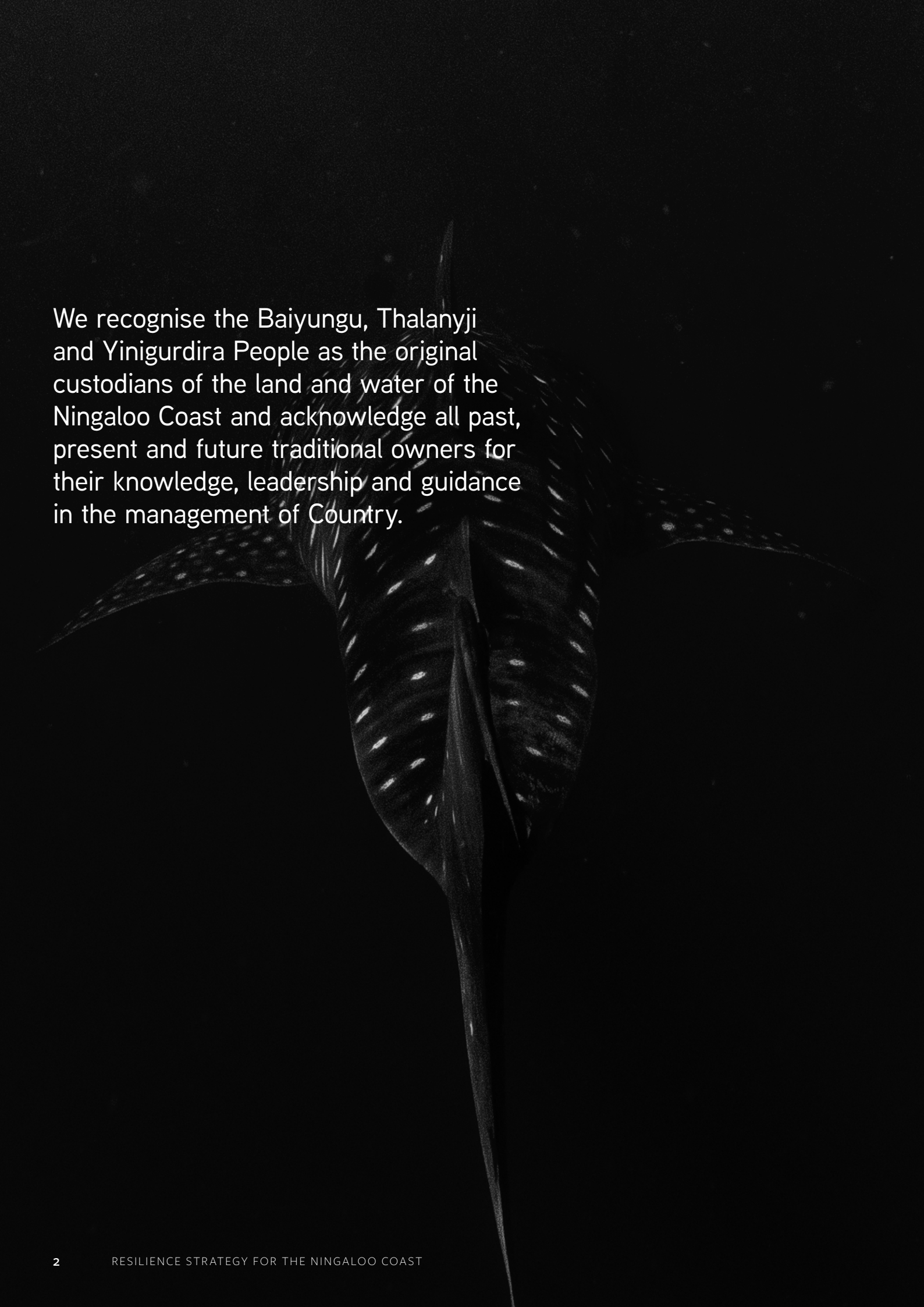
RESILIENCE STRATEGY for the Ningaloo Coast



We recognise the Baiyungu, Thalanyji and Yinigurdira People as the original custodians of the land and water of the Ningaloo Coast and acknowledge all past, present and future traditional owners for their knowledge, leadership and guidance in the management of Country.

This Strategy was developed by the Resilient Reef Initiative a global partnership between the Great Barrier Reef Foundation UNESCO, The Nature Conservancy's Reef Resilience Network, Columbia University's Center for Resilient Cities and Landscapes, Resilient Cities Catalyst, AECOM and BHP Foundation, in collaboration with the Department of Biodiversity, Conservation and Attractions.

Queries regarding the management of Ningaloo Marine Park or relevant actions under this Strategy should be directed to:

Department of Biodiversity, Conservation and Attractions (DBCA)
20 Nimitz St
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Letter of Support
Great Barrier Reef Foundation

The Great Barrier Reef Foundation is delighted with the launch of the Resilience Strategy for the Ningaloo Coast, delivered through our global Resilient Reefs Initiative. This $14 million global coral reef climate resilience program includes the Ningaloo Coast as a critical pilot site. Partnering with five World Heritage Sites, the Resilient Reefs Initiative connects local reef managers and communities with a global network to take action in building both reef and community resilience, together and at scale.

Each of these diverse and treasured natural wonders are under threat from a combination of both shared and site-specific challenges. Resilient Reefs partners with the reef management organisations of these sites and provides a wide range of resources, connections, and technical expertise, all focused on building concrete solutions. This included funding for a new Chief Resilience Officer (CRO) position, technical support to develop a Resilience Strategy, connection to a global knowledge network of climate resilience leaders and access to a $5M fund to support the implementation of priority resilience actions.

Ningaloo Coast was the first Resilient Reefs partner site to establish a Chief Resilience Officer and is now the first to deliver a Resilience Strategy. We warmly congratulate all involved in showing the world what a new approach to resilience-based management of coral reefs can look like. This strategy looks different from a typical reef management plan, and trying something new is hard, courageous work. We truly believe this is the best chance for reefs and reef-dependent communities to respond to the changes ahead – and it has been a privilege to witness the eagerness of the Ningaloo Coast community, stakeholders, and reef management authority to embrace the challenge of a new approach.

If the pandemic taught us anything, it's that building the resilience of our communities and planet in the face of shocks and stresses is paramount. It has tested individuals, communities, governments, and economies to adapt to ongoing change and threats. Over the last few years in Australia, we've seen devastating floods, bushfires, coral bleaching on the east and west coasts, and an equally unprecedented hurricane season in the Atlantic, and confirmation that climate change the biggest threat to World Heritage (IUCN World Heritage Outlook 3). It has never been a more crucial moment in time for this vital work.

Partnering with the Department of Biodiversity, Conservation and Attractions—and so many stakeholders and partners in the development of this Ningaloo Strategy—has been a rewarding and inspiring experience, setting the scene for the possibilities of what could be.

This Resilience Strategy presents an ambitious vision which aims to strengthen the community's resilience through actions such as supporting local livelihoods and diversifying the economy, while advancing best in class pilots on reef restoration and adaptation, and partnering closely with the community to monitor and manage this treasured resource.

Across its five key pillars, this Strategy is truly holistic – spearheading action and change across broad sections of the community – and doesn't shy away from committing to challenging actions to achieve its bold vision.

The Great Barrier Reef Foundation is immensely proud to lead the Resilient Reefs Initiative and on behalf of the entire Resilient Reefs network – including our partners, UNESCO, The Nature Conservancy's Reef Resilience Network, Columbia University's Center for Resilient Cities and Landscapes, Resilient Cities Catalyst, AECOM and BHP Foundation – we celebrate the incredible work Ningaloo has accomplished and look forward the next chapter in Nigaloo's journey.

Anna Marsden
Managing Director

Executive Summary

The Ningaloo Coast is unique. Home to one of the longest near-shore coral reefs in the world which hosts internationally-important aggregations of whale sharks, humpback whales and marine turtles, the Ningaloo Coast is a jewel in the crown of Western Australia's many distinctive and diverse landscapes. The Ningaloo Coast's exceptional natural beauty and unique biodiversity have led to its recognition as one of only 50 UNESCO sites. The reef, marine and coastal environment generate over $110 million in additional value for the local economy and support over 1000 jobs , as well as being a vital aspect of the character and culture of the region, a source of pride, enjoyment and recreation for residents and deep cultural significance for traditional owners.

Ningaloo Reef is remarkably intact compared with other coral reef systems around the world, protected by very low levels of development along its fringes, a high level of legislative and regulatory protections, and the activities of committed managers and local residents. Globally, however, the majority of the world's coral reefs are predicted to be in decline by 2030. Along with mounting local pressures, coral reefs are facing the existential threat of global climate change, including warming sea temperatures, ocean acidification and more extreme storm events. Rapidly warming ocean temperatures are already causing mass bleaching events around the world, and the best available science tells us that within 20 years, Ningaloo Reef will experience severe coral bleaching as a result of marine heatwaves at a rate of twice per decade, may be beyond its natural ability to recover.

Pressures are intensifying and future impacts are uncertain. As existing pressures are intensifying and new pressures are predicted, the environmental conditions of the Ningaloo Coast are starting to shift, and ecosystems are beginning to change in character and function. How these changes will affect the reef and the communities that rely upon it, and the exact timing of impacts, is uncertain.

Adaptive and flexible approaches to planning and management that accommodate uncertainty and strengthen the ability of ecosystems and communities to adapt to change will be vital for sustaining the vibrant ecological, economic and social systems of the Ningaloo Coast. In the future, the Ningaloo Coast is likely to face challenges related to climate change, changing levels of visitation, fishing pressure and a desire for economic growth. Regardless of the challenge, resilient systems remain strong, retaining their core functions and characteristics while undergoing change and transformation.

In many ways, the resilience of the reef has been managed for countless years already, through the activities of management agencies and committed local residents, and for thousands of years through the custodianship of traditional owners. However, the rapidly changing climate could mean the loss of key species, foundational habitats and ecosystem functions. Resilience-based management guides proactive decision-making under risk and uncertainty, identifying potential actions that may achieve multiple objectives under different future scenarios and sustain ecosystems and human well-being for generations to come.

A resilience strategy for the future of the Ningaloo Coast. In 2020, extensive stakeholder engagement was undertaken with community members, local businesses, community groups, management agencies, researchers and resilience experts to understand the current state of resilience of the Ningaloo Coast, core community values and management priorities for the next 20 years. The result is this Resilience Strategy, which sets out an ambitious vision for ecosystems, communities and governance systems that are able to cope with, recover from and adapt to change and disturbance. Engagement with the community identified innovative, holistic solutions that will strengthen and support the resilience of the reef, coastline and communities, encapsulated within the five Pillars of: *Thriving, resilient ecosystems*; *An educated and empowered community*; *Sustainable development and livelihoods*; *Adaptive management systems*; and *Leadership in sustainability and resilience*.

Under these five Pillars, 16 objectives and 34 strategies have been defined that will enhance resilience through: minimising local pressures to ensure ecosystems are as healthy as possible; preserving important species, habitats and functional processes that support resistance, recovery and adaptation; assisting ecosystems to recover after disturbances; diversifying local livelihoods; supporting holistic,

Resilience is the capacity of reef ecosystems – as well as the individuals, businesses and communities that rely upon them – to survive, adapt and recover from stresses and shocks.

collaborative strategic planning and adaptive management; empowering the community to be involved in planning and management; sharing knowledge and information to build trust and stewardship; and building adaptive capacity, the ability to adapt and transform in response to new conditions.

It will take time to realise these outcomes. The Strategy plans for the long-term by providing a list of objectives and strategies that are flexible to adjust to new information and management approaches. Potential actions are currently unfunded and not all will be implemented, but these provide guidance on community aspirations and best-practice resilience-based management to guide decision making.

The implementation of this Resilience Strategy requires the resources, experience, skills and knowledge of many management agencies, organisations, researchers and individuals to be successful. The objectives, strategies and potential actions contained within this Strategy are broader than a single organisation can achieve alone, and are therefore intended as a framework for partnership and ongoing cooperation in ensuring the preservation of the Ningaloo Coast and sustaining ecosystems and human well-being for generations to come.

The character and way of life of the Ningaloo Coast's local communities depend on the amazing natural ecosystems, which support valuable tourism and fishing industries, underpin local economies, provide natural protection for coastlines and infrastructure, and offer unparalleled opportunities for recreation and enjoyment. Maintaining or restoring historic levels of biodiversity may be an unrealistic objective in a warming world. Even under best-case emissions trajectories, coral reefs will likely be transformed by climate change in the future – how significantly will depend on the success of global emissions reductions and local adaptation. Though there is little control at the local scale over emissions, this Strategy aims to strengthen the ability of the reef to adapt to changing conditions while retaining its core functions, and to empower local communities to prepare for, cope with, and adapt to change.

"Healing Thunardi...healing the ocean" (words by traditional owner Hazel Walgar)

For us traditional owners we have seen the changes. We have seen the impacts. Seagrass, mangroves, corals, fish, marine mammals are all being impacted. The changes are obvious to us.

We have seen the influx of people here – on the water and on the coast. The ecosystems are impacted by so many things – unsustainable fishing, boat fumes, suncreens, climate change – it is so many things. Back in the days we did not have those impacts. We only went to the water to take what we needed and that was it. Seagrass and mangroves are important. Nutrients from these system help make food, health, vitamins and minerals. The coral reefs are important.

We grieve and are sad when we go on Country now. When we see what's happening to the coral, the fish, the land and the sea, we feel so sad. We feel so sad with how many fish are being taken. We are sad at what we see at the fish cleaning tables.

As children, the coral was always healthy. We did not have torches near the water or corals. We always had our campfire way back and walked onto the reef in the dark. 'Why can't we have torches' we would ask the elders. They told us it will change the coral and change the ocean. The torches and light can kill marine life. We know that. The light harms our Majun, our turtles too.

Dunes have now been eroded. Places we use to sit with protection are now eroded and gone. Marine life where we use to get a feed, we can't get a feed anymore. We use to be able to catch big Wurrawurra (blue bone) close to shore but now nothing. Spangled emperor, red emperors, dhufish, and all the cods – they come from our dreaming places and are sacred fish for us. We protect the old fish. Fishing competitions every year are impacting the ocean.

There use to be more turtle nesting areas but now there are fewer. Dugong – we don't see them as often anymore – they are frightened by all the boats.

We have seen all these changes, especially over the past 10-20 years.

We all need to start "Healing thunardi...healing the ocean". We need to heal Country together. We need to heal Sea Country with the community and with other traditional owners from other places like the Great Barrier Reef.

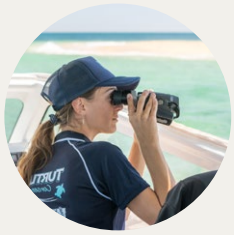
The Strategy at a Glance

The Ningaloo Coast is a unique and vibrant part of Western Australia:

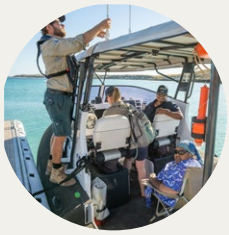
Deep cultural significance for traditional owners

World Heritage-listed ecosystem

Generates over $110 million locally and supports 1000+ jobs



A source of pride, enjoyment and recreation for residents



In the future, the Ningaloo Coast will face a range of challenges, including:

Climate change

- Rising sea level
- Rising temperatures
- Changing ocean currents
- Ocean acidification

Extreme events

- Increased marine heatwaves and coral bleaching
- Increased cyclone intensity

Human impacts and visitor pressure

- Physical impacts on coral and habitat
- Disturbance to iconic wildlife
- Increased pressure on fish stocks

New development or industrialisation

- Increased human pressures on reefs
- Physical impacts on reefs, habitat or iconic wildlife

Resilience is the capacity of reef ecosystems – and the individuals, businesses and communities that depend upon them – to survive, adapt and recover from stresses and shocks.

This Resilience Strategy outlines objectives and strategies to help sustain the ecosystems and communities of the Ningaloo Coast for generations to come.

