Application of the Climate Vulnerability Index for Shark Bay, Western Australia

Scott F. Heron, Jon C. Day, Cheryl Cowell, Phil R. Scott, Di Walker, Jenny Shaw

CVI

Application of the Climate Vulnerability Index for Shark Bay, Western Australia

The Climate Vulnerability Index (CVI) is a rapid assessment tool custom-designed for application in World Heritage properties. This report describes outcomes from its application for the *Shark Bay, Western Australia* property. Vulnerabilities of the World Heritage values and attributes, and of the community associated with the property were each assessed in the highest category.

Authors: Scott F. Heron[1,2], Jon C. Day[2], Cheryl Cowell[3], Phil R. Scott[4], Di Walker[4,5], Jenny Shaw[6]

Affiliations:
[1] Physics, College of Science and Engineering, James Cook University, Townsville Q4811, Australia
[2] ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville Q4811, Australia
[3] Shark Bay World Heritage Property, Department of Biodiversity, Conservation and Attractions, Western Australia, Denham WA 6537, Australia
[4] Shark Bay World Heritage Advisory Committee, Denham WA 6537, Australia
[5] School of Biological Sciences, The University of Western Australia, Perth WA 6009, Australia
[6] Western Australian Marine Science Institution, Perth WA 6009, Australia

Front cover image: Big Lagoon, Shark Bay (Credit: Richard Gale)

Publication date: May 2020

Citation:
Heron SF, Day JC, Cowell C, Scott PR, Walker D, Shaw J (2020) Application of the Climate Vulnerability Index for Shark Bay, Western Australia. Western Australian Marine Science Institution, Perth, Western Australia, 80pp.

Available electronically from: *www.wamsi.org.au/cvi-shark-bay*

ISBN: 978-0-9872761-3-1

Author Contributions:
SFH and JCD led the structuring of the report. All authors contributed to the drafting of sections, and the editing and finalising of the report.

Corresponding author and Institution:
Scott Heron (James Cook University, Townsville, Queensland)
scott.heron@jcu.edu.au, cvindex.heritage@gmail.com

Funding Sources: Funding support for this project is described in the Acknowledgements, page 45.

Competing Interests: The authors have declared that no competing interests exist.

APPLICATION OF THE CLIMATE VULNERABILITY INDEX FOR SHARK BAY, WESTERN AUSTRALIA

CONTENTS

Zuytdorp Cliffs

EXECUTIVE SUMMARY

Climate change has been identified as the fastest growing global threat to World Heritage. Many World Heritage properties around the world have already experienced climate impacts including from warming temperature, sea level rise, extreme precipitation, flooding, coastal erosion, drought and worsening wildfires. This has resulted in significant negative impacts, damage and degradation to the properties, as well as to the communities associated with them. Recently observed trends are expected to continue and accelerate as climate change intensifies, increasing the climate vulnerability of heritage.

This report describes outcomes from two workshops to apply the **Climate Vulnerability Index** (CVI) for Shark Bay, Western Australia. The CVI process was developed to rapidly assess climate impacts – both to Outstanding Universal Value (OUV) and the associated 'community' (local, domestic and international) – for all types of WH properties (natural, cultural or mixed). The CVI workshop held in Denham (September 2018) was the first time the CVI process had been undertaken anywhere in the world. A follow-up workshop was held in Perth (June 2019) to complete the CVI for Shark Bay.

The **key climate stressors** identified for Shark Bay were:

- Air Temperature Change;
- Storm Intensity and Frequency; and
- Extreme Marine Heat Events.

The Shark Bay World Heritage property was determined to have **High OUV Vulnerability** to potential impacts of key climate stressors, with low capacity of the system to adapt to climate change. By 2030-2050, there is the potential for major loss or substantial alteration of the majority of the values that comprise the OUV of the property.

The **High Community Vulnerability** for the Shark Bay property was determined by considering economic, social and cultural (ESC) aspects of the associated community. The assessment was derived from the High OUV Vulnerability together with the economic dependence of key business types upon the property, the local population's connection with the property, and the assessed low level of adaptive capacity across these ESC components.

Climate change is expected to threaten the resilience of areas in Shark Bay and to increasingly impact upon the attributes that collectively contribute to the Outstanding Universal Value, recognised through World Heritage listing. These impacts are expected to have a high degree of impact upon the community associated with the property. The identified high levels of vulnerability emphasise the importance of developing effective strategies for climate change adaptation at Shark Bay.

Big Lagoon

SECTION 1. INTRODUCTION

1.1 Background to this report

Climate change is the fastest growing global threat to World Heritage (WH) properties[1,2], many of which – natural, cultural and mixed – are already being impacted. The severity of current climate impacts on individual WH properties varies, as does the range of climate stressors causing those impacts (see Sections 4 and 5), and the rate at which they are occurring. In most cases, climate change has negative impacts on WH values (and the attributes that support them), which degrades the Outstanding Universal Value (OUV) for those WH properties (see Table 2.1 and Appendix 1).

> ***"Climate change is the fastest growing threat to … World Heritage … the most significant potential threat and, for a number of sites, this threat is materialising, with tangible impacts on World Heritage values".*** IUCN[1]
>
> ***"…climate change has become one of the most significant and fastest growing threats to people and their heritage worldwide…"*** ICOMOS[2]
>
> ***"Climate change is fast becoming one of the most significant risks for World Heritage sites worldwide…. direct and indirect impacts of climate change may present a threat to their OUV, integrity and authenticity"***
> UNESCO, UNEP and UCS[3]

Currently the United Nations Educational, Scientific and Cultural Organisation (UNESCO) Operational Guidelines for the Implementation of the World Heritage Convention[4] (the documentation used for managing all WH properties) has limited 'tools' to deal with impacts to WH values. The primary tool in the Guidelines is WH In-Danger, which was developed to deal with local and regional threats that a State Party can resolve given sufficient capacity and the political will. Furthermore, many WH properties could realistically be considered as being potentially vulnerable to the impacts of climate change, but it would be unrealistic to place all (or many) WH properties on the WH In-Danger list (due to climate vulnerability or for any other reason). The Intergovernmental Panel on Climate Change (IPCC) has predicted with 'high confidence' that '*Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate*"[5]. The IPCC has therefore advised (again with high confidence), *"Climate-related risks for natural and human systems (will)… depend on the magnitude and rate of warming, geographic location, levels of development and vulnerability, and on the choices and implementation of adaptation and mitigation options*"[5].

1.2 Overview of the Climate Vulnerability Index (CVI)

The Climate Vulnerability Index (CVI, *https://cvi-heritage.org*) process was developed to rapidly assess climate impacts – both to Outstanding Universal Value (OUV) and the associated 'community' (local, domestic and international) – for all types of WH properties (natural, cultural or mixed). The methodology (see Appendix 2) is based on a risk assessment approach and comprises two distinct primary outcomes (see Figure 5.1), assessing:

- **OUV Vulnerability**, evaluating potential impacts to the values and attributes for which the property is recognised; and
- **Community Vulnerability,** assessing the level of economic, social, and cultural dependence that associated communities (local, national and international) have on the WH property (collectively referred to as “ESC dependencies”) and their adaptive capacity to cope with climate change (building upon work by Marshall et al.[6]).

Both of these vulnerability assessments are highly relevant for key stakeholders, including site managers, responsible management agencies, businesses that are dependent on the property and local communities around the property. The structure of the CVI process allows for a systematic evaluation of the threats of climate change. Through its application, the CVI enables managers and stakeholders to consider appropriate adaptive capacities for the management of their natural, cultural and community assets.

The concept of the CVI for WH properties was introduced at an expert workshop on the Baltic island of Vilm in 2017, co-convened in response to a decision of the WH Committee to update the climate policy applicable to WH properties[7]. One recommendation from that workshop was the establishment of a climate vulnerability index that could be applicable to all properties to complement the WH In-Danger list[8].

The CVI was initially developed in Australia, building upon the vulnerability framework described by the Intergovernmental Panel on Climate Change (IPCC)[9]. Input and guidance for the CVI has subsequently come from many experts around the world including from the International Council on Monuments and Sites (ICOMOS) and the International Union for Conservation of Nature (IUCN), two of the advisory bodies for the World Heritage Committee.

The CVI process is best undertaken through a workshop of diverse stakeholders (including site managers, researchers, community representatives, dependent business owners, management agency representatives, and other stakeholders) and systematically works through the steps outlined in Chapter 5.

The CVI methodology is currently in a developmental phase, so the Shark Bay workshops, along with a series of other pilot workshops occurring nationally and internationally over the next 18 months involving different types of heritage properties, will be used to help improve and refine this methodology.

1.3 Why was Shark Bay chosen for a CVI workshop?

Shark Bay’s location on the boundary between temperate and tropical ecosystems results in a unique mix of species, both marine and terrestrial, and its unique geomorphology, shape and geographic setting make it an ideal refuge for native fauna. For decades, a succession of advisory committees with responsibility for the Shark Bay World Heritage Area (SBWHA) have been advocating for an assessment of climate change impacts on Shark Bay’s OUV. In 2008, climate change was recognised in the SBWHA Strategic Plan[10] as being a significant threat to the OUV of Shark Bay, with a series of actions identified. However, it wasn't until the 2010/11 marine heatwave when 900 km^2 of large, temperate, meadow-forming seagrass was lost (and other OUV attributes impacted) that this became an area of more intense focus.

Following a workshop in June 2018 arranged by West Australian Marine Science Institution (WAMSI) that gathered together available scientific data[11], the Shark Bay World Heritage Advisory Committee (SBWHAC) decided to convene a workshop to identify the possible impacts of climate change on Shark Bay OUV. The primary aim of the workshop was to lay the foundations for the development of a climate change adaptation strategy and action plan for the Shark Bay World Heritage property. The workshop was conducted in Denham in September 2018 (Figure 1.1) and featured presentations from subject matter experts – including an update on what elements of climate are predicted to change, at what rate and with what confidence level those predictions are made. The workshop also provided an opportunity to apply the CVI methodology, which had been specifically developed to assess the climate vulnerability of World Heritage properties.

As the Denham workshop completed only the first part of the CVI assessment[12], a follow-up CVI workshop was held in Perth in June 2019 (Figure 1.2); more details about the two workshops are in Appendices 2 and 3). In summary, the aims of the two workshops were to:

- Understand the CVI framework and its application in Shark Bay;
- Understand the significant values that comprise the OUV for SBWHA plus the other Significant Property Values (SPVs) for Shark Bay;
- Understand the likely future climate change scenarios facing Shark Bay;
- Assess the climate change stressors impacting the values of Shark Bay and select key climate change stressors;

(list continues next page)

Figure 1.1 Undertaking the first phase of the CVI process during the September 2018 workshop in Denham.

- Evaluate the vulnerability of the OUV to the key climate change stressors, considering exposure and sensitivity;
- Consider the economic, social and cultural dependencies (sensitivity) and adaptive capacity to determine the Community Vulnerability; and
- Progress toward a climate change adaptation strategy and adaptation plan.

The SBWHAC members appreciated the fact they were undertaking a 'world-first' trial of the CVI methodology in order to test its usefulness as a rapid assessment tool for assessing the vulnerability of climate impacts.

This Shark Bay report, together with the report following a trial of the CVI for a cultural WH property (Heart of Neolithic Orkney)[13], has implications for other WH properties and substantiates the value of the CVI process for assessing the vulnerability of WH properties and other natural and cultural heritage properties around the world.

Figure 1.2 Undertaking the second phase of the CVI process during the June 2019 workshop in Perth.

CITED REFERENCES

[1] Osipova E., Shadie P., Zwahlen C., Osti M., Shi Y, Kormos C., Bertzky B., Murai M., Van Merm R., Badman T. (2017) IUCN World Heritage Outlook 2: A Conservation Assessment of All Natural World Heritage Sites. Gland, Switzerland: IUCN. doi: 10.2305/IUCN.CH.2017.17.en *https://portals.iucn.org/library/sites/library/files/documents/2017-053-En.pdf*

[2] ICOMOS (2017) Resolution 19th General Assembly of ICOMOS, 2017.

[3] Markham A., Osipova E., Lafrenz Samuels K., Caldas A. (2016) World Heritage and Tourism in a Changing Climate. United Nations Educational, Scientific and Cultural Organization, United Nations Environment Programme, and Union of Concerned Scientists. *https://whc.unesco.org/en/activities/883/*

[4] UNESCO (2019) Operational Guidelines for the Implementation of the World Heritage Convention. *https://whc.unesco.org/en/guidelines/*

[5] IPCC [Intergovernmental Panel on Climate Change] (2019) Global Warming of 1.5^{O}C: Summary for Policy-makers (Revised January 2019). Intergovernmental Panel on Climate Change, Switzerland. *www.ipcc.ch/sr15/*

[6] Marshall N.A., Tobin R.C., Marshall P.A., Gooch M., Hobday A.J. (2013) Social vulnerability of marine resource users to extreme weather events. Ecosystems 16: 797-809. doi: 10.1007/s10021-013-9651-6

[7] WH Committee (2016) Decision 41 COM 7, paragraph 25. *https://whc.unesco.org/en/decisions/6940/*

[8] UNESCO (2017) International Expert Workshop "World Heritage and Climate Change – Towards the update of the *Policy Document on the Impacts of Climate Change on World Heritage Properties".* *https://whc.unesco.org/en/news/1736/*

[9] IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry M.L., Canziani O.F., Palutikof J.P., van der Linden P.J., Hanson C.E. (eds.) Cambridge, UK: Cambridge University Press.

[10] Department of Environment and Conservation, Western Australia (2008) Shark Bay World Heritage Property Strategic Plan 2008-2020. Perth, Western Australia.

[11] WAMSI (2018) Adapting to ecosystem change in the Shark Bay World Heritage Site. Western Australian Marine Science Institution. *www.wamsi.org.au/shark-bay-workshop*

[12] NESP Earth Systems and Climate Change Hub (2018) Climate change and the Shark Bay World Heritage Area: foundations for a climate change adaptation strategy and action plan, Earth Systems and Climate Change Hub Report No. 7, NESP Earth Systems and Climate Change Hub, Australia. *http://nespclimate.com.au/wp-content/uploads/2016/03/SBWHA-CC-workshop-report.pdf*

[13] Day J.C., Heron S.F., Markham A., Downes J., Gibson J., Hyslop E., Jones R.H., Lyall A. (2019) Climate risk assessment for Orkney World Heritage: An application of the Climate Vulnerability Index. Historic Environment Scotland, Edinburgh. *www.historicenvironment.scot/hono-cvi*

Stromatolites

SECTION 2. SHARK BAY, WESTERN AUSTRALIA WORLD HERITAGE PROPERTY

2.1 Location

The *Shark Bay, Western Australia* WH property is located at the most westerly point of the Australian continent, on the Western Australian coast around 800 km north of Perth (Figure 2.1). Encompassing 22,000 km^2, it has around 1,500 km of coastline and is close to 70% marine environment. It spans almost from Carnarvon in the north to the Zuytdorp Nature Reserve to the south. The western boundary is up to three nautical miles off the coast, whilst the inland boundary extends approximately 100 km towards the North West Coastal Highway. Although the township of Denham and the areas around Useless Loop and Useless Inlet are within the WH boundary, these are specifically excluded from the WH property as they were already highly modified areas at the time of inscription in December 1991. Areas within the WH property continue to be added to conservation estate, the most recent being Dirk Hartog Island which was declared a National Park in 2009.

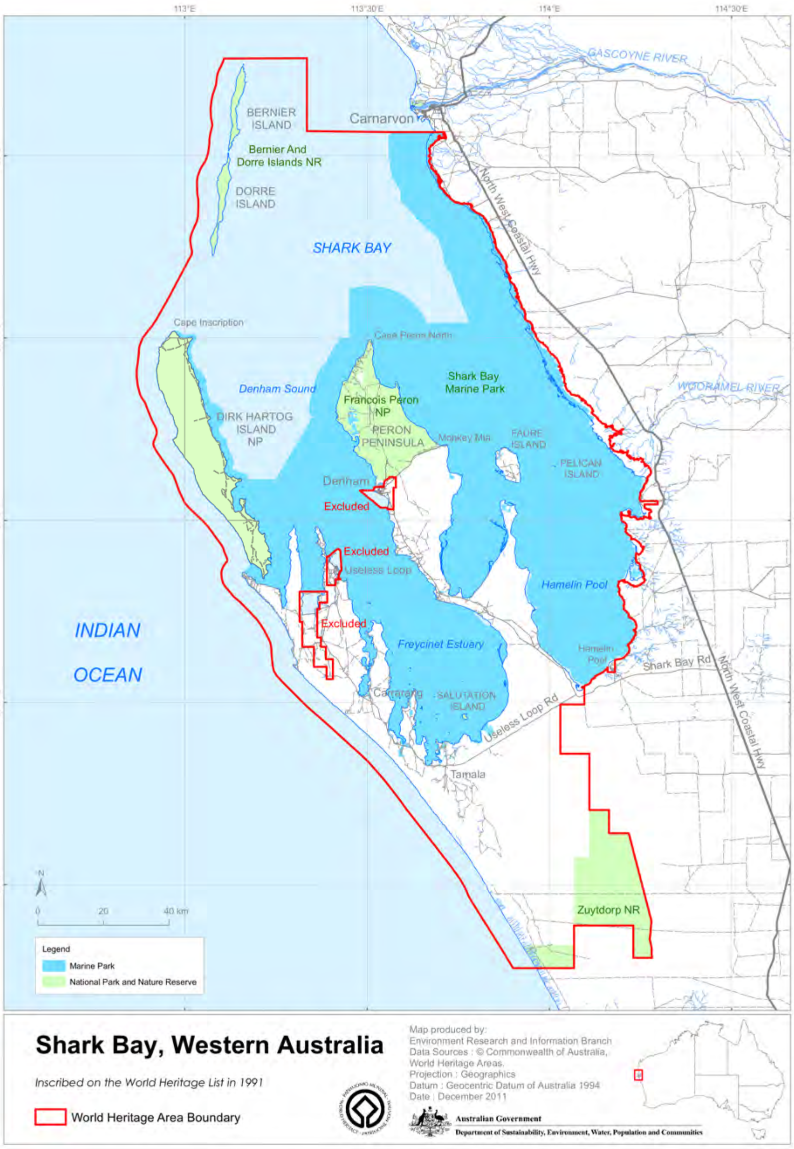

Figure 2.1 Map of Shark Bay, Western Australia.

2.2 The World Heritage Property

Inscribed on the WH List in 1991, as the ninth of Australia's World Heritage properties and the first in Western Australia, Shark Bay is currently one of only 21 WH properties worldwide that fulfils all four natural criteria:

Criterion (vii): contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;

Criterion (viii): be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;

Criterion (ix): be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; and

Criterion (x): contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of Outstanding Universal Value from the point of view of science or conservation.

Shark Bay is a biodiverse region of ecological, geological and hydrological significance as well as a region of exceptional beauty. The key exceptional natural features that contribute significantly to the OUV (the four "S"s) are:

- **Seagrass**: its extensive seagrass beds, which are the largest (4,800 km^2) and the most diverse in the world;
- **Salinity**: the salinity gradients and hypersaline environments;
- **Stromatolites** (colonies of microbial mats that form hard, dome-shaped deposits that are among the oldest life forms on earth): the stromatolites and microbial mats in the shallows of Hamelin Pool are the most diverse in the world and tolerate extremes of temperature and exposure, which results in few competitors and predators, and hence, their abundance in Hamelin Pool Marine Nature Reserve; and
- **Species**: that it is one of the world's most significant and secure strongholds for the protection of dugong and many other species assemblages – including some that are found nowhere else in the wild.

