Ecological Connectivity of Kimberley Marine Communities

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WAMSI Kimberley Marine Research Program

Final Report

Project 1.1.3

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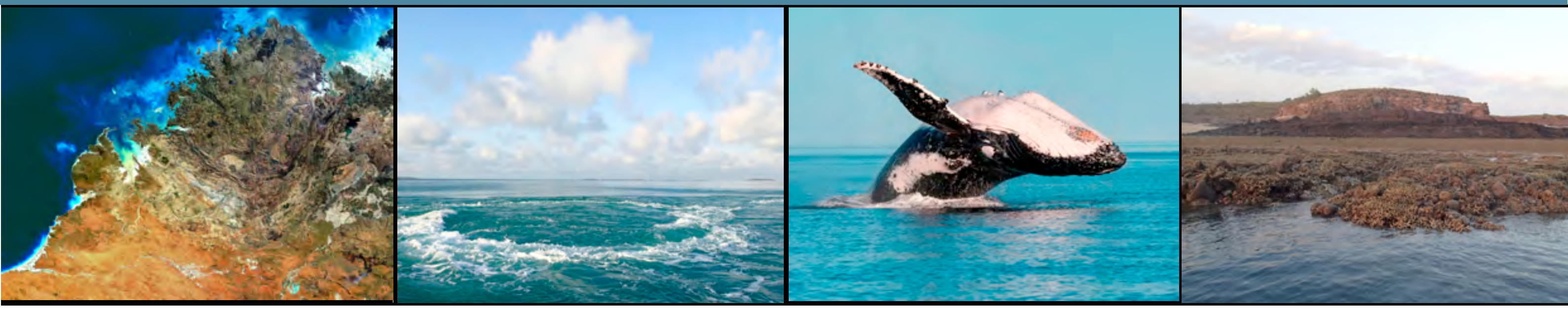

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WAMSI Kimberley Marine Research Program

Initiated with the support of the State Government as part of the Kimberley Science and Conservation Strategy, the Kimberley Marine Research Program is co-invested by the WAMSI partners to provide regional understanding and baseline knowledge about the Kimberley marine environment. The program has been created in response to the extraordinary, unspoilt wilderness value of the Kimberley and increasing pressure for development in this region. The purpose is to provide science based information to support decision making in relation to the Kimberley marine park network, other conservation activities and future development proposals.

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Image 1:	Satellite image of the Kimberley coastline (Image: Landgate)
Image 2:	Powerful currents are a feature of the Kimberley marine environment. Whirlpool in Sunday Strait (Image: Kathryn McMahon)
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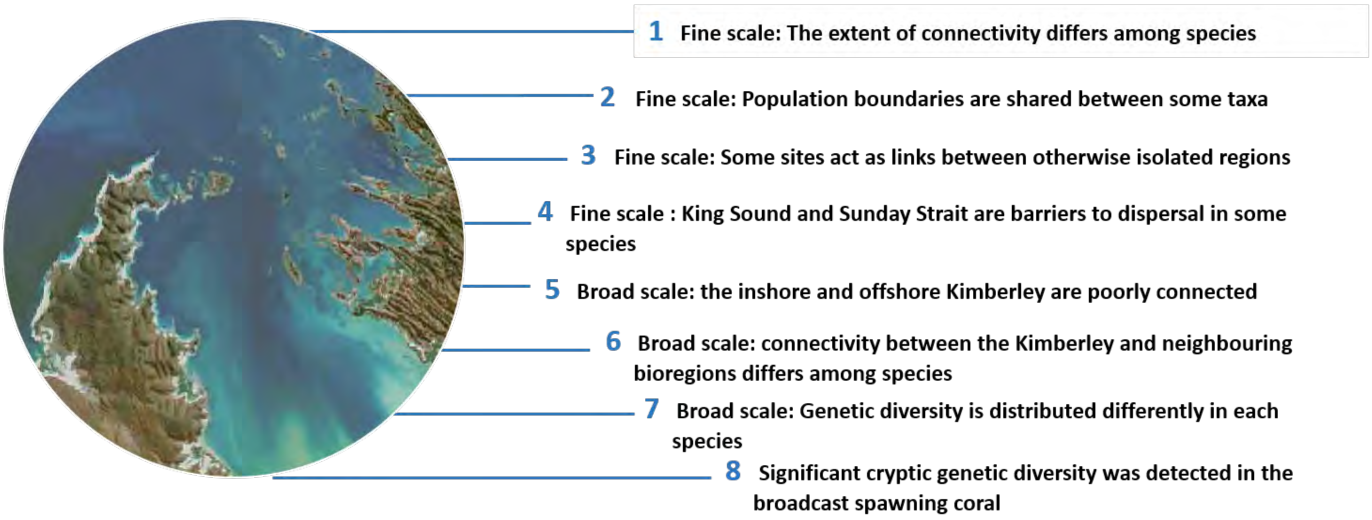
Contents

1 Executive Summary

The overarching objective of KMRP Project 1.1.3 (Ecological Connectivity of Kimberley Marine Communities) was to provide the first estimates of ecological connectivity (demographic inter-dependence) across multiple spatial scales for a suite of representative marine organisms from the Kimberley. The full report for this project is structured as five individual sub-reports each focusing on different representative marine organisms. Here, we summarise the key findings of these sub-reports. Further summary and synthesis of the key findings for the entire project provided in sub-report 1.1.3a (Synthesis).

