & NH_4^+), and total dissolved phosphorus and PO_3. Suspended particulate organic matter filtered from the water column samples, as well as sedimentary particulate organic matter collected by cores, will be analysed for total organic C, N and P.

Rates of nitrogen fixation of cyanobacteria mats will be determined across three zones along a gradient of tidal influence or elevation to account for the potential variability in N fixation due to different levels of wetting and drying. Replicate samples (1 cm^2) of cyanobacteria mat will be stamped out of the mat at each tidal position and assessed for nitrogen fixation using the acetylene reduction assay (ARA, Brocke et al. 2018). The sections of mat will be taken back to the laboratory, placed in bottles and incubated in flow-through aquaria under controlled day/night and temperature conditions for 24 hours following the procedures of Brocke et al. (2018). Dry weight of the cyanobacteria samples will be determined at the end of the experiment. These data will be used to upscale rates of N fixation at the three sites, where replicate samples of cyanobacteria mat will be collected across the gradient of tidal influence or elevation, dried and weighed. Upscaling at broader spatial scales will be estimated from the habitat mapping in Project A.

To determine the role of cyanobacteria mats in the cycling of nutrients, these mats will be assessed to determine the dominant taxa, followed by metagenomics to determine their functional roles. Replicate samples will be aseptically collected within the mats and stored on ice in sterile bags for DNA extraction, avoiding contamination across samples. Samples will be collected over environmental gradients (e.g. locations exposed to desiccation for different periods over the tidal cycle). DNA extractions will be performed on samples using modified protocols for FastDNA® Spin Kit for Soil (MP Biomedicals). All DNA samples will be quantified, quality checked and sent for 16S rDNA (bacteria) 18S rDNA (eucaryotes) and ITS (fungi) diversity sequencing at Australian Genomics Research Facility (AGRF). Metagenome sequencing will be performed on samples selected based on the diversity analysis results.

The transport of particulate material can also occur through the detachment of cyanobacterial mats. As cyanobacterial mats occur over a narrow range of elevation, reflecting their inundation niche, they can be highly dynamic (Lovelock et al. 2021). When they are desiccated, they can become detached from the sediment and then transported with water flow generated from tides or surface flows. These mats can also become detached during fast surface flows associated with flooding events and transported to the coastal zone. Observations at Giralia, Exmouth Gulf, suggest that detached cyanobacterial mats are transported seaward into adjacent mangroves during ebbing tides, or with southerly winds. How often this occurs (event driven) and how much material is transported is unknown. We will qualitatively measure transport of detached mats using a combination of approaches such as digital imagery from fixed cameras or with a live feed if possible and traps to assess this transport.

For Objective 2b, the food web structure will be determined through a combination of gut content analyses (GCA) and stable isotope analyses (SIA) for the two time periods (e.g. late wet and late dry) and across the different community types (e.g. cyanobacterial mats, saltmarsh and mangroves). For SIA, replicate samples of potential sources of production, including cyanobacterial mat, mangroves, saltmarsh, phytoplankton, benthic microalgae and detritus, will be collected from the key BCHs, and detrital samples and terrestrial vegetation will be collected from the catchments. SIA for these sources and sinks (detritus) will allow the source of material contributing to the detritus across the landscape. In addition, replicate samples of key consumers in each BCH, including benthic meiofauna and macroinvertebrates, zooplankton, insects, and fish will be collected. Benthic invertebrates will be collected using a range of methods including cores and dip nets, while fish will be collected using seine, fyke, gill, scoop and/or throw nets. Species targeted will depend on the relative abundances of species during sampling. Samples will be processed for the determination of $\delta^{15}N$, $\delta^{13}C$ and $\delta^{34}S$ (and possibly $\delta^{2}H$, which has been shown to be a useful tool in mangrove systems; Then et al. 2021). The main potential sources being assimilated by different consumers will be determined using MixSIAR, a Bayesian stable isotope mixing model incorporating uncertainty and variability. Replicate samples of the same consumer species used for SIA will be used for GCA following traditional methods (e.g. Hyndes et al. 1997, Campbell et al. 2021). GCA data will be compiled and subjected to a range of multivariate statistical techniques (i.e. PERMANOVA, RELATE, ordination and shade plots) to determine the main components of the diet of each species and whether they differ spatially, temporally and with increasing size of the taxa.

Feeding ecology of shore birds will be examined using direct observations and dropping analysis from the most abundant species from different size classes (representing different feeding guilds) and when possible, listed species under the EPCA Act. Direct observations provide information on shorebird foraging behaviour, inter- and intra-specific interactions, diet and prey selection. Using video recording, collection of at least 20 to 30 observations (from different individuals) per species, per site and per period will occur prior to other sampling (droppings, invertebrate sampling). When possible, birds will be filmed using digiscoping (camera attached to a telescope) (Estrella et al. 2007, Estrella et al 2015). Where possible, droppings will be collected for shorebirds (Kuwae et al. 2012) for dropping analysis and SIA. Dropping analysis (Dekinga & Piersma 1993, Estrella and Masero 2010) will offer information about diet and prey selection. At least 20 fresh droppings per species per site per period will be collected from monospecific roosts or from areas where only one species has been observed feeding. Droppings will be preserved and analysed in the lab. Droppings will be dis-aggregated in filtered water and sieved though a 50 µm mesh. Hard parts of prey (chironomid heads, polychaete jaws, bivalve hinges, crustacean parts etc.) will be identified and measured. When possible, correlations between prey size and prey hard part size will be developed. SIA for shorebird droppings offer reliable information on short-term diets in shorebirds (Kuwae et al. 2022), and will be analysed as described above for fish samples.

Objective 3 – Key physical drivers

The key physical drivers that affect cyanobacterial mat productivity, nutrient cycling including nitrogen fixation and the flow of nutrients with events will be assessed through a combination of field and mesocosm experiments. The drivers investigated will include soil salinity, surface water salinity including addition of fresh water to simulate rainfall events, elevation, tidal inundation frequency, wetting and drying duration and frequency. These variables have been selected because inundation regimes are linked to intertidal elevation, but are modified by wind speed and direction, sea level and sea level variation, evaporative demand influencing salinity, and attenuation of tidal flows by mangroves (Lovelock et al. 2010, Prieto-Barajas et al. 2018). The field experiments will start in Year 1 and continue into Year 2 whilst preliminary mesocosm experiments will commence in Year 1, but with most focus in Year 2. Opportunistic sampling is also planned over an event such as a large rainfall event to understand how these events influence the flux of nutrients from the cyanobacterial mats to the marine environment. This event sampling requires an event to occur over the project period which is not too extreme as this will likely limit access. The data collected in Objective 1, 2 and 3 can be incorporated into Project B to model the fluxes. For example, the leaf litter production can be used to estimate particulate fluxes and the nutrient pools and flows can be used to estimate dissolved fluxes. Due to logistic reasons, all aspects of this objective will not be conducted at all three sites. For example, it would not be possible to access all sites over an event.

Field and experimental studies will be linked with mapping of cyanobacterial mats in Project A and modelling in Project B to assess how climate (e.g. wind, temperature, humidity) moderates tidal inundation over the intertidal landscapes and NPP and nutrient fluxes of cyanobacterial mats.

Field experiments

The approach for the field experiments is to assess the associations in the natural environment over gradients to understand potential drivers. As these assessments will take place in the field, it will need to take a different measurement approach to Objective 1 and 2. Firstly, productivity and nutrient fluxes will be assessed over gradients based on elevation/tidal inundation and over tidal cycles (e.g. falling vs rising tide and spring vs neap tides). These gradients will be characterised by elevation with RTK GPS, water level and inundation and salinity using loggers. The photosynthetic activity of the cyanobacterial mats will be assessed using a pulse amplitude modulated (PAM) fluorometer giving an estimate of active or dormant mats. Chamber experiments that measure oxygen evolution and nutrient fluxes will quantify the rates of productivity and nutrient fluxes along this gradient. For example, for productivity these small-scale, short-term chamber assessments will measure oxygen evolution using FireSting™ 3 mm robust REDFLASH technology sensors (Pyroscience) following a similar approach to Said et al (2021).