But changes are occurring:

Water temperatures have risen 1°C over the past 30 years

Corals have declined at some monitoring sites since 2011

Ningaloo is predicted to experience severe bleaching twice per decade by 2041, which is likely to cause significant mortality

These challenges, if not addressed, have the potential to result in:

Risks to livelihoods and infrastructure

Declining condition of reef, marine and coastal ecosystems

Changing character of communities and community

Declines in economically and ecologically-important species

The resilience of the Ningaloo Coast can be enhanced by:

- Minimising local pressures
- Supporting recovery
- Diversifying livelihoods
- Holistic, integrated planning
- Collaboration and cooperation
- Adaptive, proactive management
- Supporting ecosystems and communities to evolve and adapt to change

Resilience Strategy for the Ningaloo Coast

PILLAR A - THRIVING, RESILIENT ECOSYSTEMS

OBJECTIVES		STRATEGIES	
A1	Local pressures on the reef and other ecosystems are minimised.	A1.1	Support sustainable recreational use and tourism to mitigate human pressures on marine and coastal ecosystems.
		A1.2	Identify and where appropriate provide a management response to outbreaks of coral predators and diseases.
		A1.3	Enhance compliance and educate the community in compliance effectiveness.
A2	Key ecosystem features and functions that support resilience are preserved.	A2.1	Identify and preserve habitats and ecosystems that are disproportionately important to resilience (i.e., areas that best support ecological, social, economic and cultural values).
		A2.2	Identify, monitor and preserve key resilience attributes, species and functional relationships necessary for maintaining healthy ecosystems, including identifying thresholds for foundational species or ecosystem functions.
		A2.3	Support healthy populations of iconic species.
		A2.4	Maintain current fish abundance and diversity..
A3	The ability of the reef to recover from bleaching events and other disturbances is supported.	A3.1	Develop collaborative partnerships to undertake research and experimental trials to identify the cost, feasibility and practicality of potential management interventions which support recovery and adaptation.
		A3.2	Develop a framework for responding to disturbances.
		A3.3	Adaptively deploy appropriate interventions based on identified thresholds (to be determined through research).
A4	The ability of the reef to evolve and adapt to changing environmental conditions is supported.	A4.1	Identify and protect a diversity of species, functional groups and populations with genetic, physiological, or ecological traits that are resilient to future stressors (including heat stress, disease, cyclone damage, acidification and predation) or exhibit high levels of adaptive capacity.
		A4.2	Enhance the processes of adaptation by promoting the development of resistant coral species.

PILLAR B - AN EDUCATED AND EMPOWERED COMMUNITY

OBJECTIVES		STRATEGIES	
B1	The community is informed about the current status, trends and threats to the reef and community.	B1.1	Provide information to the community about the current state of scientific understanding about ecosystem health and actions that enhance resilience.
		B1.2	Investigate opportunities for climate change and resilience education programs for the community, as appropriate.
B2	The community are involved in planning and management.	B2.1	Enhance opportunities for community engagement and participation in planning, management and research activities.

PILLAR C - SUSTAINABLE DEVELOPMENT AND LIVELIHOODS

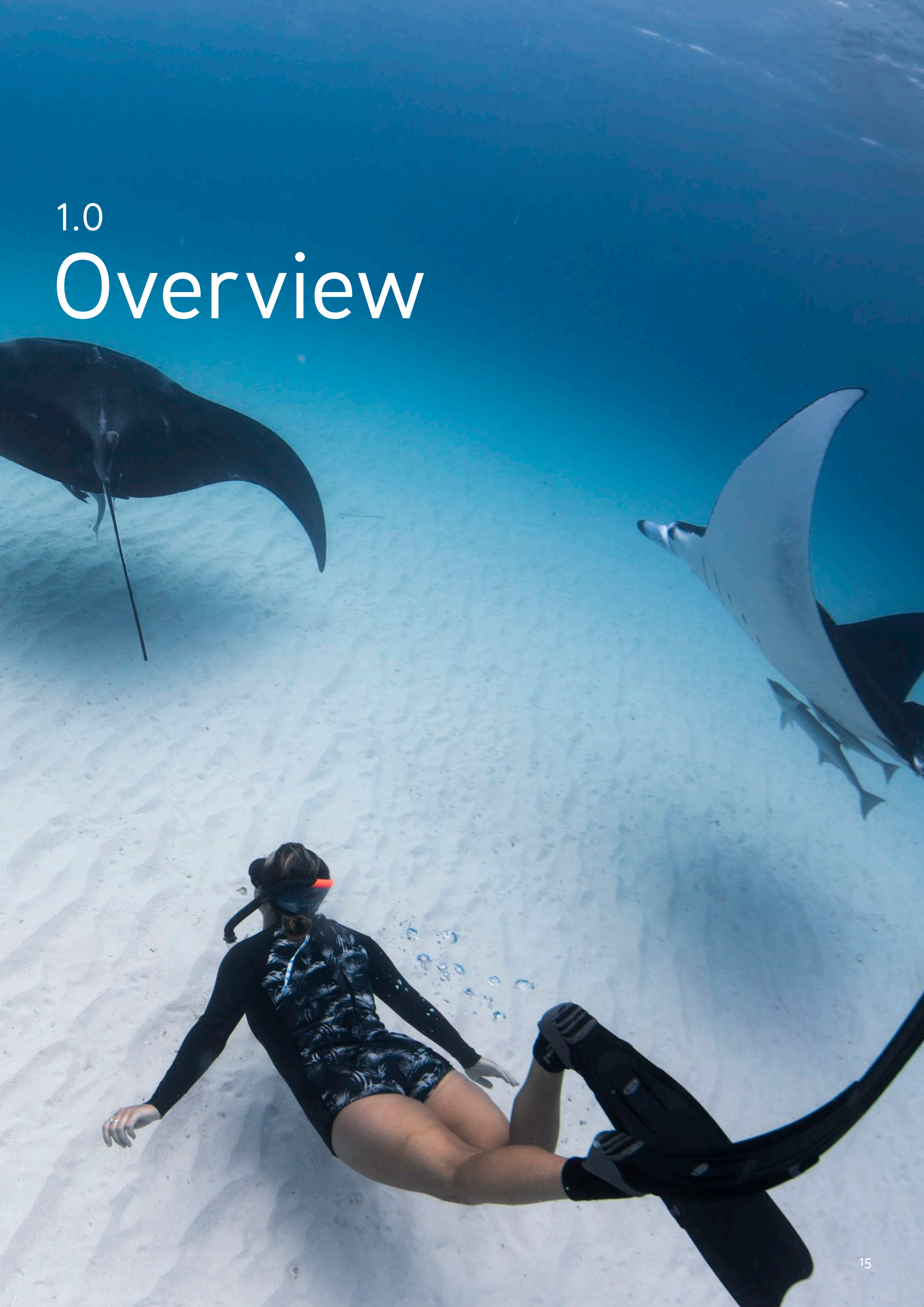
OBJECTIVES		STRATEGIES	
C1	Sustainable utilisation and enjoyment of the Ningaloo Coast aligns with ecological and community values.	C1.1	Understand appropriate or 'optimal' levels for population, tourism, extractive activities, infrastructure, services and utilities to sustain and support the maintenance of ecosystem health and community values.
		C1.2	Encourage and support sustainable development and livelihoods that align with ecological and community values.
C2	Sustainable livelihood diversification reduces local pressures on the reef and strengthen economic resilience.	C2.1	Support the diversification of tourism products, sub-sectors and across other sectors to reduce pressure on marine and coastal ecosystems.
C3	The resilience of local businesses and communities is enhanced.	C3.1	Support local operators to strengthen their ability in responding to changes in business conditions as a result of changes in reef health.

PILLAR D - ADAPTIVE MANAGEMENT SYSTEMS

OBJECTIVES		STRATEGIES	
D1	Management planning and approaches are integrated and adaptive.	D1.1	Develop adaptive planning structures and management arrangements that can be iteratively modified as new information becomes available or environmental conditions change.
		D1.2	Support the trialling of new approaches to build resilience as they become available.
		D1.3	Pursue integrated approaches to planning and management of the Ningaloo Coast.
D2	The knowledge, values, experience and skills of multiple stakeholders are valued in adaptive management.	D2.1	Strengthen multi-agency collaboration at the strategic level. Align the strategic goals and objectives of various management agencies where possible.
		D2.2	Generate tailored strategic research that informs management and is responsive to evolving needs.
D3	Resilience is embedded within existing planning and management processes.	D3.1	Foster the ongoing consideration of resilience as part of general operations and day-to-day decision-making.
		D3.2	Ensure that climate change is considered in management planning.
D4	Funding for resilience-based management is increased.	D4.1	Collaborate to increase the funding available for resilience-based management.

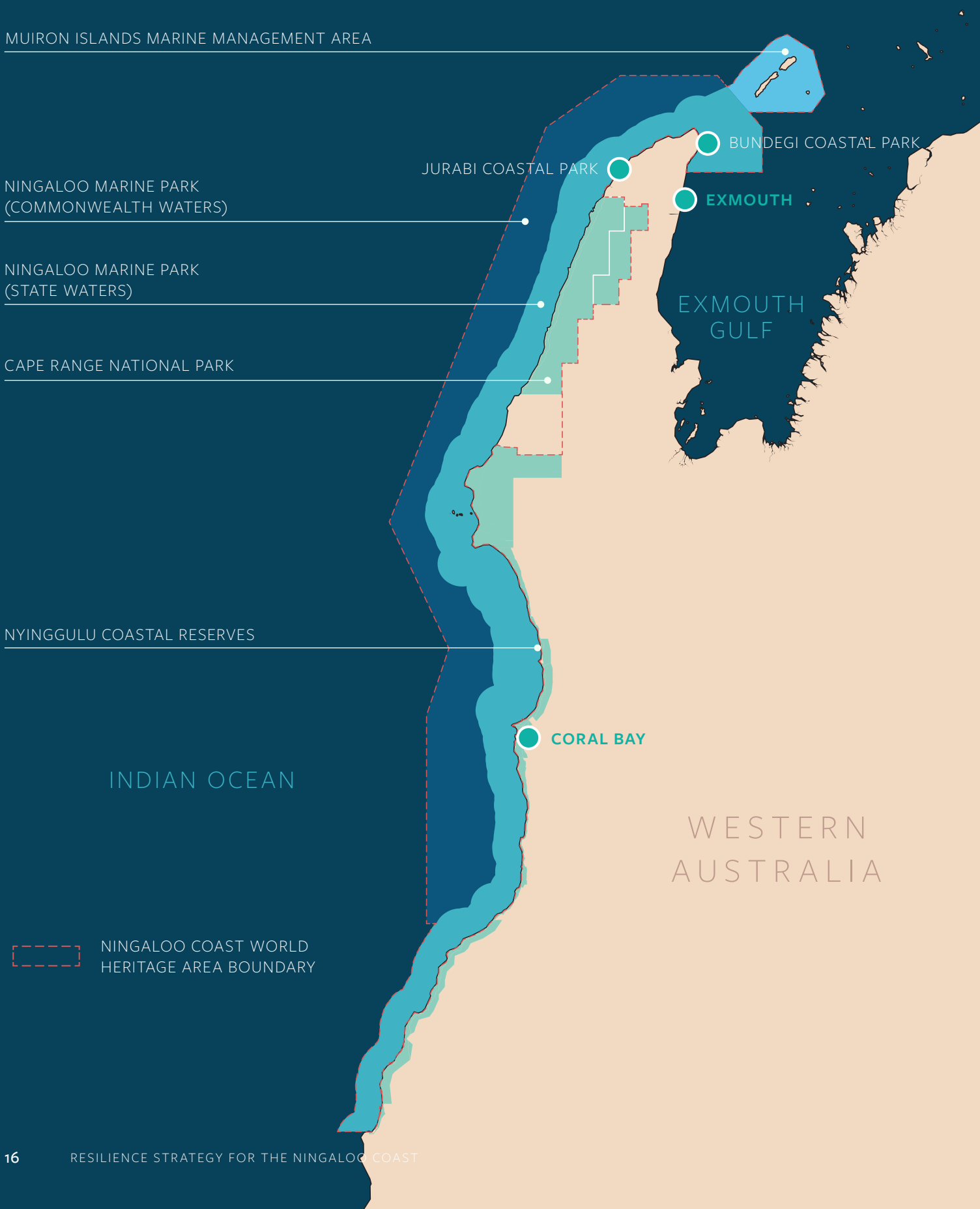
PILLAR E - LEADERSHIP IN SUSTAINABILITY AND RESILIENCE

OBJECTIVES		STRATEGIES	
E1	Ecosystems that store carbon and support marine life are protected.	E1.1	Monitor, assess and protect seagrass, macroalgal and mangrove habitats.
E2	The carbon footprint is minimised.	E2.1	Encourage the uptake of renewable energy, improved waste management and emissions reduction within the region.
		E2.2	Support influential institutions to lead a transition to a low carbon economy.
E3	Ningaloo Coast management agencies and communities are leaders in sustainability and resilience.	E3.1	Communicate the importance of mitigation and adaptation to the preservation of Ningaloo Reef.
		E3.2	Seek avenues to foster the development of a resilience and climate change innovation hub for education, research, management, community collaboration and knowledge sharing with other regions.
		E3.3	Educate and empower visitors to be ambassadors for marine conservation.
		E3.4	Promote good practice and progress in minimising environmental footprint to encourage a shift in social norms.



1.0 Overview

Map of the Ningaloo Coast



1.1 Overview of the Ningaloo Coast

The scope of this Resilience Strategy is the Ningaloo Coast, including the ~300km of fringing reef that extends down the western side of North West Cape to Red Bluff, as well as the marine and coastal areas and communities that are associated with this ecosystem. This includes:

- **Ningaloo Marine Park (State waters)** – DBCA Parks and Wildlife Service, in joint management with traditional owners, is primarily responsible for the management of the Ningaloo Marine Park (State waters) which spans the length of the reef from Bundegi to Red Bluff. DBCA works in collaboration with other State Government agencies such as the Department of Primary Industries and Regional Development and the Department of Transport in the implementation of management strategies for the marine park. Adjacent to the marine park is the Muiron Islands Marine Management Area. The Muiron Islands are managed by DBCA and the Shire of Exmouth.
- **Ningaloo Marine Park (Commonwealth waters)** – Parks Australia is primarily responsible for management of the Commonwealth waters, which covers 2,435 square kilometre, ranging from a water depth of 300 to 500 metres.
- **Jurabi and Bundegi Coastal Parks** – The Jurabi and Bundegi Coastal Parks on North West Cape are managed by DBCA and Shire of Exmouth. Adjacent to these Parks, the Harold E. Holt Naval Communication Station is managed by the Commonwealth Department of Defence.
- **Cape Range National Park** – Adjacent to the northern portion of the Ningaloo Marine Park (State waters), from Tantabiddi to south of Yardie Creek, the Cape Range National Park is jointly managed by DBCA Parks and Wildlife Service and the Baiyungu, Thalanyji and Yinigurdira traditional owners.
- **Exmouth Gulf** – Exmouth Gulf is a large, shallow embayment to the eastern side of North West Cape. In December 2021, the WA Government announced a new marine park would be established for the eastern and southern parts of the Gulf.
- **Nyinggulu (Ningaloo) Coastal Reserves** – Extending from Winderabandi in the north to Red Bluff in the south, the Nyinggulu Coastal Reserves encompass the coastal strip adjacent to and including terrestrial portions of Ningaloo Marine Park (State waters) and the Ningaloo Coast World Heritage Area. The reserves will be jointly vested with the Conservation and Parks Commission and the Nganhurru Thanardi Garrbu Aboriginal Corporation via an Indigenous Land Use Agreement (ILUA).
- **Pastoral leases** – The area to the south of Cape Range National Park has a long history of management via pastoral leases, which also support tourist nodes for coastal camping. Cardabia, Warroora, Gnaraloo and Quobba Stations are adjacent to the Nyinggulu Coastal Reserves and the NMP and are managed by leaseholders and traditional owners.
- The communities of **Exmouth and Coral Bay**
- **Commonwealth Defence Land** on the northern and eastern parts of North West Cape, and
- **Various Unallocated Crown Land** adjacent to the tenures listed above.

This Resilience Strategy does not propose changes to tenure or existing management arrangements, or management plans and agreements in place for the Ningaloo Coast. This Resilience Strategy is designed to be complementary to existing management plans and agreements.

Ningaloo Coast World Heritage Area

Covering 604,500 hectares of marine and terrestrial tenure, the Ningaloo Coast World Heritage Area encompasses tjhe Ningaloo Marine Park (State and Commonwealth waters), Jurabi and Bundegi Coastal Parks and the Cape Range National Park. Inscribed on the UNESCO World Heritage List in 2011, it is listed under two criteria of Outstanding Universal Value:

Criteria (vii) - superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance

- Large-scale marine, coastal and terrestrial environments
- Interconnected 'and contrasting' ocean and arid coast
- One of the longest near shore reefs in the world
- Important aggregations of whale sharks and marine mammals

Criteria (x) - important and significant natural habitats, including those containing threatened species of outstanding universal value

- High marine species diversity and abundance
- Unusual diversity of marine turtle species
- The highest cave fauna diversity in Australia

For more information: https://whc.unesco.org/en/list/1369/

1.2 Future Challenges for the Ningaloo Coast

In the next 20-50 years, the Ningaloo Coast is predicted to experience a range of pressures and challenges, including: impacts of climate change; increased visitation and human pressures as a result of a growing population and increases to tourism; and the potential for new onshore or offshore developments and industrialisation. Rising temperatures, localised human impacts and seasonal visitor pressures are occurring now. More frequent and intense marine heatwaves and increased storm and cyclone intensity may be felt in the next 20 years, whereas rising sea level, ocean acidification and changes in ocean currents may be felt within the next 50 years. The real impacts of these changes are unknown. The potential impacts of pressures on the environment and community outlined below were developed through stakeholder consultation and review of relevant literature.