The key findings of this study are summarized in Figure 1:



1. **Fine scale: The extent of connectivity differs among species**
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6. **Broad scale: connectivity between the Kimberley and neighbouring bioregions differs among species**
7. **Broad scale: Genetic diversity is distributed differently in each species**
8. **Significant cryptic genetic diversity was detected in the broadcast spawning coral**

Figure 1. Key findings of KMRP Ecological Connectivity Project 1.1.3.

1.1 Fine scale: The extent of connectivity differs among species

Despite experiencing a common set of environmental conditions, the extent of ecological connectivity differed among the focal organisms, and not always in predictable ways. Habitat forming organisms (coral, Report 1.1.3.1; seagrass, Report 1.1.3.2) typically exhibited the most localised population structure, with evidence for limitations to routine dispersal evident on scales of 10s of kilometres or less. In the remaining organisms (fishes, Report 1.1.3.4a; trochus, Report 1.1.3.3), population structure was weaker or not detectable, and limits to dispersal were evident on scales of 80 to several 100s kilometres. Some of these results were unexpected. For example, the seagrass with floating seeds had finer scale genetic structure compared with the seagrass with sinking seeds, and similarly, the pelagic spawning fish also had finer scale genetic structure compared to the benthic spawning fish. Further, the mollusc with a short larval duration exhibited the lowest level of genetic structure of all taxa. **Clearly, expectations of realised connectivity based on simple life history characteristics are unreliable, and patterns therefore need to be assessed on a species by species basis**.

1.2 Fine scale: Population boundaries are shared between some taxa

Major population boundaries were identified in several taxa, notably the habitat-forming corals (Report 1.1.3.1), and seagrasses (Report 1.1.3.2), and the pelagic spawning fish (Report 1.1.3.4b), but not the mollusc (Report 1.1.3.3), nor the damselfish (Report 1.1.3.4a). **Broadly, the divisions in seagrasses, corals and fish were between the Dampier Peninsula and Buccaneer Archipelago sites**, but the specific positions and breadths of the boundaries differed for individual taxa. For example, in *T. hemprichii,* the seagrass with buoyant seeds, the northern Buccaneer Archipelago sites were differentiated from those in the southern Buccaneer Archipelago and Dampier Peninsula, whereas both the broadcast spawning and brooding corals exhibited a strong division between the Dampier Peninsula and the Buccaneer Archipelago. A division also exists in the fish, *L. carponotatus*, but it occurred as a broad transition zone in which the genetic composition changes across a distance of *c*. 40km at the tip of the Dampier Peninsula from the Kimberley bioregion signature to the Pilbara/Canning bioregion signature (see also Major Finding 1.6). In contrast, ***T. niloticus* forms a single highly-mixed genetic unit within the Dampier Peninsula and Buccaneer Archipelago,** suggesting considerable exchange of larvae occurs throughout this region.

1.3 Fine scale: Some sites act as links between otherwise isolated regions

Although restricted connectivity was detected in the region of Sunday Strait and the Dampier Peninsula for corals (Report 1.1.3.1), seagrasses (Report 1.1.3.2), and *L. carponotatus* (Report 1.1.3.4b), exchange of genes across this barrier over multiple generations occurs through the important stepping-stones at Tide Rip, Mermaid and Bedford Islands for corals and seagrass. For *L. carponotatus* a similar transition zone was detectable between Tallon Island and Emeriau Point (Dampier Peninsula).

1.4 Fine scale: King Sound, Sunday Strait are barriers to dispersal in some species

The region at the mouth of King Sound is characterised by the largest tropical tidal range and the fastest tidal currents in the world including the input of massive volumes of freshwater in a highly turbid plume from the Fitzroy catchment in the wet season; a time when propagules from many of these species are in the plankton. These extreme environmental conditions appear to restrict connectivity. Coupled with the finding of a highly divergent population of *I. bruggemanni* on the western side of Dampier Peninsula, these results demonstrate that **the tip of Dampier Peninsula is an important intra-specific genetic barrier for various marine taxa with range of life histories.**

1.5 Broad scale: The inshore and offshore Kimberley are poorly connected

The species of corals (Report 1.1.3.1) and trochus (Report 1.1.3.3) that were sampled over broader scales at the offshore reefs of Rowley Shoals, Scott Reef, and Ashmore Reef showed that these **inshore Kimberley reef populations are highly divergent from the offshore ‘oceanic’ reef populations, strongly indicating that these regions are ecologically and evolutionary independent.** This likely reflects the limited hydrodynamic connectivity between these reefs, but in addition, genetic patterns suggest **strong environmental differences between these regions has driven local adaptation in these species**.