The second proposed approach is to place settlement structures in the field along the established gradient to identify where cyanobacteria mats develop. The colonisation and increase in biomass over time will be an estimate of NPP. The approach of gradients used by Kirwan and Guntenspergen (2015) for evaluating growth of saltmarshes over inundation gradients will be used where a series of PVC pipes of different lengths that represent different levels of elevations/inundation will be deployed in the cyanobacterial mat habitat. Sediment surfaces within the pipes that are colonised by cyanobacteria indicate inundation levels that support cyanobacterial mat development.

Laboratory experiments

The field experiments will identify potential drivers of productivity and nutrient fluxes in cyanobacterial

mats where the controlled laboratory experiments will enable testing of the drivers under controlled conditions. These results will feed into modelling and enable simulation of scenarios of rainfall or surface flows which are not possible to measure in the field. There are several potential factors that can be tested in these experiments and these will be confirmed following insight from the field work. For example, how salinity from fresh (representing rainfall) to hypersaline (representing cyanobacterial mat conditions) could be manipulated to assess the effect on productivity and nutrient fluxes. Other factors could include the duration and frequency of drying and wetting, and the response time for cyanobacterial mats to become productive. To carry out these experiments, sections of cyanobacterial mat will be removed from the site and transported to mesocosm facilities at ECU. Under controlled day/night conditions cyanobacterial mat will be exposed to a range of treatments. It is envisaged that multiple experiments will be carried out to test a range of different factors (e.g. salinity, wetting and drying duration and frequency). Like in the field experiments, O_2 production will be measured over the course of the experiment as an estimate of NPP, as well as nutrient fluxes, and the production of soluble materials (complex carbohydrate films) which is more challenging to measure in the field.

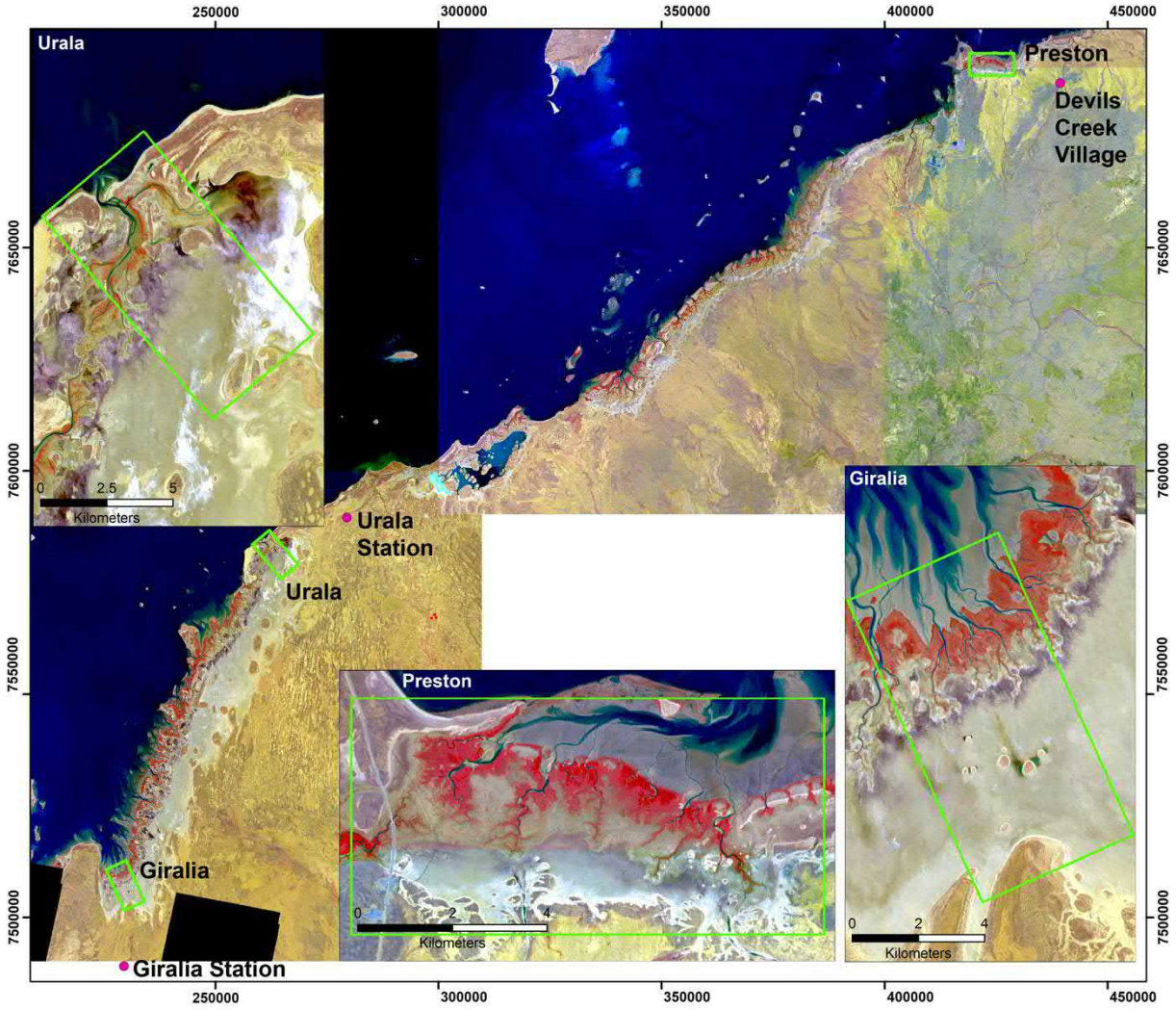


Figure 1. Indicative locations for sampling sites for Projects A, B and C. The final locations will be confirmed at the beginning of the project and after negotiations with land and facility holders and engagement with traditional owners.

Objective		Community type	Year 1	Year 2	Event	Lead
Obj. 1	Productivity	Cyanobacterial mat				McMahon & Lovelock
		Mangrove & Saltmarsh				McMahon & Lovelock
Obj. 2	Nutrient transfer & energy flows	Nutrients				Hyndes & Watkin
		Food webs				Hyndes, Marin-Estrella & Tweedley
Obj. 3	Physical Drivers	Cyanobacterial mat				McMahon

Figure 2. The timing of the four objectives in Project C.

Describe how data will be secured during the project.

Collected data will be stored on solid state drives and also uploaded to secure cloud storage available to all project investigators and research staff and students.

Linkages

Mardie Salt Projects.

Project C has strong links and co-dependence with Projects A and B. We will work closely together to ensure the required data is collected at the appropriate spatial and temporal resolution to enable integration and to maximise efficiencies. Mapping of the BCHs in Project A will allow data collected from this study to be scaled up to regional levels, while this study will also provide data for modelling of the potential effects of sea level rise on BCHs and identifying the significance of salt projects in preventing the adaptation of intertidal BCH to sea level rise in Project B.

External projects

Project C also has synergies with other external projects including:

- The offset project entitled “Primary productivity and energy transfer between marine ecosystems” being carried out in the Dampier Archipelago by DBCA.
- ARC Australian Laureate Fellowship of Prof. Lovelock on activating blue carbon for coastal restoration with sites established in the Pilbara.

Implications for Management

This project will identify and provide key data on the ecological roles, values and functions of intertidal benthic communities and habitat in the Pilbara that will feed into background information for future EIAs of proposed solar salt production developments in the region.

Risks to delivery and how they will be managed.

The following outline the risks associated with the project:

1. The delay in getting sign-off on the agreement leads to a delay in the start of the project and the ability to order equipment in advance and recruit staff to collect samples and analyse the data (High risk). This will be managed by gaining feedback on the draft agreement from ECU's legal services in advance and fast-tracking of staff recruitment to the best of our ability.
2. The delay in sign-off on the agreement leads to missing key sampling times that are restricted to climatic conditions in the Pilbara region, e.g. high temperatures and cyclone events. This would lead to delays in field sample collection and subsequent processing and data analyses (High risk). Management of this risk will depend on when the agreement is signed, staff can be recruited, and timing in relation to key sampling times.
3. Delayed or lack of access to sites and nearby facilities for field activities, leading to a need to determine and negotiate access to new field sites. This will be managed by starting negotiations on site and facility access before the agreement has been signed.
4. Mesocosm equipment failure leading to delay in cyanobacteria mat experiments (Medium risk). This will be managed by ensuring the equipment is maintained regularly.
5. Tampering, damage or loss of equipment such as temperature and depth loggers (Low risk). This will be managed by ensuring that the deployed equipment is concealed and secured as much as possible.
6. Staff and PhD student resignation/sickness leading to delays in progress (Low risk). Staff and students will be managed and mentored effectively. In the event staff member resigns, recruitment for a replacement will take place. All team members, with the exception of the two new staff to be employed, are on continuing contracts.