CHANGING CLIMATE

	Rising temperatures	Rising sea level	Ocean acidification	Changes in ocean currents
ENVIRONMENT	Increased coral bleaching risk Potential for increased coral predators or diseases Changing species ranges and timing of biological events. Possible decline in turtle populations if all hatchlings are born female	Possible damage to reefs from increased wave action Increased coastal erosion if reefs cannot keep up with sea level rises Potential loss of seabird and turtle nesting areas	Potential for reduced coral growth and increased reef fragility to storms Potential reduction in phytoplankton and zooplankton that support whale sharks and other marine species	Altered patterns of recruitment / supply of larvae Changes in the natural range of species
COMMUNITY	Potential impacts on human health and wellbeing. Potential impacts on tourism Increased seasonality of residency Potential increase in energy costs	Higher storm surge and related flooding Loss of recreation areas and property Damage to cultural sites along the coast	Decline in tourism if the reef is degraded Decline in tourism if whale shark aggregations are affected	Changes in tourism activity if the reef is degraded

Not what, but how often: Coral reefs are inherently dynamic systems with an innate capacity for natural recovery from major disturbances like cyclones or marine heat waves. However, climate change is increasing not only the intensity of these disturbances, but also the frequency - reefs will face severe disturbances more often in the future, which will limit the time they have to recover.

The best available science predicts that Ningaloo Reef will experience severe bleaching events twice per decade by 2041, and annually by 2049[viii].

EXTREME EVENTS

More frequent and intense marine heatwaves

- Possible recurring mass coral bleaching
- Possible changes to seagrass and macroalgae habitats
- Possible changes to reproduction and recruitment of marine species
- Potential fish kills

- Decline in tourism if major bleaching occurs
- Changes to fish populations, potentially affecting recreational fishing

Increased storm and cyclone intensity

- Damage to corals, seagrass, mangrove, macroalgal and coastal habitats
- Potential declines in key species due to loss of habitat
- Increased sedimentation following flood events

- Damage to property and infrastructure
- Flooding from storm surge
- Reduced productivity of fisheries
- Potential water scarcity
- Road access cut more frequently

HUMAN PRESSURES

Human impacts and visitor pressure

- Potential for increased disturbance of iconic species
- Pressure on fish stocks
- Physical damage to habitat and wildlife
- Potential for increased pollution
- Potential impacts on coastal vegetation, habitats and animal species

- Decline in visitation if fish stocks or reef condition decline dramatically
- Loss of core community values
- Impact to recreational appeal due to overcrowding
- Capacity of local infrastructure and services exceeded

New developments or industrialisation

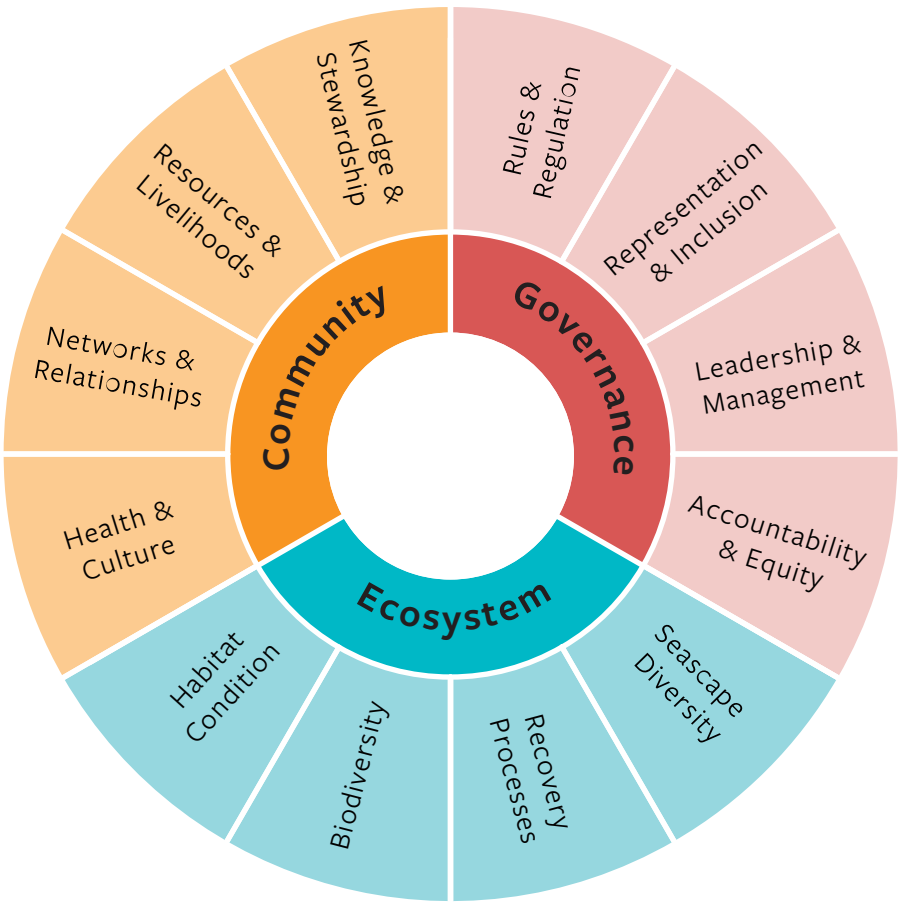
- Potential for increased disturbance of iconic species
- Potential degradation or loss of habitat
- Potential increases in pollution
- Possible introduction of new pests or diseases (e.g. in ballast water)
- Increased visitation/ human pressures due to larger population or increased accessibility

- Reputational risk of development to 'pristine' image of Ningaloo Coast
- Potential change to core community values
- Broader economic base and job creation
- Reduced social cohesion due to divisive community views on development

1.3 The Resilient Reefs Initiative

Resilient Reefs[vi] is a global initiative to support coral reefs - and the communities that depend on them - to adapt to climate change and local threats. The Ningaloo Coast is one of just five World Heritage-Listed coral reefs to be a part of the initiative, which seeks to bring together community members, reef managers and global resilience experts to develop and pilot resilience-based approaches to management. Resilient Reefs supports communities and management agencies to develop resilience strategies through the funding of a Chief Resilience Officer, technical support and capacity building in resilience-based management, and connection to a global Knowledge Network of resilience experts. Following the development of this Strategy, up to $1 million in seed funding is initially available through the Resilient Reefs Initiative to implement innovative solutions.

The Reef Resilience Framework was developed to support reef communities and managers to better understand the current state of resilience of their reef and communities, identify strengths and weaknesses and prioritise actions. The framework looks holistically at coral reefs, the communities that depend on them, and the governance arrangements that influence them as an integrated system.



"Being a part of the community forum was inspiring - by the end of the forum we could see the steps community members can start to take to be a part of the solution."

Vikki Hoff,
Ningaloo Reef Dive

"... everyone was really energised, and you finally felt like something that you really cared about, and thought was important for the future had been heard."

Michael Tropiano,
Exmouth resident

"It's one of those things that you hear a lot about, but sometimes you don't actually see it happening: It was really good to see the community and DBCA all working together, addressing issues and potentially solving some problems."

Caitlin Rae,
Coral Bay resident

1.4 Developing the Strategy

Collaboration, common understanding and shared goals are fundamental to effective management.

This Strategy is informed by existing research, management plans and policy documents, as well as the experience and knowledge of a wide range of traditional owners, managers, researchers, local operators and business owners, and residents. Development of the Strategy involved collaboration at all stages, generating innovative solutions in partnership with the local community, researchers, managers and global experts. The process of developing the Strategy included analysis of projected climate change and socio-economic trends, historical disturbances, key ecological functions and processes, community values and priorities, existing research, policy documents and the current condition of, and pressures on, ecological, community and goverance systems.

Stakeholder engagement sought to understand the values, aspirations and priorities of those who live on and rely upon the Ningaloo Coast, as well as challenges to achieving this vision for the future. Engagement resulted in defining potential actions and approaches that will strengthen the ability of ecosystems and the community to adapt to change. Stakeholder engagement activities included:

The Resilient Reefs Working Group including representation from traditional owners, DBCA, the Shires of Exmouth and Carnarvon, the Gascoyne Development Commission, the Exmouth Chamber of Commerce, Cape Conservation Group, DPIRD, the local tourism industry (Exmouth and Coral Bay), the Ningaloo Coast World Heritage Committee and the Exmouth District High School.

Interviews with over 80 stakeholders directly, including residents, business owners, managers, researchers, utility providers and community groups.

Online engagement via an interactive engagement portal which gave stakeholders the opportunity to complete online surveys and share ideas, photos and stories on public discussion boards.

Three community workshops held in Exmouth and Coral Bay in September 2020 with over 100 individuals in attendance.

Traditional owner engagement which included supporting the mapping of cultural and traditional values and knowledge, on-Country discussions, and regular updates on Resilient Reefs to the Nyinggulu Coast Joint Management Body.

Other outreach included coral reef documentary screenings; community Q+A sessions, updates via social media and newsletters; and presentations to local, state, national and international audiences.

The Resilient Reefs Knowledge Network facilitated engagement with other reef site managers and resilience experts from around the world and global resilience experts via the Resilient Reefs Knowledge Network. This network shared leading-practice management approaches and technical expertise in resilience that helped shape the approach and potential actions contained within this Strategy.

Resilience Co-Benefits:

During the Resilience Strategy development process, stakeholders identified eight themes that were fundamental to successful management of resilience. These themes are termed 'Resilience co-benefits' and will be considered in potential action development and implementation where appropriate.

- → Partner with traditional owners
- → Increase education for visitors and locals
- → Retain/enhance core community values
- → Empower the community
- → Improve the health of reef, marine, coastal and terrestrial ecosystems
- → Create new opportunities for diverse livelihoods
- → Foster working partnerships
- → Develop adaptive planning and management approaches

1.5 A Resilience Approach

Resilience is the capacity of reef ecosystems - and the individuals, businesses and communities that depend upon them - to survive, adapt and recover from the stresses and shocks that they experience. Regardless of the challenge, resilient systems are able to remain strong, retaining their core functions and characteristics while undergoing change and transformation.

For the Ningaloo Coast, resilience is...

A holistic and integrated approach of ecosystem and community resilience to multiple threats

This Strategy focusses not only on ecological resilience, but also the resilience of the community, strengthening its ability to prepare for and recover from disturbances, adapt to changing circumstances and plan for an uncertain future.

Managing adaptively

Resilience recognises that ecosystems and communities are complex, dynamic systems. Change is inevitable – what matters is the ability to adapt to change while retaining core functions, characteristics and values. Adaptive management is a proactive and flexible approach, continually refining actions incorporating new information and changing conditions.

Values-driven

Managing for resilience requires a clearly-articulated, shared understanding of the important values, functions and characteristics to be retained along the Ningaloo Coast. Extensive stakeholder engagement has established the values within this Strategy. These values will guide the appropriate goals, priorities and management approaches going forward.

An understanding of how the values, processes, functions and attributes of the Ningaloo Coast will be impacted by pressures, and when interventions may be needed, can be informed by encouraging research, and the use of tools such as scenario planning, early warning systems, monitoring, modelling and decision support systems.

Collaborative

The integrated nature of this approach to management means that one agency cannot achieve all the necessary outcomes alone. Strengthening the resilience of ecosystems and community requires the resources, expertise and experience of many management agencies, organisations, researchers and individuals. The outcomes, objectives and potential actions contained within the Strategy are therefore intended as a framework for partnership and cooperation between multiple stakeholders to ensure the preservation of the Ningaloo Coast for generations to come. While the development of this Strategy was led by the Resilient Reef Initiative in collaboration with DBCA, potential actions are intended to be considered for implementation by range of stakeholders, including management agencies, local industry, researchers and the community.

Building on strong foundations

Resilience is a fundamental aspect of the existing management arrangements of the Ningaloo Coast. The activities of traditional owners, management agencies, community organisations and residents in managing pressures, responding to disturbances and preserving key ecological, cultural, economic, aesthetic and recreational values have underpinned the resilience of both ecosystems and communities, and will continue to do so. The objective of this Strategy is to identify complementary strategies and potential actions that build upon current plans, strategies and activities.

The scope of the Resilience Strategy...

...includes any systems, actions or pressures that **significantly impact on, or are impacted by, the health of the reef**. These include the condition of surrounding ecosystems such as mangroves, macroalgae, seagrasses and coastal habitats; user activities that may increase or decrease pressure on marine ecosystems; the sustainability of local livelihoods and economies; and the ways in which these systems and activities are managed by various agencies.

Core Principles of Resilient Systems

Aware

Thorough understanding of how ecological and social systems function and interact, and the impacts of changing future conditions.

Robust

The ability to absorb, withstand and recover from disturbances.

Integrated

Holistic management of multiple pressures on social, economic and ecological systems.

Inclusive & Cohesive

Characterised by a sense of shared ownership and stewardship, collective action, and the broad support and engagement of diverse stakeholders.

Diverse & Flexible

Maintaining multiple options or alternative solutions that may be enacted on the basis of changing conditions.

Adaptive

The capacity to change and adapt in response to changing circumstances.

Sustainable

Underpinned by governance, management and financing structures that are maintained over the long term and do not require ongoing external input.

A Resilient Ecosystem...

... is robust in the face of natural disasters or local disturbances

... supports sustainable tourism, recreation and cultural activities

... supports a diversity of life, including ecologically and economically important species

... is able to adapt to changing environmental conditions while retaining core functions

Resilience is supported by...

Resistance

- Minimising local pressures to ensure ecosystems are as healthy as possible
- Preserving key species, habitats and functional processes
- Strong legislative and regulatory protection and effective management

Recovery

- Assisting ecosystems to recover (e.g. restoration)
- Connectivity with healthy source populations
- Sustained reproduction and recruitment

Adaptation

- Maintaining a diversity of species, genes and habitats
- Promoting the development of resistant species
- Supporting the evolutionary potential of reefs

A Resilient Community...

... maintains community wellbeing in the face of disasters

...supports livelihoods in the face of economic shocks

... is able to retain its core community values while continually evolving in the face of change

... is equitable and can meet the basic needs of all

... is aware of, and plans for, current and future shocks and stresses

Resilience is supported by...

Resistance

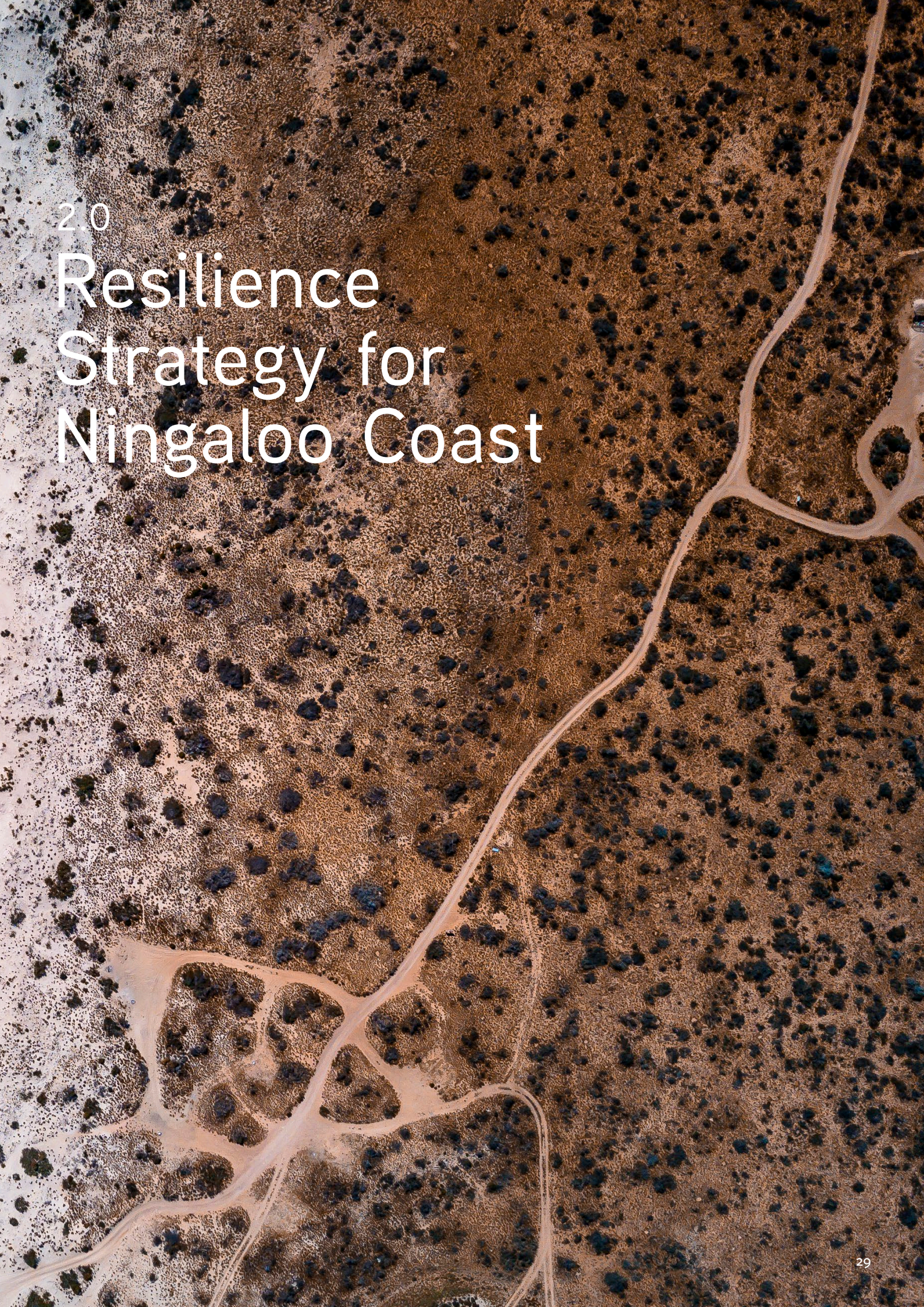
- Robust infrastructure and services
- Holistic, integrated planning
- Access to adequate resources

Recovery

- Economic and livelihood diversification
- Community cohesion, cooperation and support for management
- Effective emergency planning and management

Adaptation

- Collective learning, experimentation and innovation
- Participatory and collaborative decision-making
- Common goals and objectives
- Flexible, adaptive approaches to management



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Resilience Strategy for Ningaloo Coast

Embedding Resilience into Projects and Trials

Around the world, community groups, researchers and reef managers are developing ways to restore small areas of reefs following bleaching or cyclones. Techniques involve collecting and reattaching coral fragments, growing corals in nurseries for later out-planting, harvesting coral spawn and releasing the larvae onto degraded reefs, or creating structures that stabilise the ocean floor for corals to establish on. Parts of Ningaloo Reef (such as those that are important tourism sites) might require restoration in the future. Restoration of small areas of coral is a growing field, however its cost, feasibility and practicality as a management response requires further investigation. Trialling different restoration methods will give reef managers a good idea of the cost and feasibility of restoration and whether there are techniques suitable for Ningaloo Reef.