1.6 Broad scale: connectivity between the Kimberley and neighbouring bioregions differs among species

The species that were sampled across the broader north-west coast of Australia exhibited some consistencies in their broad-scale patterns of connectivity. The seagrass *T. hemprichii* (Report 1.1.3.2) and the damselfish *P. milleri* (Report 1.1.3.4a) exhibited a sharp discontinuity between the Kimberley and Pilbara, indicating negligible exchange, and probably reflecting discontinuous habitat between these regions. In contrast, Pilbara and Kimberley populations of *L. carponotatus* (Report 1.1.3.4b), exhibited only weak genetic distinctiveness. Furthermore in *L. carponotatus*, the transition zone between Kimberley and Pilbara genetic groups occurred at Sunday Strait rather than corresponding to the Pilbara and Kimberley Bioregions like *T. hemprichii* and *P. milleri*. *Lutjanus carponotatus* samples from the Northern Territory were weakly genetically distinct from those in the Kimberley, but it is unclear whether this represents limited demographic exchange, or incomplete sampling in the intervening region.

The preliminary otolith geochemistry results (Chapters 1.1.3.4c) generally concur with the findings of the genetic companion studies of the two fish species (Chapters 1.1.3.4a,b), and add support to their conclusions that the movement of both species between the Kimberley, Pilbara and Gascoyne bioregions is restricted. This preliminary result should be considered cautiously as the margin otolith microchemistry only tells part of the story (adult phase) and additional core samples (larval and post-larval phase) will need to be analysed to allow interpretation of population connectivity. Furthermore, while the marginal elemental composition of *P. milleri* otoliths from Shark Bay differed significantly from all bioregions further north, thereby paralleling genetic results, there was no such difference for *L. carponotatus*. This may be a genuine environmental effect, reflecting the more offshore oceanic marine environment where *L. carponotatus* samples were collected compared to the more enclosed and inshore marine environment where *P. milleri* samples were collected within the western Gulf of Shark Bay.**Broad scale: Genetic diversity is distributed differently in each species**

Within the Dampier Peninsula – Buccaneer Archipelago region, some organisms (coral, Report 1.1.3.1; seagrass Report 1.1.3.2) exhibited large variation between sites in amount of genetic diversity observed, whereas others (fishes, Report 1.1.3.4a; trochus, Report 1.1.3.3) exhibited similar amounts of diversity at each site. Across the broader north-west coast of Australia, species varied significantly in their distributions of genetic diversity. Populations of the seagrass *T. hemprichii* from the Kimberley exhibited significantly lower genetic diversity than those in the Pilbara. In contrast, in the damselfish *P. milleri*, genetic diversity was highest in the Kimberley and declined progressively with latitude towards the Gascoyne bioregion. In the stripey snapper, *L. carponotatus,* levels of genetic diversity were consistent across the entire north-west coast. These contrasting results likely reflect: 1) differences in population size; 2) differences in connectivity between regions (physical and environmental); and 3) differences in colonisation history of the different regions. Further, multiple hotspots (i.e. areas with high genetic diversity or unique variants) were identified at particular sites for coral and seagrass (e.g. West Montalivet for *I. brueggemanni* and Bedford Island south for *H. ovalis*), and these are discussed further in the specific taxon reports.

1.7 Cryptic genetic diversity exists in the broadcast spawning coral

Four genetically distinct, but morphologically cryptic, genetic lineages were detected in the *A. aspera* collection (Report 1.1.3.1), strongly suggesting that these lineages are reproductively isolated, even though they look the same and live side by side, and thus likely **represent unique evolutionary significant units and/or unrecognised species.**

2 Implications for Management

This research has highlighted commonalities and disparities in patterns of connectivity among taxa representing a range of trophic levels and life histories. Many of these findings have important implications for management of Kimberley marine ecosystems. Threats to these ecosystems include local anthropogenic impacts such as overfishing, tourism, industrial development and oil spills, as well as the impacts of climate change, which operates over broader spatial scales and longer time-frames. The resilience of marine ecosystems to these threats depends critically on how they affect ecological processes such as connectivity, which promote population persistence and regeneration. Management strategies that protect healthy sources of recruits and maintain the exchange of adaptive genes will nurture resilience in marine ecosystems. To this end, below we summarise how the patterns of connectivity identified in this project would best inform management of Kimberley marine ecosystems.