Outcomes.

- The outputs of this project will help meet the conditions of MS1175 under Condition 14-1(3) by identifying the ecological roles, values and functions of intertidal benthic communities and habitat.
- The outputs of this project will feed directly into the EIA process for future salt production developments in the Pilbara region.
- This project will provide baseline data on primary productivity in space and time for algal (cyanobacterial) mat and other BCH.
- This project will identify the pathways for transfer of nutrients from catchments to and between BCHs, and trophic transfer (flow of energy and food web structure) into and out of BCHs, to understand ecosystem function.
- This project will provide an understanding of the nutrient cycling, including nitrogen fixation, of algal (cyanobacterial) mats.
- This project will identify key physical drivers that influence primary productivity of cyanobacteria mats, focusing on this BCH's response to the wetting and drying associated tidal movement, and episodic events such as rainfall.

Project Team.

Name	Organisation	Role	• Tasks
Prof Glenn Hyndes	ECU	Project co-lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at ECU. Design of field and mesocosm experiments and approach. Review of analysis and report writing. Involved with other projects related to this one to facilitate the exchange of samples and data to minimize costs and duplication.
A/Prof Kathryn McMahon	ECU	Project co-lead	• Co-project lead responsible for the overall coordination of the project, management of research staff employed on the project, and budget management at ECU. Design of field and mesocosm experiments and approach. Review of analysis and report writing. Involved with other projects related to this one to facilitate the exchange of samples and data to minimize costs and duplication.
Dr James Tweedley	MU	Team member	• Design of field work and approach for trophic food web studies with a particular focus on invertebrates and fish. Review of analysis and report writing.
Prof. Elizabeth Watkin	ECU	Team member	• Design of field and laboratory work for and approach for cyanobacterial mat function using genomic analyses. Review of analysis and report writing.
Dr Sora Marin-Estrella	ECU	Team member	• Design of field and laboratory work and approach for trophic food web studies with a particular focus on birds. Review of analysis and report writing.
Prof. Catherine Lovelock	UQ	Team member	• Design of field work and approach for primary productivity estimates. Review of analysis and report writing.
Postdoctoral Fellow	ECU	Team member	• Coordinating field and laboratory work, data curation, complex statistical analysis of data and report writing.
Research Assistant	MU	Team member	• Assisting fieldwork and sample processing.
2 PhD students	ECU and MU	Team member	• Develop research that complement/extend on plans. Assisting fieldwork and sample processing, statistical analysis and writing.

Data and IP Management

This project will generate the following types of data.

(i) Primary productivity data for cyanobacteria mats, mangroves and saltmarshes at different locations and times. Data will be in Excel format with associated meta-data.

(ii) Concentration data for particulate and dissolved organic and inorganic carbon and nutrients in different habitats across locations and times, as well as nitrogen fixations data for cyanobacteria mats. Data will be in Excel format and include imagery with associated meta-data.

(iii) DNA sequencing and metagenomic data for the diversity and functional groups contributing to the cyanobacterial mat communities. Data will be in Excel format with associated meta-data.

(iv) Dietary data from GCA and birds from direct observations and dropping analyses across habitats, locations and times. Data will be in Excel format and include imagery with associated meta-data.

(v) Isotopic signatures (Carbon, Nitrogen and, for some taxa, Sulphur) for a suite of biota ranging from primary producers to apex predators. Essentially an Excel spreadsheet of the sample, the signatures and associated meta-data.

(vi) Data on the key physical drivers that affect cyanobacterial mat productivity, nutrient cycling including nitrogen fixation from field and mesocosm experiments. Data will be in Excel format with associated meta-data.

These data will be stored on solid state drives and also uploaded to cloud storage available to both project leads, the post-doctoral fellow and research assistant, and PhD students.

Edith Cowan University and Murdoch University are strong supporters of open access data and have long-standing commitments to curation and storage of research data. We follow the *Responsible Conduct of Research Policy*, developed in accordance with the *Australian Code for the Responsible Conduct of Research*. This involves correct collection, storage, protection and retention of data that we gather, as part of our research. WAMSI is also committed to the management and longevity of research data, with policies on *Access, storage, management and security of data* for the purpose of preserving data from unauthorised access, loss and misuse, and to ensure fulfilment of compliance requirements, ensure privacy and to optimise storage space. Publishing our outcomes will require that data sets are submitted to curated, citable, publicly available archiving sites, such as the Dryad Digital Repository (www.dryad.org), when required for journal publication.

Background IP

IP associated with this project includes:

- Previous data collected by Prof Lovelock and team in the Pilbara including timeseries data on mangrove, saltmarsh and cyanobacterial mat productivity, nutrient transfer and cycling in these habitats and environmental drivers of these processes.
- Previous data collected by ECU in the Pilbara on groundwater discharge in nearshore coastal including nutrient and metal concentrations and surface water nutrient data and nutrient composition and isotopes of primary producers.
- Previous data collected by ECU on mangrove standing biomass and productivity as well as environmental drivers of mangrove and saltmarsh distribution and productivity in the Pilbara.
- Previous data collected by ECU stable isotopes of biota in intertidal areas of Roebuck Bay, north-western Australia.

Project Funds Requested.

The budget is based on salary and operational costs over 2.5 years, starting in April 2023. The total funds requested amounts to $1,000,000 that is to be supported by a total in-kind contribution of $1,484,030 and cash contribution of $100,000 from the partner institutes.

Salaries: A Postdoctoral Fellow will be required to coordinate the extensive field campaigns and undertake key aspects of the laboratory work, along with writing the report (Postdoctoral Fellow Level B Step 1, 1.0 FTE for 2.5 years, $385,761 including 17% oncosts for superannuation, salary tax). A Research Assistant will be required for a 2.25-year period to assist with the field work and extensive laboratory processing for core aspects of the project (HEW5 Step 1, 1.0 FTE, $228,567). A total $15,600 is allocated for consultancy services (Dr Ben Fitzpatrick) for advice on the region during a planning workshop and during the pilot field trip to finalise the field program for sampling trips.

Equipment costs: A Mudd-Ox all-terrain vehicle (and trailer to transport the vehicle) will be required to access the mud flats and other habitats with minimal damage to the habitats at a cost of $54,000 (excluding GST). Other equipment will be purchased from ECU's cash contribution (see Co-investment below).

Operating costs: The field work budget is based on accommodation ($500 per day), vehicle hire and fuel costs related to the transport of equipment and staff ($3,000 for 25 days plus fuel), and flights to transport remaining staff to Exmouth) for 4 field campaigns (2 each in Years 1 and 2). Return flights from Queensland have also been included for C. Lovelock (2 per year in Years 1 and 2, and 1 in Year 3). Budget is also allocated to a pilot field trip in Year 1 and an opportunistic sampling trip during a high flow event to sample nutrients off the catchment. Vehicle hire costs have also been included for travel requirements in the Perth metro region. Consumable costs include costs associated with items needed for fieldwork (e.g. bags, tags, ethanol, tapes, fuel for all-terrain vehicle and air freight costs for rapid transport of DNA samples for correct storage at ECU) and laboratory processing (e.g. tubes and tin cups for stable isotope samples, ethanol and other chemicals, and vehicle costs for transport between ECU, MU and UWA).

Stable isotopes analyses cost $17 per sample for δ13C and δ15N (ECU rates), and $24.50 per sample for δ34S (UC Davis rates). Nutrient analyses will include dissolved organic and inorganic carbon ($50 per sample at SCU) and dissolved inorganic N and P ($52 per sample at SCU). Costs for DNA and metagenomic sequencing are based on $300 per sample for each form of sequencing at AGRF. Budget is also allocated to an opportunistic nutrient sampling during a high flow event.