Trials may be designed to achieve multiple outcomes, using the resilience co-benefits developed with the community:

→ **Increase education for visitors and locals**

Trials are a great opportunity to communicate potential future impacts of bleaching on the reef and how reef managers are preparing for this.

→ **Empower the community**

There is significant interest from the community about ways that they can be involved and contribute to reef management. Restoration trials could provide an opportunity for volunteering or citizen science projects that educate and empower the community.

→ **Improve the health of reef, marine, coastal and terrestrial ecosystems**

Restoration trials inform management agencies and researchers on the cost, feasibility and practicality of various methods, sites and species in the context of Ningaloo Reef.

→ **Foster working partnerships**

High-profile and innovative trial restoration projects are an opportunity to establish working partnerships between management agencies, researchers, funding bodies, tourism operators and the community.

→ **Create new opportunities for diverse livelihoods**

Around the world, innovative models of restoration incorporate opportunities for paying visitors to get hands-on with planting corals, as part of interactive and engaging tourism products.

→ **Partner with traditional owners**

There are numerous opportunities to engage with traditional owners in identifying restoration trial sites and contributing to the design of restoration trials, as well in providing avenues for traditional owners to contribute to Sea Country conservation through constructing, monitoring and maintaining trial projects.

→ **Develop adaptive planning and management approaches**

Identifying when and where restoration is appropriate requires a detailed understanding of key ecological processes, cost-benefit analysis and risk-based assessments.Decision-support systems can assist managers to make informed and strategic choices about which techniques and species might be appropriate and when and where to deploy them. Before any potential actions are undertaken, all social, economic and ecological risks should be considered in conjunction with the benefits.

How to read
The Resilience Strategy

The Resilience Strategy for the Ningaloo Coasts includes 16 objectives and 35 strategies under the five resilience pillars. The following section will provide details about each outcome, the objectives that underpin it, and how it addresses the Resilience Framework, resilience challenges and co-benefits that have been established in consultation with technical experts, partners and the community.

1 Pillar
Five Pillars or themes have been defined which will strengthen the resilience of the Ningaloo Coast.

2 Aspiration
The desired end state that represents resilience within each Pillar.

3 Objectives
Under each pillar, objectives have been defined that describe an intended result which will support resilience.

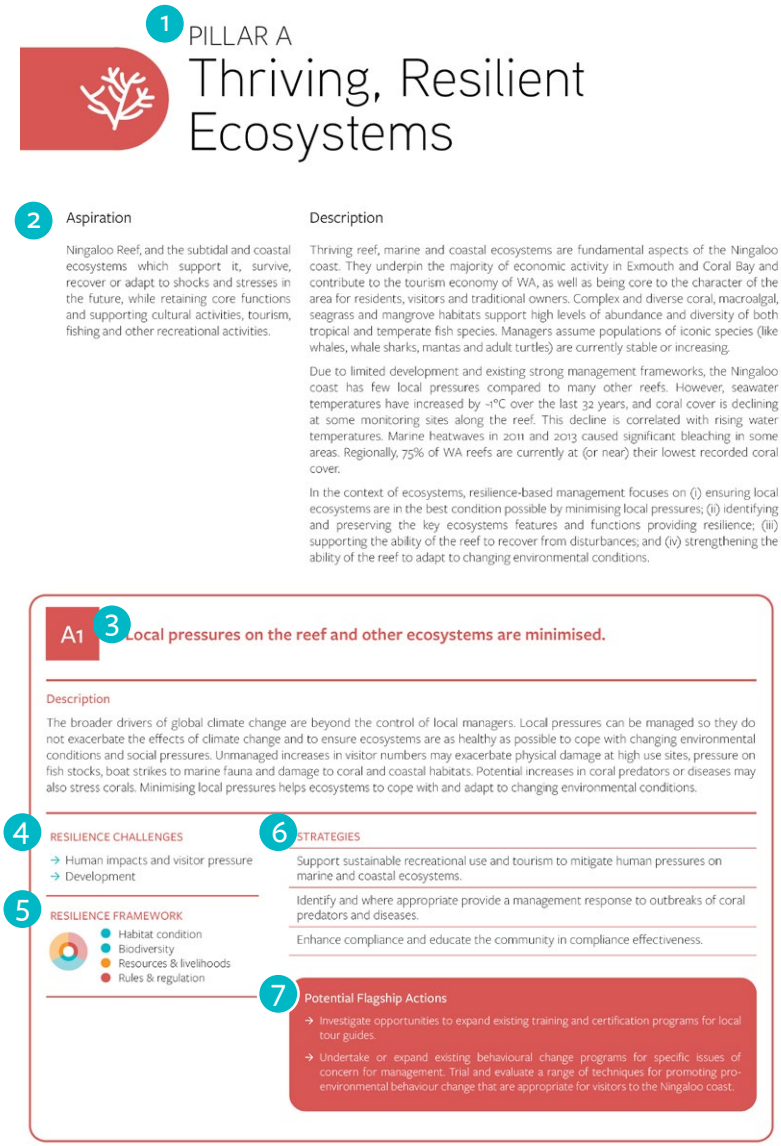
4 Resilience Challenges
The objective is intended to address any number of the following four Resilience Challenges (p. 10).

- Climate change
- Extreme events
- Human impacts and visitor pressure
- Development

5 Reef Resilience Framework
The objectives and strategies are intended to address the following attributes within RRI's Reef Resilience Framework.

6 Strategies
Strategies describe discrete goals to achieve the intended objective.

7 Potential Flagship Actions
Examples of the types of potential actions that would be considered for potential partnership and funding in meeting the objectives (See *Appendix A: Potential Resilience Actions* for a full listing.)



PILLAR A

Thriving, Resilient Ecosystems

Aspiration

Ningaloo Reef, and the subtidal and coastal ecosystems which support it, survive, recover or adapt to shocks and stresses in the future, while retaining core functions and supporting cultural activities, tourism, fishing and other recreational activities.

Description

Thriving reef, marine and coastal ecosystems are fundamental aspects of the Ningaloo Coast. They underpin the majority of economic activity in Exmouth and Coral Bay and contribute to the tourism economy of WA, as well as being core to the character of the area for residents, visitors and traditional owners. Complex and diverse coral, macroalgal, seagrass and mangrove habitats support high levels of abundance and diversity of both tropical and temperate fish species. Managers assume populations of iconic species (like whales, whale sharks, mantas and adult turtles) are currently stable or increasing.

Due to limited development and existing strong management frameworks, the Ningaloo Coast has few local pressures compared to many other reefs. However, seawater temperatures have increased by ~1°C over the last 32 years, and coral cover is declining at some monitoring sites along the reef. This decline is correlated with rising water temperatures. Marine heatwaves in 2011 and 2013 caused significant bleaching in some areas. Regionally, 75% of WA reefs are currently at (or near) their lowest recorded coral cover.

In the context of ecosystems, resilience-based management focuses on (i) ensuring local ecosystems are in the best condition possible by minimising local pressures; (ii) identifying and preserving the key ecosystems features and functions providing resilience; (iii) supporting the ability of the reef to recover from disturbances; and (iv) strengthening the ability of the reef to adapt to changing environmental conditions.

A1 Local pressures on the reef and other ecosystems are minimised.

Description

The broader drivers of global climate change are beyond the control of local managers. Local pressures can be managed so they do not exacerbate the effects of climate change and to ensure ecosystems are as healthy as possible to cope with changing environmental conditions and social pressures. Unmanaged increases in visitor numbers may exacerbate physical damage at high use sites, pressure on fish stocks, boat strikes to marine fauna and damage to coral and coastal habitats. Potential increases in coral predators or diseases may also stress corals. Minimising local pressures helps ecosystems to cope with and adapt to changing environmental conditions.

RESILIENCE CHALLENGES

- → Human impacts and visitor pressure
- → Development

RESILIENCE FRAMEWORK

- Habitat condition
- Biodiversity
- Resources & livelihoods
- Rules & regulation

STRATEGIES

Support sustainable recreational use and tourism to mitigate human pressures on marine and coastal ecosystems.

Identify and where appropriate provide a management response to outbreaks of coral predators and diseases.

Enhance compliance and educate the community in compliance effectiveness.

Potential Flagship Actions

- → Investigate opportunities to expand existing training and certification programs for local tour guides.
- → Undertake or expand existing behavioural change programs for specific issues of concern for management. Trial and evaluate a range of techniques for promoting pro-environmental behaviour change that are appropriate for visitors to the Ningaloo Coast.

A2 Key ecosystem features and functions that support resilience are preserved.

Description

Complex reef, marine and coastal ecosystems on the Ningaloo Coast are underpinned by a range of key species and important ecological processes that allow them to function. Corals, macroalgae and mangroves are foundational species , supporting the abundance and diversity of many other species within the ecosystem. Reproduction and recruitment are fundamental functional processes, supported by connectivity with other reefs that act as a source of larvae. Another functional process is the removal of algae by herbivores, which allows new corals to settle and grow. Identifying and preserving key species, habitats and functional processes in the face of current and future threats is vital for the continued survival of ecosystems.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Human impacts and visitor pressure
- → Development

RESILIENCE FRAMEWORK

- Recovery processes
- Seascape diversity
- Biodiversity
- Habitat condition
- Rules & regulation
- Knowledge & stewardship
- Networks & relationships

STRATEGIES

Identify and preserve habitats and ecosystems that are disproportionately important to resilience (i.e., areas that best support ecological, social, economic and cultural values).

Identify, monitor and preserve key resilience attributes, species and functional relationships necessary for maintaining healthy ecosystems, including identifying critical thresholds for foundational species or ecosystem functions.

Support healthy populations of iconic species (whale sharks, mantas, whales, turtles).

Maintain current fish abundance and diversity.

Potential Flagship Actions

- → Expand and update the existing reef resilience assessment to assess relative resilience of different reef sites to inform future reviews of the marine park management plan and zoning to protect sites with a high resilience value.
- → Develop an integrated and adaptive decision-support system which identifies: i) potential threshholds or triggers for key resilience attributes and functional variables; ii) interventions that may be deployed and iii) monitoring protocols for defined triggers or threshholds, which incorporate both social and ecological indicators.

A3 The ability of the reef to recover from bleaching events and other disturbances is supported.

Description

While some of the impacts of a warming climate will be gradual (such as shifts in environmental conditions that may change the character of the reef and cause some species to shift southwards over time), other disturbances may be sudden, such as more severe cyclones and marine heatwaves. These disturbances may be beyond the natural ability of ecosystems to withstand, causing coral bleaching, potential fish kills and damage to mangrove, macroalgal and seagrass habitats. The continued resilience of ecosystems following these events will rely on their capacity to recover. Reefs are inherently adaptive and have the ability to recover from extreme events, but as these disturbances become more severe and occur more frequently, reef managers will be called upon to support recovery processes to ensure that core ecosystem features and functions are retained. Ecosystems that are able to recover will be better equipped to withstand more frequent and severe disturbances in the future.

RESILIENCE CHALLENGES

- Climate change
- Extreme events
- Development

RESILIENCE FRAMEWORK

- Recovery processes
- Resources & livelihoods
- Networks & relationships
- Knowledge & stewardship

STRATEGIES

Develop collaborative partnerships to undertake research and experimental trials to identify the cost, feasibility and practicality of potential management interventions which support recovery and adaptation.

Develop a framework for responding to disturbances.

Adaptively deploy appropriate interventions based on identified thresholds (to be determined through research).

Potential Flagship Actions

- Develop appropriate frameworks for responding to shocks and stresses:
  - Undertake risk assessments for potential threats
  - Where needed, develop response procedures for coral bleaching, severe cyclone damage and coral disease outbreaks
  - Consider the development of a decision-support system to identify when interventions are necessary and appropriate, based on defined threshold levels for key functional aspects of the ecosystem.
- Investigate partnering with research institutions, management agencies and community groups, where appropriate, to trial methods for local mitigation and/or restoration of high-value sites, and assess the cost, feasibility and practicality for application.

A4 The ability of the reef to evolve and adapt to changing environmental conditions is supported.

Description

Ecosystems that can adapt can continue to function in the face of changing environmental conditions. Research can inform managers how best to support the adaptive capacity of reefs to change in ways that maintain their core functions, such as protecting habitat for fish species.

Evolutionary biology indicates diversity is essential for successful adaption. Whether it's a diversity of reef structures or locations, habitats, species, community compositions, genes, symbionts or environmental conditions, diversity means more evolutionary options for natural adaptation in the future. Preserving a diversity of coral reefs with differing species increases the likelihood of viable solutions when faced with future threats.

While corals are adaptable and resilient organisms, genetic adaptation is unlikely to be able to keep pace with the rapid changes being brought about by anthropogenic climate change. To retain core functions, it may be necessary to intervene to support and enhance natural processes of adaptation and evolution where appropriate. This could include promoting the establishment of coral species resistant to heat stress, disease, cyclone damage, acidification and predation, while retaining genetic diversity and adaptive potential.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events

RESILIENCE FRAMEWORK

- Recovery processes
- Seascape diversity
- Biodiversity
- Habitat condition

STRATEGIES

Identify and protect a diversity of species, functional groups and populations with genetic, physiological, or ecological traits that are resilient to future stressors (including heat stress, disease, cyclone damage, acidification and predation) or exhibit high levels of adaptive capacity.

Enhance the processes of adaptation by promoting the development of resistant coral species.

Potential Flagship Actions

- → Support research that identifies the coral genotypes and physiological characteristics present at Ningaloo Reef that may be resistant to stressors and identify resistant variants for potential propagation and translocation to key sites.
- → Identify and protect species and populations with genetic, physiological, or ecological traits characteristic of low sensitivity and high adaptive capacity to climate impacts, within and across habitats.

PILLAR B

An Educated and Empowered Community

Aspiration

The community is knowledgeable about the current state of ecosystem health and the potential impacts of current and future pressures on the environment, community values and local livelihoods. Stakeholders have meaningful opportunities to engage in planning and management activities.

Description

The communities of Exmouth and Coral Bay are characterised by a strong connection to local marine environments. There is a high level of support for current and increased levels of management and protection of the environment among locals and visitors.

Awareness of future threats and their impacts on the environment and community is the first step in proactive local adaptation. This awareness may prompt individuals and businesses to change their behaviours and activities, or plan for the future. The process of collective learning, involving multiple stakeholders generating knowledge by considering new information within the context of different perspectives, experiences, resources and skills, improves the robustness of decision-making, the legitimacy of outcomes and the sense of common values and shared goals that underpin support for management. Where stakeholders have the opportunity to be actively engaged in planning and management, opportunities for collective learning, the resources available for monitoring and management, and general level of support for management activities, are increased.