The WH area covers 2,197,300 ha and the exceptional marine environments, comprising 70% of the area, result from the unique combination of a large, sheltered, shallow body of water (average depth 9 m) and a vast coastline. A series of north-south facing peninsulas and islands also provide isolated terrestrial habitats, set in an area that contains elements of both temperate and tropical climate. Together these provide habitat to a unique mix of marine and terrestrial fauna, and act as an ideal refuge for native species.

The biology of the shallow bay reflects this unique setting, providing opportunities for stromatolites and distinctive marine and terrestrial flora to survive, as well as supporting a very productive biological environment that sustains an extensive and spectacular landscape, significant fisheries, local communities, and tourism activities. A very productive benthic marine habitat features extensive seagrass meadows, providing habitat opportunities for many other species, including species of commercial significance in the region.

The property is located at the transition zone between two of Western Australia's main botanical provinces, and therefore contains a mixture of two biotas, many at the limit of their southern or northern range. The property contains the only populations or major populations of five globally threatened mammal species, including the burrowing bettong (now classified as 'Near Threatened'), rufous hare-wallaby, banded hare-wallaby, the Shark Bay mouse and the Shark Bay bandicoot (formerly called the western barred bandicoot). Parts of the property have been used to re-introduce and conserve threatened fauna, including in the Peron Peninsula and more recently Dirk Hartog Island National Park where the above species and a suite of others are being re-introduced into an environment void of introduced predators such as foxes and cats[1].

Threatened plant and reptile species also occur in the terrestrial part of the property, of which 200,700 ha is in nature reserves and national parks. The property is also famous for its rich marine life including whales, manta rays, dolphins and several species of marine turtle. Although not abundant, coral reefs are present containing over 80 coral species.
The marine environment has undergone some modifications as a result of a past pearl shell industry, and some overfishing from an active commercial fishing industry based mostly on prawns, scallops and fish (such as whiting and snapper). Current regulations applicable to the fishing industry ensure that commercial and recreational fishing are sustainable and the marine environment is therefore largely intact.

Parts of the terrestrial environment of Shark Bay experienced a degree of habitat modification from the historical introduction of sheep, rabbits and goats, as well as predators such as foxes and cats. Pastoral leases exhibit localised areas of high disturbance, particularly around homesteads and stock watering points, and some areas show evidence of past overgrazing by stock, resulting in reduced vegetation cover and sand dune blowouts (such as those on Dirk Hartog Island). Other human activities, particularly recreational pursuits, can also impact negatively on both the terrestrial and marine environments.

2.3 The Implications of World Heritage status

The 1972 World Heritage Convention[2] deals with the identification, protection and preservation of cultural and natural heritage around the world that is of outstanding value to all humanity. The Convention has now been ratified by 193 governments, and in 2019 there were 1,121 sites on the World Heritage List.

Inscription of a site on the World Heritage List obligates the relevant State Party to ensure the protection, preservation and transmission of its OUV to future generations. Each property has a Statement of OUV (SoOUV), which is the principal reference for protection and management of the property and a baseline for monitoring and reporting.

The Operational Guidelines for the Implementation of the World Heritage Convention[3] list ten criteria that define OUV – six cultural and four natural criteria (see Section 2.2). Additionally, properties must demonstrate:

- that they possess integrity – sufficient components and of adequate size to express OUV; and an assessment of pressures that threaten the site and if they can be addressed;
- (for cultural criteria) that they are authentic – credible sources of information regarding the identified value/s; and
- protection and management to ensure that OUV (including integrity and, if appropriate, authenticity) are maintained or enhanced[3].

In addition to its OUV, Shark Bay has a range of other important historical and contemporary values of national, regional and local significance. For example, the record of aboriginal occupation of Shark Bay extends to 22,000 years before present and there are a considerable number of aboriginal midden sites. The European cultural heritage of the area includes the site at Cape Inscription where Dutch explorer Dirk Hartog in the *Endracht* made one of the first recorded landfalls by a European on Australian shores in October 1616, nailing a pewter plate to a post to record his visit.

The site where the ship *Zuytdorp* of the Dutch East India Company was wrecked in 1712 is also within the WH area, along with many other sites where French, Dutch and English maritime explorers (such as William Dampier, Willem de Vlamingh, and Louis de Freycinet) also visited. Since the early 1960s interaction of humans with wild Bottlenose dolphins has occurred regularly at Monkey Mia, providing unique interaction with wild marine fauna on a regular basis[4]. For more details of the property, refer to *www.sharkbay.org*.

The Operational Guidelines[3] make it clear that World Heritage should have a function in the life of the community, and that access and facilities for visitors appropriate to the protection and management needs of the property should be provided. However, management must ensure that sustainable use or any other change does not impact adversely on the OUV. This has implications for prioritisation and decision making in management and protection of the property.

The vulnerability of Shark Bay to the impacts of climate change has previously been highlighted as a priority concern by key stakeholders, such as WAMSI. Delivering on WH Convention commitments to preserve and transmit the WH property to future generations requires maintaining the attributes that express its OUV, ensuring the continuing integrity of the property as a whole, and managing impacts on the WH values and their attributes that combine to give the site its OUV.

Piloting the CVI in Shark Bay was an important step in identifying and ranking the potential impacts, adaptive capacity, and vulnerability of OUV for this property, and for demonstrating the effectiveness of the CVI for a variety of other WH properties. It has assisted SBWHAC to continue to advise on management of the OUV for future generations, by highlighting the vulnerabilities to climate change and starting to highlight key risks and capacities relevant to managing the impact of climate change on the property.

2.4 Identifying the values of the World Heritage property

In May 1991, the IUCN undertook its evaluation of the nomination for Shark Bay, and made the following observations[5]:

- *"There is no place on Earth quite like Shark Bay"* based on the fact that it encompassed an area with exceptional natural heritage values retaining its wild character where nature is the dominant force;
- The seagrass meadows are the most extensive and species rich in the world;
- Shark Bay is one of the world's six main strongholds for dugongs;
- The Shark Bay stromatolites are the best living examples found in the world. There are other areas of stromatolites (e.g., Hudson Bay and Great Salt Lake) but nowhere near the abundance as those growing in Hamelin Pool;

- Under the heading ‘Why is Shark Bay So Special?’ the evaluation quotes Thomson-Dans[6]: “Where else in the world can you meet a dolphin on the shore of a white sandy beach, in an astounding World Heritage Area? Or stand on a cliff overlooking the Indian Ocean on Western Australia’s largest island, where early Dutch mariners made landfall almost 400 years ago. You can experience the ancient traditions of the local Malgana people with an Indigenous guide and view caves in which Aboriginal people took shelter about 1,000 years ago. Or learn about the beginnings of the earliest life forms on the stromatolite boardwalk in the Hamelin Pool Marine Nature Reserve. There is nowhere else like Shark Bay on Earth”;
- Regarding the conditions of integrity, the area was of sufficient size and contained the components required to demonstrate all aspects of the natural processes. In terms of migratory species (whales, birds, turtles), survival will depend on their protection in regions outside the Property; and
- There are a number of concerns relating to the conditions of Integrity primarily for the terrestrial areas.

Shark Bay, Western Australia was subsequently inscribed on the list of World Heritage in 1991, but at that time there was no requirement for a Statement of Outstanding Universal Value (SoOUV). A retrospective SoOUV for Shark Bay was drafted in February 2011 and adopted by the World Heritage Committee at its 37th session in June 2013. The full text of the approved SoOUV for Shark Bay, Western Australia is reproduced in Appendix 1.

Prior to the first CVI workshop in Shark Bay, key excerpts from the Shark Bay SoOUV were identified and grouped together in a tabular form to develop a list of ‘key values’. These ‘key values’ were the basis for the assessments made throughout the CVI process as they reflect the detail behind the OUV.

However, subsequent consultation with WH experts is that these components of the SoOUV are more appropriately termed ‘attributes’ (rather than ‘key values’). Since the Shark Bay workshop, the CVI team has developed a hierarchy of these and associated terms, which are used in this report (Figure 2.2). In essence, attributes express the WH values in a more quantifiable and potentially manageable way; both the values and attributes must be derived from or refer directly to excerpts from the SoOUV. Additionally, non-OUV values directly associated with the property that were documented during the workshop were initially termed ‘Significant Local Values’; however, as the constraint inherently within the term ‘local’ can be inappropriate for large or inter-connected WH properties. As such, these non-OUV values are now referred to as other Significant Property Values (SPVs). Throughout the remainder of this report, the updated terms are used.

The breakdown of the Shark Bay SoOUV revealed 13 attributes (Table 2.1). These provided the basis for the assessments of the current condition and trend (Section 2.6), and of OUV Vulnerability (Section 5.2).

Within Shark Bay, certain **values** have been identified because of their significance.

The particular values that have been recognised as globally significant and conferring Outstanding Universal Value (under four of the World Heritage criteria) are its **WH values**.

Each of the above WH values have **attributes** (at the level at which management would occur); these may be tangible or intangible.

Other values within the property are also important; if they are considered nationally, regionally or locally 'significant', they are referred to as other **Significant Property Values** (SPVs) and are distinct from those values that comprise the OUV.

Figure 2.2 Hierarchy of World Heritage terminology as used in this CVI assessment report for Shark Bay, Western Australia.

Table 2.1 Attributes for Shark Bay, Western Australia derived from the Statement of Outstanding Universal Value (OUV), together with the assessed current condition and trend since inscription (*legend on p13*).

Attributes	Excerpts taken directly from Statement of OUV	Assessment of current condition indicated by colour-code
Seagrass	the Wooramel Seagrass Bank. Covering 103,000 ha, it is the largest structure of its type in the world … one of the largest seagrass meadows in the world with the most seagrass species recorded from one area	
Stromatolites	the most diverse and abundant examples of stromatolites (hard, dome-shaped structures formed by microbial mats) in the world	
Carbonate dominated marine environment	one of the few marine areas in the world dominated by carbonates not associated with reef-building corals	
Hypersaline waters	hydrologic structure of Shark Bay, altered by the formation of the Faure Sill and a high evaporation, has produced a basin where marine waters are hypersaline (almost twice that of seawater) the steep gradient in salinities, creating three biotic zones that have a marked effect on the distribution and abundance of marine organisms Hypersaline conditions in Hamelin Pool have led to the development of a number of significant geological and biological features including the 'living fossil' stromatolites	
Aesthetics	extensive beaches consisting entirely of shells profusion of peninsulas, islands and bays create a diversity of landscapes and exceptional coastal scenery	
Evolutionary processes	one of the world's best examples of a living analogue for the study of the nature and evolution of the earth's biosphere up until the early Cambrian outstanding examples of processes of biological and geomorphic evolution taking place in a largely unmodified environment… including: • evolution of the Bay's hydrological system • the hypersaline environment of Hamelin Pool • the biological processes of ongoing speciation, succession and the creation of refugia	
Geological significance	great geological interest due to the extensive deposit of limestone sands associated with the bank, formed by the precipitation of calcium carbonate from hypersaline waters	

(continued overleaf)

Table 2.1 *(cont.)* Attributes for Shark Bay, Western Australia derived from the Statement of Outstanding Universal Value (OUV), together with the assessed current condition and trend since inscription.

Attributes	Excerpts taken directly from Statement of OUV	Assessment of current condition indicated by colour-code
Botanical significance	located at the transition zone between two of Western Australia's main botanical provinces	Good ↗ Terrestrial
	a refuge for many globally threatened species of plants and animals.	Significant Concern ↘ Marine
Threatened species	the only or major populations of five globally threatened mammals, including … • the Burrowing Bettong (now classified as Near Threatened) • Rufous Hare Wallaby • Banded Hare Wallaby • Shark Bay Mouse • Western Barred Bandicoot	Significant Concern ↗
Marine Turtles	sheltered coves and lush seagrass beds are a haven for marine species, including Green Turtle and Loggerhead Turtle (both Endangered, and the property provides one of Australia's most important nesting areas for this second species	Good → Loggerheads Significant Concern ↘ Greens
Dugongs	one of the world's most significant and secure strongholds for the protection of Dugong, with a population of around 11,000	Good with some concerns →
	a large population of dugongs	
Whales and dolphins	Increasing numbers of Humpback Whales and Southern Right Whales use Shark Bay as a migratory staging post	Good ↗ Whales
	a famous population of Bottlenose Dolphin lives in the Bay	Good with some concerns ↘ Dolphins
Sharks and rays	Large numbers of sharks and rays are readily observed, including the Manta Ray which is now considered globally threatened	Good ↗
Integrity	impacts from pastoralism (grazing leases) and feral animals	Good with some concerns ↗
	ecosystems in Shark Bay appear relatively unaltered by human impact, although this could change if terrestrial mining of mineral sands were to take place	Good with some concerns →
	industrial activities such as salt and gypsum mining in the region, could comprise threats	Good with some concerns →
	marine environment has undergone some modification through historically intensive pearl shell, fishing, trawling and whaling activities	Good with some concerns ↗
	potential threats from: • improved technology in producing drinking water which would lead to increased tourism and residential density • upgrading of road access • agricultural developments to the east (dependent on water supply) • expansion of gypsum mining • introduction of intensive aquaculture or fishing technologies • petroleum exploration and extraction • unsustainable visitor use	Good with some concerns →

CURRENT CONDITION

Rating	Criteria
Good	The site's values are in good condition and are likely to be maintained for the foreseeable future, provided that current conservation measures are maintained.
Good with some concerns	While some concerns exist, with minor additional conservation measures the site's values are likely to be essentially maintained over the long-term.
Significant Concern	The site's values are threatened and/or may be showing signs of deterioration. Significant additional conservation measures are needed to maintain and/or restore values over the medium to long-term.
Critical	The site's values are severely threatened and/or deteriorating. Immediate large-scale additional conservation measures are needed to maintain and/or restore the site's values over the short to medium-term or the values may be lost.

TREND *(since inscription in 1991)*

→ STABLE ↗ IMPROVING ↘ DETERIORATING

2.5 Managing the World Heritage property

As a signatory to the World Heritage Convention, the Australian Government has a duty to identify, protect, conserve and transmit the WH values of properties to future generations (and if appropriate, rehabilitate those values). It also has primary responsibility for the development and implementation of national policy on World Heritage matters. A management agreement between the Australian and Western Australian (WA) Governments provides for management of the property to be carried out by the WA Government in accordance with Australia's obligations under the World Heritage Convention.

Implementation of policy and day-to-day management within Shark Bay is the responsibility of the Western Australian (WA) Government. The Department of Biodiversity, Conservation and Attractions (DBCA) - Parks and Wildlife Service (PWS) is the lead State Government agency for natural WH properties. Most of the on-ground responsibility is with the PWS; however, other State Government agencies (e.g., Department of Primary Industries and Regional Development, DPIRD) have significant responsibilities for managing fisheries and pastoral leases within the World Heritage area.

Local government also plays a role, with 60% of the WHA within the Shire of Shark Bay and 40% within Carnarvon Shire. These shires work with state agencies to maintain the World Heritage values of the area. Across these three levels of government there are several items of legislation for the protection and management of Shark Bay. Additionally, management is supported by the Shark Bay World Heritage Advisory Committee through a number of management and strategic plans. Together these bodies ensure effective management of the Shark Bay World Heritage property.

Shark Bay hosts a number of industries that influence management of the property, the most significant (in financial value) being tourism, fishing and salt production. The town of Denham is surrounded by the WH property and represents the largest permanent settlement in the bay. Several pastoral leases have been resumed by Government or purchased by privately funded conservation groups.

Management issues raised at the time of inscription included the control of human use through both zoning and designation of conservation areas, restrictions on public access to certain areas, the management of the trawl fisheries to protect values, the purchase of land for conservation use and increased staffing[5]. Since then, climate change has emerged as an additional potential threat to the World Heritage values.

2.6 Evaluation of current condition and trend of the World Heritage attributes

The workshop participants used the table of attributes that make up the OUV for Shark Bay to undertake a rapid assessment of the current condition and trend of these attributes since the time of inscription (Table 2.1). Section 5 provides a description of the CVI process and results for Shark Bay.

CITED REFERENCES

[1] *www.sharkbay.org/restoration/dirk-hartog-island-return-1616/*

[2] UNESCO (1972) Convention Concerning the Protection of the World Cultural and Natural Heritage. *https://whc.unesco.org/en/conventiontext/*

[3] UNESCO (2019) Operational Guidelines for the Implementation of the World Heritage Convention. *https://whc.unesco.org/en/guidelines/*

[4] Cath Roberts, Manager, Monkey Mia Reserve (pers. comm.).

[5] Advisory Body (IUCN) evaluation of Shark Bay nomination; *https://whc.unesco.org/document/153804*

[6] Thomson-Dans C. (2008) Shark Bay: Twin Bays on the Edge. Western Australian Department of Environment and Conservation.

Seagrass

SECTION 3. THE CONTEXT FOR SHARK BAY

3.1 Physical geography and landscape

Shark Bay is a complete marine ecosystem containing many important features, including: (i) the Wooramel seagrass bank; (ii) the Faure sill (which helps to limit water exchange with the open ocean and hence leads to hypersaline conditions in Hamelin Pool where the stromatolites are located); and (iii) ecosystems dominated by benthic microbial communities reminiscent of the beginnings of life on earth that flourish in the hypersaline embayment.

The geology is simultaneously ancient, modern and constantly changing. Land that was dry during the last ice age is now flooded. Sediments trapped by seagrass meadows have created barriers affecting salinity, tidal flow and ecosystems, and created WH values.

Shark Bay features colourful and diverse landscapes and seascapes with Peron Peninsula's red sand hills interspersed with salty hollows and rolling onto white beaches with clear waters. To the west, white dunes and rocky outcrops terminate with the Zuytdorp Cliffs plunging into the sea.

The seascapes and landscapes of Shark Bay are a significant visual resource value of the WH property. Features of significance include:

- exceptional coastal scenery with sea cliffs such as the Zuytdorp Cliffs and the dune formations of Dirk Hartog Island;
- extensive shell deposits of L'Haridon Bight and Hamelin Pool, Heirisson and Bellefin Prongs;
- wide sweeping beaches of sand and shells interspersed by rocky platforms, headlands, peninsulas and islands;
- low rolling hills interspersed with low, flat claypans or birridas, lagoons and coastal features of Peron Peninsula; and
- shallow bays, lagoons, channels, extensive seagrass meadows, coral, sand flats, mangroves and limestone reef.

The scale and lack of habitation in these landscapes add to their value.

These landforms must be managed to ensure that human activities and threatening processes do not have a negative impact on the integrity and scenic values of the property (Appendix 7). A detailed landscape study to identify and document the exceptional natural beauty and aesthetic qualities of the property was completed by the then WA Department of Conservation and Land Management in 2001[1,2]. This study also established objectives and guidelines for the management of these values.