1. **To protect hard corals, the crucial habitat forming organisms of coral reef ecosystems and also seagrass, an important food source for dugongs and turtle, and a nursery habitat for fishes, marine protected areas and indigenous protected areas need to incorporate strategies that account for the spatial dispersal of these organisms.** Protected areas that are large enough to encompass routine dispersal distances of corals (10–20 km), and are spaced at similar distances, will not only maintain self-replenishment, but also aid recovery after disturbance through connectivity between protected areas.

2. **Corals and seagrasses of Buccaneer Archipelago and Dampier Peninsula need to be managed as demographically independent populations**. Furthermore, negligible exchange between the inshore Kimberley and the offshore coral reefs and neighbouring bioregions means that populations of the inshore Kimberley are reliant on standing genetic variation as the basis of adaptation to climate change or other disturbances.

3. **Current estimates of species diversity in corals are likely to be substantial underestimates**. The cryptic *Acropora* coral lineages detected here reveal that current assessments of the diversity of hard coral species in the Kimberley are likely substantial underestimates and further integrated taxonomic research is needed to clarify species diversity patterns in all taxon groups.

4. **Management of *T. niloticus* on the Dampier Peninsula and Buccaneer Archipelago should treat the region as being effectively a single stock on the ecological timeframes relevant to harvest management.** Over-harvested sites within this region will be replenished with recruits from neighbouring sites within years, assuming they exist, and allowing for the slow growth of the species.
5. **Management of *T. niloticus* at offshore oceanic reefs should treat each oceanic shoal as being effectively isolated on the ecological timeframes relevant to harvest management.** Recruitment from outside will not replenish over-harvested stocks at these locations. Occasional recruits may be drawn from other offshore shoals, but will contribute to genetic diversity not offset over-harvest. Supplementation of populations should recognise that coastal *T. niloticus* populations may be mal-adapted to oceanic conditions.

6. **The Kimberley and Pilbara bioregions exchange few recruits in seagrasses and reef-obligate damselfishes, and therefore operate largely independently on the ecological timeframes relevant to management.**

7. **Demographic exchange between the Kimberley and Pilbara/Canning bioregions in the harvested stripey snapper, *L. carponotatus*, occurs in a broad transition zone located near the Sunday Strait. The distinctiveness of the Shark Bay *L. carponotatus* samples from all other bioregions indicates that the Gascoyne management boundary is not supported because sites north of Shark Bay have greater affinities to sites in the Pilbara Bioregion. This information should be considered within management arrangements.**

8. **Genetic differentiation between samples of *L. carponotatus* from the Kimberley and Northern Territory may represent limited demographic exchange between these separately-managed stocks, but to be confirmed this requires further samples from the intermediate region.**

3 Key Residual Knowledge Gaps

3.1 Habitat Forming: Two Species of Corals

- Further integrated taxonomic study that includes micro-morphological examination of the *Acropora aspera* lineages in tandem with investigations of reproductive biology is required to resolve species boundaries within the Kimberley A. aspera complex.

- In both the spawning and brooding species, this study indicated a lack of cross-shelf connectivity between the southern inshore Kimberley and Ashmore Reef. There was only one exception to this regional scale divergence; I. brueggemanni corals from the most northern site sampled, West Montalivet (Bonaparte Archipelago), exhibited genetic affinities with Ashmore Reef. The current study should be extended to include more populations from the central and northern Kimberley to evaluate if there is a higher degree of cross-shelf connectivity in the central or northern Kimberley.

- The study of I. brueggemanni corals indicated that the population on the far west side of Dampier Peninsula (Kooljaman) was very divergent from the other inshore Kimberley populations and was characterised by the lowest gene diversity of all sites, suggesting that it is a small and isolated population that may be vulnerable to local extinction. Further comparative studies on other species of coral are needed to clarify if this result is reflective of a wider trend.

- This study indicated that the dispersal of both brooded and broadcast spawned larvae is restricted between of the Buccaneer and Dampier systems across the Sunday Strait. We hypothesize that Tide Rip and Mermaid Islands do however provide important stepping stones facilitating genetic exchange across this barrier. Further examinations are needed to determine the diversity and extent of subtidal reef communities in the vicinity of these islands which present themselves as important transition habitats.

3.2 Habitat Forming: Two Species of Seagrasses

- Increasing the understanding of genetic connectivity of these species outside of the main study area, east into the northern Kimberley, south into the rest of Canning marine bioregion, and more extensively into the Pilbara region.
- Developing a better understanding of the significance of dugong foraging as a mechanism for dispersing seagrasses with dormant seeds (e.g. *H. ovalis*, *H. uninervis*).