B1 The community is informed about the current status, trends and threats to the reef and community

Description

Access to meaningful information about the current state of the environment, future pressures, and how they will affect lived experience is important for an informed community. Informed communities are able to plan and make decisions to proactively address threats and pressures. Raising public awareness about the marine environment and management activities increases levels of confidence in management, encourages environmental stewardship, and encourages communities and businesses to adapt their behaviours or change their activities in response to risks.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Human impacts and visitor pressure
- → Development

RESILIENCE FRAMEWORK

- Knowledge & stewardship
- Networks & relationships
- Accountability & equity

STRATEGIES

Provide information to the community about the current state of scientific understanding about ecosystem health and actions that enhance resilience.

Investigate opportunities for climate change and resilience education programs for the community, as appropriate.

Potential Flagship Actions

- → Support forums for community members, local decision-makers and researchers to discuss current knowledge and implications for management.

B2 The community is involved in planning and management.

Description

Meaningful community consultation and engagement can dramatically increase the knowledge, skills and capacity available to manage natural resources. Engaging people in an active and participatory manner introduces new ideas and knowledge about the ecosystem and how it is perceived by users. This can also increase awareness of the challenges of management and generating a 'social licence to operate';

Empowered communities have higher levels of environmental stewardship and show higher levels of support for management. Communities that are engaged within management activities are more likely to be:

- aligned in their objectives and activities,
- aware of the threats and impacts within the system,
- prepared when dealing with disturbances,
- innovative when identifying solutions, and
- efficient when deploying resources.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Human impacts and visitor pressure
- → Development

RESILIENCE FRAMEWORK

- Knowledge & stewardship
- Networks & relationships

STRATEGIES

Enhance opportunities for community engagement and participation in planning, management and research activities

Potential Flagship Actions

- → Investigate the development of citizen science monitoring and/or management programs for Ningaloo Reef utilising existing modalities, enabling users to contribute to research and data collection in relation to bleaching, coral disease and predators, coral condition or changing abundance or distribution of species.
- → Identify and support local leaders in coordinating and promoting stewardship of reef, marine and coastal ecosystems. Investigate programs to empower community members to become advocates of good behaviour on the reef.

PILLAR C

Sustainable Development and Livelihoods

Aspiration

Local and regional planning and development actively support the sustainability of the ecosystems of the Ningaloo Coast and the livelihoods of residents.

Description

The local economy and livelihoods within Exmouth and Coral Bay are inextricably linked to reef health. The Reef and coastline contributes around $110 million annually to the local economy and supports over 1000 jobs, mainly in tourism. The local economy is mainly reliant on marine-based tourism, and consequently is vulnerable to external influences that are beyond local control (e.g. coral bleaching, increases in fuel prices, competition from other destinations, pandemics). Increasing visitation is likely to result in increased pressure on the environment (e.g. damage to vegetation, fishing, sewage and waste disposal, increased water demands and disturbance to wildlife). The appropriate balance between sustainable economic development and environmental protection is an active debate. Many in the community emphasise the need for diversification of the local economy and greater fulltime employment opportunities, but not at the expense of the natural environment.

Enhancing the resilience of both the environment and the local economy will require an understanding of sustainable levels of utilisation without compromising the health and condition of the ecosystem. While the Ningaloo Coast is globally-renowned for its relatively pristine coral reef and a high level of biodiversity, the condition of these ecosystems is predicted to be impacted by more severe and frequent disturbances in the future, which may in turn affect the economic prospects of the local communities. Diversifying livelihoods to take pressure off the reef and broadening the economic base of the region can achieve both environmental and economic objectives. It will also be important to support local operators to remain viable during periods when the reef is recovering and to develop new non-reef dependent tourism products.

C1 Sustainable utilisation and enjoyment of the Ningaloo Coast aligns with ecological and community values.

Description

As the population, visitation and economic activity along the Ningaloo Coast increases, there are corresponding increases in human pressures on the environment, related to disturbance of iconic wildlife, fishing pressure, damage to habitat and pollution. Balancing conservation of the natural environment with a desire to build a more diverse and sustainable local economy is a key objective of the Shire of Exmouth's Exmouth Strategic Community Plan and the State Government's Ningaloo Coast Regional Strategy Carnarvon to Exmouth.. To achieve this, there is a need to establish sustainable levels of utilisation of natural and community resources, whilst supporting development and livelihoods that align with ecological and community values.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Human impacts and visitor pressure
- → Development

RESILIENCE FRAMEWORK

- Resources & livelihoods
- Networks & relationships
- Habitat condition
- Biodiversity

STRATEGIES

Understand appropriate or 'optimal' levels for population, tourism, extractive activities, infrastructure, services and utilities to sustain and support the maintenance of ecosystem health and community values, and the economic wellbeing of local communities.

Encourage and support sustainable development and livelihoods that align with ecological and community values.

Potential Flagship Actions

- → Facilitate research that models the impacts and sustainable limits in terms of visitors to high use sites, visitors to the region, interactions with megafauna and extractive activities, in order to establish evidence-based targets or limits in relation to key resources.
- → Support the collaborative development of a long-term strategic masterplan outlining guidelines for appropriate growth and development within the Ningaloo Coast region. Support a feasibility study on various alternative sustainable livelihood options that align with ecosystem and community values and the development of diversification strategies for key climate-exposed sectors such as tourism.

C2 Sustainable livelihood diversification reduces local pressures on the reef and strengthen economic resilience.

Description

A significant proportion of local economy is based on reef or reef-related tourism. Local livelihoods in the tourism, accommodation, hospitality and retail sectors rely on these tourists; they are therefore vulnerable to fluctuations in the tourism market and to deterioration in the health of the reef. The 2016 bleaching event on the Great Barrier Reef, for example, was estimated to result in the loss of 10,000 tourism jobs and up to $1 billion in revenuexii. Livelihood diversification will provide new opportunities for sustainable employment, ensure the local economy is robust during periods when the reef is recovering and may reduce the proportion of visitors who utilise the reef, minimising visitation pressure. Diversification can be explored both within the tourism sector (increasing the proportion of non-reef-related attractions) or more broadly within other sectors of the local economy in areas that align with ecological and community values.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Human impacts and visitor pressure

RESILIENCE FRAMEWORK

- Resources & livelihoods
- Habitat condition

STRATEGIES

Support the diversification of tourism products, sub-sectors and across other sectors to reduce pressure on marine and coastal ecosystems.

Potential Flagship Actions

- → Encourage product innovation, alternative tourism models and cooperation across stakeholders in ways that broaden and diversify tourism and reduce pressure and reliance on the reef.

C3 The resilience of local businesses and communities is enhanced.

Description

Home to a world-class nature-based tourism industry, Exmouth and Coral Bay rely on exceptional tourism experiences drawing visitors from around the world. Local tourism operators are an essential component of the fabric of Ningaloo Coast tourism, as well as helping to support many other businesses within the region. Ensuring local businesses are resilient to fluctuations in market conditions and the condition of the reef is therefore vital to the overall resilience of the local economy and communities.

RESILIENCE CHALLENGES

- Climate change
- Extreme events
- Human impacts and visitor pressure

RESILIENCE FRAMEWORK

- Resources & livelihoods

STRATEGIES

Support local operators to strengthen their ability in responding to changes in business conditions as a result of changes in reef health.

Potential Flagship Actions

- Support local tourism operators and businesses though providing business resilience information and training.
- Support the development of a climate change strategy for the tourism industry, outlining the potential impacts of climate change on tourism and actions that operators can undertake to strengthen their business in the face of changing environmental conditions.

PILLAR D

Adaptive Management Systems

Aspiration

Adaptive approaches are institutionalised into planning and management activities to enable proactive management of new or evolving challenges.

Description

The Ningaloo Coast has significant regulatory and legislative protection at the local, state and federal level. Further to this, World Heritage status provides international leverage to ensure environmental protection. The area is actively managed by multiple agencies (traditional owners, DBCA, Shire of Exmouth and Carnarvon, DPIRD and Parks Australia) through joint managment and collaborative arrangements. Residents have a strong understanding of and support for the current rules and regulations associated with the Ningaloo Marine Park. In general, users are confident that the marine park is well managed. Stakeholder engagement revealed opportunities to implement proactive and adaptive management approaches, further enhance community confidence in management, and undertake collaborative strategic planning between agencies. More effective knowledge-sharing and co-design of research were also identified as opportunities.

One of the most important aspects of socio-ecological resilience is the development of governance systems (i.e. the ways that people, environments and communities along the Ningaloo Coast are organised and managed via planning, legislative, regulatory, organisational and management frameworks) that are able to adapt to new challenges and changing conditions. Adaptive management systems are characterised by:

- Flexible management approaches that are able to be altered in response to disturbances or changing environmental conditions (e.g. ability to rezone areas in response to a bleaching event, or change management strategies in relation to fish stock assessments);
- Integrated approaches incorporating a broad range of social, ecological, economic and demographic indicators to assess the impacts of many different types of threats and pressures;
- Iterative management approaches designed to be continually altered in response to changing environmental conditions and include regular cycles of research, experimentation, evaluation, alteration and renewal,
- Collaborative and inclusive decision-making empowering collective action, increases trust and legitimacy, promotes learning and innovation, and improves outcomes by considering multiple cultural and disciplinary perspectives, and
- Innovative approaches to management that: take into account evolving knowledge, learn from disturbance, encourage experimentation, and use scenarios and simulations to explore consequences of alternative policy options.

D1 Management planning and approaches are integrated and adaptive.

Description

An integrated approach to strategic planning considers pressures and impacts holistically, incorporating, for example, ecological, climatic, demographic, economic, social, technological, and cultural drivers of change. Integrated planning allows managers to consider and prepare for a broad range of potential challenges in the future, and to understand how the environmental, social and economic outcomes of potential management actions may interact. Integrated strategic planning aims to reduce the risk of unintended or undesirable outcomes, prioritises actions that are robust under a range of possible future scenarios, and can identify opportunities for efficiencies through partnering to achieve multiple objectives. Integrated strategic planning actively addresses the impacts of multiple threats (natural disasters, economic or market fluctuations, industry collapse, environmental incidents, demographic changes etc) on environment, community and governance systems to prepare managers for a wide range of eventualities. This requires collaboration and cooperation between management agencies and with multiple stakeholders, the identification of shared or common goals, and the use of scenario planning, impact modelling or similar analysis techniques to explore the outcomes of future changes and management actions.

RESILIENCE CHALLENGES

- Climate change
- Extreme events
- Human impacts and visitor pressure
- Development

RESILIENCE FRAMEWORK

- Leadership & management
- Accountability & equity
- Knowledge & stewardship

STRATEGIES

Develop adaptive planning structures and management arrangements that can be iteratively modified as new information becomes available or environmental conditions change.

Support the trialling of new approaches to support resilience as they become available.

Pursue integrated approaches to planning and management of the Ningaloo Coast.

Potential Flagship Actions

- Support the uptake of flexible and adaptive planning and management structures to allow for alterations in response to changing environmental conditions, incorporating regular evaluation, alteration and renewal of strategic plans, as feasible and appropriate.
- Support management agencies to undertake scenario planning and/or modelling of projected futures under different environmental conditions and policy settings to inform adaptive management, as required.

D2 The knowledge, values, experience and skills of multiple stakeholders are valued in adaptive management.

Description

Collaboration increases the efficiency, legitimacy and robustness of outcomes by ensuring objectives and activities are aligned with the expectations of all users. Having a diversity of skills, experiences and resources can improve a management system's capacity to detect and respond to shocks and disturbances. Involving multiple stakeholders within decision-making is therefore vital for resilience in the face of uncertainty.

Effective management is supported through applied research that informs decision-making and is appropriate to the spatial and temporal scales of management activities. Ensuring research is strategic and presented in ways that are appropriate to the intended audience are therefore key building blocks of evidence-based decision-making.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Human impacts and visitor pressure
- → Development

RESILIENCE FRAMEWORK

- Networks & relationships
- Representation & inclusion
- Accountability & equity
- Leadership & management

STRATEGIES

Strengthen multi-agency collaboration at the strategic level. Align the strategic goals and objectives of various management agencies where possible.

Continue to generate strategic research that informs management and is responsive to evolving needs.

Potential Flagship Actions

- → Develop a standard of practice for research co-design when planning and conducting research intended to inform management decisions.
- → Establish or build on existing multi-agency agreements to collaborate in strategic planning.

D3 Resilience is embedded within existing planning and management processes.

Description

Embedding and integrating resilience principles into existing planning and management processes will be required in order to realise the outcomes of integrated, adaptive and collaborative decision-making and to ensure resilience-based management is sustainable over the long term. Embedding resilience will require sustained multi-level organisational support and integration into planning and design processes, risk assessments, existing plans and policies, performance reporting and day-to-day operations.

Embedding resilience within planning and management will:

- ensure alignment of strategic direction and objectives,
- result in more efficient and effective prioritisation of funding and management activities, and
- ensure that outcomes are sustainable over the long term.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Human impacts and visitor pressure
- → Development

RESILIENCE FRAMEWORK

- Leadership & management
- Accountability & equity

STRATEGIES

Foster the ongoing consideration of resilience as part of general operations and day-to-day decision-making.

Ensure that climate change is considered in management planning.

Potential Flagship Actions

- → Support the community, local businesses and management agencies to undertake a climate vulnerability assessment for the region.
- → Incorporate resilience characteristics (i.e. ecological triggers and thresholds, social and cultural values) within KPIs, metrics and assessment criteria for new management plans. Where appropriate, incorporate these into existing plans.
- → Investigate and assess the impacts of climate change on operations, management activities and infrastructure in the future.
- → Investigate where climate change-specific actions are required within existing management plans, and integrate climate change assessment into future management planning.

D4 Funding for resilience-based management is increased.

Description

Strengthening the resilience of ecosystems and communities to respond to change is a long-term initiative that will require sustainable funding on an ongoing basis. While some resilience activities are project-based, many core enablers (such as long-term monitoring) require ongoing funding commitments. The actions within this Strategy represent a wide range of collaborative funding opportunities, and new and innovative sources of financing and partnerships will be required to effectively enhance resilience.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Human impacts and visitor pressure
- → Development

RESILIENCE FRAMEWORK

- Leadership & management

STRATEGIES

Collaborate to increase the funding available for resilience-based management, exploring innovative financing arrangements and developing sustainable funding partnerships where possible.

Potential Flagship Actions

- → Develop ongoing public-private partnerships and innovative financing arrangements to support coral reef management and resilience actions.
- → Explore options for visitors and users to contribute to the funding of potential resilience actions. Work with partners to identify tailored funding opportunities for specific resilience activities, such as voluntary contribution schemes that allow donators to experience and be involved in on-site activities.

PILLAR E

Leadership in Sustainability and Resilience

Aspiration

Ningaloo Coast management agencies and communities are recognised as leaders in sustainable resource use, climate change adaptation and resilience-based management.

Description

Adaptation to climate change and other stressors is a necessity, given the current rate of global warming and increasing population pressures. However, adapting to changing environmental conditions alone may not be enough to sustain coral reefs, and the species that rely on them, around the world. Despite the best efforts to build resilience, under severe climate change, it is predicted reefs will decline and transition to a different ecosystem state. Therefore, it is important managers combine strategies to adapt with strategies to encourage sustained and meaningful reductions in emissions, along with reductions in other stressors on coral reefs, in order to limit the impacts of climate change. Community engagement revealed a clear desire to not only manage energy, waste and water usage more effectively, but to demonstrate leadership in sustainability and resilience. While the contribution of the Ningaloo Coast to global issues like greenhouse gas emissions and pollution is small, it's impact is potentially significant. As an iconic, globally-recognised ecosystem hosting over 200,000 visitors each year, the communities and management agencies of the Ningaloo Coast have the opportunity to be leaders in promoting the minimisation of environmental 'footprint' and to assist other communities and ecosystems adapting to change.

E1 Ecosystems that store carbon and support marine life are protected.

Description

Mangroves, macroalgae and seagrass are vitally important to coastal and marine ecosystems, providing foundational habitat and acting as nurseries for many important species, sustaining complex food webs and providing other ecosystem services. They also store carbon, acting as a 'sink' for carbon dioxide (CO_2) emissions that sequester more than forty times as much carbon as forests. However, these 'blue carbon' ecosystems can also release these stores of carbon when damaged, and the 2010-11 marine heatwave in WA was estimated to have released millions of tonnes of CO_2 back into the atmosphere through seagrass dieback.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Development

RESILIENCE FRAMEWORK

- Habitat condition
- Biodiversity

STRATEGIES

Monitor, assess and protect seagrass, macroalgal and mangrove habitats.

Potential Flagship Actions

- → Explore blue carbon opportunities for generating carbon credits from activities that establish, protect or restore mangrove, macroalgae or seagrass habitat.