3.2 Ecology

Shark Bay's four most significant attributes, recognised in the Statement of OUV, are its extensive seagrass beds, salinity gradient, stromatolites and species assemblages (including some species that are not found anywhere else in the world). More information about Shark Bay's significance is available on the Shark Bay World Heritage website[3].

The September 2018 CVI workshop explored the exposure to climate change of four of the key attributes.

- **Seagrasses** – Shark Bay has extensive seagrass beds. They cover more than 4,000 km^2 and produce 8 million tonnes of leaves annually. They are comprised of 12 species of seagrass, the greatest seagrass diversity in any one place on the planet. The most abundant species is *Amphibolis antarctica* (southern wireweed), which covers approximately 3,700 km^2 of the bay[4]. The seagrass meadows are the foundation of the marine ecosystem in Shark Bay. They provide food, shelter and nursery areas for many marine animals, including dugongs. The seagrass beds have also modified Shark Bay's geology and chemistry. Faure Sill is a massive seagrass bank that restricts tidal flow to Hamelin Pool, contributing to its hyper-salinity.

- **Salinity** – Shark Bay has a strong salinity gradient from marine to metahaline to hypersaline[4]. This is caused by a combination of the seagrass banks, high evaporation rates, shallow water and climate. Water in L'Haridon Bight and Hamelin Pool has almost twice the salt concentration of the open ocean. The high salinity conditions mean species like the cockleshell *Fragum erugatum* can flourish, leading to unusual phenomena such as Shell Beach, and the waters are relatively free of predators and competitors for salt tolerant species. The hypersaline Hamelin Pool Marine Nature Reserve is the only marine nature reserve in Western Australia.

- **Stromatolites** – The hypersaline environment of Hamelin Pool (and consequent absence of predators) has allowed salt-tolerant micro-organisms to thrive and form microbial mats, which are diverse and complex ecosystems. When these mats trap particles and create stone they become microbialites. Tall, layered microbialites are called stromatolites. The micro-organisms that built the stromatolites are similar to those found in fossil evidence of the first life on earth, around 3.7 billion years ago. The Shark Bay stromatolites are the world's most extensive and diverse system of living stromatolites.

- **Species** – Shark Bay is a transition zone between temperate, sub-tropical and desert zones, contributing to its significant biodiversity. The region has 145 known plant species at their northern limit and 39 known plant species at their southern limit. There are 98 species of reptiles and amphibians, a number of which are at the northern end of their range, and 230 species of birds. There is a rich and diverse range of marine megafauna and marine life, with around 10% of the world's dugong population as well as dolphins, sharks, rays, fish and turtles (including Australia's largest nesting colony of loggerhead turtles).

  The islands of Shark Bay also provide refuges for wild populations of endangered and threatened animals. There are over 120 isolated islands in Shark Bay. Bernier and Dorre Islands are nature reserves and are home to some species now found nowhere else in wild populations – banded hare-wallaby, rufous hare-wallaby (Mala), Shark Bay bandicoot (formerly named western barred bandicoot) and Shark Bay mouse. The islands are relatively free of feral cats, foxes and rabbits.

  Feral cats and introduced herbivores were declared eradicated from Dirk Hartog Island National Park in October 2018, making it the largest island (620 sq km) in the world to be freed of cats. This has led to the very successful introduction of banded and rufous hare-wallabies, translocated from Bernier and Dorre Islands. The wallabies will soon be joined by translocated populations of both the Shark Bay bandicoot and the dibbler. The native ash-grey and sandy inland mice are also thriving in the absence of feral cats and goats, which has resulted in a higher survival of offspring and increased vegetation, which provides both habitat and food.

Salutation Island is home to a thriving population of re-introduced greater stick-nest rats that, though once found throughout south and western arid Australia, became extinct on the mainland in the 1930s[5].

Species and communities that are already located at the limit of their climatic ranges are likely to be more vulnerable than those located well within their climatic range. The National Biodiversity and Climate Change Action Plan 2004-2007[6] details other species and communities that may be more vulnerable to climate change including those with:

- very limited or restricted climatic ranges;
- limited dispersal ability;
- very specialised habitat requirements; and
- small populations and/or low genetic diversity.

Within the Shark Bay World Heritage property there are a number of species and communities that are endemic or at or near the limits of their range[7] and that are likely to be particularly vulnerable to climate change.

Shark Bay's abundant animal diversity includes various mammals and reptiles, including endemic species and several recognised as endangered or threatened.

3.3 Economic context

Various industry sectors are active in the Shark Bay region. Several of these are directly associated with the WH property and the values for which it was inscribed. To assist workshop participants in evaluating vulnerability of the associated community, data on annual economic value, employment and dependence upon the WH property were compiled for key sectors (Table 3.1).

Fisheries: Commercial fishing is one of the most significant industries in Shark Bay and comprises some of the State's most valuable fisheries including the Shark Bay prawn and scallop fisheries. Combined, these fisheries typically have landed annual catches around $40-50 million (Table 3.1)[8]. Although invertebrates dominate the commercial catch (crabs and cockles are also harvested), a significant proportion of the State's pink snapper and whiting are also caught in Shark Bay[8]. The Department of Primary Industry and Regional Development (DPIRD) has statutory responsibility for and regulates fishing activity in Shark Bay. DPIRD has prepared several fisheries management papers for the area to guide fisheries management for sustainable resource use for commercial and recreational fishers.

Tourism: Tourism is synonymous with Shark Bay, drawing approximately 120,000 visitors annually and employing around 90 people[9]. They comprise international (28%) and interstate and domestic visitors (72%), who stay four nights, on average, and inject about $64m into the local economy (Table 3.1)[10]**.** The attractions for visitors include the significant and diverse range of natural values and features. As existing opportunities to view and experience the WH property are limited, nature-based tourism represents an opportunity for expansion as well as increasing community knowledge, understanding and enjoyment of the Shark Bay environment with minimal impact on the integrity of WH values.

Salt Production: Shark Bay salt production at Useless Loop and Useless Inlet was established in 1965, prior to the World Heritage inscription. At $40m, the economic value of the production is significant (Table 3.1)[11]. Salt production on the project site is undertaken in conjunction with the infrastructure maintenance, including upgrading

Table 3.1 Approximate Economic value, employed participants and World Heritage reliance.

SECTOR	APPROXIMATE VALUE	EMPLOYMENT	WH RELIANCE
Fishing	**$50m (landed catch)**	**306**	**High**
Tourism	**$64m (visitor spend)**	**90**	**High**
Government departments	**$8m**	**50**	**Low, Moderate & High**
Education and research		**150 (approx.)**	**Low, Moderate & High**
Mining	**$40m (approx.)**	**150 (approx.)**	**High**

of wharf facilities, dredging of the Denham channel and potential expansion. As the area had been highly modified and would not meet the natural criteria and integrity requirements, it was excluded from the inscribed property. This activity, and how it is managed, were deemed to not be a threat to the heritage values or integrity, despite some activities of the operation, such as dredging of the Denham channel and disposal of dredge spoils, occurring within the property.

Basic Raw Material: Basic raw materials extracted within the property include gravel, sand, limestone, gypsum and shell grit (known as coquina) and are used for construction and maintenance purposes. Other mineral resource exploration and development in the WH property would only be permitted if it were to be demonstrated that the activity was compatible with the protection of heritage values.

Pastoral use: A large area of land in Shark Bay is located within pastoral leases, making pastoralists important resource managers in the property. Areas of land from a number of pastoral leases within and adjacent to the property have been identified for conservation. Nanga and Dirk Hartog Island pastoral leases have been purchased; and parts of Yaringa, Murchison House, Carrarang, Tamala and Nerren Nerren pastoral leases have been added as a buffer for the property. A further nine pastoral leases are adjacent to the boundary of the WH property. Approximately 21% of the land area within the Shark Bay property is leased for pastoral purposes, totalling about 142,000 ha.

Other Resource Use: A number of smaller commercial industries use natural resources within the WH property including craftwood production, wildflower picking and seed collecting. Adjacent to the property in Carnarvon there is intensive and extensive horticultural operations, whilst on the Wooramel River there is a small horticulture operation. There is potential for other natural resource use industries to develop in the WH property. In addition, the Australian Wildlife Conservancy has acquired the Faure Island pastoral lease as a wildlife sanctuary. Activities that have the potential to impact on heritage values are subject to an environmental impact assessment process.

Services and Infrastructure: Services and infrastructure, such as roads, electricity, water, accommodation/housing, communications, waste disposal, and tourism developments are necessary to service the towns, pastoral leases and other businesses within and adjacent to the property. The provision of new services and infrastructure has the potential to impact on WH values, depending on location and type. Such impacts may include the clearing of vegetation, introduction of weeds, visual impacts and the destruction of important habitats.

Groundwater: Groundwater from the Carnarvon Artesian Basin aquifer provides an important water resource for the settlements of Denham, Useless Loop, Monkey Mia, Nanga and the pastoral leases within the property. While it is unlikely that the current level of extraction or usage of groundwater is impacting heritage values, any significant increase in extraction could potentially have an impact on the values.

3.4 Social and cultural context

The Malgana people are recognised as the first people of Shark Bay or 'Gathaagudu' (meaning 'two bays') and have native title over the immediate area. Shark Bay has been occupied for up to 30,000 years, based on material collected from the Peron Peninsula[12]. Malgana values include a suite of natural, cultural, social, historical, livelihood and ecological values that, although not well recorded by Europeans, provide a wealth of knowledge from millennia of living in Shark Bay[13].

The population in the Shire of Shark Bay was just under 1,000 people in 2016[14]. This includes those living in the town of Denham, at Monkey Mia, Useless Loop salt mining operation (closed town), several roadhouses and on pastoral leases. The resident population of Denham fluctuates between 700–750 people and can swell to around 2,500 during the tourist season in the winter months. Shark Bay has the highest proportion of residents aged 55 and over in Western Australia. Approximately 9% of the population of Denham identify as Indigenous (i.e., 60-65 people)[15]. A variety of factors have discouraged further human settlement in the Shark Bay region including remoteness, aridity, limited fresh water supply, high summer temperatures, limited medical facilities and the relatively high cost of energy[16]. Denham is one of the most racially tolerant towns in WA, which may derive from the influence of Chinese, Filipinos, Malays and Kupangers who came to Shark Bay for the pearling industry last century and the subsequent inter-ethnicity of the local population[17].

From quiet beginnings, the Shark Bay region has quickly become a premier tourism destination. Having been virtually cut off from the rest of Western Australia (WA) for decades, the sealing of 130 km of road from the North West Coastal Highway to Denham in 1986 brought with it an influx of visitors. There are potentially 6,000 beds available for visitors to the Shire, with Monkey Mia Resort having the capacity to accommodate up to 1,100 people.

Although the WH property has been primarily established because of the international significance of its natural values, Shark Bay has (in addition to its Indigenous heritage) European cultural values of both national and international significance. Historically, because it is the location of the earliest recorded site of European landfall on the WA coast, many early studies and collections were made by explorers, including some of the earliest records of Australia's native flora and fauna. In addition to several historic shipwreck sites, the site has non-indigenous cultural heritage associated with the pearling, fishing, pastoral and (guano) mining industry. The Shark Bay area has six historic listed sites on the Australian Heritage database[7].

During the WH inscription process, there was a vocal group among the local population who objected to WH designation for the area. Much effort was undertaken to increase public awareness of WH together with assurances that WH inscription would not affect sustainable commercial fishery, the existing solar salt works, appropriate tourism and continuing use of viable pastoral leases[16]. Many partners are now working together to manage this extraordinary location to educate locals and visitors about the reasons Shark Bay has been listed as a WH property and to ensure it maintains its significant values.

CITED REFERENCES

[1] CALM (2001) Shark Bay World Heritage Property Landscape Study: Resource Document, Department of Conservation and Land Management, Perth.

[2] CALM (2001) Shark Bay World Heritage Property Landscape Study: Summary Document, Department of Conservation and Land Management, Perth.

[3] www.sharkbay.org

[4] Nomination of Shark Bay, Western Australia to the World Heritage List (1990). https://catalogue.nla.gov.au/Record/2099917

[5] www.wildliferesearchmanagement.com.au/sticknest%20rats.html

[6] DEH (2004) National Biodiversity and Climate Change Action Plan 2004-2007. Department of the Environment and Heritage, Canberra. 52pp. www.deh.gov.au/biodiversity/publications/nbccap/pubs/action-plan.pdf

[7] McCluskey P. (2008) Shark Bay World Heritage Property Strategic Plan 2008-2020. Department of Environment and Conservation, Perth. 101pp.

[8] Gaughan D.J., Molony B. and Santoro K., eds. (2019) Status Reports of the Fisheries and Aquatic Resources of Western Australia 2017/18: The State of the Fisheries. Department of Primary Industries and Regional Development, Western Australia.

[9] Tourism Council WA (2016) The Western Australian Tourism Work Atlas. http://tourismworks.com.au/wp-content/uploads/2016/11/3060-TCWA-Tourism-Work-Atlas.pdf

[10] Tourism WA Strategy and Research (2019) Shire of Shark Bay visitor factsheet. Three year average – 2016/2017/2018. www.tourism.wa.gov.au/Publications%20Library/Research%20and%20reports/2018/LGA%20Profiles%202018/Shark%20Bay_2018%20Factsheet.pdf

[11] Information from the CEO, Shark Bay Salt (pers. comm.).

[12] Bowdler S. (1990) The silver dollar site, Shark Bay: An interim report. Australian Aboriginal Studies 1990(2): 60-63.

[13] Sutton A.L. and Shaw J.L. (2020) A Snapshot of Marine Research in Shark Bay (Gathaagudu): Literature Review and Metadata Collation (1949-2020). Prepared for the Western Australian Marine Science Institution, Perth, Western Australia.

[14] Australian Bureau of Statistics, 2016 census.

[15] Shire of Shark Bay/C. Cowell data.

[16] Advisory Body (IUCN) evaluation of Shark Bay nomination. https://whc.unesco.org/document/153804

[17] Australian Geographic (April–June 1989) There is no place on Earth quite like Shark Bay. Australian Geographic 14. www.australiangeographic.com.au/product/issue-14/

Wooramel Coast

SECTION 4. CLIMATE AND ITS INFLUENCE ON SHARK BAY

4.1 Current climate

Shark Bay has a semi-arid climate with hot, dry summers and mild winters. Shark Bay's annual average of daily maximum air temperature is 27°C (Denham, 1989-2018[1]). February is usually the hottest month with an average maximum of 32°C, although temperatures can exceed 40°C. July is the coolest month with an average maximum temperature of 22°C[1].

Average annual rainfall is around 225 mm (Denham, 1907-2018[1]), predominantly occurring during winter or associated with tropical cyclones. June has the highest average rainfall of 53 mm, while December is the driest month with rainfall averaging 2.5 mm[1].

This mild climate is paired with a sometimes intense southerly wind, especially between October and April. December is the windiest month with an average wind speed of 32 kph (17.5 knots, northern bay, 1988-2016)[2]. Cyclone season is from November to the end of April, although cyclones are not frequent. The seasonal pattern of weather is driven by the position of the subtropical ridge, which is typically around the latitude of Shark Bay in winter and moves to the south of Australia in summer (when the monsoon trough moves southward bringing summer rainfall).

Sea-surface temperature (SST) in Shark Bay typically ranges from below 20°C in late-winter (September) to around 26°C in summer (March) but can exceed 30°C, such as during the extreme marine heatwave of March 2011[3]. Summertime SST typically increases from the mouth of the bay towards land in both sections (separated by Peron Peninsula); in contrast, wintertime SST is typically warmer at the mouth than in shallow sections.

Circulation within Shark Bay is dominated by tides and wind, with influence from the southward flowing Leeuwin Current. Intrusions of oceanic water provide some exchange near the entrance but not further into the bay. Residence times near the mouth of the bay are considerably shorter than those farthest into the bay (~7 days cf. >30 days).

The high salinity environment of Shark Bay is a result of high evaporation rates, little freshwater input (low rainfall and run-off) and limited circulation. Hypersaline conditions in Hamelin Pool and L'haridon Bight are due to their separation from the main bay by the shallow Faure Sill, which allows sea water to flow in but restricts outflow. These waters are around twice as salty as the open ocean.

Other climate influences on Shark Bay include (i) the El Niño-Southern Oscillation (ENSO), in which the El Niño phase is linked with a slowed Leeuwin Current and cooler SST and the La Niña phase is linked with a stronger Leeuwin Current and warmer SST; (ii) the Indian Ocean Dipole, in which the positive phase has cooler SST and can have reduced rainfall, and the negative phase has warmer SST and can have enhanced rainfall; and (iii) the Madden-Julian Oscillation, which is a 30-60 day pulse of cloud and rainfall that influences the timing, development and strength of monsoon patterns, leading to enhanced rainfall.

Details of current climate for the Shark Bay region are available from the Australian Bureau of Meteorology (*www.bom.gov.au*).

4.2 Observed climate trends

Recent patterns in climate variables provide evidence of climate change.

Air temperature: The long-term trend in annual mean surface air temperature for the Shark Bay region has increased at around 0.1°C/decade since 1910[4]. In recent decades (1989-2018), the annual average of daily maximum air temperature at Denham has exceeded this rate, warming at 0.35°C/decade[1] (Figure 4.1-top). This has resulted in the annual number of days exceeding 30°C increasing by just under one per year (from 67 days averaged across 1989-1998 to over 87 days on-average for 2009-2018; Figure 4.1-top). The annual number of days exceeding 35°C has increased more slowly at just under one per decade (from 22 to over 25 days across the two periods; Figure 4.1-top).

Rainfall: At Denham, annual rainfall decreased by 4.6 mm/decade over the period 1907-2018[1]. Regional estimates of trend in annual rainfall around Shark Bay indicate a decrease of up to 20 mm per decade in recent decades (1970-2017)[4].

Wind: Wind speed (monthly-averaged) in the north of Shark Bay increased by 0.35 m/s per decade over the period 1988-2016[2] (Figure 4.1-bottom). Increases were greatest in January and February (over 0.6 m/s per decade), whilst July and August showed small trends (0.003 m/s and -0.096 m/s).