<u>Co-investment</u>

In-kind salaries (FTE) are based on the contributions of team members employed at ECU, MU and UQ. ECU and MU have waived their University Service Charge (USC) on research grant income. For consistency across universities, a 30% USC has been applied to the total funds requested for each institute as in-kind contributions. Other in-kind contributions relate to use of infrastructure such as aquarium and mesocosm facilities, as well as relevant equipment. ECU and MU will each provide a PhD scholarship (total of 2) at ~$30,000 per year, and ECU will provide a cash contribution of $100,000 to contribute towards equipment and consumable costs. Salinity and temperature loggers (4), temperature loggers (10) and FireSting probe sensors to measure O_2 production will be provided as in-kind support to measure environmental variables that are likely to form major drivers of NPP and diversity in the BCHs. Digital camera traps (7) and Zeiss binoculars will be provided by ECU, while corers and fishing nets will be provided as in-kind support from both ECU and MU. MU will also provide an Eckman grab. ECU will provide basic lab equipment for DNA extraction and preparation for sequencing of the mat samples.

Additional salinity and temperature loggers (@$1,800) and water level loggers (@$745), and replacement FireSting probes (Total $8,000) will need to be purchased from ECU's cash support. In addition, telescope attached to an SLR camera will be required for bird foraging surveys, and additional nets will need to be constructed for fish sampling.

Table 1. Funds requested from WAMSI

Year	2023	2024	2025	TOTAL
Salaries-Postdoctoral Fellow (2.5 yrs)	107.4	154.7	123.6	385.8
Salaries-Research Assistant (2.5 yrs)	55.6	97.5	55.5	228.6
Consultancy services	15.6			15.6
Mudd-Ox all-terrain vehicle & trailer	54.0			54.0
Field costs (vehicle, accommodation and food)	38.6	38,6	5.0	82.1
Perth metro travel-car hire	0.6	0.6	0.3	1.5
Consumables	10.0	10.0	4.0	24.0
Airfares	8.2	8.2	0.9	17.3
LiDAR/Hyperspectral data (shared across 3 projects)	75.0			75.0
Stable isotope analyses	15.2	15.2	5.0	35.4
DNA sequencing analyses	9.9	9.9		19.8
Nutrient analyses	20.3	20.3	20.3	60.9
Total WAMSI ($'000)	**434.3**	**355.8**	**209.9**	**1,000.0**

Table 2. Co-investment (staffing)

Organisation	2023		2024		2025	
	FTE	($'000)	FTE	($'000)	FTE	($'000)
G. Hyndes (ECU)	0.2	50	0.2	50	0.2	50
K. McMahon (ECU)	0.2	43	0.2	43	0.2	43
S. Marin-Estrella (ECU)	0.1	16	0.1	16	0.1	16
E. Watkin (ECU)	0.1	25	0.1	25	0.1	25
J. Tweedley (MU)	0.1	40	0.1	40	0.1	40
C. Lovelock (UQ)	0.05	25	0.05	25	0.05	25
Total	0.75	200	0.75	200	0.75	200

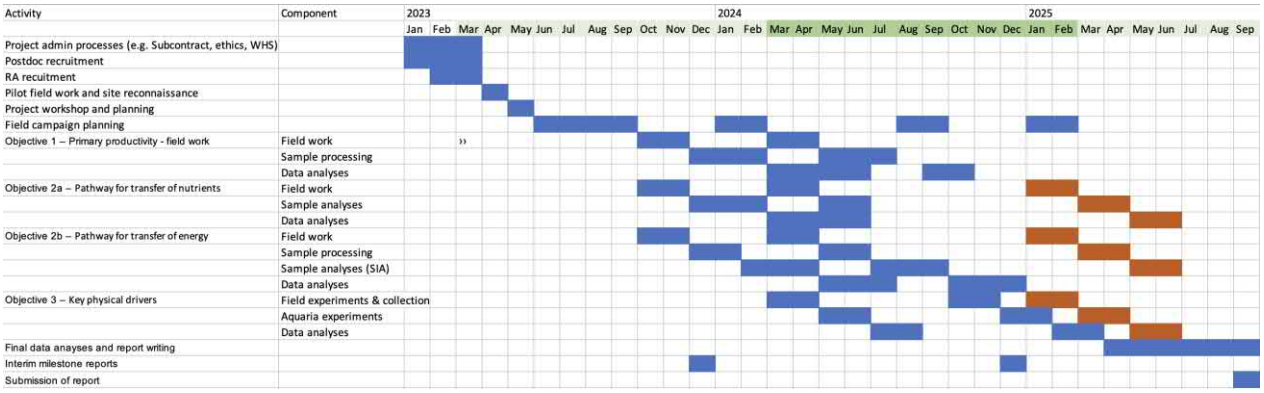
Table 3. Co-investment (cash and in-kind)

Organisation	2023		2024		2025	
	Cash ($'000)	In-kind ($'000)	Cash ($'000)	In-kind ($'000)	Cash ($'000)	In-kind ($'000)
ECU	80.0	130.9	20.0	107.3		46.8
MU		59.4		59.7		45.1
Total	**80.0**	**190.3**	**20.0**	**167.1**		**121.8**

Project deliverables and timing.

Deliverable:	Completion date
1. 1st Annual presentation	Last quarter 2023
2. Milestone report	December 2023
3. 2nd Annual presentation	Last quarter 2024
4. Milestone report	December 2024
5. 3rd Annual presentation	July 2025
6. Final report	September 2025

Table 1 – Project C schedule



Note: timing for event sampling represented in orange will depend on when or if an event occurs during the project's timeline.

Milestones, activity, and payments

Year	Milestones / Major activities	Activity (A) or Milestone (M)	Expected Completion Date	WAMSI Funding ($'000)
2023				
1.1	Agreement signed	M	December 2022	436.3
1.2	MU agreement signed	A	February 2023	
1.3	Appoint Postdoc and RA	A	April 2023	
1.4	Pilot field trip and workshop	A	May 2023	
1.5	Season 1 field trip/data collection	A	November 2023	
1.6	Annual report on activities 1.3-1.5	M	December 2023	357.8
2024				
2.1	Season 2 field trip/data collection	A	April 2024	
2.2	Mesocosm experiments		June 2024	
2.3	Sample processing & data analyses	A	September 2024	
2.3	Physical drivers field trip	A	November 2024	
2.4	Annual report on activities 2.1-2.3	M	December 2024	105.9
2024/25				
3.1	Mesocosm experiments	A	February 2025	
3.2	Seasonal event field trip/data collection	A	February 2025	
3.3	Sample processing & data analyses	A	April 2025	
3.4	Deliver final report • Primary productivity • Pathway for transfer of nutrients • Pathway for transfer of energy • Key physical drivers	M	September	100.0

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ATTACHMENT 6

WAMSI SUMMARY OFFSETS PLAN

Mardie Project – Migratory Shorebirds

Table of Contents

1. Introduction

This Research Project is proposed as an attachment to the broader WAMSI Research SOP being undertaken using funding provided by BCI Minerals as part of its implementation of the Mardie Solar Salt project.

The work proposed under this Research Proposal will link strongly with the Objective 2b of Project C detailed in the Western Australian Marine Science Institution (WAMSI) Summary Offset Proposal (SOP), through a commitment to undertake additional fieldwork across established WAMSI research sites and proposed new sites in the Mardie Project area to obtain new habitat use and trophic ecological data.

There is a significant lack of knowledge on migratory shorebirds' habitat use and basic ecology (including diet and food webs that support migratory shorebirds) in the Pilbara region (see Estrella *et al*. 2015). New knowledge in these areas is required to meet Australian Commonwealth Government policy objectives to protect, conserve and manage migratory shorebirds in the Pilbara region (Commonwealth of Australia, 2015 and 2017).

Aligned with this, a key outcome of this research program will be to inform the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 Marine Research Objectives by undertaking on-site field work to acquire information that will allow the identification of critical habitat across the West Pilbara Coast important to Migratory bird species.

This study will be led by research members from Edith Cowan University (ECU) and Birdlife Australia, with support from WAMSI and oversight from BCI Minerals.