E2 The carbon footprint is minimised.

Description

The continued existence of reefs and many marine species come will rely on rapid reductions in emissions at a global level. While the Ningaloo Coast's direct contribution may be minimal, it can demonstrate leadership by minimising community 'footprint' and becoming an example for other regional areas in Australia and the world to follow in reducing emissions and pollution.

RESILIENCE CHALLENGES

→ Climate change

RESILIENCE FRAMEWORK

- Resources & livelihoods
- Networks & relationships
- Leadership & management
- Accountability & equity

STRATEGIES

Encourage the uptake of renewable energy, improved waste management and emissions reduction within the region.

Support influential institutions to lead a transition to a low carbon economy.

Potential Flagship Actions

→ Encourage the uptake of renewable energy and emission reduction activities among residents and visitors, through showcasing practical initiatives, supporting aligned projects and creating local employment related to these outcomes, where appropriate. Encourage local operators to reduce their emissions and energy usage.

→ Encourage management agencies and other high-profile institutions within the region to adopt targets for a transition to a low carbon economy (i.e. commitment to renewable energy and/or carbon zero).

E3 Ningaloo Coast management agencies and communities are leaders in sustainability and resilience.

Description

Coral reefs and the communities that rely upon them will be some of the first to be affected by climate change. In order to preserve Ningaloo Reef and all reefs around the world, rapid and sustained emissions reductions are required at a global scale. Global emissions are beyond the control of reef managers and local communities. However, these iconic ecosystems are effective vehicles to raise awareness and catalyse broader change. The Great Barrier Reef has focused heavily on educating a global audience on the threat of climate change and what stands to be lost if rapid emission reductions do not not occur. The Ningaloo Coast has a similar role to play in making a case for global action.

The community has expressed a strong desire to demonstrate leadership in sustainability and resilience. While actions at a local scale have minimal impact on global emissions and pollution, through educating and empowering visitors to be ambassadors for marine conservation once they return home, this small area can have a significant impact. Exmouth can become a hub for innovation, education, community action and research, sharing lessons learnt with other reef communities and regional areas who are looking to minimise their footprint, adapt to climate change and increase their resilience.

RESILIENCE CHALLENGES

- → Climate change
- → Extreme events
- → Human impacts and visitor pressure
- → Development

RESILIENCE FRAMEWORK

- Leadership & management
- Representation & inclusion
- Knowledge & stewardship

STRATEGIES

Communicate the importance of mitigation and adaptation to the preservation of Ningaloo Reef.
Seek avenues to foster resilience and climate change innovation for education, research, management, community collaboration and knowledge sharing with other regions.
Educate and empower visitors to be ambassadors for marine conservation
Promote good practice and progress in minimising environmental footprint to encourage a shift in social norms.

Potential Flagship Actions

- → Support the development of a reef resilience centre of excellence based in Exmouth to develop and trial techniques, share learnings and support outreach, in ways that catalyses ongoing support and investment in reef resilience.
- → Seek opportunities to promote the achievements of the region and models for good practice in other towns, regions and jurisdictions.

3.0 Implementing the Strategy

3.1 Approach to Implementation

This Resilience Strategy identifies potential actions that may support resilience. Aspects of this Strategy are already funded through existing management programs, however many of the potential actions identified are not currently funded and implementation would require new financing and partnerships. Potential actions may be funded and implemented by a range of agencies and stakeholders within the region. The objectives and potential actions within the Strategy are therefore intended to provide a strategic framework for funding and implementation, enabling various funders, management agencies, partners and stakeholders to understand how individual actions and activities contribute to strengthening the resilience of the Ningaloo Coast.

3.1.1 Action planning cycle

A long-range approach to planning for resilience is necessary – it takes time and committed effort to build working partnerships, foster social cohesion and trust, develop understanding about complex ecosystem processes and trial and refine interventions. However, changing environmental conditions and the uncertainty of climate change also means that managers need to be able to adjust management approaches as conditions change and knowledge develops. Therefore, the potential actions and activities required to achieve the objectives in this Strategy are intended to be implemented over short, medium and long-term timeframes and reviewed, evaluated and refined as necessary. The potential resilience actions identified throughout the development of this Strategy are included as Appendix A.

3.1.2 Research prioritisation

Adaptive management relies on an understanding of system dynamics, changing environmental conditions, pressures and effectiveness of management actions. Managers rely on strategic and responsive scientific research and monitoring to inform decision-making. It is recognised that a key enabler of strategic and responsive research to inform management of the Ningaloo Coast is a clearly-defined list of research priorities, developed in collaboration between reef managers and the research community.

In developing this Strategy, research questions that inform resilience-based management were prioritised in consultation with managers and over 40 prominent researchers with extensive knowledge and experience of the Ningaloo Coast. The results of this prioritisation are included as Appendix B. It is intended that this research prioritisation is reviewed as necessary, and that it provides clear guidance to the research community about the current priorities for resilience-based management.

3.1.3 Monitoring and evaluation

A central aspect of resilience-based management is monitoring and evaluation. This helps decision-makers understand trends, impacts and the effectiveness of management. This ongoing process enables managers to trial different approaches, track progress against changing environmental conditions, evaluate what worked and what didn't, and adjust management approaches iteratively.

Resilience is an extremely complex and multi-faceted process to capture within simple metrics. It is very difficult, for example, to determine objectively whether there has been an improvement in the ability of an ecosystem or community to adapt to changing conditions. In order to adequately provide feedback which is useful in the context of management, this Strategy will utilise a mix of quantitative progress indicators and qualitative actions as necessary.

3.1.4 Potential progress indicators

As potential actions are implemented, progress indicators may be defined that illustrate the value and impact of resilience-based management in the context of achieving overarching resilience goals. These indicators should be measurable, relevant and easily-trackable and assist in quickly and simply communicating the general state of resilience within that Pillar. They may address some specified (but certainly not all) objectives within the Pillar. In some cases, these progress indicators may define a target or desired end state, or otherwise may enable reporting against a baseline. Funding and supporting guidance will be required to outline the processes for collecting, analysing, selecting and reporting progress indicators identified in this Strategy.

3.2 Partnerships to Implement the Strategy

Partnership is already a key aspect of the management of the Ningaloo Coast. DBCA is in joint management with traditional owners, as well as collaborating with a range of other management agencies including the Shire of Exmouth, Department of Primary Industries and Regional Development (DPIRD), Department of Transport, Conservation and Parks Commission, and Parks Australia. There are long-standing relationships with a wide range of scientists and research institutions, including locally-based, state-of-the-art marine research facilities in Exmouth. This research has significant potential to directly inform and support resilience-based management. In addition, several key management programs are supported by private-public partnerships, including the Ningaloo Turtle Program, Western Shield and Resilient Reefs.

The Strategy was developed collaboratively and is intended to be delivered collaboratively. Its success will rely on participation and partnership in the funding, design and delivery of potential actions. This is an exciting area of growth for the future and has the potential to bring new resources and expertise to the Ningaloo Coast.

There is already significant interest from potential funding partners in opportunities to have enduring positive impacts on an iconic, globally-recognised and much-loved Australian reef ecosystem. Where resilience objectives overlap and align with existing priorities, there are also opportunities for efficiencies at a local level in the coordination of activities, sharing of resources and potential to access new sources of finance. More broadly, partnerships can increase the social licence for effective management and conservation through demonstrating integrated and holistic approaches to planning and management.

Seeking aligned objectives

The integrated and holistic resilience objectives identified in this Strategy are broader in scope than any one agency can deliver alone. While this brings challenges, it also creates opportunities where objectives overlap with the existing priorities of other management agencies, research institutions or funding bodies. In these circumstances, multiple sources of financing (public, private, philanthropic) will be sought where the objectives of multiple parties are met. This may relate to the contribution of in-kind support instead of a financial commitment, such as personnel, vehicles/boats, monitoring/maintenance activities, materials or the use of infrastructure and facilities.

Leveraging co-financing

As part of the Resilient Reefs Initiative, the Ningaloo Coast is able to access up to $1 million in seed funding to implement potential resilience actions outlined within the Strategy. While this is a substantial sum, the financing required to navigate towards resilience over the next 20 years is far greater. Therefore, where possible and appropriate, the initial seed funding will be used leverage co-funding, catalysing the commitment of other partners and increasing the impact of seed funding far beyond the initial $1 million figure.

Even where an action or activity could be completed by one agency in isolation, outcomes will be improved and resilience strengthened where activities are designed to enhance collaboration, cooperation and partnership.

Potential partners

- Traditional owners
- Community groups and NGOs
- Local management agencies
- International reef research or management agencies
- State or Federal Government agencies
- Research institutions
- Private enterprise
- Philanthropic organisations
- Coral reef research programs

Potential sources of funding

- Existing grant programs
- Co-contribution from implementing partners
- Corporate sponsorship
- Private/public partnerships
- Crowd-funding
- Public donation programs
- User contribution
- State or Federal financing programs (e.g. Our Marine Parks Grants, National Environmental Science Program)
- Research grant programs (e.g. National Environmental Science Program (NESP), Australia Research Council (ARC) Grants)
- Carbon offsets / Reef Credits
- Green financing (e.g. green bonds)

Glossary

TERM	DEFINITION
Acidification	Acidification refers to a reduction in the pH of seawater over an extended period of time, caused primarily by uptake of carbon dioxide from the atmosphere. This increase causes the seawater to become more acidic and causes carbonate ions to be relatively less abundant, making it more difficult for calcifying organisms (such as clams, sea urchins, shellfish, crustaceans, corals, and plankton) to build and maintain their shells and calcium carbonate skeletons.
AECOM	Global consulting firm providing support for strategy development and implementation
Adaptive management	Management and planning approaches are able to rapidly and proactively adapt to new challenges and changing conditions. Adaptive management systems are characterised by: flexible management approaches that are able to be altered in response to disturbances or changing environmental conditions; integrated approaches incorporating a broad range of social, ecological, economic and demographic indicators to assess the impacts of many different types of threats and pressures; iterative management approaches designed to be continually altered in response to changing environmental conditions and include regular cycles of research, experimentation, evaluation, alteration and renewal; collaborative and inclusive decision-making, and; innovative approaches to management that take into account evolving knowledge, learn from disturbance, encourage experimentation, and use scenarios and simulations to explore consequences of alternative policy options.
Adaptive (Resilience Principle)	The capacity to change, evolve and adapt in response to changing circumstances.
Bleaching (coral)	Corals are a symbiotic relationship between small animals call 'polyps', which build the skeletal-like hard structure of the coral, and a marine algae called zooxanthellae, which live inside the tissues of the polyps, providing them with nutrients and their vivid colours. When corals are stressed, such as during marine heatwaves, they react by expelling this algae, leaving just the bright white skeleton behind. This is known as 'coral bleaching'. If conditions return to normal within a short period of time, corals can regain their algae, return to their bright colours and survive. However, if warm waters persist, bleached corals will eventually die.
Chief Resilience Officer (CRO)	The CRO is a position funded through the Resilient Reefs Initiative which leads resilience-based management, working across the Ningaloo Coast locally as well as an ambassador globally. The CRO leads the partnership with the Resilient Reefs Initiative.
Community	Includes individuals, traditional owners, community groups, local businesses, industry, government agencies and non-governmental organisations (NGOs).
DBCA	Department of Biodiversity, Conservation and Attractions
DPIRD	Department of Primary Industries and Regional Development - WA Government; which is primarily responsible for fishing and fisheries management in the region.
Ecosystem services	The benefits that individuals and communities gain from ecosystems. An example of an ecosystem service provided by reefs is coastal protection - reef systems protect shorelines and infrastructure from damage during storm surges by buffering the impact of waves.

Governance	The planning, legislative, regulatory, organisational and management frameworks which govern reef ecosystems and communities, and the interactions between them. Governance includes policies, practices, responsibilities, rules and regulations. These are usually established and implemented by organisations, such as marine park management authorities, traditional Owner groups, government organisations, community groups, peak industry bodies, businesses etc.
Integrated (Resilience Principle)	Holistic management of multiple threats and pressures on social, economic and environmental systems.
Reef ecosystem	Includes corals and the reef structures that they create, as well as the immense diversity of species that they support. Reef ecosystems also include associated species and habitats, such as seagrasses, mangroves, islands and adjacent coastal systems.
Reef Resilience Framework	A Framework developed by global tehnical experts with the Resilient Reefs Initiative to assist reef communities and managers to better understand the current state of resilience of their reef and communities, identify strengths and weaknesses, prioritise actions, and evaluate success with regards to addressing resilience challenges.
Resilience	The capacity of reef ecosystems – as well as the individuals, businesses and communities that rely upon them – to survive, adapt and recover from stresses and shocks.
Resilience co-benefits	A suite of important outcomes that contribute to resilience, identified by the community as part of stakeholder engagement. These aspirations can be used to design actions to achieve multiple outcomes.
Resilient Reefs Initiative	A capacity building program supporting leaders in world heritage sites around the world to advance integrated resilience planning for an uncertain future.
Shocks	Sudden, short-term events that disrupt or damage reef ecosystems and communities. Examples of shocks include cyclones, coral bleaching, or oil spills.
Stresses	Influences that gradually but persistently weaken reef systems and communities. Stresses can reduce the ability of exological and community systems to function normally, and recover after shocks. Stresses may also increase the vulnerability of either system to shocks. Examples of stresses include overfishing, economic decline, and chronic food or water shortages.
Sustainable (Resilience Principle)	Underpinned by governance, management and financing structures which are maintained over the long term and do not require ongoing external input.
Trial	An experiment to test the applicability or usefulness of a particular management intervention or approach.
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WA	Western Australia

End Notes

[i]DBCA, 2020. Economic contribution of Ningaloo: one of Australia's best kept secrets. Report produced by Deloitte Access Economics, July 2020.

[ii]According to the Reefs at Risk Revisited global report, one of the most detailed assessment of threats to coral reefs ever undertaken, 75 percent of the world's coral reefs are currently threatened by local and global pressures. In Western Australia, 75% of our reefs are already at or near their lowest levels of coral cover.

[iii] Coral are extremely adaptable and resilient organisms, and reefs in the past have successfully weathered significant changes in sea level and water temperatures. However, in the past, these changes occurred over hundreds, or even thousands, of years, giving these slow-growing corals time to evolve and to physically move as the sea level fluctuated. The pace of anthropogenic climate change is highly accelerated – changes that took thousands of years are now predicted to occur within decades, leaving scientists concerned that corals won't have sufficient time to evolve and relocate.

[iv]Anthony KRN, Helmstedt KJ, Bay LK, Fidelman P, Hussey KE, Lundgren P, Mead D, McLeod IM, Mumby PJ, Newlands M, Schaffelke B, Wilson KA, Hardisty PE. Interventions to help coral reefs under global change-A complex decision challenge. PLoS One. 2020 Aug 26;15(8):e0236399. doi: 10.1371/journal.pone.0236399. PMID: 32845878; PMCID: PMC7449401.

CORE PRINCIPLES OF RESILIENT SYSTEMS

Aware: Proactive resilience-based management must be based on a thorough understanding of the key processes, functions and attributes which support the functioning of ecological and social systems, how they work together and interact, how these will be impacted by pressures and threats, and when interventions are necessary (based on identified feedback loops, thresholds or triggers). This can be developed through encouraging leading research which informs management; developing the capacity to anticipate future conditions through early-warning systems or resilience-based monitoring; and the use of tools such as scenario/contingency planning, forecasting or socio-ecological modelling of impacts or outcomes of potential actions, or obtaining other specific information that is required to inform management decision-making.
Robust: Robustness (incorporating both resistance and recovery), is the ability to absorb and withstand disturbances. Resilient systems must be both strong in terms of resisting the impacts of shocks and stresses, as well as being able to recover when impacts occur. For a given disturbance, a robust system is likely to experience less damage, be able to repair itself and restore critical functioning, and experience less of a decline in wellbeing. One aspect of robustness is 'redundancy' which refers to having excess capacity and back-up systems which ensure that if a key element of the system is removed, its function is still carried out. For example, this may involve grid electricity being backed up by local co-generation or home solar, or functional redundancy within an ecosystem, where multiple species of herbivores are present to keep corals clean even if one species of parrotfish decline.
Integrated: When planning for the future and identifying appropriate interventions, potential resilient actions must be responsive to a range of potential threats (social, economic and environmental) and robust under multiple future scenarios. Integrated approaches to planning and management take advantage of the opportunities to address multiple issues when solving challenges. An aspect of an integrated approach is coordination - all investments are should be mutually supportive of a common outcome.
Inclusive and Cohesive: Cohesive systems are characterised by a sense of shared ownership and stewardship, collective action, social learning, holistic strategic planning, and the broad support and engagement of diverse stakeholders. Actions which strengthen the ability of people and institutions to find different ways to achieve their goals or meet their needs during a shock or when under stress will increase their resilience.
Diverse and Flexible: Flexible systems maintain a suite of options that may be enacted on the basis of changing conditions. As and when conditions change, high levels of diversity increase the chance that certain species or approaches will be suitable and thrive under the new regime. Actions which foster a diversity of solutions include those which preserve or enhance biodiversity (species, genes, functional groups), spatial heterogeneity (different habitat types in different locations) or management approaches, or diversify of livelihood opportunities. Enacting permanent solutions that rely on current conditions persisting over the long term (e.g. extensive investment in long-lived infrastructure or management approaches which requires extensive up-front capital investment) leads to lock-in and sunk costs, reducing flexibility.
Adaptive – Flexible and adaptive ecosystems and communities can adapt in response to changing circumstances. Adaptive systems are characterised by systematic learning, monitoring, innovation and experimentation. Adaptive programs, plans and policies incorporate regular evaluation, alteration and renewal, allowing for iterative modification of management strategies on the basis of new information or changing conditions. Decision-support systems, which incorporate and interpret diverse information in ways which guide decision-making, can also be useful in informing adaptive management.
Sustainable: To be sustainable over the long term, resilient systems create governance structures that can be replicated and iterated, and are underpinned by sustainable financing models. Sustainable systems also minimise the need for external inputs for key functions, being linked to a network of materials, resources and knowledge without relying on them to meet basic needs.