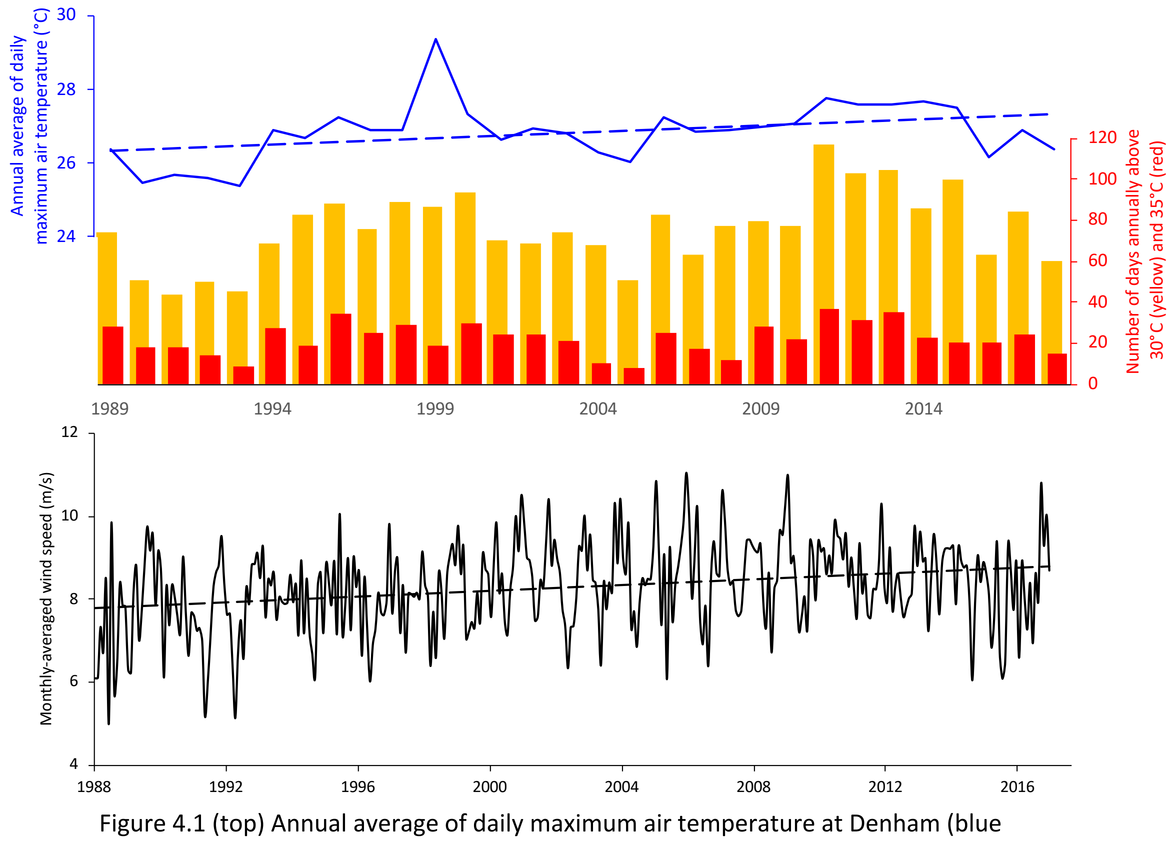

Figure 4.1 (top) Annual average of daily maximum air temperature at Denham (blue solid) for 1989-2018 with 30-year trend (blue dashed), together with number of days exceeding 30°C (yellow bars) and 35°C (red bars). (bottom) Monthly-averaged wind speed in the north of Shark Bay for 1988-2016 with 29-year trend (dashed).

Sea-surface temperature: The long-term trend in SST adjacent to the Shark Bay region was an increase of 0.04°C/decade (1854-2018;Figure 4.2)[5]. Recent decades of satellite temperature measurements show warming of 0.14°C/decade at the mouth of the bay and a slight cooling (-0.06°C/decade) in the southern Hamelin Pool[3] (Figure 4.2). Heat stress at the mouth of Shark Bay, as measured by the Degree Heating Week (DHW) metric, repeatedly exceeded the threshold linked to significant mortality from coral bleaching (8°C-week) during the satellite era[6].

Sea level change: Sea level in Shark Bay rose at a rate of 4.5 cm/decade over the period 1993-2018[7]. The context for this recent rate is an observed 1.6 cm/decade rise in sea level globally over the period 1880-2013[8].

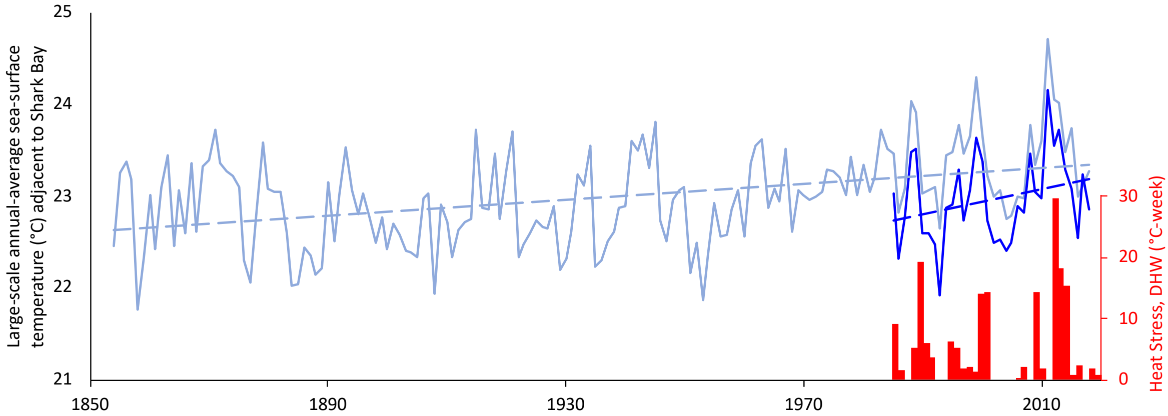

Figure 4.2 Annual-average sea-surface temperature and heat stress. Large-scale values (2° grid) adjacent to the Shark Bay region for 1854-2018 (light blue) complemented by satellite measurements from the mouth of Shark Bay for 1985-2018 (0.05° grid, blue). Trends for each are shown (dashed). Heat stress is given by the Degree Heating Week (DHW) metric for the satellite era (red bars).

4.3 Anticipated climate change

Global climate change and the Paris Agreement

Signed by 195 countries under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC), the 2015 Paris Agreement seeks to keep “the increase in global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels”[9]. According to the Intergovernmental Panel on Climate Change (IPCC), global average temperature is already 1°C warmer than pre-industrial times[10]. Rising temperatures are accelerating sea level rise, driving more intense and frequent extreme weather events, worsening drought and wildfires, and causing more damaging coastal flooding and storm surges. Warming oceans are causing coral bleaching and changes in the range and populations of fish species that provide benefits (such as food, income and coastal protection) for hundreds of millions of people.[6]

Climate projections for Shark Bay

Unless otherwise noted, climate change projections provided here are drawn from the “Rangelands (South)” sub-cluster of Australia’s national climate change projections[11], developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BoM) in 2015 and funded through the Commonwealth

Natural Resource Management project. These are drawn from the report[4] developed out of the initial CVI workshop (in September 2018) that summarised outcomes described in the Rangelands report[11]. Projections are reported for three emissions scenarios (representative concentration pathways, RCPs): RCP 2.6 – a mitigation (low emissions) scenario; RCP 4.5 – a stabilisation scenario; and RCP 8.5 – a business-as-usual (high emissions) scenario.

Temperature: Continued increase in temperature is projected (with very high confidence) to occur in all seasons. By 2050, warming is projected in the range 0.7-1.5°C for the low emissions scenario (RCP 2.6) and may be as high as 1.4-2.4°C in a high emissions scenario (RCP 8.5). A consequence of this warming is the projected increase in the number of days exceeding 35°C, continuing the observed trend in recent decades. In 2050, Denham is projected to experience 37 days each year above 35°C under the stabilisation scenario (RCP 4.5), or as many as 41 days each year under the high-emissions RCP 8.5 scenario. Approximately one third of each year is projected to have a daily maximum exceeding 30°C in 2050 (120 days for RCP 4.5; 129 days for RCP 8.5).

Rainfall: At Carnarvon, annual rainfall is projected to be 20-25% lower than 1995 levels in both stabilisation (RCP 4.5) and business-as-usual (RCP 8.5) scenarios throughout the 21st century. The consistency of these projections through time and across the emissions scenarios may reflect the lower level of certainty in this parameter. However, there is greater confidence in increased occurrence of extreme precipitation events, including in locations where total rainfall decreases.

Wind: Most models indicate little change in wind speed; however, there is limited confidence in these projections. There is some indication of increased wind speeds (by as much as 10%) in December-February.

Sea-surface temperature: Continued increase in SST is projected (with very high confidence) to occur. By 2030, ocean warming off Carnarvon is projected to be fairly consistent across the range of emissions scenarios (0.6-0.8°C), whilst warming in 2090 is more dependent upon the emissions scenario considered, with projections in the range 0.7-2.6°C (RCP 2.6-RCP 8.5). Severe heat stress, linked to significant mortality from coral bleaching, is projected to occur twice per decade from as soon as 2038, and annually from 2047 (RCP 8.5)[6].

Sea-level change: Sea level rise off Carnarvon is projected to continue through the 21st century. Increased sea level of 0.12-0.13 m in 2030, is projected to accelerate to 0.39-0.62 m by 2090, depending upon greenhouse gas emissions (RCP 2.6-RCP 8.5). Future sea level rise will largely be determined by the rate and extent of loss of the Greenland and Antarctic ice sheets.

Climate change in Shark Bay will likely translate into myriad impacts upon the natural heritage. These may include the effects of marine heatwaves on seagrass (which may have knock-on effects on marine fauna, as well as altering the stability of mechanisms that lead to the hypersaline environment of the stromatolites), impacts of reduced precipitation on terrestrial flora but also the potential for increased extreme rainfall events, and changes to air temperature that affect vegetation and turtle nesting.

CITED REFERENCES

[1] Data acquired from the Australian Bureau of Meteorology. *www.bom.gov.au*

[2] Data from the NOAA Blended Sea Winds product. *www.ncdc.noaa.gov/data-access/marineocean-data/blended-global/blended-sea-winds*

[3] Data from NOAA Coral Reef Watch's CoralTemp product. *https://coralreefwatch.noaa.gov*

[4] NESP Earth Systems and Climate Change Hub (2018) Climate change and the Shark Bay World Heritage Area: foundations for a climate change adaptation strategy and action plan, Earth Systems and Climate Change Hub Report No. 7, NESP Earth Systems and Climate Change Hub, Australia. *http://nespclimate.com.au/wp-content/uploads/2016/03/SBWHA-CC-workshop-report.pdf*

[5] Data from the NOAA Extended Reconstructed Sea Surface Temperature v5 dataset. *www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst-v5*

[6] Heron S.F., Eakin C.M., Douvere F., Anderson K., Day J.C., Geiger E., Hoegh-Guldberg O., van Hooidonk R., Hughes T., Marshall P., Obura D. (2017) Impacts of Climate Change on World Heritage Coral Reefs: A First Global Scientific Assessment. UNESCO World Heritage Centre. *https://whc.unesco.org/document/158688*

[7] Data from IMOS aggregated satellite altimeter.

[8] Data from CSIRO Reconstructed global mean sea level.

[9] *https://treaties.un.org/doc/Treaties/2016/02/20160215%2006-03%20PM/Ch_XXVII-7-d.pdf*

[10] IPCC (2018) Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Masson-Delmotte, V., et al. (eds.). 616pp.

[11] Watterson I., *et al.* (2015) Rangelands Cluster Report*, C*limate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports In: Ekström M., *et al.* (eds.). CSIRO and Bureau of Meteorology, Australia.

Shark Bay daisies at Big Lagoon

SECTION 5. APPLYING THE CLIMATE VULNERABILITY INDEX (CVI) TO SHARK BAY

The Climate Vulnerability Index (CVI) is a rapid assessment tool that has been specifically developed for application to World Heritage properties. The CVI framework builds upon the vulnerability framework approach described in the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)[1]. Vulnerability of OUV is determined by assessing the exposure, sensitivity and adaptive capacity with respect to determined climate stressors. The OUV Vulnerability becomes the exposure term to assess the vulnerability of the community associated with the property, combining with assessments of economic-social-cultural dependency (sensitivity) and adaptive capacity (Figure 5.1). A customised spreadsheet-based worksheet is used to determine outcomes based on user inputs. A more detailed outline of the CVI methodology is provided by *Day et al.*[2]. The process was undertaken during two workshops: OUV Vulnerability was assessed in September 2018, whilst Community Vulnerability was assessed in June 2019.

In September 2018, workshop participants from a range of backgrounds, the majority based in the Shark Bay region or regularly visiting there, worked through the following foundational steps:

- Determined the attributes for Shark Bay (Table 2.1) derived from the Statement of OUV (Appendix 1) and identified other SPVs (Appendix 6);
- Identified the three key climate stressors that would be most impactful on the Shark Bay OUV (see *Day et al.*[2]); and
- Identified the current condition and trend of the attributes of OUV (Table 2.1).

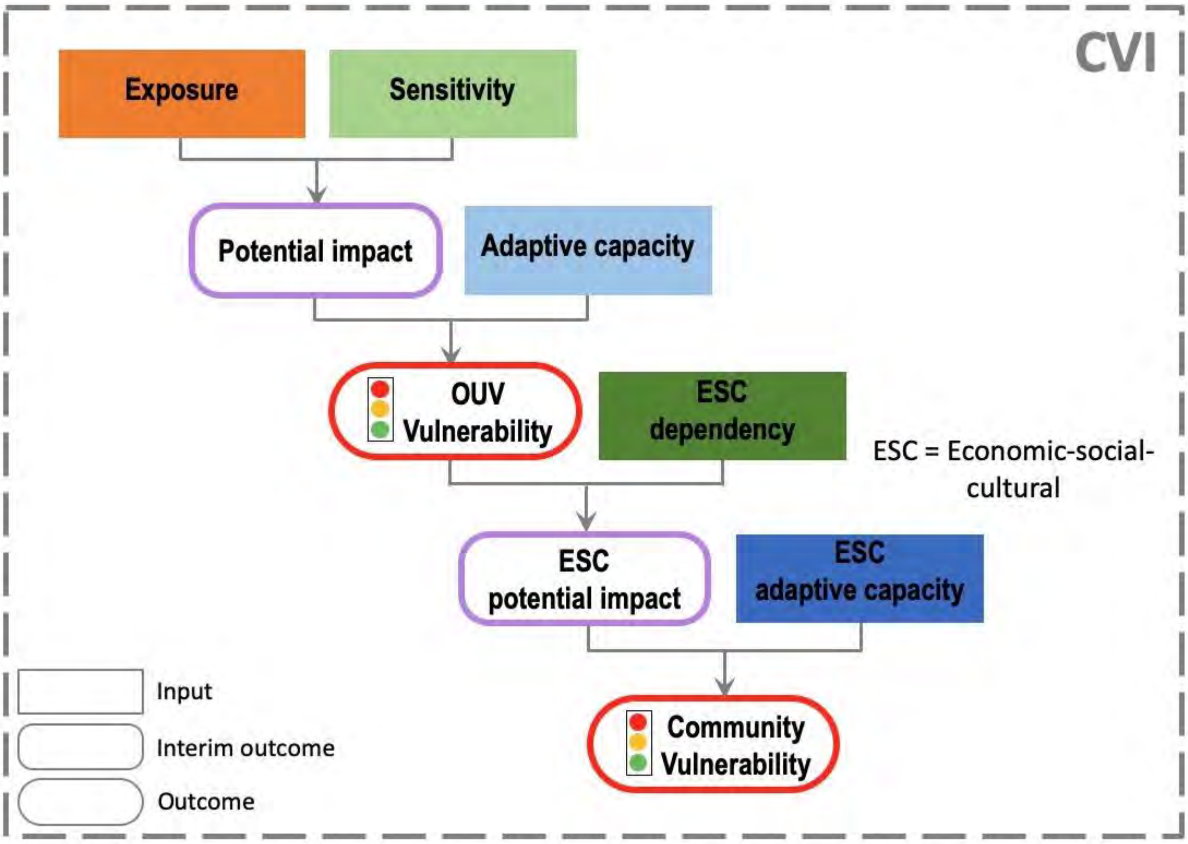

Figure 5.1 The CVI framework to undertake rapid assessment of climate change vulnerability of World Heritage properties and associated communities.

The following eight steps aligned with the CVI framework (Figure 5.1) were then applied to Shark Bay:

- Conducted a high-level risk assessment (**exposure** and **sensitivity**) to OUV of the chosen three key climate stressors within the agreed time frame (i.e., by 2050). This process also considered the influence of important **modifiers** that may vary these assessments;
- Used the spreadsheet-based worksheet to identify the **potential impacts** of the three key climate stressors on the attributes;
- Considered the likely **adaptive capacity** of OUV in relation to the three key climate stressors;
- Used the worksheet to determine the **OUV Vulnerability** to the three key climate stressors;
- Considered, and assessed separately, the relevant **economic**, **social** and **cultural dependencies (ESC)** upon the WH property;
- Used the worksheet to determine the **ESC potential impact** to the ESC dependencies upon the WH property;
- Considered, and assessed separately, the level of **ESC adaptive capacity** for the same ESC components considered above; and
- Used the worksheet to determine the **Community Vulnerability**.

The first four of the eight steps above were addressed in the September 2018 workshop and the latter four in June 2019.

5.1 Foundational steps

Excerpts from the Statement of OUV were compiled under 13 headings representing the attributes for the Shark Bay WH site (Table 2.1). These attributes (and the excerpts from which they were derived) had been distributed to participants before the workshop; participants confirmed the summation to 13 attributes was appropriate during the workshop.

Workshop participants considered which of the attributes of OUV may be of greater importance or priority than others. Seagrass was considered foundational to the other attributes and therefore of higher priority in evaluating climate vulnerability.

In addition to the values within the OUV, there are other local values of significance. Input to a list of other SPVs was sought from participants during the workshop. These were compiled for consideration during the workshop and future reference (Appendix 6); however, these values were not included in the final analysis that focused on the attributes.

A list of 13 climate stressors had been provided to participants before the workshop (Table 5.1). Definitions of these were clarified during the workshop and the likely magnitude and rate of change, as well as level of certainty in the predictions, were based on information provided by the CSIRO/NESP ESCC presentations augmented with other scientific outputs. During the workshop, the participants analysed which would be likely to have the most impact on each of the attributes of OUV (Table 5.1). The time scale selected by the workshop to consider impacts was ca. 2030-2050. The climate stressors appearing in the top three for each value (including equal-third) were used to rank the stressors (Table 5.1, Figure 5.2). From this, the three climate stressors likely to have greatest impact on the OUV were determined as:

- Extreme Marine Heat Events;
- Air Temperature Change; and
- Storm Intensity and Frequency.

Implicit within the methodology used to determine the three key climate stressors is an equal weighting across all attributes of OUV. When considering the comparative importance of attributes, participants confirmed these three stressors as most appropriate for the analysis. Examples of impacts identified from these stressors were seagrass die-off (Extreme Marine Heat Events), impacts on terrestrial flora and fauna, and turtle reproduction (Air Temperature Change) and turbidity increase during storm events (Storm Intensity and Frequency).

Table 5.1 Climate stressors identified as likely to have the greatest impact for each of 13 attributes of OUV. Marked cells indicate that the climate stressor was in the top three responses for each key value. Stressor impacts were assessed for ca. 2030-2050.