3.3 Harvested: A Large Gastropod (Trochus)

This investigation had a limited geographic scope in comparison to the broad Indo-Pacific range of *T. niloticus*, capturing the south-westernmost part of its range. Indeed, even within the Kimberley region, the region of high density in the Buccaneer Archipelago is disjunct from other high density populations in Australia, Indonesia and on offshore atolls. The broad distribution of *T. niloticus* in the tropical Indo-Pacific incorporating a diversity of reef types and hydrodynamic conditions means that it is unlikely that the spatial scale of genetic structure observed here will be reflected throughout its range. Considering the economic and cultural significance of the species to many people, a broader investigation of population structure in *T. niloticus* and its biophysical drivers deserves consideration.

3.4 Reef-dwelling: A Coral Reef Fish

- *Pomacentrus milleri* is a useful model for small reef-dependent species. However, this study has only examined a fraction of the species' range*. Pomacentrus milleri's* range extends into the Northern Territory and New Guinea. The extent of connectivity between *P. milleri* in Western Australia and other regions is unknown.

- Although the results presented here have revealed evidence for geographically structured adaptive diversification in *P. milleri*, the specific environmental drivers have not been identified.

- *Pomacentrus milleri* shares a life history with many small reef-dependent fish species. It is anticipated that this would be reflected in comparable population genetic structure in similar species, but this hypothesis requires empirical testing.

3.5 Harvested: A Demersal Fish

- Genetic differentiation between samples of Stripey Snapper from the Kimberley and NT may represent limited demographic exchange between these currently separately managed stocks. Further sampling from the intermediate region is needed to confirm this.

- Ocean currents are likely to play a significant role in distributing the larvae of Stripey Snapper. Models of hydrodynamic processes throughout NWA are available, however it would be useful to evaluate how well these models predict the observed genetic structure in Stripey Snapper, since that would provide confidence that the models accurately reflect biological processes and therefore may be applied to other bioregions and/or species.

- In contrast, the transition zone identified around the Dampier Peninsula that separates the Kimberley from the Pilbara/Canning populations is likely to be influenced by the extreme tidal flushing at the head of King Sound, rather than ocean currents. A fine-scale hydrodynamic model for this region was prepared by WAMSI Kimberley Project 2.2.7 (M. Feng, CSIRO, pers. comm.). It would be useful to test whether this model can account for the observed genetic structure in this highly dynamic zone that supports harvest of numerous fishes.

- Evidence for temporal variation in population structure was revealed through the analysis of historically collected samples. For these temporal samples we explored the reason for their observed divergence and were able to exclude at least one mechanism of DNA degradation. This result may therefore represent a real shift in allele frequencies over time, potentially indicative of changing patterns of larval connectivity. However, since we did not sample these exact locations again, it's unclear whether the pattern is wholly temporal or also has a spatial component. Additional sampling at these historical sites is required to resolve this question.

4 Report Structure

The full report for WAMSI project 1.1.3 is structured as an executive summary, six individual sub-project reports that focus on different marine organisms, and a synthesis report, which provides an overview and regional perspective through summarising the key findings for each sub-report, and the broader management implications these have for the region and the State. The following sub-reports are included as separate documents:

1.1.3a	Ecological Connectivity in Kimberley Marine Communities: a Synthesis Report
1.1.3.1	Population connectivity and genetic diversity in brooding and broadcast spawning corals in the Kimberley
1.1.3.2	Population genetic diversity, structure and connectivity of two seagrass species, *Thalassia hemprichii* and *Halophila ovalis* in the Kimberley
1.1.3.3	Isolation of oceanic and coastal populations of the harvested mother-of-pearl shell *Tectus niloticus* in the Kimberley
1.1.3.4a	Genomic Connectivity in a Tropical Reef Fish from the Kimberley, Pilbara and Gascoyne Bioregions of Western Australia
1.1.3.4b	Population connectivity of the Stripey Snapper *Lutjanus carponotatus* along the ecologically significant coast of Northwestern Australia
1.1.3.4c	Population connectivity of two reef fish species in northwestern Australia using otolith geochemistry: a pilot study

5 Communication

5.1 Students supported

Mr Udhi Hernawan was supported in the completion of his PhD with field and laboratory resources from this project for his work on seagrass (1.1.3.2). The Kimberley work on *Thalassia hemprichii* forms one chapter in his dissertation, which was submitted in July 2016. The analysis on *T. hemprichii* in this report was undertaken by Mr Hernawan.

5.2 Journal publications

Hernawan U, van Dijk K, Kendrick G, Feng M, Biffin E, Lavery P, McMahon K. (2017) Historical processes and contemporary ocean currents drive genetic structure in the seagrass Thalassia hemprichii in the Indo-Australian Archipelago. Molecular Ecology 26, 1008-1021.