[vi]For more information, visit **www.barrierreef.org/resilient-reefs**.

[vii]The following climate projections have been sourced from the Climate Change in Australia Cluster Report for the Rangelands (North) Region (with a confidence interval indicating the 10th and 90th percentile given in brackets), though the Ningaloo Region also extends into the Rangelands (South) Region. Two-time periods have been chosen for this review – 2030, representing near-future scenarios, and 2090, representing far-future scenarios. The RCPs reported here are for a high emissions (RCP8.5) which is the current trajectory for global emissions. Historical averages are sourced from BOM Climate Statistics for Australian Locations for the Learmonth Airport (accessed 06/09/2018). Sea level rise data for Exmouth was sourced from the National Climate Change Adaptation Research Facility Coast-Adapt website (Accessed 07/08/2018).

VARIABLE	HISTORICAL (1981-2010)[viii]	2030	2090
Annual Maximum Daily Temperature (°C)	31.9°C	1.2 (0.8 to 1.6)	4.5 (3.1 to 5.8)
Annual Minimum Daily Temperature (°C)	17.7°C	1.1 (0.8 to 1.5)	4.3 (3.3 to 5.6)
Annual Rainfall (mm)	232.4mm	1 (-11 to +8)	-4 (-31 to +19)
Annual Solar radiation (%)	22.8MJ/m2	0.1 (-1.4 to 0.9)	-0.8 (-3.3 to 1.2)
Annual mean wind speed (%)	20.0km/h	-0.1 (-1.3 to 0.8)	0.2 (-4.8 to 2.4)
Average Annual Relative humidity, 3pm (%, absolute)	34%	-0.7 (-1.9 to +0.9)	-1.9 (-7.3 to +1.1)
Annual Evapotranspiration (%)	-	3 (1.4 to 4.2)	11.7 (6.7 to 17.7)
Soil moisture (%)	-	-0.3 (-1.3 to 1.2)	-1 (-5.2 to 2.6)
Sea Level Rise (m)	-	0.13 (0.08 to 0.17)	0.61 (0.40 to 0.85)
Ocean pH	-	-0.07 (-0.08 to -0.07)	-0.30 (-0.31 to -0.29)
Sea Surface Temperature (°C)	-	0.8 (0.6 to 1.0)	2.9 (2.4 to 3.7)

[viii]Heron et al. 2017. Impacts of Climate Change on World Heritage Coral Reefs : A First Global Scientific Assessment. Paris, UNESCO World Heritage Centre.

[ix]Western Australia. Marine Parks and Reserves Selection Working Group. & Western Australia. Department of Conservation and Land Management. (1994). A representative marine reserve system for Western Australia : report of the Marine Parks and Reserves Selection Working Group. Como, W.A : Dept. of Conservation and Land Management

[x]A suite of existing policy and planning documents were reviewed as part of this background analysis, including, but not limited to:

- Management Plan for the Ningaloo Marine Park (State Waters) and Muiron Islands Marine Management Area 2005 – 2015 (DBCA)
- Nyinggulu (Ningaloo) Coastal Reserves: Red Bluff to Winderabandi draft joint management plan 2019 (DBCA)
- Cape Range National Park Management Plan Management Plan No 65 2010) (DBCA)
- Jurabi and Bundegi Coastal Parks and Muiron Islands Management Plan, 1999-2009 (Shire of Exmouth, DBCA)
- Exmouth 2030 Strategic Community Plan (Shire of Exmouth)
- Ningaloo Coast Strategic Management Framework (World Heritage listing) (Department of Environment)
- North-west Marine Parks Network Management Plan (Parks Australia, 2018)
- Ningaloo Coast Regional Strategy Carnarvon to Exmouth (WAPC, 2004) and Future Directions for the Ningaloo Coast Regional Strategy Carnarvon to Exmouth (DPLH and WAPC, 2019)
- Selected Commonwealth and State Legislation and Regulations

[xi]The findings of Cvitanovic et al. (2018) further indicate that community members want decision-makers to communicate the results of scientific research more effectively with them.

[xii]Swann, T. & Campbell, R. (2016). Great Barrier Bleached - Coral bleaching, the Great Barrier Reef and potential impacts on tourism. Discussion Paper, The Australia Institute. https://australiainstitute.org.au/wp-content/uploads/2020/12/Swann-Campbell-2016-Great-Barrier-Bleached-FINAL-w-cover.pdf

[xiii]Matz, M. V., Treml, E. A., Aglyamova, G. V., & Bay, L. K. (2018). Potential and limits for rapid genetic adaptation to warming in a Great Barrier Reef coral. PLoS genetics, 14(4), e1007220. https://doi.org/10.1371/journal.pgen.1007220

Appendices

Appendix A
Potential Resilience Actions

The potential actions required to achieve the objectives and strategies outlined in this Resilience Strategy are intended to be reviewed, evaluated and refined as needed in response to new information and changing priorities, allowing management to change course as necessary. This provides a flexible approach to achieving the Resilience Strategy objectives.

Potential actions include a range of ongoing, short, medium and long-term activities. Where appropriate, potential actions are listed in the order that they may be implemented under each objective.

Potential actions were prioritised by managers and the Chief Resilience Officer based on whether they: are *high impact* in developing resilience; *create or strengthen partnerships*; are a *foundational action* which catalyse many other actions; are *iconic* and *innovative*; are *quick and easy to implement*; can *attract external funding*, and; *build internal capacity* for resilience. Each potential action was scored according to whether or not it met each of the given criteria. Criteria were weighted using pair-wise comparison. The combined prioritisation has been included as a ranking of high, medium or low 'Resilience Priority'.

Objective	Strategy	Potential Resilience Actions	Resilience Priority
PILLAR A - Thriving, resilient ecosystems			
A1 Local pressures on the reef and other ecosystems are minimised.	A1.1 Support sustainable recreational use and tourism in order to mitigate human pressures on marine and coastal ecosystems.	Investigate the need for an interactive app to provide visitor information and enable citizen science, behaviour change and data collection to inform management.	High
		Investigate opportunities to expand existing training and certification programs for local tour guides. that includes information on: the latest science and management information about the reef and connected ecosystems, World Heritage values, traditional knowledge and priorities, and climate change and other pressures.	High
		Work with tourism operators to identify and develop tourism products which incorporate monitoring, research and intervention activities, reef education and/or conservation outcomes.	Medium
		Undertake or expand existing behavioural change programs for specific issues of concern for management. Trial and evaluate a range of techniques for promoting pro-environmental behaviour change appropriate for visitors to the Ningaloo Coast.	Medium
		Undertake review of the effectiveness of current education and interpretation, and design innovative education/communication materials and methods (e.g. in-water snorkel trails).	Medium
		Investigate options for managing visitor access and capacity through visitor management plans.	Low
		Educate users about appropriate anchoring practice to protect corals from anchor damage.	Low
	A1.2 Identify and where appropriate provide a management response to outbreaks of coral predators and diseases.	Undertake research to understand dispersal patterns of predators and diseases and develop a decision-support protocol for interventions, as necessary.	Low
		Investigate the development of a monitoring program for coral predators and diseases (may include citizen science and/or scientific monitoring programs).	Low
	A1.3 Enhance compliance and educate the community in compliance effectiveness.	Communicate compliance activities and results to the community. Review formal channels for members of the community to report non-compliance.	Low
		Investigate interventions to promote social norms of voluntary compliance and promote voluntary stewardship to protect reef recovery species.	Low
		Explore options for sea ranger programs to provide meaningful opportunities for traditional owners to be involved in caring for Country and to enhance organisational capacity for management activities and compliance.	Medium
A2 Key ecosystem features and functions that support resilience are preserved.	A2.1 Identify and preserve habitats and ecosystems that are disproportionately important to resilience (i.e., areas that best support ecological, social, economic and cultural values).	Expand and update the existing reef resilience assessment to assess relative resilience of different reef sites to inform future reviews of the marine park management plan and zoning to protect sites with a high resilience value.	High
		Identify and support the protection of ecologically significant areas such as nursery and spawning areas, significant feeding areas, critical habitat for threatened and endangered species, and areas of high species diversity.	High
		Investigate opportunities and challenges for dune, mangrove and/or seagrass restoration and implement in collaboration with the community, traditional owners and local stakeholders, as and when appropriate. Support actions which preserve connectivity between reefs, and with adjacent ecosystems (seagrasses and mangroves).	Medium
		Support high-resolution coral larval dispersal simulation and research to understand seasonal variability and environmental drivers of connectivity under the impacts of a changing climate.	Medium
		Consider commissioning a study to map ecological, social and cultural values along the Ningaloo and Exmouth Gulf coastlines to inform management decisions.	Medium

Objective	Strategy	Potential Resilience Actions	Resilience Priority
	A2.2 Identify, monitor and preserve key resilience attributes, species and functional relationships necessary for maintaining healthy ecosystems, including identifying critical thresholds for foundational species or ecosystem functions.	Support research to identify the important functional relationships and key resilience attributes which support reef health and recovery at Ningaloo Reef. Identify sustainable limits, thresholds and trigger points for foundational species or ecosystem functions.	High
		Collaborate with partners to identify, monitor and preserve important functional species and groups (herbivores, foundational species, apex predators etc) which are necessary for maintaining the health of reefs and other ecosystems.	High
		Develop an integrated and adaptive decision-support system which identifies: i) potential threshholds or triggers for key resilience attributes and functional variables; ii) interventions that may be deployed and iii) monitoring protocols for defined triggers or threshholds, which incorporate both social and ecological indicators.	High
		Support research to understand the impacts of climate change on reproduction and recruitment patterns of corals at Ningaloo Reef. Support the resistance and resilience of source populations of corals that can provide recruitment and support recovery in other areas.	Medium
	A2.3 Support healthy populations of iconic species (whale sharks, manta rays, whales, orca, turtles and dolphins).	Promote research to evaluate climate change impacts on iconic species, including impacts on the migration and aggregation patterns of whale shark, whale and manta ray populations, and risks to turtle populations.	Medium
		Continue the development and implementation of codes of conduct for interaction with marine megafauna and coral viewing.	Low
	A2.4 Maintain current fish abundance and diversity..	Support further research on: • key spawning and aggregation sites and seasons for target or important fish species. Provide additional protections where appropriate. • the current status and trends in fish diversity and abundance, including fishing pressure, to support the development of management targets for recreationally targeted species. • species which contribute significantly to ecosystem resilience that require protection from fishing.	High
		Collaborate with partners to undertake monitoring of fish diversity and abundance and annual recruitment of key targeted species at Ningaloo Reef on an ongoing basis. Investigate models for flexible, adaptive management of fishing pressure on the basis of this monitoring.	High
		Promote or establish social norms which encourage minimising take (including behavioural change programs, promoting wilderness fishing practices, working with influential members of the fishing community and local recreational fishers). If required, undertake research and modelling to determine the most efficient and socially acceptable way to reduce take while sustaining recreational fishing opportunities.	Medium
		Investigate the effectiveness of temporal restrictions such as seasonal closures and temporary zoning to protect spawning aggregations and manage fishing effort to support faster recovery during times of stress or depletion.	Medium
A3 The ability of the reef to recover from bleaching events and other disturbances is supported.	A3.1 Develop collaborative partnerships to undertake research and experimental trials to identify the cost, feasibility and practicality of potential management interventions which support recovery and adaptation.	Investigate partnering with research institutions, management agencies and community groups, where appropriate, to trial methods for local mitigation and/or restoration of high-value sites, and assess the cost, feasibility and practicality for application.	Medium

Objective	Strategy	Potential Resilience Actions	Resilience Priority
	A3.2 Develop a framework for responding to disturbances.	Develop appropriate frameworks for responding to shocks and stresses: • Undertake risk assessments for potential threats • Where needed, develop response procedures for coral bleaching, severe cyclone damage and coral disease outbreaks • Consider the development of a decision-support system to identify when interventions are necessary and appropriate, based on defined threshold levels for key functional aspects of the ecosystem.	High
		Undertake a spatial assessment of coral loss and investigate priority areas for potential trials of methods and techniques for mitiation and/ or restoration, includng identification of high value sites (in terms of tourism, education or resilience value).	Medium
		Facilitate knowledge exchange with other reef sites to share lessons learned about current best practice, innovative management interventions, leading research approaches and how traditional owners and traditional knowledge have contributed to management.	Medium
	A3.3 Adaptively deploy appropriate interventions based on identified thresholds (to be determined through research).	Following the investigation of feasibility of methods and techniques, develop a Reef Restoration Assessment, including risk assessment, potential licencing conditions, a decision-support system for when and where restoration may be appropriate and an outcomes-based monitoring and evaluation framework for restoration projects.	High
		Investigate the need for a nursery or stock of locally-sourced coral colonies with identified heat resistance, as well as sufficient genetic diversity within other identified areas, to supply restoration trials.	Low
A4 The ability of the reef to evolve and adapt to changing environmental conditions is supported.	A4.1 Identify and protect a diversity of species, functional groups and populations with genetic, physiological, or ecological traits that are resilient to future stressors (including heat stress, disease, cyclone damage, acidification and predation) or exhibit high levels of adaptive capacity.	Support research that identifies the coral genotypes and physiological characteristics present at Ningaloo Reef that may be resistant to stressors and identify resistant variants for potential propagation and translocation to key sites.	Medium
		Identify and protect species and populations with genetic, physiological, or ecological traits characteristic of low sensitivity and high adaptive capacity to climate impacts, within and across habitats.	Low
	A4.2 Enhance the processes of adaptation by promoting the development of resistant coral species.	Explore options for assisted evolution/adaptation, managed selection and breeding, and/or managed relocation of corals.	Medium

Objective	Strategy	Potential Resilience Actions	Resilience Priority
PILLAR B - An educated and empowered community			
B1 The community is informed about the current status, trends and threats to the reef and community	B1.1 Provide information to the community about the current state of scientific understanding about ecosystem health and actions that enhance resilience.	Support forums for community members, local decision-makers and researchers to discuss current knowledge and implications for management.	Medium
		Provide relevant information for local communities, businesses and management agencies related to resilience and climate change. Work with community members and groups to develop relevant education and communication materials, including strategies, locations and effective methods for information delivery such as public events.	Medium
		Investigate the development and maintenance of an online resilience portal. Maintain a repository for information/published articles related to the Ningaloo Coast.	Low
	B1.2 Investigate opportunities for climate change and resilience education programs for the community, as appropriate.	Support school curriculum and school holidays activities focussed on reef health and resilience.	Low
B2 The community is involved in planning and management.	B2.1 Enhance opportunities for community engagement and participation in planning, management and research activities	Investigate the development of citizen science monitoring and/or management programs for Ningaloo Reef utilising existing modalities, enabling users to contribute to research and data collection.	Medium
		Identify and support local leaders in coordinating and promoting stewardship of reef, marine and coastal ecosystems. Investigate programs to empower community members to become advocates of good behaviour on the reef.	Medium
		Continue to improve opportunities for greater community involvement in planning processes, including meaningful community feedback, inclusive stakeholder engagement processes, more responsive outreach, and trialling deliberative democracy approaches to participatory decision-making.	Low
		Work with traditional owners to develop and distribute educational materials which inform visitors about traditional knowledge, concerns and priorities and how scientific and traditional knowledge are both useful for management.	Medium