	Air Temperature Change	Change in Wind	Drought Frequency and Severity	Extreme Temperature Events	Humidity Change	Precipitation Change	Storm Intensity and Frequency	Water Temperature Change	Storm Surge	Extreme Marine Heat Events	Sea Level Change	Ocean Acidification	Changing Ocean Currents
Attributes of OUV	**Climate stressors**												
Seagrass							X			X			
Stromatolites		X					X						
Carbonate dominated marine environment							X			X			
Hypersaline waters	X							X					
Aesthetics							X		X		X		
Evolutionary processes			X	X		X							
Geological significance		X					X				X		
Botanical significance	X		X			X							
Threatened species	X		X			X							
Marine Turtles	X						X		X				
Dugongs							X			X			
Whales and dolphins							X	X		X			
Sharks and rays								X		X			
Total	4	2	3	1	0	3	8	3	2	5	2	0	0

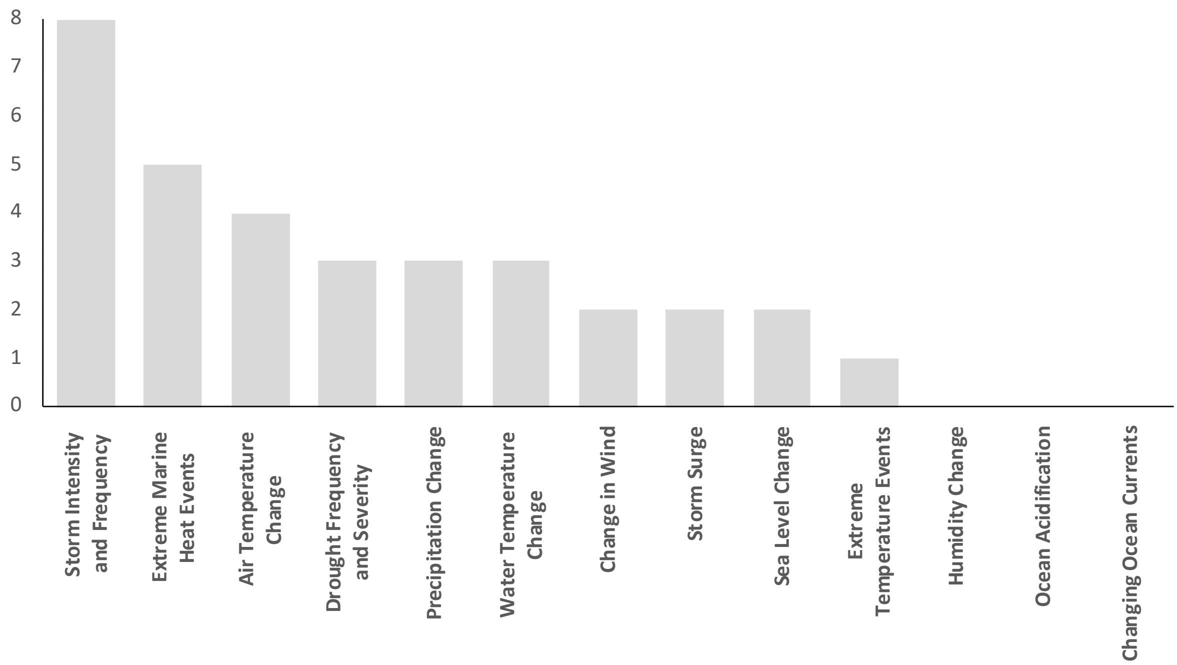

Figure 5.2 Histogram of impacts on 13 attributes of OUV from 13 climate stressors whose impacts were assessed for ca. 2030-2050.

5.2 OUV Vulnerability

For the identified three key climate stressors, assessments of **exposure** and **sensitivity** of the OUV system to each stressor were undertaken using a five-point categorical scale, adapted from categories used by IPCC[1] and IUCN[3] analyses (see *Day et al.*[2] for details). Modifiers were applied to the initial assessments to include effects of temporal scale and trend (for exposure), and spatial scale and compounding factors (for sensitivity). These assessments were undertaken in small breakout groups, which provided the potential for a range of responses that were then discussed in plenary to resolve the final selections.

Exposure to Air Temperature Change and Extreme Marine Heat Events were each determined as very likely (>90%), whilst exposure to Storm Intensity and Frequency was likely (67-90%). Sensitivity of OUV to Extreme Marine Heat Events was determined as very high, indicating potential for major loss or substantial alteration of the majority of key WH values, whilst sensitivity to Air Temperature Change and to Storm Intensity and Frequency were each determined as high, indicating loss or alteration of many key WH values will occur. Notably, the sensitivity of OUV with respect to Air Temperature Change was increased from the initial assessment (moderate) to the final assessment (high) through application of the modifiers (Table 5.2).

The **potential impact**, derived from exposure and sensitivity, was determined as extreme (on a four-point scale, low to extreme) for all three key climate stressors.

Table 5.2 Rapid assessment of OUV Vulnerability to identified three key climate stressors. Assessed values of exposure, sensitivity and adaptive capacity contribute to derived outcomes for potential impact and OUV Vulnerability. Colours refer to the elements of the CVI framework (Fig. 5.1).

Key Climate Stressors:	Air Temperature Change	Storm Intensity and Frequency	Extreme Marine Heat Events
Exposure	Very likely	Likely	Very likely
Temporal scale	On-going	Occasional	Intermittent
Trend	Slow increase	Slow increase	Slow increase
Exposure	**Very likely**	**Likely**	**Very likely**
Sensitivity	Moderate	High	Very high
Spatial scale	Very widespread	Extensive	Very widespread
Compounding factors	Medium probability	Medium probability	Medium probability
Sensitivity	**High**	**High**	**Very high**
Potential impact	**Extreme**	**Extreme**	**Extreme**
Local management response	Low	Low	Low
Scientific/technical support	Moderate	Moderate	Moderate
Effectiveness	Very low/negligible	Low	Very low/negligible
Adaptive capacity	**Very low**	**Low**	**Very low**
OUV Vulnerability	**High**	**High**	**High**
Combined OUV Vulnerability	**High**		

The capacity of a system to adapt to stress can mitigate (i.e., reduce) the potential impacts of that stress. **Adaptive capacity** of the OUV system was assessed for each key climate stressor by considering the levels of local management response and scientific/ technical support (four-point scale), as well as the effectiveness of these to address impacts from each stressor (four-point scale). For Storm Intensity and Frequency, the adaptive capacity was determined to be low (four-point scale, very low to high), whilst for Air Temperature Change and Extreme Marine Heat Events was very low.

OUV Vulnerability (three-point scale, low to high) was determined to be high for all three key climate stressors. The combined OUV Vulnerability for Shark Bay was determined as High (Table 5.2).

5.3 Community Vulnerability

Vulnerability of the community associated with the WH property was assessed in the June 2019 workshop through consideration of economic, social and cultural (ESC) components of dependency (i.e., the sensitivity term) and adaptive capacity:

- **Dependency** reflects the extent to which the key climate stressors will affect economic, social and cultural indicators in the future, using the previously defined time scale (i.e., ca. 2030-2050). Note that these effects may be positive or negative (four-point scale in each direction, high-negative to minimal-negative then minimal-positive to high-positive) in their nature (e.g., some business types may experience an increase in value under projected climate change).

- **Adaptive capacity** reflects the current level of capacity within each component to adapt in the face of the key climate stressors (four-point scale, minimal to high). Note that adaptive capacity only has a positive directionality.

Assessments were undertaken in small breakout groups, which again resulted in a spectrum of responses for each that was resolved in plenary.

A specific scenario was provided to participants to guide assessment of likely climate change impacts on the economic, social and cultural aspects. The selected scenario elements were (i) Extreme Marine Heat Events occurring five times per decade (based on projections of severe heat stress leading to coral bleaching in Shark Bay[4]); (ii) Air Temperature Change of+1 °C from present conditions; and (iii) doubling of frequency of severe storms.

The economic component includes only tangible (i.e., market or direct) economic effects on businesses that are directly dependent upon the WH property. These were grouped into six business types for assessment: Fishing; Tourism; Government departments; Education & research; Mining; and Non-government organisations. Pastoralism was considered as a possible business type during the assessment process but was deemed to be associated but not dependent upon the WH property. While assessments of economic dependency were undertaken for each group, recent data on economic valuation (Table 3.1) indicated that fishing, tourism and mining businesses predominate, and this was taken into consideration for the final assessment. Economic dependency was assessed as moderate-negative (i.e., a negative impact at a moderate level), whilst the adaptive capacity was low (Table 5.3).

Table 5.3 Rapid assessment of Community Vulnerability to identified three key climate stressors. Assessed values of economic, social and cultural (ESC) dependency (sensitivity, ranging from negative to positive) and adaptive capacity contribute to derived outcomes for ESC potential impact and Community Vulnerability.

Economic	Moderate-negative
Social	Moderate-negative
Cultural	Moderate-negative
ESC dependency	**[-] Moderate-negative [+]**
ESC potential impact	**High**
Economic	Low
Social	Low
Cultural	Moderate
ESC adaptive capacity	**Low**
Community Vulnerability	**High**

Intangible effects (e.g., social cohesion, aesthetics) were considered within the social and cultural components. An important distinction between these components is that social connections require a physical interaction with the property (i.e., visit), whereas cultural connections can exist without a physical interaction. For each component, three groupings of people were considered to assess dependency and adaptive capacity: local, domestic and international.

Social indicators used to inform the assessments can be considered within four categories: Human capital; Social capital; Natural capital; and Built capital (after *Costanza et al.*[5]). Social dependency was considered by the workshop to be predominated by local people and this was taken into consideration for the final assessment. Social dependency was assessed as low-negative, whilst the adaptive capacity was low (Table 5.3).

Cultural indicators can also be considered within four categories: Self-centric; People-centric; Environment- centric; and Pleasure-centric (after *Marshall et al.*[6]). Cultural dependency was considered by the workshop to be predominated by local people and this was taken into consideration for the final assessment. Cultural dependency was assessed as moderate-negative, whilst the adaptive capacity was moderate (Table 5.3).

Combining the three components, the overall ESC dependency was determined as moderate-negative, which, combined with the OUV Vulnerability (as the exposure term), resulted in the ESC potential impact being assessed as high (three-point scale, low to high; Table 5.3). The combined ESC adaptive capacity was assessed as low (three-point scale, low to high). These outcomes determined the Community Vulnerability as high (three-point scale, low to high; Table 5.3).

It is of note that the CVI process biases the analysis toward the greatest level of impacts, such as through selecting the three climate stressors considered to be most impactful. This is appropriate as the loss of integrity and/or authenticity of one component of OUV is contrary to the tenets of World Heritage, to preserve and maintain the site for the values described in the Statement of OUV. Furthermore, there will always be uncertainties in future impacts of projected climate change, and especially in how interactions between impacts may occur (synergistically, antagonistically, independently). Given both the high standard required within WH and the uncertainty of future impacts, the described bias within the CVI process is consistent with the precautionary principle[7].

5.4 Summary

Air Temperature Change, Storm Intensity and Frequency, and Extreme Marine Heat Events were identified as the three climate stressors likely to most impact the Shark Bay WH site. Potential impact from each of these key stressors was scored in the highest category (Extreme). With adaptive capacity to mitigate impacts being assessed as very low-to-low, the OUV Vulnerability was determined to be in the highest category (High). Impacts from the key climate stressors were judged as likely to lead to a negative future impact at a moderate level on the economic, social and cultural aspects of the community associated with the Shark Bay WH site, resulting in a high level of potential impact on the community. As the adaptive capacity of the community was determined to currently be at a low level, the overall Community Vulnerability was assessed to be in the highest category (High)

CITED REFERENCES

[1] IPCC (2007) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland.

[2] Day J.C., Heron S.F., Markham A. (2020) Assessing the climate vulnerability of the world's natural and cultural heritage. Parks Stewardship Forum 36: 144-153. *https://escholarship.org/uc/item/92v9v778*

[3] IUCN (2012). IUCN Conservation Outlook Assessments - Guidelines for their application to natural World Heritage Sites, Version 1.3. *www.iucn.org/sites/dev/files/import/downloads/guidelines___iucn_conservation_outlook_assessments_08_12.pdf*

[4] Heron S.F., Eakin C.M., Douvere F., Anderson K., Day J.C., Geiger E., Hoegh-Guldberg O., van Hooidonk R., Hughes T., Marshall P., Obura D. (2017) Impacts of Climate Change on World Heritage Coral Reefs: A First Global Scientific Assessment. UNESCO World Heritage Centre. 16pp. *https://whc.unesco.org/document/158688*

[5] Costanza R., Fisher B., Ali S., Beer C., Bond L., Boumans R., Danigelis N.L., Dickinson J., Elliott C., Farley J., Gayer D.E., Glenn L.M., Hudspeth T., Mahoney D., McCahill L., McIntosh B., Reed B., Abu Turab Rizvi S., Rizzo D.M., Simpatico T., Snapp R. (2007) Quality of life: An approach integrating opportunities, human needs, and subjective well-being, Ecological Economics 61: 267–276.

[6] Marshall N.A., Thiault L., Beeden A., Beeden R., Benham C., Curnock M.I., Diedrich A., Gurney G.G., Jones L., Marshall P.A., Nakamura N., Pert P. (2019) Our Environmental Value Orientations Influence How We Respond to Climate Change, Front. Psychol. 10: 938. doi: 10.3389/fpsyg.2019.00938.

[7] Kriebel D., Tickner J., Epstein P., Lemons J., Levins R., Loechler E.L., Quinn M., Rudel R., Schettler T., Stoto M. (2001) The precautionary principle in environmental science. Environmental Health Perspectives 109, No. 9. doi: 10.1289/ehp.01109871.

Loggerhead turtle, Dirk Hartog Island

SECTION 6. NEXT STEPS

6.1 Findings from the CVI process

The Shark Bay WH property was determined to have **High vulnerability** to the impacts of the three key climate stressors identified by the workshop participants. By 2030-2050, there is the potential for major loss or substantial alteration of the majority of the values that comprise the OUV of the WH property. Each of the key stressors was considered in terms of how it would be expressed (acute or chronic) and the degree of confidence in the predicted trend for the Shark Bay area (based on climate projections from CSIRO[1]).

OUV Vulnerability

The three key climate stressors identified to have the greatest potential impact on the heritage value of Shark Bay were:

Air Temperature Change: Chronic stressor (rather than acute; i.e. a continuous gradual increase in average air temperature), with a high level of confidence in the projection. Potential impacts from Air Temperature Change were considered to potentially impact on the process of evaporation and maintenance of hypersaline waters, create additional risks for flora (botanical significance) and fauna (threatened species) particularly at the extremes of their ranges; and have been noted to impact on reproduction of marine turtles through influence on sand temperature[2]. This led to the assessment of an Extreme level of potential impact on OUV from this stressor.

Storm Intensity and Frequency: Acute effects from storm intensity, but a chronic increase in frequency, with a moderate level of confidence in the projection. The high sensitivity of the OUV system to Storm Intensity and Frequency led to an assessment of potential impact at the highest level (Extreme). Attributes relevant to this stressor included seagrass, stromatolites and those describing marine megafauna. It was noted that the 2011 marine heatwave was concurrent with storm driven runoff that input large volumes of fresh, sediment laden water into the bay. The freshwater and sediment inputs are noted to impact seagrass.

Extreme Marine Heat Events: Acute effects from discrete events (such as was seen from the 2011 marine heatwave) with a moderate level of confidence in the projection. Loss of approximately 26% of seagrass during the marine heatwave of 2011 illustrated the magnitude of threat from this climate stressor, which extends to other attributes directly (various marine megafauna) and indirectly (e.g., altered water chemistry affecting the carbonate dominated marine environment; integrity of the biogeological Faure Sill and potentially affecting hypersaline waters and stromatolites). Damage from the event led to short term closures to crab and scallop fisheries. The ‘Very High’ likelihood of exposure combined with ‘Very High’ sensitivity, led to the assessment of potential impact on OUV from this stressor as Extreme.

Community Vulnerability
Economic, social and cultural aspects were determined to have a **High vulnerability**, derived from the high OUV Vulnerability, the economic dependence of key business types upon the property, the local population's connection with the property, and the assessed low level of adaptive capacity across the ESC components.

6.2 Gaps identified

The considerable research conducted in Shark Bay has produced a wealth of knowledge; however, key knowledge and management gaps identified through the workshops included:

*Research need*s

- Additional condition data is needed to understand specific requirements of stromatolites to continue to survive and grow in Hamelin Pool;
- Knowledge of linkages between marine water conditions, chemical processes, seagrass, and organo-mineralisation processes in carbonate dominated marine environment, and thresholds for impacts on key attributes of OUV;
- Defined thresholds for the protection of key elements of OUV;
- The effect of compounding and interacting factors;
- Consistent monitoring data relevant to OUV of Shark Bay;
- Impact of seagrass loss on integrity of Faure Sill and, therefore, hypersaline environment;
- Long-term variability of Faure Sill;
- Study of dolphin populations since 2014, to determine status since the reported decline to 2014;
- Better understanding of indigenous cultural and economic interactions with World Heritage values; and
- Assessment of overall economic value of Shark Bay WHA.

Policy and guidance gaps

- Should key strategy decisions be to (i) do the things we are capable of, (ii) develop capability for dealing with the most significant impacts, or (iii) develop capability for the impacts we are likely to be able to influence; and what assessment tools are needed to help make these investment decisions?
- Determine how to achieve the degree of alignment and integration of strategy, policy and actions required to ensure the required actions are embedded into agency plans and budgets and owned by the agencies;
- Prioritise and acquire resources for specific monitoring of World Heritage values;
- Address need for socio-economic long-term monitoring program (also for Ningaloo Coast WH property);
- Procure more information on cultural heritage aspects (indigenous and non-indigenous); and
- Consideration of climate vulnerability beyond World Heritage; i.e., effects on Significant Property Values (SPVs; Appendix 6).

6.3 Lessons for other properties

The CVI workshops for Shark Bay provided an opportunity for representatives of other WH properties from Western Australia to experience the process. Each workshop was attended by one or two delegates from the Ningaloo Coast property (Peter Barnes, Simon Woodley), the nearest WH property to Shark Bay and one that shares some similar aspects of natural heritage. The second workshop was also attended by Luke Donegan, a heritage conservation manager from Fremantle Prison (part of the Australian Convict Sites property), who was also the Chair of the Australian World Heritage Advisory Committee. Discussions continue with each of these properties for potential application of the CVI.

The success of the CVI application for Shark Bay demonstrated the value of the process for natural marine properties in identifying key points of vulnerability to climate change as well as opportunities to manage impacts to both the natural system and the associated community. In addition to WH, interest has been generated in applying the CVI to assist in the development of strategic planning and research for other locations of significance in Western Australia.

6.4 Revisiting the CVI process

The rapid assessment approach of the CVI means that it can be regularly repeated to determine if changes have occurred to the condition of attributes, or to the vulnerability of OUV and the community associated with Shark Bay. Re-assessment should follow any updated release of climate change projections or other relevant knowledge to provide current information for WH Periodic Reports (approximately every six years).

6.5 Wider applications

The application of the CVI methodology and process is of interest and relevance to those managing other heritage sites in Western Australia. In addition, other WH properties across Australia and potentially other properties across the globe may find this report particularly useful due to similarities in climate. Notably, due to the proximity to and degree of similarity with the Ningaloo Coast property, together with participation in the workshop by representatives of that property, outcomes here could inform vulnerability (though not to the extent that a dedicated application of the CVI would achieve).

The process is flexible and rigorous enough for much wider application and it is anticipated that others will find the format and process useful when considering the attributes and climate change challenges at heritage sites worldwide.

On the basis of its trial application at Shark Bay, the CVI has been demonstrated as a useful tool to apply more generally to WH properties to assess climate vulnerability and assist in identifying focus areas and gaps to address. The urgency of responding to climate change has recently been demonstrated through unprecedented impacts on Australian WH properties; e.g., significant coral mortality in the Great Barrier Reef and Lord Howe Island Group, and wildfires devastating large areas of the Blue Mountains, Gondwana Rainforests and Tasmanian Wilderness. More than ever there is a need for planning and funding response capabilities whilst also taking greater action to reduce greenhouse gas emissions and atmospheric concentrations responsible for climate change.