Joseph DiBattista, Michael Travers, Glenn Moore, Richard Evans, Stephen Newman, Ming Feng, Rebecca Gorton, Samuel Moyle, Thor Saunders, Oliver Berry (2017) Seascape genomics reveals fine-scale patterns of dispersal for a reef fish along the ecologically divergent coast of Northwestern Australia. Molecular Ecology 26, 6206-6223.

Richards ZT and O'Leary M (2015) The coralline algal cascades of Tallon Island fringing reef, NW Australia. Coral Reefs, 34(2), 595-595

5.3 Submitted manuscripts

Hernanwan, U, van Dijk, KJ, Kendrick, GA, Feng, M, Berry, O, Kavazos, C, McMahon, K. Extreme ocean currents and habitat characteristics drive genetic divergence in a tropical seagrass. In review Molecular Ecology

Hernawan U, van Dijk K, Kendrick G, Feng M, Biffin E, Lavery P, McMahon K. Historical processes and contemporary ocean currents drive genetic structure in the seagrass Thalassia hemprichii in the Indo-Australian Archipelago. In review Molecular Ecology

5.4 Presentations

Sarah Hearne, Alison Blyth, Jennifer McIlwain, Michael Travers, Richard Evans, Kate Trinajstic (2017) Connectivity of fishes from the Kimberley region, Western Australia, using otolith geochemistry. Australian Society of Fish Biology annual conference held in Albany, WA, 21-23 July 2017.

Oliver Berry, Michael Travers, Richard Evans, Glenn Moore, Ming Feng, Udhi Hernawan, Bernd Gruber (2017) Complex ocean currents promote adaptive diversification and lower dispersal in a tropical reef fish from north-western Australia. Australian Marine Science Association Annual Conference, Darwin, July 2- 7, 2017.

Joseph DiBattista, Michael Travers, Glenn Moore, Richard Evans, Stephen Newman, Ming Feng, Rebecca Gorton, Samuel Moyle, Thor Saunders, Oliver Berry (2017) Genomics reveals fine-scale patterns of dispersal for a reef fish along the ecologically significant coast of Northwestern Australia. Australian Marine Science Association Annual Conference, Darwin, July 2- 7, 2017.

Oliver Berry, Glenn Moore, Zoe Richards, Udhi Hernawan, Bernd Gruber, Michael Travers (2017) Genomic evidence for isolation of offshore and coastal populations of Trochus in the Kimberley. Australian Marine Science Association Annual Conference, Darwin, July 2- 7, 2017.

Oliver Berry, Jim Underwood, Kathryn McMahon, Zoe Richards, Mike Travers, Glenn Moore, Udhi Hernawan, Joey DiBattista, James Gilmour (2016) Ecological Connectivity of Kimberley Marine Communities: Lunch and Learn session, Department of Parks and Wildlife, Kensington.

Zoe Richards (2016) Some like it HOT! Hard coral diversity of the Kimberley, NW Australia. Presented to five research institutions in Japan (Fisheries Research Agency, Tokyo Institute of Technology; University of Miyazaki; Sesiko Marine Station; University of the Ryukyus) under a JSPS short term fellowship awarded to Dr Richards.

Zoe Richards (2016) High cryptic diversity, taxonomic uncertainty and the risk of silent extinctions in corals. International Society for Coral Reefs Symposium, Honolulu.

Jim Underwood (2016) Genomics of spawning corals in the Kimberley. AMSA snapchat

Oliver Berry, Jim Underwood, Kathryn McMahon, Zoe Richards, Mike Travers, Glenn Moore, Udhi Hernawan, Joey DiBattista, James Gilmour (2015) Genetic Connectivity in an Extreme Marine Environment. Society for Australian Systematic Biologists Annual Conference, Fremantle.

Oliver Berry, Jim Underwood, Kathryn McMahon, Zoe Richards, Mike Travers, Glenn Moore, Udhi Hernawan, James Gilmour (2015) Ecological Connectivity in the Kimberley. WAMSI Dredging and Kimberley Nodes Symposium, Library of Western Australia, Perth.

Jim Underwood, Zoe Richards, James Gilmour, Oliver Berry (2015) Genetic connectivity and cryptic diversity in corals of the Kimberley. Society for Australian Systematic Biologists Annual Conference, Fremantle.

Kathryn McMahon, Udhi Hernawan, Gary Kendrick, Korjent van Dijk, Paul Lavery, Oliver Berry, Mike Travers, Jim Underwood (2015). Genetic connectivity of the seagrass Thalassia hemprichii in the Kimberley and Pilbara. Australian Marine Sciences Association, Geelong, Australia.