2. Objectives and scope

2.1. Research objectives

The overall objective of the proposed Migratory Bird research program is to meet the marine research objectives prescribed by EPBC approval 2018/8236 (issued on 12 January 2022), which are to inform the:

- strategic protection,
- better management, and
- long-term ecological functionality

of migratory shorebirds habitat.

The general objective of the proposal will be data collection which will inform presence, abundance, and identify the trophic transfer from significant habitats of the West Pilbara Coast to migratory birds.

The specific objectives of the proposal will be to:

- Evaluate migratory shorebird habitat use considering potentially significant habitats in the Pilbara coast for shorebirds such as intertidal areas, tidal channels, salt flats/cyanobacteria mats.
- Assess trophic transfer and food web structure that support migratory shorebirds in the region.

The expected research outputs will be:

- Data documenting the presence and abundance of migratory shorebirds near the SOP study sites.
- Information on habitat attributes at locations where migratory bird presence / absence and abundance data are collected, and
- Improved knowledge on trophic transfer, including identification of main primary producers that support migratory shorebirds food webs, obtained through analysis and interpretation of eDNA and stable isotope samples.

2.2. Scope

Proposed field work locations include established WAMSI research sites at Giralia in southern Exmouth Gulf, Urala Station, Gnoorea, Onslow, and the Mardie Project area (Figure 1**Error! Reference source not found.**). Not all field techniques will be used at every location.

Fieldwork will be undertaken using conventional habitat usage methods such as GPS tracking and camera traps alongside collection of biological samples for environmental DNA (eDNA) and Stable Isotope analysis (SIA).

GPS tracking and camera traps provide the opportunity to use two complementary methods, and offer a robust combination to gain knowledge on individual species visiting specific habitat types along the Pilbara coast. The combination of SIA and eDNA methods would provide a comprehensive approach to determine what prey shorebirds are feeding on, and if their diets match what is available within these intertidal areas.

Data collection from this research proposal will also document the presence and abundance of shorebirds and will contribute to an improved understanding of the food web structure and trophic transfer from intertidal zones to migratory birds.

Field surveys will include observations of species presence and abundance and will include recording information to describe habitat attributes/characteristics (e.g. tidal channel, mangrove, seagrass meadow or cyanobacteria matt presence). This information will help in defining which habitats or habitat attributes represent 'critical habitat' for the targeted species.

Field data will be considered alongside laboratory data to develop recommendations for management of key habitat(s).

Target migratory shorebird species include:

- Bar-tailed Godwit *Limosa lapponica menzbieri* – The subspecies Yakutian Bar-tailed Godwit is found on the west coast of the Australian continent. Listed Endangered/ Migratory (EPBC Act). It is an abundant medium to large migratory shorebird in the study area. Tactile feeder.

- Greater Sand Plover *Charadrius leschenaultii* – Listed Vulnerable/Migratory (EPBC Act). It is a common medium size migratory shorebird in the study area. Visual feeder.

- Far Eastern Curlew *Numenius madagascariensis* - Listed Critically Endangered/Migratory (EPBC Act). It is the largest shorebird in the world, and is relatively common in the study area, although never found in large numbers. It has been observed feeding on fiddler crabs on the saltpan areas in the region. Visual/tactile feeder.

- Red-necked Stint - Listed Migratory Species (EPBC Act). It is an abundant small-sized migratory shorebird in the study area. It has been observed feeding on the supratidal areas in the region. Visual and tactile feeder.

- The above list of species does not preclude the collection of data of other species of migratory shorebirds, particularly others listed Critically Endangered, Endangered or Vulnerable such as Curlew Sandpiper *Calidris ferruginea*, Common Greenshank *Tringa nebularia* or Great Knot *Calidris tenuirostris*.

2.3. Link to Mardie Project EMP Monitoring Provisions

The Proposal will take into consideration and utilise the following monitoring and management plans for the Mardie Project, as relevant:

- **Long-term migratory shorebird monitoring program**

The ongoing migratory bird counts (i.e. under the Long-term migratory shorebird monitoring program) will inform WAMSI Project C in its consideration of the habitat usage of different communities present across the intertidal zone. These learnings from Mardie will be directly relevant to the equivalent habitats at other WAMSI study sites.

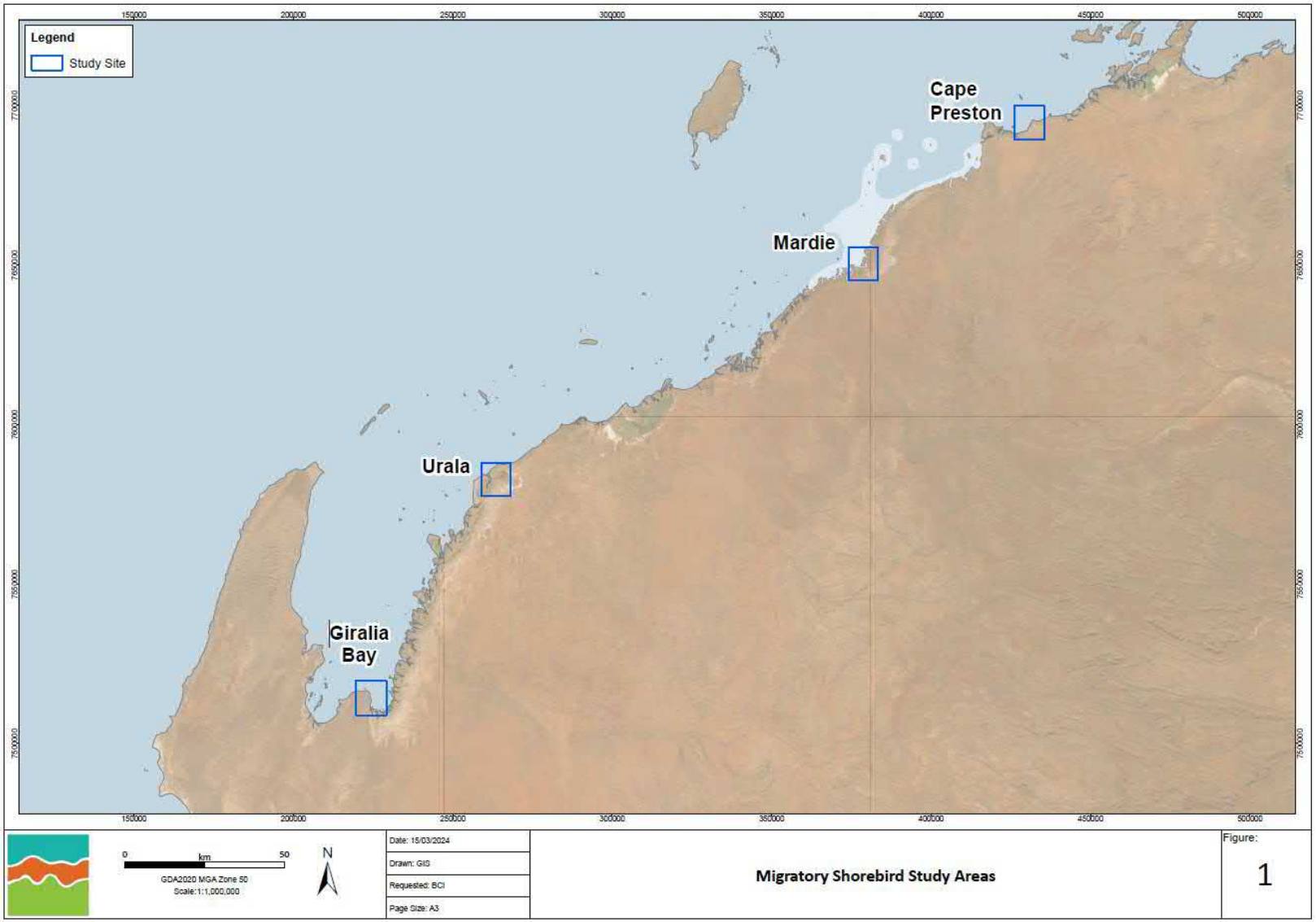

Figure 1: WAMSI field study sites along the Pilbara coast

3. Alignment with Commonwealth policy objectives

3.1. Conservation Plan for Migratory Shorebirds

Within the conservation and recovery actions stated in the Conservation Advice for *Numenius madagascariensis* (Far Eastern Curlew), one of the two primary conservation objectives is to "*minimise further loss of habitat critical to the survival of Far Eastern Curlew throughout Australia".* Exmouth Gulf, located approximately 200 km southwest of the Mardie project area, is an internationally and nationally important shorebird habitat for the species (Weller et al. 2020), and it is therefore considered critical to the survival of the species. Evaluating habitat use by Far Eastern Curlews at multiple study sites in the Pilbara coastal region will help to identify feeding and roosting areas (critical habitat) and improve site protection and management. Similarly, Exmouth Gulf is also a nationally important habitat for Yakutian Bar-tailed Godwit *Limosa lapponica menzbieri*, Great Knot *Calidris tenuirostris* and Greater Sand Plover *Charadrius leschenaultia* among other species of migratory shorebirds (Weller et al. 2020).