CITED REFERENCES

[1] NESP Earth Systems and Climate Change Hub (2018) Climate change and the Shark Bay World Heritage Area: foundations for a climate change adaptation strategy and action plan, Earth Systems and Climate Change Hub Report No. 7, NESP Earth Systems and Climate Change Hub, Australia. *http://nespclimate.com.au/wp-content/uploads/2016/03/SBWHA-CC-workshop-report.pdf*

[2] Fuentes M.M.P.B., Hamann M., Limpus C.J. (2010) Past, current and future thermal profiles of green turtle nesting grounds: Implications from climate change. Journal of Experimental Marine Biology and Ecology 383: 56-64.

Banded hare-wallaby

ACKNOWLEDGEMENTS

We are grateful for the contributions of various people and organisations upon which the success of the CVI workshops was built, including:

- Facilities for the workshops were provided by DBCA Parks and Wildlife Service, Shark Bay District (September 2018) and the Western Australian Marine Science Institution (June 2019).
- Funding support for the workshops was provided by the Australian Government Department of the Environment and Energy; Western Australian Department of Biodiversity, Conservation and Attractions; the NESP Earth Systems and Climate Change Hub; the Australian Marine Conservation Society; and the NASA ROSES Ecological Forecasting grant #16-eco4cast-0032 to the University of Hawaii.
- Thanks to the workshop participants (Appendix 5) who provided their time and expertise from a diverse range of perspectives.
- Background presentations were provided at the beginning of the first workshop by Luke Twomey, Cheryl Cowell, Therese Morris, Simon Allen and Scott Heron.
- Thanks to Alicia Sutton for her roles in the second workshop (and to WAMSI for support toward this) and for the subsequent collation of workshop notes.
- Thanks also to Ana Giraldo Ospina and Belinda Martin for assisting with the conduct of the second workshop.
- Sincere thanks to Christina Cameron for review comments on the report, and especially her critical insight regarding World Heritage terminology; and to Mandy Hopkins and David Karoly of CSIRO/NESP ESCC Hub for reviewing the climate information presented in Section 4.
- The Steering Committees formed for the workshops (indicated in Appendix 5) provided oversight for all preparations and arrangements to ensure success in applying the CVI process.

PHOTO CREDITS

Facing page i, Zuytdorp Cliffs – Rory Chapple, DBCA, Parks and Wildlife, WA
page ii, Big Lagoon – Cheryl Cowell, DBCA, Parks and Wildlife, WA
page 6, Stromatolites, Carbla – Cheryl Cowell, DBCA, Parks and Wildlife, WA
page 16, Seagrass - David Holley, DBCA, Parks and Wildlife, WA
page 19, Montage of animals: rufous hare-wallaby – Borrill; banded hare-wallaby – Brett Fitzgerald, DBCA; western blue-tongued lizard – Gary Warner; Shark Bay mouse – Jiri Lochman; West-coast laterite ctenotus – DBCA; woma python – Kathy Himbeck, DBCA
page 24, Wooramel Coast – Kirsty Dixon, DBCA
page 30, Shark Bay daisies at Big Lagoon – Rory Chapple, DBCA, Parks and Wildlife, WA
page 39, Loggerhead turtle, Dirk Hartog Island – Group 1 tagging team, Parks and Wildlife, WA
page 44, Banded hare-wallaby – DBCA, Parks and Wildlife, WA
page 46, Shell Beach – DBCA, Parks and Wildlife, WA


Shell Beach

APPENDIX 1: STATEMENT OF OUTSTANDING UNIVERSAL VALUE – SHARK BAY, WESTERN AUSTRALIA

(Below is the text of the approved SoOUV – it is also available at https://whc.unesco.org/en/list/578/)

Brief synthesis

On the Indian Ocean coast at the most westerly point of Australia, Shark Bay's waters, islands and peninsulas covering a large area of some 2.2 million hectares (of which about 70% are marine waters) have a number of exceptional natural features, including one of the largest and most diverse seagrass beds in the world. However it is for its stromatolites (colonies of microbial mats that form hard, dome-shaped deposits which are said to be the oldest life forms on earth), that the property is most renowned. The property is also famous for its rich marine life including a large population of dugongs and provides a refuge for a number of other globally threatened species.

Criterion (vii): One of the superlative natural phenomena present in this property is its stromatolites, which represent the oldest form of life on Earth and are comparable to living fossils. Shark Bay is also one of the few marine areas in the world dominated by carbonates not associated with reef-building corals. This has led to the development of the Wooramel Seagrass Bank within Shark Bay, one of the largest seagrass meadows in the world with the most seagrass species recorded from one area. These values are supplemented by marine fauna such as dugong, dolphins, sharks, rays, turtles and fish, which occur in great numbers.

The hydrologic structure of Shark Bay, altered by the formation of the Faure Sill and a high evaporation, has produced a basin where marine waters are hypersaline (almost twice that of seawater) and contributed to extensive beaches consisting entirely of shells. The profusion of peninsulas, islands and bays create a diversity of landscapes and exceptional coastal scenery.

Criterion (viii): Shark Bay contains, in the hypersaline Hamelin Pool, the most diverse and abundant examples of stromatolites (hard, dome-shaped structures formed by microbial mats) in the world. Analogous structures dominated marine ecosystems on Earth for more than 3,000 million years.

The stromatolites of Hamelin Pool were the first modern, living examples to be recognised that have a morphological diversity and abundance comparable to those that inhabited Proterozoic seas. As such, they are one of the world's best examples of a living analogue for the study of the nature and evolution of the earth's biosphere up until the early Cambrian.

The Wooramel Seagrass Bank is also of great geological interest due to the extensive deposit of limestone sands associated with the bank, formed by the precipitation of calcium carbonate from hypersaline waters.

Criterion (ix): Shark Bay provides outstanding examples of processes of biological and geomorphic evolution taking place in a largely unmodified environment. These include the evolution of the Bay's hydrological system, the hypersaline environment of Hamelin Pool and the biological processes of ongoing speciation, succession and the creation of refugia.

One of the exceptional features of Shark Bay is the steep gradient in salinities, creating three biotic zones that have a marked effect on the distribution and abundance of marine organisms. Hypersaline conditions in Hamelin Pool have led to the development of a number of significant geological and biological features including the 'living fossil' stromatolites.

The unusual features of Shark Bay have also created the Wooramel Seagrass Bank. Covering 103,000 ha, it is the largest structure of its type in the world. Seagrasses are aquatic flowering plants that form meadows in near-shore brackish or marine waters in temperate and tropical regions, producing one of the world's most productive aquatic ecosystems. Australia has one of the highest diversity of seagrasses globally, with 12 species occurring in the Bay.

Criterion (x): Shark Bay is a refuge for many globally threatened species of plants and animals. The property is located at the transition zone between two of Western Australia's main botanical provinces, the arid Eremaean, dominated by *Acacia* species and the temperate South West, dominated by *Eucalyptus* species, and thus contains a mixture of two biotas, many at the limit of their southern or northern range. The property contains either the only or major populations of five globally threatened mammals, including the Burrowing Bettong (now classified as Near Threatened), Rufous Hare Wallaby, Banded Hare Wallaby, the Shark Bay Mouse and the Western Barred Bandicoot. A number of globally threatened plant and reptile species also occur in the terrestrial part of the property.

Shark Bay's sheltered coves and lush seagrass beds are a haven for marine species, including Green Turtle and Loggerhead Turtle (both Endangered, and the property provides one of Australia's most important nesting areas for this second species). Shark Bay is one of the world's most significant and secure strongholds for the protection of Dugong, with a population of around 11,000. Increasing numbers of Humpback Whales and Southern Right Whales use Shark Bay as a migratory staging post, and a famous population of Bottlenose Dolphin lives in the Bay. Large numbers of sharks and rays are readily observed, including the Manta Ray which is now considered globally threatened.

Integrity
At time of inscription in 1991 it was noted that human impacts, while not as pronounced as in other World Heritage properties due to the property's relative remoteness, have had some effects including impacts from pastoralism and feral animals. The small, local centre of Denham, along with industrial activities such as salt and gypsum mining in the region, could comprise threats if not properly managed. Tourism and recreational boating also needs to be carefully managed. The marine environment has undergone some modification through historically intensive pearl shell, fishing, trawling and whaling activities. However, the ecosystems in Shark Bay appear relatively unaltered by human impact, although this could change if terrestrial mining of mineral sands were to take place. Other potential threats could be from improved technology in producing drinking water which would lead to increased tourism and residential density, the upgrading of road access, agricultural developments to the east (dependent on water supply), expansion of gypsum mining, and the introduction of intensive aquacultural or fishing technologies. Climate change could also impact on the complex marine ecosystem. While the property meets the required conditions of integrity and contains the components required to demonstrate all aspects of the natural processes, it is important that the property's management arrangements provide the framework in which these integrity issues can be monitored and addressed.

Protection and management requirements
The Shark Bay World Heritage property encompasses a number of different land tenures and thus a variety of statutory and management arrangements protect its values. At the time of nomination of the property, existing conservation reserves totalled approximately 200,000 hectares and mainly consisted of small island nature reserves, Bernier and Dorre Islands and the Hamelin Pool Nature Reserve. Specific suggestions to increase the conservation tenure boundaries included expanding the northern boundary of the Hamelin Pool Class A Marine Nature Reserve; extending the southern boundary of the terrestrial park on the northern end of the Peron Peninsula; the inclusion of the Gladstone Embayment in the Hamelin Pool Marine Nature Reserve; the extension of the northern boundary line of the Marine Park in the Denham Sound area; securing reserve status for Dirk Hartog Island and the incorporation of the southern part of Nanga pastoral station into the reserve system.

Since inscription, Francois Peron National Park (52,586 hectares), Shell Beach Conservation Park (517 hectares), Monkey Mia Reserve (446 hectares), Monkey Mia Conservation Park (5 hectares), Zuytdorp Nature Reserve (additional 58,850 hectares), Nanga pastoral lease (176,407 hectares), part

Tamala pastoral lease (56,343 hectares), South Peron (53,408 hectares), part Carrarang pastoral lease (18,772 hectares), Bernier, Dorre and Koks Islands Nature Reserves (9,722 hectares) and Dirk Hartog Island National Park (61,243 hectares) have been added to the conservation estate.

With the designation of the Shark Bay Marine Park (748,725 hectares) in 1990, incorporating the Hamelin Pool Marine Nature Reserve, the total formal conservation area of the World Heritage property is approximately 1.24 million hectares. In addition, the coastal portion of the Yaringa pastoral lease (19,396 hectares), part of Nerren Nerren pastoral lease (104,351 hectares) and part of Murchison House pastoral lease (37,578 hectares) have been added as a buffer. The Yaringa portion adjoins the Hamelin Pool Nature Reserve and in addition to having very high conservation value, is of strategic significance in bordering the World Heritage property.

A management agreement between the Australian Government and the State of Western Australia provides for management of the property to be carried out by the Western Australian Government in accordance with Australia's obligations under the World Heritage Convention. In addition, a comprehensive programme of management and administrative structures and planning processes has been implemented. Under the terms of the Agreement, a ministerial council and two advisory committees (scientific advisory and community consultative) were formed. The Shark Bay World Heritage Advisory Committee replaced the two previous Scientific Advisory and Community Consultative committees with a new committee consisting of community, scientific and Indigenous representatives. Owing to the diversity of land tenures and managing agencies and individual interests within the property, the *Shark Bay World Heritage Property Strategic Plan 2008-2020* was prepared to develop a partnership between governments and the community.

From July 2000, any proposed activity which may have a significant impact on the property became subject to the provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), which regulates actions that will, or are likely to, have a significant impact on World Heritage values. In 2007, Shark Bay was added to the National Heritage List, in recognition of its national heritage significance under the Act.

Management issues raised at the time of inscription included the control of human use through both zoning and designation of conservation areas, restrictions on public access to certain areas, the management of the trawl fishery to protect values, the purchase of land for conservation use, and increased staffing. Since then, climate change has emerged as an additional potential threat to the World Heritage values. Fire also represents a threat to species that are highly restricted in their distribution, particularly populations which only survive on islands which could be severely affected by a single large fire. Australia has introduced a range of measures at both the national, and property-specific, level to address these potential threats.

APPENDIX 2: SUMMARY LIST OF WORLD HERITAGE VALUES – SHARK BAY

Compiled by Cheryl Cowell

1. **Outstanding examples representing the major stages of the earth's evolutionary history.**
    - Stromatolites and microbial mats of Hamelin pool
    - Hamelin Pool and L'Haridon Bight
    - Holocene deposits adjacent to Hamelin Pool and L'Haridon Bight

2. **Outstanding examples representing significant ongoing geological process, biological evolution and man's interaction with his natural environment.**

Marine Environment

- Unique hydrological structure, banks and sills, steep salinity gradients, three biotic zones
- Faure sill
- Hypersaline environment of Hamelin Pool
- Microbial communities
- *Fragum eragatum* shell deposits
- High genetic biodiversity due to steep environmental gradients (e.g. snapper, venerid clams, bivalves)
- Seagrass meadows, and their role in the evolution of the marine environment
- Expanse of meadows and diversity of seagrass species
- Wooramel seagrass bank
- Carbonate deposits and sediments
- Northern limit of transition region between temperate and tropical marine environments, resulting in high species diversity (e.g., 323 fish species, 218 bivalve species, and 80 coral species)

Terrestrial Environment

- Botanical province transition zone, most pronounced in the southern parts of Nanga and Tamala Stations
- Range limits (145 plant species at northern limit, 39 species at southern limit, and 28 vascular plant species endemic)
- Isolation of fauna habitats on islands and peninsulas – five threatened mammals on Bernier and Dorre Islands
- Range limits and fauna species richness (100 species of herpetofauna – nine endemics; 230 species of birds representing 35% of Australia's total species)
- Species evolution illustrated in rufous hare-wallaby and banded hare-wallaby

3. **Superlative natural phenomena, formation or features, for instance, outstanding examples of the most important ecosystems, areas of exceptional natural beauty or exceptional combinations of natural and cultural elements.**
    - Stromatolites
    - Hypersaline environment of Hamelin Pool
    - Faure sill
    - Wooramel seagrass bank

- Coastal scenery of Zuytdorp cliffs, Dirk Hartog Island, Peron Peninsula and Heirisson and Bellefin Prongs
- *Fragum* beaches of L'Haridon Bight
- Inundated birridas and lagoons such as Big Lagoon
- Strongly contrasting colours of the dunes/cliffs, beaches and adjacent sea of Peron Peninsula
- Abundance of marine fauna (dugongs, dolphins, sharks, rays, turtles and fish)
- Annual wildflower season display

4. **The most important and significant natural habitats where threatened species of animals or plants of outstanding universal value still survive.**
    - Five of Australia's 26 endangered mammals (Shark Bay mouse, banded hare-wallaby, rufous hare-wallaby, Shark Bay bandicoot, and burrowing bettong)
    - Bernier Island subspecies of ash-grey mouse
    - Twelve threatened reptiles (e.g. Baudin Island skink and woma python)
    - Endemic sandhill frog
    - Thirty-five migratory bird species
    - Threatened thick-billed grasswren
    - Endemic Dirk Hartog subspecies of the southern emu-wren
    - Dugong (approx. one eighth of the world's population)
    - Humpback whale
    - Loggerhead and green turtles
    - Some threatened flora species

APPENDIX 3: OVERVIEW OF THE CVI WORKSHOPS IN SHARK BAY AND PERTH

The initial Shark Bay workshop (September 2018) was the first time the CVI had been applied and was used to assess OUV Vulnerability. The culmination of the CVI process, through assessing economic, social and cultural aspects, was subsequently undertaken (in June 2019) as the first application in a natural WH property.

Participants: The aim was for 20-25 participants, covering a broad range of relevant expertise areas. These included advisory committee members, property managers, government and academic researchers, representatives of non-government organisations and climate science experts (see full list at Appendix 5). The latter group, principally from the Earth Systems and Climate Change (ESCC) Hub of the National Environmental Science Programme (NESP), were critical to ensuring consistent understanding of historical and projected climate conditions. Limiting workshop numbers in this way ensured that small groups were of manageable number (four) and size (4-6 participants) whilst including a diversity of backgrounds and expertise (as far as possible, ensuring a similar mix across each group of background, experience and agency representation).

Workshop programme: The first workshop ran for two and a half days, plus a pre-workshop dinner and introductory event; the second workshop was completed within a single, albeit extended, day (Appendix 4 details the schedule). Each consisted of a mixture of plenary and **s**mall group sessions (with the latter reporting back to the subsequent plenary).

Workshop venues: The first workshop was mainly held in the offices of the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA) in Denham, with the plenary sessions held in the main conference room and small groups also dispersed across other conference facilities and offices. The pre-workshop introductory event was held at the Shark Bay Recreation Centre. The second workshop was held in the Indian Ocean Marine Research Centre (IOMRC) at the University of Western Australia (Perth). Plenary sessions were conducted in the board room, with small groups also dispersed across other meeting spaces and offices in the Centre.

Pre-workshop: Prior to the first workshop, documents distributed to participants for preparation were: (i) identified attributes derived from the Statement of OUV; (ii) identified other SPVs (i.e., non-OUV values that have local, regional or national significance); (iii) a summary of climate change stressors that could result in impacts on the OUV; and (iv) an outline of the workshop schedule. Prior to the second workshop to assess Community Vulnerability, the initial report from the first workshop[1] was distributed, as was the workshop schedule that included a proposed scenario for considering economic-social-cultural impacts.

Climate science: Information on historical and projected climate conditions was provided during the workshop by representatives of the ESCC Hub of the NESP. This information was critical to ensuring consistent understanding of relevant climate stressors, as reflected in the initial report from the first workshop[1].

Main outcomes from the workshops: Vulnerability assessments of OUV (High) and the associated community (High), as well as the interim outputs determined through the process, were key outcomes from the workshops. As the first application of the CVI methodology to assess OUV Vulnerability, the first workshop demonstrated the success of and potential for the approach. Useful feedback was provided during and after the workshop on ways to strengthen and improve the methodology (e.g., improved terminology; dynamic workshop processes). The second workshop to assess Community Vulnerability benefited from learnings of the application in Orkney, which occurred between the two Shark Bay workshops. Learning and feedback from the second Shark Bay workshop has again led to improvements for subsequent applications of the CVI process.

Success factors identified: The success of the workshops can be attributed to many things, including:

- the collaboration of the organisers in testing and refining (including while underway) the CVI methodology;
- the coordination by organisers/steering committee via regular conference calls in the lead up to each workshop;
- preparation of climate change history and projections by the CSIRO participants;
- compilation of economic data for business types associated with the property;
- small group break-out sessions effectively collected information, which then stimulated discussion and final decisions in plenary; and
- the CVI developers acted as independent facilitators and maintained momentum throughout the workshops.

Post-workshop: The outcomes from the workshop were presented during a side-event of the 2019 WH Committee meeting (43COM) in Baku, Azerbaijan, as well as at the associated Site Managers Forum and World Heritage Watch forum. The CVI project team – led by James Cook University – are following-up with other WH properties and national agencies that are interested in hosting CVI workshops, including the tri-national Wadden Sea (Netherlands/Germany/Denmark), Vega Archipelago (Norway), Wet Tropics of Queensland and Fraser Island (Australia), Belize, Palau and Saudi Arabia.