Udhi Hernawan, Kathryn McMahon, Gary Kendrick, Korjent van Dijk, Paul Lavery (2015). Coastal and Estuarine Research Federation, Oregon, Portland, USA. So near, yet so far: Genetic connectivity of the seagrass Thalassia hemprichii in tropical Australia.

Kathryn McMahon (2015). Molecular ecology of seagrasses: tools for conservation and management. University of Jogjakarta, Natural resources from local to global conference. 2015. Invited speaker.

Kathryn McMahon (2015). Management and conservation of valuable seagrass ecosystems. Indonesian Institute of Sciences.

Kathryn McMahon (2015). What we know about connections in seagrasses: Long-distance dispersal, millennial movements and emerging patterns in NW WA. ECU Research Week

Udhi Hernawan, Kathryn McMahon, Gary Kendrick, Korjent van Dijk, Paul Lavery (2015). Predictors of genetic structure in marine organisms in the Indo-Australian Archipelago: Generalisable patterns and a seagrass-case study. ECU Research Week.

Udhi Hernawan, Kathryn McMahon, Gary Kendrick, Korjent van Dijk, Paul Lavery. Genetic connectivity of a tropical seagrass in an extreme environment: It is not just going with the flow. ECU Postgraduate Symposium.

Udhi Hernawan, Kathryn McMahon, Gary Kendrick, Korjent van Dijk, Paul Lavery, Oliver Berry, Mike Travers, Jim Underwood (2015). Going with the Flow: Ecological Connectivity of the seagrass Thalassia hemprichii in the Kimberley and North West Cape, Western Australia. WAMSI Kimberley Symposium.

5.5 Other communications achievements

WA Science Network - Kimberley reef life considered on a microscopic level - http://www.sciencewa.net.au/topics/fisheries-a-water/item/3545-kimberley-reef-life-considered-on-a-microscopic-level

Oliver Berry, Kathryn McMahon, Jim Underwood (2016) Going with the Flow. *Kimberley Tides Newsletter*. Department of Parks and Wildlife and Department of Fisheries

KMRP 1.1.3 Summary (July 2016) – Ecological Connectivity in the Kimberley Marine Communities https://indd.adobe.com/view/23b0943a-6eff-4499-bd39-f94ba9d1cf12

5.6 Knock on opportunities created as a result of this project

Proposal for postdoctoral position at AIMS for J. Underwood to work on a collaborative project (with AIMS, Curtin University and Parks and Wildlife among others) to further coral genetics, particularly in the northern Kimberley where MPA's exist and to address questions of reef resilience.

Proposal for ARC Linkage Grant led by Z. Richards to work on coral biodiversity and resilience in the Kimberley.

Through this project additional genetic connectivity work has been funded as part of a collaboration between ECU and Parks and Wildlife , to investigate further the genetic connectivity of the seagrass *H. ovalis* though the Pilbara. This will allow increasing the scope of the existing beyond the Kimberley and link with previous work by McMahon in the southern Pilbara.

A project on connectivity in the stripey snapper (*L. carponotatus*) across its entire Australian range between Western Australia and Queensland has been initiated through collaborations with researchers at James Cook University. Those researchers are seeking to generate a compatible dataset so that it can be combined with the data generated for this project.

5.7 Key methods for uptake

Lunch and Learn presentation at Parks and Wildlife (August 2016l) www.wamsi.org.au/ecological-connectivity and meeting with Node Leader and KMRP Advisory Group to discuss management needs and application.

An open presentation was made at Parks and Wildlife followed by an in- depth discussion with relevant managers on the KMRP Advisory Committee that was used to communicate the key findings and their application by managers and planners as well as to inform and improve the management implications sections of this report.

6 Appendix

Appendix 1: Questions outlined in the Kimberley Marine Research Program Science Plan