Objective	Strategy	Potential Resilience Actions	Resilience Priority
PILLAR C - Sustainable development and livelihoods			
C1 Sustainable utilisation and enjoyment of the Ningaloo Coast aligns with ecological and community values	C1.1 Understand appropriate or 'optimal' levels for population, tourism, extractive activities, infrastructure, services and utilities to sustain and support the maintenance of ecosystem health and community values.	Facilitate research that models the impacts and sustainable limits in terms of visitors to high use sites, visitors to the region, interactions with megafauna and extractive activities, in order to establish evidence-based targets or limits in relation to key resources.	High
	C1.2 Encourage and support sustainable development and livelihoods that align with ecological and community values.	Support the collaborative development of a long-term strategic masterplan outlining guidelines for appropriate growth and development within the Ningaloo Coast region. Support a feasibility study on various alternative sustainable livelihood options that align with ecosystem and community values and the development of diversification strategies for key climate-exposed sectors such as tourism.	High
C2 Sustainable livelihood diversification reduces local pressures on the reef and strengthen economic resilience.	C2.1 Support the diversification of tourism products, sub-sectors and across other sectors to reduce pressure on marine and coastal ecosystems.	Encourage product innovation, alternative tourism models and cooperation across stakeholders in ways that broaden and diversify tourism and reduce pressure and reliance on the reef.	Medium
C3 The resilience of local businesses and communities is enhanced.	C3.1 Support local operators to strengthen their ability in responding to changes in business conditions as a result of changes in reef health.	Support local tourism operators and businesses though providing business resilience information and training.	Medium
		Support the development of a climate change strategy for the tourism industry, outlining the potential impacts of climate change on tourism and actions that operators can undertake to strengthen their business in the face of changing environmental conditions.	Medium

Objective	Strategy	Potential Resilience Actions	Resilience Priority
PILLAR D - Adaptive management systems			
D1 Management planning and approaches are integrated and adaptive.	D1.1 Develop adaptive planning structures and management arrangements that can be iteratively modified as new information becomes available or environmental conditions change.	Support the uptake of adaptive planning and management structures to respond to changing environmental conditions, incorporating regular evaluation, alteration and renewal of strategic plans, as feasible and appropriate. Support management agencies to undertake scenario planning and/or modelling of projected futures under different environmental conditions and policy settings to inform adaptive management, as required.	Medium
	D1.2 Support the trialling of new approaches to support resilience as appropriate.	Where appropriate, utilise modelling to develop or narrow options for management approaches and then test using experimentation.	Medium
		Actively engage with best-practice research and development programs around the world to stay informed about emerging techniques and management approaches, assess their relevance for the context of the Ningaloo Coast, and trial new methods as they become available.	Low
	D1.3 Pursue integrated approaches to planning and management of the Ningaloo Coast.	Consider commissioning holistic, socio-ecological modelling that considers the effects of multiple pressures and how they interact, assesses sustainable limits and evaluates the ecological and social effects of alternate management approaches. Undertake and incorporate habitat mapping as appropriate for the Exmouth Gulf.	High
D2 The knowledge, values, experience and skills of multiple stakeholders are valued in adaptive management.	D2.1 Strengthen multi-agency collaboration at the strategic level. Align the strategic goals and objectives of various management agencies where possible.	Establish or build on existing multi-agency agreements between management agencies to collaborate in strategic planning.	Low
	D2.2 Continue to generate strategic research that informs management and is responsive to evolving needs.	Maintain an updated list of management priorities and the research needed to assist in informing management.	Medium
		Develop a standard of practice for research co-design when planning and conducting research intended to inform management decisions.	Medium
		Explore the establishment of formal communication channels between key research institutions, funding partners and managers to articulate management priorities and strategically plan research. Encourage co-design with managers to be a criteria within funding applications.	Low
		Establish service level agreements with researchers, where appropriate, in order to maintain and adapt outputs over time.	Low
		Where appropriate, encourage researchers to synthesise findings into recommendations for management.	Low
D3 Resilience is embedded within existing planning and management processes.	D3.1 Foster the ongoing consideration of resilience as part of general operations and day-to-day decision-making.	Incorporate resilience characteristics (i.e. ecological triggers and thresholds, social and cultural values) within KPIs, metrics and assessment criteria for new management plans. Where appropriate, incorporate these into existing plans.	Low
		Investigate and assess the impacts of climate change on operations, management activities and infrastructure in the future.	Low
		Investigate where climate change-specific actions are required within existing management plans, and integrate climate change assessment into future management planning.	Low
	D3.2 Ensure that climate change is considered in management planning.	Support the community, local businesses and management agencies to undertake a climate vulnerability assessment for the region, and update existing plans to include climate change considerations.	High
		Develop guidelines for integrating climate change and resilience into new design or planning processes, where appropriate. Ensure climate risk and scenario planning exercises are considered as part of management and community planning in future.	Medium

Objective	Strategy	Potential Resilience Actions	Resilience Priority
D4 Funding for resilience-based management is increased.	D4.1 Collaborate to increase the funding available for resilience-based management, exploring innovative financing arrangements and developing sustainable funding partnerships where possible.	Develop ongoing public-private partnerships and co-financing arrangements to support coral reef management and resilience actions.	Medium
		Explore options for visitors and users to contribute to the funding of potential resilience actions. Work with partners to identify tailored funding opportunities for specific resilience activities, such as voluntary contribution schemes that allow donators to experience and be involved in on-site activities.	Low
PILLAR E - Leadership in sustainability and resilience			
E1 Ecosystems that store carbon and support marine life are protected.	E1.1 Monitor, assess and protect seagrass, macroalgal and mangrove habitats.	Undertake baseline surveys of the extent of seagrass, macroalgal and mangrove systems within the region. Assess the current and potential sequestration rates of seagrass, macroalgal and mangrove systems. Explore blue carbon opportunities for generating carbon credits from activities which establish, protect or restore mangrove, macroalgal and seagrass habitats.	Medium
		Identify and protect areas for expansion of mangrove systems with rising sea levels.	Low
E2 The carbon footprint is minimised.	E2.1 Encourage the uptake of renewable energy, improved waste management and emissions reduction within the region.	Encourage the uptake of renewable energy and emission reduction activities among residents and visitors, through showcasing practical initiatives, supporting aligned projects and creating local employment related to these outcomes, where appropriate. Encourage local operators to reduce their emissions and energy usage.	Medium
		Support projects to prevent, reduce, reuse, recycle or recover waste in the Exmouth and Coral Bay communities and in Parks and Reserves, and explore options to participate in and support the development of a circular economy in the region. Partner with local community groups and other management agencies in addressing waste management issues in areas of adjacent or shared tenure.	Medium
	E2.2 Support influential institutions to lead a transition to a low carbon economy.	Support and encourage management agencies and other high-profile institutions within the region to adopt targets for a transition to a low carbon economy (i.e. commitment to renewable energy and/or carbon zero).	Low
E3 Ningaloo Coast management agencies and communities are leaders in sustainability and resilience.	E3.1 Communicate the importance of mitigation and adaptation to the preservation of Ningaloo Reef.	Communicate the implications of climate change for coral reefs and the broader benefits of emissions mitigation to national and international audiences, appropriate international conventions and forums, and sharing experiences with other reef sites around the world.	Low
	E3.2 Seek avenues to foster the development of a resilience and climate change innovation hub for education, research, management, community collaboration and knowledge sharing with other regions.	Support the development a reef resilience centre of excellence based in Exmouth to develop and trial socio-ecological techniques for enhancing resilience, share learnings and support outreach, and catalyse ongoing support and investment in reef resilience.	Medium
		Seek opportunities to promote the achievements of the region and models for good practice in other towns, regions and jurisdictions.	Low
		Support the establishment of a grant funding program to support local projects which address climate change and embed resilience.	Low
		Develop communication materials and outreach to educate visitors about leading practice within Exmouth and Coral Bay to promote broader change.	Low
	E3.3 Educate and empower visitors to be ambassadors for marine conservation.	Support a review of best practice techniques that create sustained behavioural change as a result of visitor experiences.	Low
	E3.4 Promote good practice and progress in minimising footprint to encourage a shift in social norms.	Develop a mechanism to showcase local champions, share information on best practice and innovation and foster a network of green leaders within Exmouth and Coral Bay.	Low

Appendix B
Priority Research Topics

Robust research that advances the understanding of ecological and social systems is vital for resilience-based management. However, to ensure that science informs management in meaningful and practical ways, there needs to be a clear articulation of priorities and objectives. This document articulates the research priorities that reef managers have identified as the most important for guiding management, which have been informed by the views and recommendations of the scientific community.

These research priorities were developed through a Horizon Scanning prioritisation activity involving over 30 prominent researchers with extensive experience conducting research on the Ningaloo Coast. Researchers were invited to propose research topics that would inform resilience-based management, and then asked to prioritise the resulting combined list. This prioritised list was then reviewed and topics were grouped and revised to ensure they suited the needs of managers.

Priority research topics are presented below as broad categories of inquiry that are intended to guide future efforts while still providing flexibility for researchers and managers to co-design research projects as knowledge evolves.

Foundations: What are the foundational species, attributes and functional processes that maintain the current system?	Identify key species, attributes and functional processes which are fundamental in maintaining and regenerating marine ecosystems on the Ningaloo Coast, at physiological (population and species levels), ecological and evolutionary scales.
	Map the hydrodynamic and genetic patterns of larval connectivity between reef areas within Ningaloo Marine Park, Exmouth Gulf, and other coastal regions in the Pilbara. Advance current understanding of the drivers of sporadic 'pulses' of coral and fish recruitment and how the frequency of these events may be altered under various climate change scenarios.
	Assess, and identify cost-effective ways to expand, long-term monitoring in relation to its applicability to resilience-based/adaptive management. This may include opportunities for robust citizen science programs.
	Establish the current state, trends and dynamics of targeted fish abundances at the scale of the Ningaloo Marine Park, including rates of recruitment, growth, reproduction and mortality, and the impacts of recreational fishing pressure and projected environmental changes.
	Understand, and where possible quantify, the social and cultural ecosystem services provided by the Ningaloo Coast, and identify approaches to integrate traditional knowledge and social values into resilience-based management.

Change: What are the expected environmental changes, at spatial and temporal scales which are relevant for management?	Obtain downscaled regional climate change projections for ocean warming, sea level rise, coastal upwelling, rainfall variability, average and extreme air temperature, and acidification risks to inform climate change impact assessments.
	Model the future changes to the Leeuwin current and ENSO, which are key determinants of environmental conditions on the reef, and the potential changes to recruitment patterns and the migration and aggregation of iconic species.
	Collect and collate data on current temperature variability and variations in thermal stress across the Ningaloo Marine Park, and model how these patterns may be altered by climate change using local hydrodynamic modelling.
	Model the impact of future sea level rise and extreme events on beaches, coastal ecosystems and ecological and social values along the Ningaloo Coast.
	Conduct studies to estimate the timing and effects of acidification on corals, and potential interventions that are applicable at scale.
Impacts: How will changing conditions impact ecologically and economically important species, habitats and ecosystems? What is the current adaptive capacity and evolutionary potential of species and ecosystems?	Develop an integrated environmental model at a reef-system scale, which incorporates hydrodynamic, biogeochemical, climatic, benthic, remote sensing, connectivity, temperature variability and predicted climate risk models, as well as observational data related to resilience mapping and local stressors/human impacts. Identify areas of higher predicted resilience value to inform decision-support systems, spatial planning (i.e., zoning), monitoring, management of disturbances (such as bleaching or cyclones) and interventions (such as fisheries management or restoration activities).
	Map the ongoing and predicted shifts in species distribution and abundance, using niche/bioclimatic modelling or species distribution models, and evaluate potential changes to community structure and functional dynamics. Identify the determinants of current and historical distributional range shifts of species, with regard to the interaction of multiple environmental (e.g. temperature, weather, hydrographical conditions) and human–derived factors (e.g. habitat destruction). Particular attention to be given to species which are functionally-important for reef resilience and iconic species (whales, whale sharks, mantas, turtles). Identify triggers, thresholds and monitoring metrics.
	Model the potential impacts of predicted environmental changes on growth and persistence of foundational habitats (coral, seagrass, macroalgal beds and mangroves). Identify thresholds for the current structure and function of habitats, and potential effects of regime shifts, trophic cascades and community re-structuring on the broader ecosystem.
	Investigate the evolutionary potential and phenotypic plasticity of corals, macroalgae, fish and invertebrate species, and the speed at which they can adapt to changing environmental conditions, which will help to determine when restoration is appropriate.
	Identify the defining features which maximise coral recovery from disturbance (bleaching, cyclones), understand recovery patterns of corals, and model how recovery may be altered under future environmental change. Identify local stressors which influence population recovery at the species level.
	Model potential increases in existing, or the presence of new and novel, coral diseases and/or predators due to changing environmental conditions. Assess the likelihood of migration, increased survivorship and/or outbreaks of Crown-of-Thorns Starfish and Drupella.
	Assess the impact of climate change on visitation and visitor use patterns for the Ningaloo Coast, reef and within the surrounding communities.
	Design and undertake integrated modelling of potential future impacts and interventions to respond to climate change, which identify implications and trade-offs in terms of social and environmental outcomes and provide a framework for adaptive management and decision-making. Implement in ways which support learning amongst stakeholders and as a platform for stakeholder engagement.
	Increase current understanding of the relationship between the drivers of primary productivity (including coral spawning and upwellings) and aggregations of whale sharks. Model how phytoplankton and zooplankton production may change in extent, timing and duration as a result of climate change, and the effects of this on aggregation activity.

Management: What are the key initiatives or interventions that strengthen resilience and maintain ecosystem functioning?	Undertake resilience mapping to identify high-value resilience sites (coral reefs and macroalgal nurseries), including those sites which have a positive impact on network connectivity, enhanced levels of resistance or recovery, and/or reduced exposure or sensitivity to multiple stressors. This mapping should integrate local human pressures which may operate within the area and known species physiological tolerance limits. Assess whether current zoning and management are adequate to protect these areas under current and projected future conditions.
	Identify resistant coral species/variants which have a natural adaptive capacity for heat tolerance, acidification or disease/predation resistance. Identify specific physiological characteristics that support resilience and/or resistance.
	Identify triggers, thresholds and monitoring metrics which are functionally-important in the maintenance of the ecosystem health. This may include thresholds in general ecosystem structure and function, or species-specific threshold responses to disturbances or changing environmental conditions.
	Identify the level of recreational fishing that can be sustained without altering energy flows, trophic systems and reef recovery, with regard to current and projected fishing pressure, rates of shark depredation, and known or expected environmental changes. Define management targets for targeted species, including threshold levels or triggers for intervention, and an effective and resource-efficient monitoring program which informs adaptive management of pressures. Undertake an assessment of sustainable fishing limits and a socio-economic study to model optimal management approaches in support of defined management targets.
	Develop modelling and monitoring which supports the creation of early warning systems for known environmental changes and extreme events.
	Undertake studies to identify sustainable levels of (i) visitor capacity at high use sites, incorporating an assessment of temporal and spatial distribution of visitor use, visitor perceptions of crowding/satisfaction surveys, and rates of pressure on key features, (ii) visitation rate to the region on the basis of services, infrastructure, community perceptions and values, and environmental impacts, (iii) recreational fishing pressure on local target fish abundance, and (iv) interactions with marine megafauna. This includes identifying thresholds for ecological condition, user experience and community values in order to establish evidence-based targets or limits in relation to key resources.
	Undertake research which models interactions between ecological, economic and social values in relation to future development along the Ningaloo Coast, which provides practical guidance for long-term strategic planning and decision-making within the region. Undertake socio-ecological modelling to understand the relative benefits, trade-offs and social acceptability of particular interventions in conferring resilience and/or identify thresholds in the interactions between ecological, economic and social values.
	Assess the extent to which visitor behaviours are currently having impacts at an ecological scale within Ningaloo Marine Park and model the effectiveness of potential management interventions using applied behavioural theory strategies.
	Undertake risk assessments of coastal assets and values (e.g. turtle nesting areas, infrastructure, cultural sites) under likely climate change scenarios to support planning for protection, retreat and/or rehabilitation.
	Identify and assess the effectiveness of techniques for restoring ecosystem components at a scale which meaningfully promotes conservation.
	Partner with research institutions, management agencies and community groups, where appropriate, to trial methods and techniques for coral restoration for the purpose of localised mitigation and restoration at high-value sites.
	Develop knowledge-management and decision-support systems to enable the adaptive management of functional aspects of marine ecosystems, including the abundance of key species, condition of foundational habitats and response to identified threats and pressures. Decision-support systems are underpinned by modelled or observed thresholds, monitoring of identified indicators, and identified interventions that will be enacted upon reaching the threshold.
	Assess the effectiveness of current communication and engagement strategies in promoting pro-environmental behaviours among community members and visitors of the region, and adapt or design new engagement strategies where appropriate. Undertake behavioural change studies for specific issues of concern for management (i.e. tramping and anchor damage to coral, maximising fish take, driving on beaches, visitor behaviour on nesting beaches - dogs, trampling, lights, interactions etc) and design innovative approaches that influence user behaviour.