---

[1] NESP Earth Systems and Climate Change Hub (2018) Climate change and the Shark Bay World Heritage Area: foundations for a climate change adaptation strategy and action plan, Earth Systems and Climate Change Hub Report No. 7, NESP Earth Systems and Climate Change Hub, Australia. *http://nespclimate.com.au/wp-content/uploads/2016/03/SBWHA-CC-workshop-report.pdf*

APPENDIX 4: AGENDA FOR CVI WORKSHOPS

OVERARCHING GOAL

To lay the foundations for the development of a Climate Change Adaptation Strategy and Action Plan for the Shark Bay World Heritage Property using a rapid assessment tool (Climate Vulnerability Index).

Outline of the first CVI workshop in Shark Bay, Western Australia
16-19 September 2018

Sunday 16 September (pre-workshop)
6:00pm-9:00pm, Shark Bay Recreation Centre

Dinner and background presentations describing community and economic aspects, and the marine heatwave event of 2010-11 (Luke Twomey, Cheryl Cowell, Therese Morris, Simon Allen, Scott Heron).

Monday 17 September (Day 1)
8:30am-12:30pm, DBCA Offices

Introduction.

1. Overview of aims and introduction to key concepts of the workshop, use of plenary and small-group sessions, logistics (toilets, lunch, etc.).

AIM 1: Understand the significant values that comprise the Outstanding Universal Value (OUV) plus the other significant (but non-OUV) values for Shark Bay.

2. In plenary, present OUV and values tables.
3. Ensure all participants are aware of the Statement of OUV for Shark Bay (Attachment 1) and how Table 1 was derived from the SoOUV.
4. Ask participants to check/confirm that Table 2 comprises other attributes of significance to Shark Bay (Attachment 2), and ensure they understand the distinction between Tables 1 and 2.

AIM 2: Agree on consistent terms to describe CC stressors. Discuss the list of CC stressors and their potential to impact the values of Shark Bay.

5. In plenary, show list of CC stressors. Check: (i) missing? (ii) understanding? (iii) timescales? Briefly introduce IPCC scenarios. Do example together of brainstorming key CC stressors impacting ONE value from Table 1. Discuss stressor linkages, cascading impacts.
6. Using the list of CC stressors as agreed above (#5), ask participants in small groups to brainstorm what are the key CC stressors likely to impact the values in Tables 1 and 2. Split OUV and non-OUV lists of values between groups.
7. Bring outputs from #6 back to plenary and ensure all participants agree on which CC stressors have the greatest potential to impact the values in Tables 1 and 2.

Monday 17 September (Day 1)
1:00pm-5:00pm, DBCA Offices

AIM 3: Discuss possible future CC scenarios facing Shark Bay.... and agree to consider two scenarios for future of Shark Bay ('Business as Usual' and 'Paris Agreement')

8. Understanding climate variability, extremes and change. Current, changing and future climate of the Shark Bay World Heritage Area. Projections for business-as-usual and Paris scenarios (Presentation by Vanessa Hernaman, CSIRO).
9. Provide overview of CC scenarios and what they might mean for Shark Bay – stromatolites for example. Ensure all participants understand the two scenarios being proposed for further consideration in the workshop.

AIM 4: To provide focus, conduct a high-level risk assessment (likelihood and consequence) of all CC stressors impacting the values (prioritising the OUV) of Shark Bay – identifying the stressors representing the highest risks to OUV… and then prioritising those risks.

10. In plenary, introduce likelihood and consequence categories, as well as the risk matrix that combines these. Do example together for one OUV value from Tables 1 and 2.
11. Participants in small groups to assess the risk (i.e., the likelihood and consequence) of the key CC stressors which will impact the values in Tables 1 and 2 using a risk assessment matrix - do this for both scenarios (as agreed in 7) with the objective to determine which are High or Extreme risks under both scenarios.
12. Bring outputs from #11 back to plenary and ensure all participants agree on the risk levels caused by CC stressors impacting upon the values in Shark Bay (i.e., in both Tables 1 and 2). After consideration of both scenarios, then prioritise all the risks.

Tuesday 18 September (Day 2)
8:30am-12:30pm, DBCA Offices

AIM 5: Commence development of diagrams of key CC stressors impacting the highest risk values of Shark Bay.... and then determine what are the related physical, ecological, economic and social impacts

13. In plenary, show blank worksheet that links CC stressors to physical, ecological, economic and social impacts. Do example for ONE identified key CC stressor (High or Extreme risk).
14. Participants in groups develop diagrams of the values assessed as High or Extreme risk, for only the values that comprise OUV. Plot the key CC stressors and determine the related physical, ecological, economic and social impacts (using Worksheet at Attachment 3).
15. Repeat #13 in small groups, for the High or Extreme risk non-OUV values.
16. Bring outputs from #14 and #15 back to plenary and get consensus from all participants on the physical, ecological, economic and social impacts on values of Shark Bay (i.e., endorse final versions of Worksheet at Attachment 3).

Tuesday 18 September (Day 2)
1:00pm-5:00pm, DBCA Offices

AIM 6: Discuss proposal for Climate Vulnerability Index (CVI) and test its applicability using Shark Bay as a case study

17. In plenary, provide full overview of CVI concept, followed by questions.
18. Participants in plenary work through CVI worksheet under a 'Business as Usual' scenario, getting consensus on relative scores.
19. Participants in small groups work through CVI worksheet under a 'Paris Agreement' scenario.
20. Bring outputs from #19 to plenary, raising any issues about the worksheet/process.

AIM 7: Discuss possible adaptation strategies to address the priority impacts.

21. In plenary, conduct discussion on adaptation – what it is, how to plan for it.
22. Participants get consensus on the priority impacts and discuss possible adaptation strategies for those that are agreed as High or Extreme vulnerability.
23. What climate change science information is needed for risk assessment?

Wednesday 19 September (Day 3)
8:30am-11:00am
DBCA Offices

24. Review of Workshop Outcomes.

Outline of the second CVI workshop in Perth, Western Australia
10 June 2019, University of Western Australia

Monday 10 June (Day 1)
8:30am-12:30pm

1. Overview of workshop aims, use of plenary and small-group sessions, 'parking lot', logistics (toilets, coffee-breaks, etc.).
2. Introductions by participants (<1 min max/person).

AIM 1: Ensure all participants understand the CVI framework and how the OUV Vulnerability was derived at the previous workshop

3. In plenary, provide brief overview of CVI framework.
4. Recap on previous CVI workshop (Sept 2018) – results up to the assessment of OUV vulnerability.
5. Undertake current condition and trend assessment of key aspects of OUV.

AIM 2: Ensure participants understand the scenario to be used during remainder of the CVI assessment

6. In plenary, discuss scenario for use in ESC discussion (using same timescale as previously: 2030-2050):
   a) Extreme marine temperature events: 5/decade (determined using coral report analysis for RCP8.5).
   b) Doubling of frequency of severe storms.
   c) Air temperature increase: 1°C.

AIM 3: Consider economic, social and cultural dependencies (sensitivity) and adaptive capacity, to determine Community Vulnerability

7. In plenary, discuss businesses directly dependent upon WH property.
8. Outline process for analysing economic, social and cultural dependency, including the socio-economic potential impact matrix that combines these.
9. Participants in small groups assess the economic dependency.

Monday 10 June
1:15pm-5:30pm

AIM 3 (cont.)

10. Bring outputs from #9 back to plenary and discuss any variation in assessments of and finalising economic dependency.
11. Participants in small groups assess the social and cultural dependency.
12. Bring outputs from #12 back to plenary and discuss any variation in assessments of and finalising social and cultural dependency (thus determining socio-economic potential impact).
13. Revisit process for analysing economic, social and cultural adaptive capacity.
14. Participants in small groups assess the ESC adaptive capacity for the property.
15. Bring outputs from #14 back to plenary and discuss any variation in assessments of and finalising adaptive capacity (thus determining Community vulnerability). Examine any effect of these on Community vulnerability.

AIM 4: Summary, feedback and next steps

16. In plenary, summarise outcomes from workshop, following final analysis worksheet.
17. Recap on any items that had been 'parked' during the workshop.
18. Conduct workshop evaluations; other feedback from participants. Receive feedback on CVI framework and workshop process.

APPENDIX 5: LIST OF PARTICIPANTS IN THE CVI WORKSHOPS

September 2018 workshop – OUV Vulnerability (Steering Committee members indicated by *)

PARTICIPANT	ORGANISATION	EXPERTISE
Simon Allen	UWA	Dolphins
Peter Barnes	DBCA Marine	Ningaloo Marine Park
Kim Branch	DBCA	Nature Conservation
Patrick Cavalli	DPIRD Fisheries	Fisheries
Arani Chandrapavan	DPIRD Fisheries	Fisheries
Cheryl Cowell*	SBWHAC	WHA OUV/Shark Bay
Vanessa Hernaman	NESP ESCC Hub	Climate change
Scott Heron*	NOAA Coral Reef Watch	CVI developer – co-facilitator
Mandy Hopkins	NESP ESCC Hub	Climate change
Alan Kendrick	DBCA Marine Science Program	Marine science
Elisabeth McLellan	Bush Heritage, SBWHAC member	Conservation/landscape manager
Therese Morris	Ex-SBWHAC member	Sedimentology
Steve Nicholson	DBCA, District Manager	Shark Bay
Karen Pearce	NESP ESCC Hub	Science communication
Phil Scott*	SBWHAC member, environmental consultant	WHA OUV – co-facilitator
Luke Twomey	WAMSI, CEO	Marine science
Ricky Van Dongen	DBCA, research officer	Remote sensing
Diana Walker	SBWHAC member, research scientist	Seagrass
Shaun Wilson	DBCA senior research scientist	Marine science
Simon Woodley	NCWHAC member	Ningaloo Coast WHAC Chair

June 2019 workshop – Community Vulnerability (Steering Committee members indicated by *)

PARTICIPANT	ORGANISATION	EXPERTISE
Will Alston	Oyster industry	Industry
Paul Anderson	CEO, Shire of Shark Bay	Local Government
Juliane Bush*	SBWHAC member, GDC	Tourism
Patrick Cavalli	DPIRD Fisheries	Fisheries
Arani Chandrapavan	DPIRD Fisheries	Fisheries
Cheryl Cowell*	SBWHAC project officer	WHA OUV/Shark Bay
Jon Day*	James Cook University	CVI developer – co-facilitator
Geoff Diver	Scallop/seafood industry	Industry
Luke Donegan	Heritage Conservation Manager, Fremantle Prison	Cultural WH
Matthew Fraser	UWA Oceans Institute	Marine
Ana Giraldo Ospina	UWA	Marine ecology
Sue Graham-Taylor	WA Museum, former SBWHAC member	Culture/history
Scott Heron*	James Cook University	CVI developer – co-facilitator
Gary Jackson	DPIRD Fisheries	Marine
Belinda Martin	UWA	Marine science
Elisabeth McLellan	Bush Heritage, SBWHAC member	Conservation/landscape manager
Lenore Morris	DoEE	Australian World Heritage
Phil Scott*	SBWHAC member, environmental consultant	WHA OUV
Jenny Shaw*	WAMSI Research Director	Marine science
Elizabeth Sinclair	UWA Oceans Institute	Seagrass research
Luke Skinner	DBCA Marine Park Co-ordinator	Marine park management
Alicia Sutton	WAMSI	Marine science
Diana Walker*	SBWHAC member, research scientist	Seagrass

Workshop participants, September 2018

APPENDIX 6: LIST OF PROPERTY VALUES THAT ARE LOCALLY, REGIONALLY OR NATIONALLY SIGNIFICANT FOR SHARK BAY

Broad groupings of values	Significant Property Values (SPVs)
Marine values	Macroalgae
	Bony fish (including Snapper)
	Seabirds
	Marine invertebrates
	Mangroves
	Soft sediments
	Corals
	Sea snakes
Terrestrial values	Islands
	Saltmarsh
	Wildflowers
	Heathland/shrubland
	Grass/ sedgelands
	Birds
	Reptiles
	Other mammals
	Terrestrial invertebrates
	Birridas (salt pans)
	Ark for fauna conservation
Other key natural/chemical processes	Ocean currents
	Sedimentation
	Sea level
	Sea temperature
	Ocean acidity
	Microbial processes
	Primary production
	Connectivity
Marine invasives or disease	Marine disease outbreaks
	Algal blooms
Terrestrial invasives or disease	Introduced species
	Disease
Indigenous values	Cultural practices, observances, customs lore, culturally significant species
	Sacred sites, sites of particular significance, places important for cultural tradition
	Stories, song-lines, totems and language
	Archaeology, Indigenous structures, technology, tools
Other heritage values	Historic shipwrecks
	Historic structures and activities e.g guano, whaling, pastoral
	Places of historic significance (Dutch, English and French etc)

Broad groupings of values	**Significant Property Values (SPVs)**
Community values	Tourism/
	Recreational 4WD
	Beachside camping
	Income
	Employment
	Recreational boating
	Personal connection/space
	Health benefits
	Aesthetics
Economic	Commercial seafood (prawns, scallops and cockles)
	Other commercial fishing (especially Whiting and Snapper)
	Tourism
	Salt production
Other values	Weather in winter (escape cold and wet)
	Cultural – a place for passing on the knowledge and experience
	Living laboratory for research

APPENDIX 7: AESTHETICS OF THE SHARK BAY WORLD HERITAGE PROPERTY

Table A7.1 Aesthetics of the Shark Bay World Heritage property.

Extent	Statement of OUV excerpt	Environmental attributes	Experiential attributes	Special places
Marine Park	*Fragum erugatum* shell deposits	Fragum beaches of L'haridon Bight and Hamelin Pool. Hamelin Cockle – green algae lives within cockle's mantle and gills, shallow waters mean lots of sunlight for algae	Accumulated shells on sea floor, washed ashore continuously. Shells built up to form spectacular white beaches of cockle shells. Shells have compacted together to form coquina rock	Shell Beach, Hamelin Pool, L'haridon Bight Sanctuary Zone, Hamelin Pool shell quarry
	Seagrass meadows – Wooramel Bank, evolution of marine environment, carbonate deposits and sediments	Extensive seagrass meadows and diversity of species have played major role in evolution of marine environment. Seagrass beds directly influence physics, chemistry, biology and geology of the Bay.	Beautiful seagrass patterns. Areas exhibiting a mosaic of shades due to shallow sandbars, intertidal flats or seagrass banks.	Faure Sill Scenic, aerial vistas – throughout Shark Bay Marine Park
	Shallow bays, lagoons, channels, coral, sand flats, mangroves and limestone reef. Hydrological structures, hypersaline, high genetic diversity	Shallow bays, seagrass banks, low rainfall and high evaporation help create hypersaline environment – climatic and geographical conditions.	Saline creeks and estuaries are lined with mangroves plus brilliant contrasts along the beaches, where white sand meets red desert dunes.	Guichenault Point spit Mangrove communities Dubaut Point and creek Petit Point
	Shark Bay Island nature reserves, plus 30+ other small islands, islets and rocks which are unallocated Crown land.	Conservation of flora and fauna. Natural values of significance also provide important seabird habitats.	Possess significant scenic qualities	Freycinet, Double, Sunday, Pelican, White, Salutation, Baudin, Egg, Three Bays, Wilds, Mary Anne, North Guano, South Guano, Charlie and Friday, Faure, Bernier and Dorre Islands
Nanga and Tamala	Botanical province – tree heath, temperate and tropical botanical zone transitions. Coastal landscapes	South-west climatic zone and desert meet at base of Peron Peninsula and Edel Land. 820 plant species – more than 24% at northern range limit. Algal mats	Possible to stand in a tree heath surrounded by south-west banksias, grevilleas, melaleucas and eucalypts and see desert's spinifex plains.	Petit Point Nanga Peninsula
Coastal	Zuytdorp cliffs Steep Point	Major recent geological event in Shark Bay - formation of Zuytdorp Cliffs. More than 200 km in length. Longest fault scarp in Australia	Steep cliffs and dissected slopes. Diverse coastline edges with platforms, beaches and headlands	Zuytdorp Cliffs Steep Point, Shelter Bay, False Entrance, Thunder Bay blowholes
Hamelin Pool	Stromatolites and microbial mats. Holocene deposits	These 'living fossils' represent a major stage in the Earth's evolutionary history. They are the first ever recorded living examples of structures previously found only as fossils in ancient rocks. These modern stromatolites help explain the role of microbes in the evolution of the Earth's biosphere. The sediment layers reflect changes in the Earth's axis and orbit around the sun.	Demonstrated evolution and geographical history in action Opportunity to commune with history	Hamelin Pool Marine Nature Reserve

Table A7.1 *(cont.)* Aesthetics of the Shark Bay World Heritage property.

Extent	Statement of OUV excerpt	Environmental attributes	Experiential attributes	Special places
Dirk Hartog Island	Dirk Hartog Island	Dune formations. Primary dunes which display areas of active weathering, e.g. blowouts on DHI. Remote island habitats	Loggerhead turtle nesting – CI, Turtle Bay to Cape Levillain.	Sunday Island Bay, Cape Inscription, Louisa Bay, Notch Point, Withnell Point, Urchin Point, Mystery Beach, Quoin Head, Herald Bay, Cape Ransonnet, Surf Point, Blowholes, Charlie's Harbour, Tetradon Loop, Turtle Bay, Cape Levillain.
Peron Peninsula	Low rolling hills interspersed with low, flat claypans or birridas	Coastal landscape features, mangroves	Land forms of unique, distinctive of contrasting colours or forms	Guichenault Point Cape Peron, Bottle Bay, Gregories, South Gregories, Cattlewell, Broadhurst, Big Lagoon
South Peron	Low rolling hills interspersed with low, flat claypans or birridas	Coastal landscapes	Colour contrasts, land forms.	Eagle Bluff and lagoon, Whale Bone, Goulet Bluff, Fowler's Camp, Dubaut Creek,
Heirisson/ Bellefin Prongs	Heirisson and Bellefin Prongs and hinterland	Vast areas of shrub land and extensive stretches of coastline – beaches, cliffs, dunes, headlands and pristine coastlines.	Loggerhead turtle nesting	Edel Land – Heirisson and Bellefin Prongs, Depuch Loop and hinterland
Terrestrial	Inundated birridas and lagoons Low rolling hills interspersed with low, flat claypans or birridas	Inundated birridas noted for ecological significance - following rain or high tide teem with brine shrimp and other invertebrates providing a feast for migratory wading birds. Dry birridas contain powdery gypsum and specially adapted plant and animal species.	Spectacular visual attractions particularly from air. Form patterns interspersed across peninsula. Flooded birridas notable for beauty by creating inland bays. More than 100 birridas on Peron Peninsula. Distinctive native vegetation creating unusual forms, lines, colours or textures e.g. samphire in salt pans.	Peron Peninsula. Big Lagoon (thriving ecosystem – seagrass, sand flats, mangroves, safe haven for dolphins, dugongs, fish nursery and crustaceans) Little Lagoon (connected to sea, shallow protected waters are important fish breeding and nursery area).
Marine	Abundance of marine mega fauna – Dugong, dolphins, sharks, rays, turtles, fish, manta rays	Meeting of tropical, desert and temperate climes – diversity of species.	The shallow waters abound with a myriad of marine life. One of the most secure populations of dugongs (10,000) in the world forage in the shallow waters. The clear waters give visitors the chance to view dugongs, manta rays, marine turtles and humpback whales, while dolphins at Monkey Mia visit the beach each day to interact with visitors	Monkey Mia beach Shark Bay Marine Park

Table A7.1 *(cont.)* Aesthetics of the Shark Bay World Heritage property.