Key Questions	Informed Response
How do macro-tidal systems influence ecological connectivity of key taxa?	In the taxa where comparisons could be made (seagrasses and fishes) connectivity was lower in the macro-tidal and topographically complex Kimberley than in the less tidal and topographically complex Pilbara. Within the Kimberley, organisms generally responded to oceanographic conditions in taxon-specific manners that broadly corresponded to their larval life-history and an isolation-by-distance pattern, but there were some exceptions. We conclude that further detailed oceanographic data is needed in tandem with more information about life-history and larval duration times in order to more fully understand connectivity in complex macro-tidal systems such as the Kimberley.
What is the extent of fine scale connectivity within and between coastal reefs (up to 100 km)?	In the Kimberley, with the exception of *T. niloticus,* which occurs as one large interbreeding population, population structure was evident between sites separated by more than a few kilometres in all species. However, the magnitudes of genetic difference between sites varied significantly among taxa, indicating that some species (corals, seagrasses) were relatively isolated, and their population structure reflected major hydrodynamic or topographic barriers, whereas the fishes experienced high levels of connectedness among sites largely reflecting isolation-by-distance effects.
What is the extent of larger scale connectivity within and between coastal and offshore reefs?	Genetic subdivision (and hence some limitation to dispersal) was observed in all taxa with the exception of *T. niloticus* within the coastal Kimberley. Inshore and offshore Kimberley populations are highly divergent for 3/3 taxa examined and the inshore Kimberley populations are also highly divergent from populations in the Pilbara for 3/4 taxa examined.
What are the dispersal distances of key taxa?	The maximum detectable scale of genetic structure, which indicates the routine dispersal distances, was taxon dependant. Habitat forming organisms (coral, seagrass) typically exhibited the most localised population structure, with evidence for limitations to routine dispersal evident on scales of 10s of kilometres or less. In the remaining organisms (fishes, trochus), population structure was weaker or not detectable, and limits to dispersal were evident on scales of 80 to several 100s kilometres (See Figure 5).
Are proposed management areas sufficient for ecological connectivity to support populations of key taxa?	The Dampier Peninsula and Buccaneer Archipelago are not included in any of the existing or proposed Kimberley Marine Protected Areas. The Bonaparte Archipelago which was superficially sampled in our broad-scale study is included in the proposed North Kimberley Marine Park. The Montalivet Island group (where a putative genetic diversity hotspot is hypothesised to occur for *I. bruggemanni*) is designated as a General Use Area. This designation offers little change in management strategy, and thus without sanctuary zoning, offers little benefit to coral reef populations. *T. niloticus* populations at Scott Reef, which are genetically and demographically independent from coastal populations and from the populations at Rowley Shoals do not benefit from existing spatial management as there is no protection from harvesting. In the case of the targeted fish *L. carponotatus*, existing fishery management does not recognise the separation of Kimberley and Pilbara populations detected in this research. The existing separate management of Northern Territory and Kimberley *L. carponotatus* is supported by the observed genetic differentiation

between these regions, but analysis of additional intermediate sites is required to better characterise the relationships between these stocks.

What are the influences of major disturbance?

Although we did not directly address this question – the major disturbance events likely to impact our study are cyclonic waves, coral bleaching, flood events and the input of sediment and nutrients. With the exception of *T. niloticus* it appears that disturbances greater than 10km in scale are likely to impact more than one relatively demographically discrete unit.

How will climate change affect dispersal patterns of key taxa?

Rapid climate change may reduce population sizes and genetic diversity through recurrent disturbance. If climate change leads to changes in the hydrodynamic regime, then this could affect dispersal patterns unless species can respond behaviourally to the changes.

How can genetic data be best incorporated into emerging oceanographic models for the region to provide more robust and detailed inferences about patterns of connectivity throughout north-west WA?

Genetic observations can be used to evaluate how well oceanographic models represent biological processes like connectivity. Such evaluations potentially validate models, which then can be generalised to other species or locations.

In this study we show (for corals, *T. niloticus* and *P. milleri*) that a simple measure of distance provides a better explanation of the observed patterns of connectivity than a fine-scale oceanographic model that does not incorporate larval behaviour. That result, along with our observation that life-history roughly predicts levels of connectivity in some of our taxa, indicates that if models are going to provide “more robust inferences” they need to include larval behaviour.

Better predictions of connectivity in the Kimberley are also likely to result from:

- Development of particle tracking (connectivity) models that better match the spatial scale of management as well as the scale of genetic analysis;
- Incorporation of additional biophysical data into predictive models of connectivity (e.g. redundancy analysis).

What role does the Kimberley play in the maintenance of systems outside of the region?

Based on the results of this study, and acknowledging that sampling of outside regions was incomplete, the Kimberley appears to be a largely a self-contained system for most taxa. It is not likely to play a major role in the maintenance of systems outside the region over ecological timescales with the exception of *L. carponotatus* which does have a degree of exchange with both the Northern Territory, and to a lesser extent, the Pilbara. The inshore Kimberley has negligible role in maintaining populations on oceanic shoals and vice versa on an ecological timescale.

How is the condition of the Kimberley influenced by external biological and anthropogenic influences?

Marine communities in the inshore Kimberley are likely to be profoundly influenced by dynamic environmental conditions at a local scale leading to a strong selective pressure and the observed pattern of high population differentiation in species.

Harvesting has the potential to impact *T. niloticus* stocks at offshore atolls, while non-sustainable fishing for *L. carponotatus* could result in impacts to Kimberley stocks of this recreationally targeted species. Anthropogenic impacts like oil spills or development are likely to have lasting impacts due to the fragmented nature of populations so recovery will be slow.