This research proposal aligns with several high or very high priority actions identified in the Commonwealth's *Wildlife Conservation Plan for Migratory Shorebirds* (Commonwealth of Australia, 2015). The approach adopted in the migratory bird research program is specifically relevant to Objective 4 of the Conservation Plan for Migratory Shorebirds:

Objective 4: Knowledge gaps in migratory shorebird ecology in Australia are identified and addressed to inform decision makers, land managers and the public.

Details are provided in Table 1.

Table 1: Priority conservation actions addressed in this research proposal

Reference Note 1	Action	Priority	Relevance to this research program
4a	Identify and prioritise knowledge gaps that are required to support the conservation and management of migratory shorebirds and their habitats.	High	The expected research outputs will be: • Data documenting the presence and abundance of migratory shorebirds near the SOP study sites. • Information on habitat attributes at locations where migratory bird presence / absence and abundance data are collected; • Improved knowledge on trophic transfer and the main primary producers that support migratory shorebird food webs, obtained through analysis and interpretation of eDNA and stable isotope samples.
4c	Survey northern and inland Australia for migratory shorebird populations and identify important habitats.	Very high	
4g	Promote exchange of shorebird conservation information between governments, NGOs and communities through use of networks, publications and web sites.	High	

Note 1: References relate to objectives and associated actions listed in the Commonwealth's *Wildlife Conservation Plan for Migratory Shorebirds* (Commonwealth of Australia, 2015). Priority ratings are taken from the same source.

3.2. Alignment with EPBC Act Environmental Offsets Policy

Appendix A of the EPBC Act Environmental Offsets Policy provides five key criteria to be addressed by a research project:

- Criteria 1 - Improve the viability of the impacted protected matter
- Criteria 2 - Be targeted toward key research/education activities
- Criteria 3 - Be undertaken in a transparent, scientifically robust and timely manner
- Criteria 4 – Be undertaken by a suitably qualified individual or organisation in a manner approved by the department
- Criteria 5 - Consider best practice approaches.

Details of how the proposed Mardie migratory shorebird research project meets these criteria are provided in Table 2.

Table 2: DCCEEW Criteria for research programs

No.	Criteria: A suitable research program must:	Project Suitability
1	Endeavour to improve the viability of the impacted protected matter	The information generated through this proposed research program will help to improve the viability of threatened migratory shorebird populations by addressing knowledge gaps related to critical habitat attributes and shorebird ecological requirements. Better understanding of these aspects can be used in the development of more effective policies and management strategies.
2	Be targeted toward key research activities as identified in the relevant Commonwealth approved recovery plan, threat abatement plan, conservation advice, ecological character description, management plan or listing document.	Table 1, above, explains how the proposed migratory shorebird research program is targeted toward key research activities set out in the *Wildlife Conservation Plan for Migratory Shorebirds* (Commonwealth of Australia, 2015).
3	Be undertaken in a transparent, scientifically robust and timely manner	Section 6 of this proposal describes proposed reporting arrangements and additional information on how research results will be shared. Section of this research proposal includes a summary timetable for delivery of key project milestones.
4	Be undertaken by a suitably qualified individual or organisation in a manner approved by the department	The research will be led by researchers from Edith Cowan University (Prof Glenn Hyndes, Prof Kathryn McMahon and Dr Sora Marin Estrella) who are experts in coastal ecology including diet, food analysis and shorebird

No.	Criteria: A suitable research program must:	Project Suitability
		ecology with a team of researchers including a shorebird experts.
5	Consider best practice research approaches.	The proposed research program will be implemented in accordance with ECU's Research Integrity Framework, which incorporates, among other matters, best practice data and information management; peer review requirements and ethics approvals.
6	Be tailored to at least a postgraduate education level	The research will be led by researchers from Edith Cowan University (Prof Glenn Hyndes, Prof Kathryn McMahon and Dr Sora Marin Estrella) who are experts in coastal ecology including diet, food analysis and shorebird ecology with a team of researchers including a shorebird experts.
7	Present findings that can be peer-reviewed.	As this is embedded in WAMSI they will be reviewed through the standard WAMSI peer-review process.
8	Publish findings in an internationally recognised peer-reviewed scientific journal or be of a standard that would be acceptable for publication in such a journal. Publications should be submitted to free open access journals. Data and information collected should have creative commons licensing and be free and accessible.	All data accessibility will follow the WAMSI SOP that includes data to be stored on open data repositories. Findings will be published in internationally recognised peer-reviewed journals as well as reported to WAMSI.
9	Result in outputs that can inform future management decisions on the protected matter and, where possible, be readily applicable to other similar matters (species groupings etc).	The research report will directly inform future management decisions on shorebirds including listed and migratory species.

4. Study Methods

4.1. Desktop work

The areas of desktop research include broadly recognised themes such as breeding, migration, trophic ecology, predation, disturbance, parasites, physiology, pollution, habitat use, habitat destruction, and climate change. Desktop literature will be focussed on:

- relevant species of waders and/or shorebirds to the Pilbara coast
- relevant coastal habitats of the Pilbara coast (tropical and subtropical mangrove fringed coastal habitats, salt flats/marsh and cyanobacteria mats, intertidal sandflats, mudflats and seagrass meadows) as well as all important shorebird habitats in the Pilbara coast included in the "Australian National Directory of Important Migratory Shorebird Habitat" (Weller et al. 2020).
- habitat use during migratory and non-migratory periods on the Pilbara coast and relevant habitats (as described before);
- trophic ecology within these on the Pilbara coast and relevant habitats (as described before); and
- disturbance and habitat destruction on the Pilbara coast and relevant habitats (as described before).

4.2. Field work

The following field work methods will be used in the Migratory Shorebird research program across the WAMSI SOP study sites and Mardie Project area:

1. Habitat usage survey approach:
    - GPS tracking of targeted bird species
    - Camera traps at key habitat locations
2. Trophic ecological sample collection methods:
    - Sediment and scat sampling for Environmental DNA (eDNA) analysis
    - Biological sampling (incl. blood and scat sampling) for Stable Isotope Analyses (SIA)

Field methods are discussed further below, including details on proposed locations, timing of surveys to the ecology of species to increase the chance of observations where possible, and proposed survey/sampling effort needed to address research objectives.

4.2.1. Habitat use data collection

GPS tracking

Subject to additional amendment to include the additional transmitters and species to the existing animal ethics approvals, GPS tracking of targeted Migratory Bird Species will be undertaken to deliver a high spatial resolution assessment of habitat use (accuracy between 2.5 m - 5 m) (Lyu et al. 2023) during the non-breeding season. Targeted species will be fitted with solar GPS-GSM or GPS-Bluetooth trackers, where data is downloaded through Bluetooth receivers or GSM (5G) network. This work would be conducted in conjunction with BirdLife Australia and the Australasian Wader Study Group in Exmouth Gulf Station or Giralia Station between October-November 2024. Applying trackers to birds at this time of year could enable us also to track migratory birds habitat use during

the non-migratory period and throughout the Pilbara as they move north from their non-breeding habitats at the bottom of the Gulf at the start of their migration. BirdLife Australia and the Australasian Wader Study Group already hold the appropriate licences and permits to trap and fit GPS trackers to several migratory shorebirds in the Exmouth Gulf.

Camera traps

Information on migratory shorebirds' habitat use will be obtained through the deployment of camera traps in potentially significant habitats such as intertidal areas, tidal channels and salt flats/cyanobacteria mats. The use of cameras and camera traps has been proven to deliver reliable information on shorebird and other waterbirds habitat use of targeted geographical locations (Boardman et al. 2023, Jackson et al. 2022, Luy et al. 2023) for extended periods compared to abundance count.