Extent	Statement of OUV excerpt	Environmental attributes	Experiential attributes	Special places
Terrestrial	Annual wildflower display	Vegetation has a rich diversity, unusual species composition and many endemic species including spring-flowering annuals.	50 flowering plants confined to Shark Bay mainland and offshore islands. Being immersed in plains of seasonal wildflowers and everlastings. Everlastings flowering in white, yellow and pink can be found on most inland roadways and the verges of highways. Flowering native bush and scrubland also occurs during this period e.g. blooming wattles	Peron Peninsula, main road into Denham, North West Coastal highway.
Terrestrial	Ecological communities, plant species range limits. Isolation and richness of fauna species	Coastal birridas, scrub-heaths, Acacia shrublands. Diversity of fauna species and endemic plants	Some of above. Scale of land and sea scapes.	Nanga and Tamala
Marine, Peron Peninsula	Exceptional coastal scenery with sea cliffs. Wide sweeping beaches of sand and shell interspersed by rocky platforms, headlands and peninsulas	Panoramic scale	Dune formations of distinctive height or shape which are visually prominent in surrounding landscapes.	Cattlewell, Gregories and South Gregories, Skipjack Point, Bottle Bay, Herald Bight, Cape Peron, Herald Bight, Red Cliff, Guichenault Point

Table A7.2 Lenses – Perspectives from which aesthetics are viewed.

Lenses	Main elements	Evidence of aesthetic attributes
Panoramic – from space, air and lookouts (P)	Seagrass bank formations	Patterns formed by seagrass visible in the clear turquoise waters. Images often contrast the clear blue waters of the shallow seagrass banks with the deep blue channels in between. Abstract patterns are captured and a great sense of beauty and remoteness is portrayed.
	120 x small islands and inlets, beaches, coastline	Islands, peninsulas and coastal headlands often with spectacular views further afield to more distant islands and beautiful white sandy beaches. The contrasting colours of the ochre cliffs, stark white beaches and aqua marine water provides superb scenery and diversity.
	Birridas and lagoons	Flooded coastal birridas create inland bays of exceptional beauty and ecological significance e.g. Big and Little Lagoons. Birridas and lagoons are spectacular visual attractions and 'superlative natural phenomena'. Unique and diverse shapes, and sheer number of birridas, are best viewed from a scenic flight.
	Zuytdorp Cliffs, Steep Point	Stunning photographic opportunities, breathtaking scenery, whales frolicking in the season.
At water or ground level (WL)	Coastline and island vistas	Views along the coast emphasise the natural beauty of the scenery as well as a sense of solitude and tranquillity.
	Seascapes and beach vistas	The aqua waters merging into the blue sky illustrating a sense of expanse and remoteness – where does the ocean stop and the sky begin? An elemental expansiveness. Views along pristine sandy beaches out to sea present an unpopulated natural idyll and retreat.
	Water activities, snorkelling, boating, beach walks	Focus on treasures of the sea and the very clear and calm waters that enable discovery. Delight in being in another realm and the sense of beauty, naturalness and tranquillity that is engendered.
	Nature studies, birdlife, terrestrial fauna and flora	Sense of discovery and immersion in the natural world.
Below water (BW)	Coral reefs, stromatolites	Underwater landscapes – expansive, diverse, colourful. Clarity of water essential in capturing the sense of beauty and naturalness of the underwater scene. Experience of being in nature and having natural environment experiences.
	Small and large fish and other marine fauna and megafauna	Awe inspiring – the natural world and its myriad shapes and forms. Sense of excitement promoted by meeting with marine life. Underwater encounters engender a great sense of discovery.
	Close up photography of fish and coral	Gleaming colour combinations and abstract patterns of the natural world. Intimate portraits of great beauty and wonder. Experiencing the beauty of coral and marine life.
	Diving and snorkelling	Observing the underwater landscape and marine life showcases different textures, colours and forms – a sense of discovery, solitude and reflection.

Table A7.3 Experiential attributes and enhancing qualities (P – Panoramic, WL – At water or ground level, BW – Below water).

Attribute	Qualities that enhance aesthetics	Lenses
Beauty	Spectacular scale and vastness	P
	Richness of colour, patterns and movement from panoramic to intimate scale	P, WL
	Sensually rich and engaging	P, WL, BW
	Abstract compositions of nature	P, BW
	Distinctive	P, WL
Naturalness	Sense of being within a vast interconnected natural world	BW
	Immersion in and engaged with nature	WL, BW
	Sense of power of nature – wind, weather, waves, currents, large marine animals	WL, BW
Tranquillity	Sensory immersion in nature – sights, sounds, smells ambience	BW
	Stillness, reflective quality. Intimacy	WL
Solitude	A sense of seclusion	WL, BW
	Lack of intrusions in the experience of the place	WL, BW
Remoteness *(n.b., perceptions of solitude and remoteness appear closely related)*	'Untouched' land and water scapes	P, WL, BW
	Sense of isolation and naturalness	WL
	Vastness, expansive and untrammelled land and seascapes	P, WL
	Apart from 'civilisation' and in the 'wilderness'	P, WL
	Sense of freedom	WL, BW
Discovery	Intensity of the experience of interacting with wildlife	WL, BW
	Witnessing and learning about 'remarkable nature'	WL, BW
	Discovering an unfamiliar and exciting environment	WL, BW
	Engaging with a real, authentic experience	WL, BW
Inspirational	Experiencing a place esteemed as an icon – a natural wonder of the world	P, WL, BW
	Dramatic, powerful, spectacular	P
	Unique	P
	Breathtaking	P, WL, BW

Table A7.4 Environmental Attributes and Enhancing Qualities (P – Panoramic, WL – At water or ground level, BW – Below water).

Attribute	Qualities that enhance aesthetics	Lenses
WH property as an entity	Vast scale	P
	Patterning of shapes and forms of coastlines, seagrass, islands and water	P, WL
	Intensity and variety of colours	P, WL, BW
	Intensity of sunlight and reflections on the water	P, BW
Coastal scenery	Diversity and complexity of formations and colours	P
	Relationship of patterns with coast, islands and seagrass banks	P, WL
	Visibility/clarity of water	P, WL, BW
Islands	Variety of landforms	P, WL
	Patterned relationship to other cays and islands	P, WL
	Contrast of form and colour with surrounding waters	WL
	Presence of white sand beaches	P, WL
	Isolated, remote individual islands or groups	P, WL
Beaches	Extensive, sweeping, pristine	P, WL
	Form and contrast with adjacent landforms, vegetation, rocky shores and water	WL
Water	Clarity and calmness	WL, BW
	Intensity of colour	WL
	Intensity of sunlight transmitted through or reflected on the water	LW, BW
Marine animals	Abundance and diversity	BW
	Large, iconic and rare species	WL, BW
	Signature fish species	BW
	Accessibility	WL, BW
Mangroves	Scale and density of mangroves	WL
	Unusual form of individual specimens	WL
Seagrass meadows	Extent	WL, BW
	Diversity	BW
	Association with dugong	BW
	Visibility at water level	WL
	Clarity of water	WL, BW
Cliffs	Diverse rock formations and colours Steep and high cliff faces	P, WL P, WL
Bays	Scale and extent large and sweeping or small and intimate	P, WL
	Framed by vegetation	P, WL
	Associated with white sandy beaches	P, WL
	Absence of evidence of human intervention	WL
Birridas	Patterned relationship of channels and inlets	P, WL
	Contrasting colours of claypans and surrounding vegetation and land forms	P, WL
	Absence of evidence of human intervention	P, WL
Birds (seabirds and terrestrial)	Size of breeding colonies	WL
	Variety of forms and colours	WL
	Size and diversity of flocks	WL
Endangered mammals		

Table A7.5 Aesthetics of Natural Elements – Summary.

Natural element	Aesthetics
In combination – islands, beaches and coastlines, estuaries, shallow water, bays inlets and cliffs	Coastline and islands which can be seen from space Place of natural wonder Spectacular pristine beauty Awesome, iconic, pristine Spiritual Majestic and calming Looked upon with pride Unique habitats Views and vistas Distinctive in forms and composition
Marine species, particularly larger animals – dugong, whales, fish, sharks, rays, sea snakes, turtles	'WOW' factor Empathetic response to large creatures Unique experiences
Water quality	Water clarity and colour
Total ecosystem	Integrity
	Largest seagrass banks in world
	Wonder of nature
	Natural beauty, diversity
	Majestic, calming, remote, solitude

APPENDIX 8: THE CLIMATE ADAPTATION PROCESS FOR SHARK BAY

Prepared by Phil Scott

The workshop considered briefly the likely key steps and considerations in the pathway toward planning to adapt to climate change in the Shark Bay WHA. In the summary of the workshop the following two graphics were presented and discussed.

The first graphic (Figure A8.1) shows how the CVI methodology was tested at Shark Bay and contributes to the development of climate change action plans, leveraging from and providing benefit to applications of these for other WH properties. For Shark Bay, there remains a need to consider and agree on strategy and an adaptation plan, to enable coordinated and appropriate planning and actions to be implemented. There will be knowledge gaps to be addressed along the way to assist in rational and considered decision making, some of which were noted in Section 6.2.

The second graphic (Figure A8.2) identifies some of the challenges to be considered along the pathway to integration, particularly the number of key stakeholders and agencies with responsibilities for management in the WH area and surrounds. Each of these organisations needs to have ownership of their components of the plan, and in order to deliver those, will require the actions to be identified and included in their own business planning processes. Ultimately, the actions need to be included in Key Performance Indicators (KPIs); management plans and systems; and, importantly, budgets. Keeping focus and momentum to deliver coordinated actions will no doubt be a key challenge for climate change adaptation.

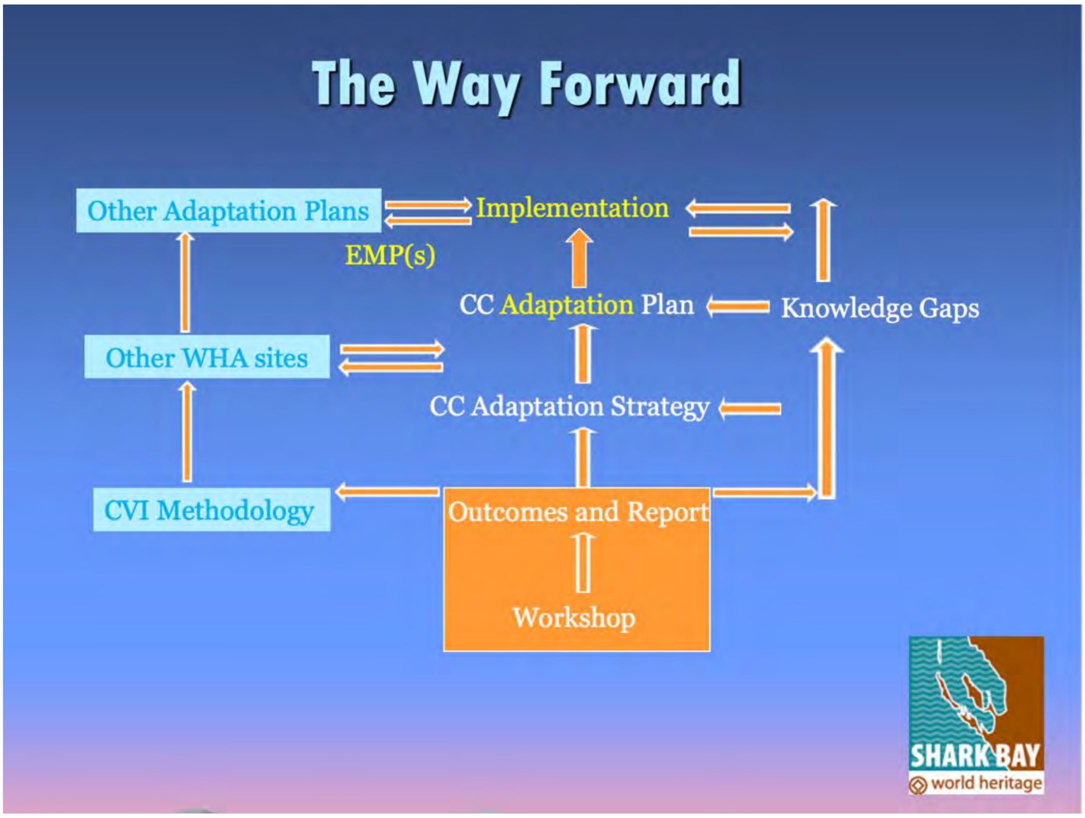

Figure A8.1 Schematic representation of the development of a climate change adaptation strategy and plan incorporating CVI.

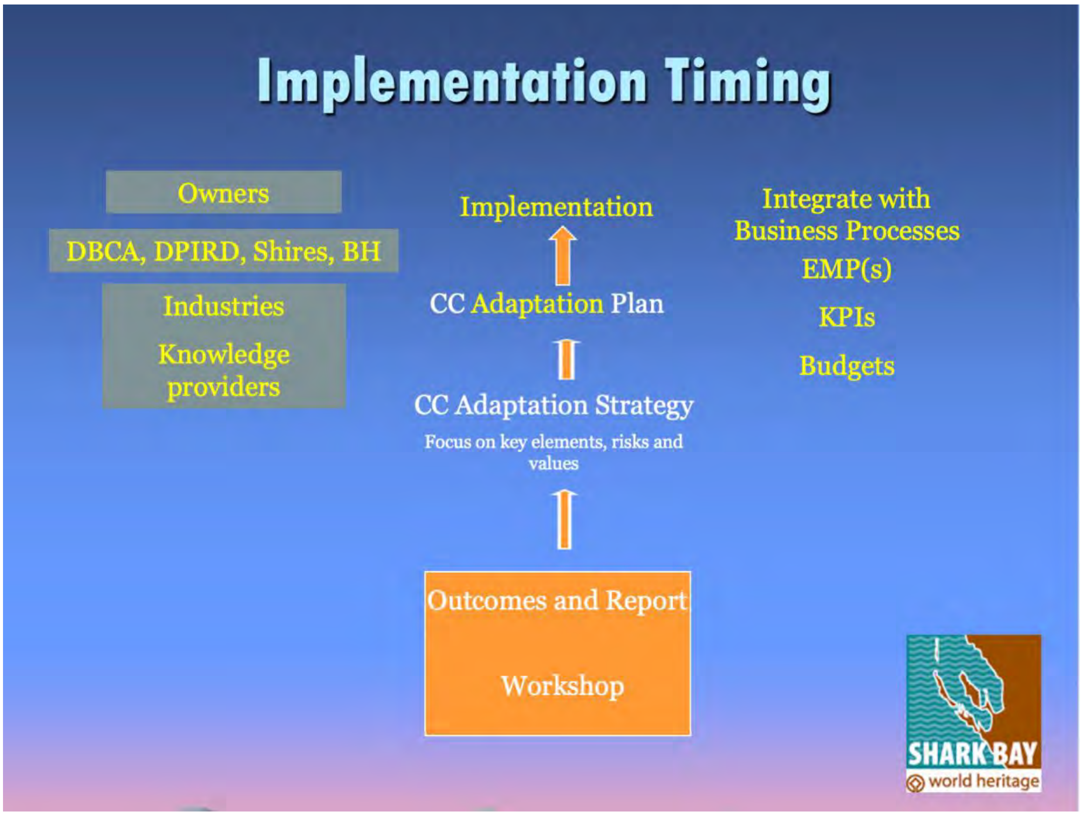

Figure A8.2 Schematic representation of the implementation of a climate change adaptation strategy and plan for Shark Bay, including the integration of key stakeholders.

APPENDIX 9: ACRONYMS AND GLOSSARY

ACRONYMS

BoM	*Bureau of Meteorology*
CEO	*Chief Executive Officer*
CSIRO	*Commonwealth Scientific and Industrial Research Organisation*
CVI	*Climate Vulnerability Index*
DBCA	*Department of Biodiversity, Conservation and Attractions (WA Govt)*
DoEE	*Department of Environment and Energy (Australian Govt)*
DPIRD	*Department Primary Industry and Regional Development*
ENSO	*El Nino Southern Oscillation*
ESC	*Economic, Social and Cultural*
ESCC	*Earth Systems and Climate Change*
GDC	*Gascoyne Development Commission*
ICOMOS	*International Council on Monuments and Sites*
IPCC	*Intergovernmental Panel on Climate Change*
IUCN	*International Union for Conservation of Nature*
JCU	*James Cook University*
NCWHAC	*Ningaloo Coast World Heritage Advisory Committee*
NESP	*National Environmental Science Program*
NOAA	*National Oceanic and Atmospheric Administration (US Govt)*
OUV	*Outstanding Universal Value*
SBWHA	*Shark Bay World Heritage Area*
SBWHAC	*Shark Bay World Heritage Advisory Committee*
SoOUV	*Statement of Outstanding Universal Value*
SPVs	*Significant Property Values*
SST	*Sea Surface Temperature*
UCS	*Union of Concerned Scientists*
UN	*United Nations*
UNEP	*United Nations Environment Programme*
UNESCO	*United Nations Educational, Scientific and Cultural Organisation*
UWA	*University of Western Australia*
WA	*Western Australia*
WAMSI	*Western Australian Marine Science Institution*
WH	*World Heritage*
WHA	*World Heritage Area*

GLOSSARY

Adaptive capacity	The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.
Climate	The composite or generally prevailing weather conditions of a region, as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds, throughout the year, averaged over a series of years.
Climate change	A change in the pattern of weather, and related changes in oceans, land surfaces and ice sheets, occurring over time scales of decades or longer.
Exposure	A measure of the contact between a system (whether physical or social) and a stressor.
Hypersaline	Waters with dissolved salt concentration markedly higher (>65 practical salinity units, psu) than generally seen in the ocean environment (typically 30-35 psu).
Metahaline	Waters with dissolved salt concentration higher (40-65 practical salinity units, psu) than generally seen in the ocean environment (typically 30-35 psu).
Sensitivity	The degree to which a system is affected, either adversely or beneficially, by climate variability or change.
Stromatolite	A calcareous mound built up of layers of lime-secreting cyanobacteria and trapped sediment.
Weather	The state of the atmosphere—its temperature, humidity, wind, rainfall and so on—over hours to weeks.

United Nations
Educational, Scientific and
Cultural Organization

Shark Bay, Western Australia
inscribed on the World
Heritage List in 1991

SHARK BAY
world heritage

JAMES COOK
UNIVERSITY
AUSTRALIA

ARC CENTRE OF EXCELLENCE
Coral Reef Studies

GOVERNMENT OF
WESTERN AUSTRALIA
Department of **Biodiversity, Conservation and Attractions**

THE UNIVERSITY OF
WESTERN
AUSTRALIA

WESTERN AUSTRALIAN
MARINE SCIENCE
INSTITUTION

CVI