These will be deployed across habitats at Giralia and Urala (Figure 2). Images captured from these cameras will provide information on species and individuals present through the non-breeding season and tidal phases.

Camera traps and GPS trackers offer the opportunity to achieve remote monitoring (collect data over extended time periods in remote locations without the need of researchers' presence) of shorebirds' habitat use.

4.2.2. Trophic ecological sampling

Environmental DNA (eDNA) sampling

This task will complement the existing Project C (Identify the ecological roles, values and functions of algal mat on the west Pilbara coast) Objective 2b (Identify the pathway for transfer of nutrients and primary productivity from intertidal benthic communities and habitats to subtidal communities and habitat). It is proposed to use environmental DNA (eDNA) and scats metabarcoding to identify prey consumed by migratory shorebirds. Samples will be sent to eDNA Frontiers at Curtin University for analysis using a metabarcoding approach.

Biological sampling (Blood and scat sampling).

In conjunction with GPS tracking survey work, blood samples will be collected (subject to additional amendment to include blood sampling collection for stable isotope analysis) during the November 2024 BirdLife Australia Exmouth expedition and used for stable isotope analysis (SIA) for trophic assessment. Blood will be collected from captured individuals not fitted with GPS trackers. BirdLife Australia and the Australasian Wader Study Group already hold the appropriate licenses and permits to trap, fit GPS loggers, and collect blood samples from migratory shorebirds in the Exmouth Gulf.

Blood samples allow for SIA of recently assimilated nutrients from their food sources, compared to the longer term of assimilation provided by other inert tissues (e.g. feathers) that is often used in stable isotope studies.

Additionally, selected scat samples collected as part of Project C Part 2b would be subjected to SIA. The number of scat samples collected as part of Project C Part 2b will be increased to provide a more robust data set for SIA and food web understanding. Survey methods used for the collection of biological samples and interactions with migratory birds will be undertaken in accordance with relevant Commonwealth statutory documents and policies, including *EPBC Act Policy Statement 3.21 - Industry guidelines for avoiding, assessing and mitigating impacts on EPBC Act listed migratory shorebird species*.

4.3. Sampling location / Sampling Effort

Proposed field work locations include established research sites at Giralia in southern Exmouth Gulf, Urala Station, Gnoorea and Onslow, along with new sites in the intertidal areas adjoining the Mardie project area (Figure 2). Not all field techniques will be used at every location. Survey efforts are detailed in Table 3 and sampling locations are shown in Figure 2.

Table 3: Sampling details

Method	Location	Survey Effort	Timing
Habitat Mapping – GPS Tracking	Conducted in conjunction with BirdLife Australia and the Australasian Wader Study Group in Exmouth Gulf Station or Giralia Station.	Data service Mini tracker x 8*	November 2024. Applying trackers to birds at this time of year will enable us to track migratory shorebirds habitat use throughout the non-breeding season (November to April) on the south section of Exmouth Gulf and potentially as they move northwards along the West Pilbara Coast at the start of their migration.
Habitat Mapping – Camera Traps	Deployed across habitats at Giralia and Urala Stations	Trap Camera x 24	Deploy in November 2024. Recovery February 2025. This will ensure that information is collected throughout most of the non-breeding period that migratory shorebirds are present in the region.
Tropic Ecological Samples 3. eDNA sampling 4. Blood and Scat collection	Exmouth Gulf Station or Giralia Station.	**WAMSI Study Area** Samples from each habitat will be collected during existing field expeditions Blood SIA x 100 Scat SIA x 100 Environmental DNA will be collected only at Giralia.	**WAMSI Study Area** Blood samples will be collected only in November 2024. Droppings and environmental DNA will be collected in November 2024 and February 2025. **Mardie Study Area**

Method	Location	Survey Effort	Timing
		<u>Mardie Project Area</u> Scat SIA x (up to) 100 Pheonix – as part of the Shorebird Migratory MMP.	December 2024 February 2025
Visual Observations	Mardie Project Area	Mardie Project area intertidal habitat will be opportunistically monitored while undertaking monitoring activities in accordance with monitoring activities undertaken while implementing the approved Environmental Management Plans.	Consultants undertaking the monitoring

*As per Lilleyman et al. 2020

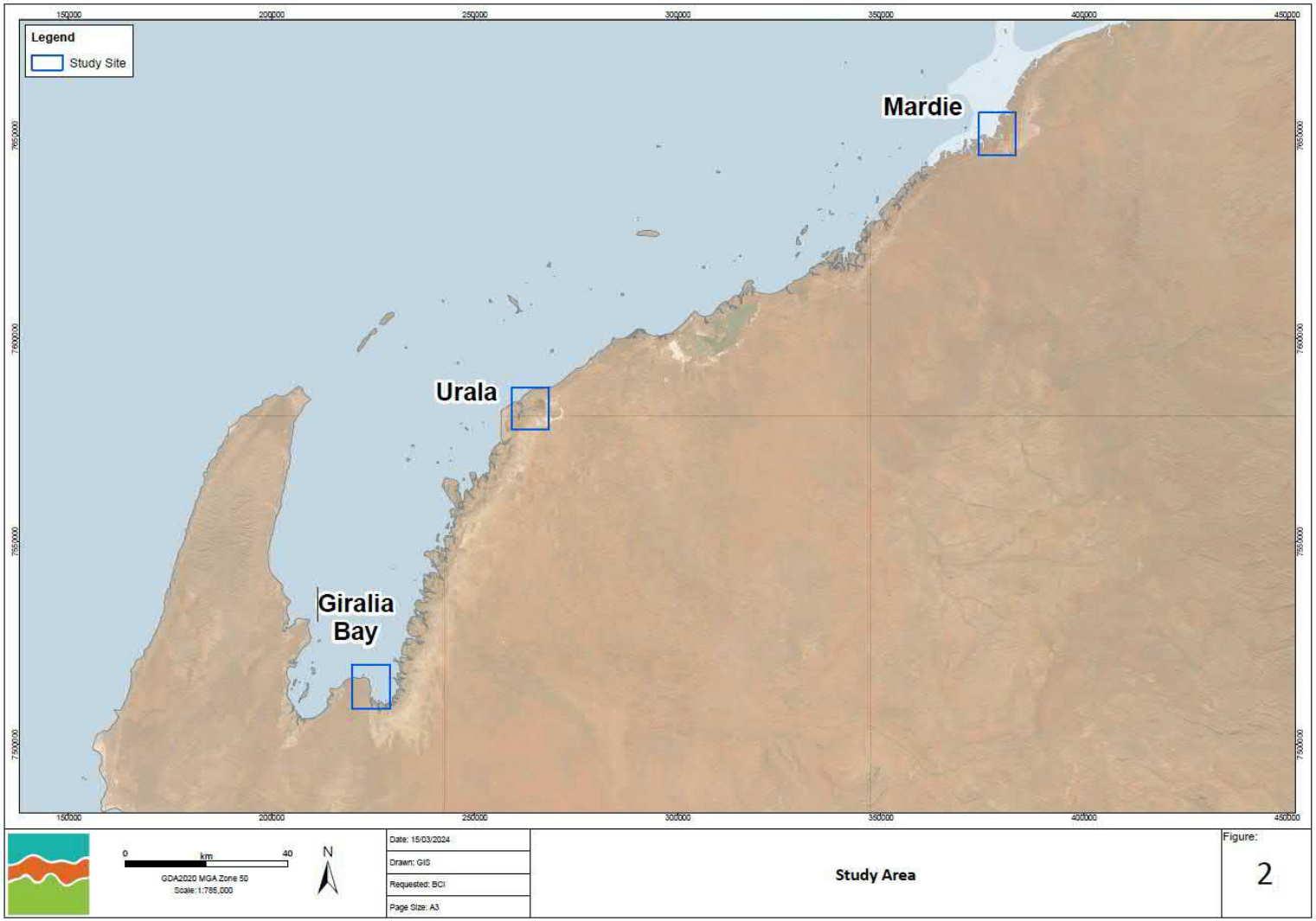

Figure 2: Proposed Study Areas

5. Data Analysis

5.1. Habitat use Data Analysis

5.1.1. GPS Tracking:

Analysing tracking data will allow for tracking migratory birds temporal habitat use throughout the non-breeding season and the tidal phases. GPS trackers could also offer information on habitat used throughout the Pilbara coast as they move northwards at the start of the migration from their non-breeding habitats at the bottom of the Gulf.

5.1.2. Camera Traps:

Images captured from the camera traps will provide spatial information on several shorebird species habitat use (present or not present and their activity, feeding and roosting) in potentially significant shorebird habitats in the Pilbara coast such as intertidal areas, tidal channels, salt flats/cyanobacteria mats.

Images captured from the camera traps will provide temporal information on several shorebird species habitat use (present or not present and their activity, feeding and roosting) in potentially significant shorebird habitats in the Pilbara coast such as intertidal areas, tidal channels, salt flats/cyanobacteria mats through time during the non-breeding season and the tidal phases.

5.2. Trophic Ecological Data Analysis

5.2.1. eDNA sample analysis

Samples of sediment from each habitat and bird scat will be collected during existing field expeditions and sent to eDNA Frontiers at Curtin University for analysis using a metabarcoding approach. Sediment samples would confirm if the prey identified within the bird scat was consumed within the intertidal habitats or other external habitats.

5.2.2. Stable Isotope analysis

Additionally, selected scat samples collected as part of Project C Part 2b would be subjected to Stable Isotope analysis (SIA), as detailed in the Project C of the WAMSI SOP, specifically to determine:

- Blood samples allow for Stable Isotope Analysis (SIA) of recently assimilated nutrients from their food sources, compared to the longer term of assimilation provided by bulk stable isotopes that is often used in stable isotope studies.
- Dropping analysis: Scat samples will be dis-aggregated in filtered water and sieved though a 50 µm mesh. Hard parts of prey (chironomid heads, polychaete jaws, bivalve hinges, crustacean parts etc.) will be identified.

This section does not include direct observations and digiscoping (videos recorded with the use of the telescope and a camera attached to it) of shorebirds feeding since information on shorebirds diet will be obtained throughout dropping analysis and previous videos from Mardie Project C Part 2b.

This information will be used to improve food web understanding.

6. Project Deliverables

Reporting will include the following key deliverables:

6.1. Report (Habitat Use):

The cameras will be collected in February 2025 and there will be a significant number of images to analyse. Tracking data for inclusion in the habitat use analysis will incorporate April 2025, therefore a final report on Habitat Use will be available in January 2026.

6.2. Reporting (Trophic ecology)

Similar to the Habitat Use report, a final report on Trophic Ecology will be available in January 2026.

6.3. Final Program Report (Marine Research Objectives)

The Final Program Report will present the key findings, discussion and conclusions including:

- Migratory shorebird presence, absence and abundance;
- Analysis of habitat attributes (e.g. tidal channel, mangrove, seagrass meadow or cyanobacteria matt presence) and habitat use;
- Interpretation of feeding ecology, based on analysis of results from eDNA and stable isotope testing.

The Final Report will be provided to the DCCEEW in January 2026 and will include a discussion on how the project findings contribute to informing the strategic protection, better management and long-term ecological functionality of migratory shorebird habitat. The final report will provide recommendations for strategic approaches to improve the viability of shorebird populations and / or to conserve habitats critical to threatened shorebird populations.

7. Project Team

7.1. ECU Project Team Leaders – Glenn Hyndes and Kathryn McMahon

Professors Glenn Hyndes and Kathryn McMahon are highly experienced coastal ecologists with 40 years experience between them. They have led multiple large research projects, and currently lead WAMSI Mardie Project C examining the ecological functions of BAHs in the Pilbara region. Dr Sora Marin Estrella is an expert in shorebird ecology with over 10 years experience working in intertidal and saltflat habitats in NW Australia. Dr Marin Estrella is also an investigator on WAMSI Mardie Project C.

The Project Team are detailed in Table 4.

Table 4: Project Roles and Responsibilities

Name	Organisation	Project Role
ECU Team Members: - Dr. Sora Marin Estrella - Prof. Glenn Hyndes - Prof. Kathryn McMahon	Edith Cowan University	Team Leaders. Experimental design and field work approach for habitat use objective (GPS trackers and camera traps) and trophic objective (stable isotopes and eDNA) for migratory shorebirds.
Bird Life Australia Team Members:	Bird Life Australia	Trapping shorebirds

- Dr. Tegan Douglas (WA Woodland Bird Program Manager National Black-cockatoo Program Manager) - Dr. Jeremy Ringma, (WA Shorebird Project Coordinator) - Dr. Roz Jessop (Australasian Wader Study Group)		and deployment GPS tracking
Mardie Project area sampling Team: - Dr Floyd Holmes - Patrick Williams - Ethan Broom	Phoenix Australia	Project data collection support – focusing on the Mardie Project area

8. Project Milestones

The project tasks are planned to span 2 years over the period April 2024 to December 2025, inclusive. An overview of the timing of the project tasks and reporting activities are outlined in Table 5.

Table 5: Project Milestones

Task	Estimated Timeframe	Party
Research Proposal Submission to DCCEWW	March 2024	BCI Minerals
Research Proposal Approval (pending feedback and finalised scope)	April 2024	Cth Minister for Environment
Kick-off Meeting	April 2024	Project Team
Apply for sampling permit extension (including under Part13 of the EPBC Act)	April 2024	Project Team
Field Trip – GPS Tracking / Blood Samples	November 2024	Project Team
Field Trip – Camera Deployment / eDNA / Scat Samples SIA	November 2024	Project Team
Mardie Project Area Field Trip 1	December 2024	Phoenix
Mardie Project Area Field Trip 2	February 2025	Phoenix
Field Trip – Camera trap collection/ Scat Samples SIA	February 2025	Project Team
Analysis	2024 - 2025	Project Team
Reporting	January 2026	Project Team

All reports, publications and supporting data provided to BCI and DCCEWW, DBCA, and Department of Water and Environmental Regulation (DWER).	January 2026	Project Team

9. Funding Arrangement

BCI will allocate the equivalent of $168,009 to this project. Project costs are currently indicative, based on a number of assumptions that need to confirmed, in relation to logistics and survey design. The final design will be completed after direct consultation with DCCEEW. The budget (Table 6) includes salary for participation of key researchers, costs for logistical and governance arrangements.

Table 6: Budget Proposal

Expense	**Price per unit (AUD)**	**Total**
Literature review		
Consultant x 80 hours	$250	$20,000
	Sub-Total	**$20,000**
Migratory shorebirds habitat use using GPS tracking		
Field expedition November 2024 (4 person airfares, accommodation, fuel, food etc)	$12,500	$12,500
Druid Mini 4G x 8	$1,672.25	$13,378
Data service for loggers	$200.67	$1,605
BirdLife Australia expedition	$22,000	$22,000
	Sub-Total	**$49,483**
Migratory shorebirds habitat use using camera traps		
Trap Camera x 24	$400	$9,600
64G SD card x 24	$128	$3,072
6-month FT RA	$52,794	$52,794
Longyard/Saxon 165-170 cm Black Steel Fence Post x 78	$95 (pack of 10)	$760
Field expedition February 2025 (4 person airfares, accommodation etc)	$12,500	$12,500
	Sub-Total	**$78,726**
Trophic ecology; diets using Environmental DNA (eDNA)		**$17,600**
eDNA analysis	$560	$16,800
Consumables	$800	$800

	Sub-Total	**$17,600**
Trophic ecology; Blood SIA		**$2,200**
SIA x 100	$14	$1400
Consumables	$800	$800
	Sub-Total	$2,200
Trophic ecology; Scatt SIA		
SIA x 100	$14	$1400
Consumables	$800	$800
	Sub-Total	$2,200
	Grand Total	**$168,009**

In-kind: Is based on a contribution of team members employed at the University of Adelaide. It is anticipated that University will waive their University Service Charge (USC) on research grant income with WAMSI governing the project with an overhead charge of 5%. Other in-kind contributions relate to use of infrastructure such as computing, imagery and LiDAR, field equipment, and lab infrastructure.

10. References

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