PACIFIC ISLAND WHALES IN A CHANGING CLIMATE

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Secretariat of the Pacific Regional Environment Programme

PROTECT PACIFIC WHALES – OCEAN VOYAGERS

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CET LAW

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Introduction

Pacific Island culture and history is intertwined with the ocean and its whale inhabitants; whether through voyage, ancestry, artefact or migration, the movements and stories cannot be separated. This interconnected chronicle continues to the current day, augmented by an economic dependence with the advent of a growing whale-watching tourism industry, and with the additional character of climate change joining the narrative.

Of all the carbon dioxide emitted by human activities, the ocean has absorbed approximately one-third and continues to do so, along with most of the 0.6°C global temperature increase over the past 30 years (Hoegh-Guldberg & Bruno, 2010). Playing no role in their creation, whales are obliged to endure the direct and indirect consequences of climate change and other human activity to their habitat. Correspondingly Pacific Islanders, who collectively produce less than 0.03% of current global greenhouse gas emissions, disproportionately bear the brunt of climate change effects, being among the first nations in the world to feel the real effects of rising seas and intensified weather patterns (SPREP, 2017).

Although there is much to still understand, this report explores the potential impacts of climate change on Pacific Island whales. By identifying the potential direct and indirect impacts of climate change on whales, and the related consequences on Pacific Island whales and whale-watching economies, we can work towards identifying solutions for humans and whales alike, since, like the story of old, we are journeying across the ocean together.

Whales of the Pacific Islands

With an area covering over 32 million km^2, surrounding 22 Pacific Islands Countries and Territories (PICTs), the Pacific Islands region administered by SPREP provides habitat to both migratory and resident, mysticeti (baleen) and odontoceti (toothed) whales (SPREP 2012). Efforts to collect data are varied across this large geography, as is their reliability (Miller & Prideaux, 2013). However, 26 different cetacean species have been verified as present in the PICT waters, and it is estimated that over half of the known cetacean species depend on the waters of PICT for feeding, migration, breeding, calving and socializing (Miller & Prideaux, 2013; SPREP, 2013).

Whales play an important role in the life and culture of the Pacific Islands. Whales feature in legends and history, serving in many roles such as guardians of voyagers on the ocean or as reincarnated ancestors. The arrival or sighting of whales can signify certain events or bring messages. Parts of whales, particularly teeth, are culturally significant when exchanged on some islands.

The Climate Change Challenge

Assessing with precision the potential impacts of climate change on whales is challenging. At the threshold, the vast, ever-changing nature and inaccessibility of the ocean hinders the collection of data for baseline and monitoring purposes. These data collection challenges are transferred to marine mammal research, and are best exemplified by over more than half of cetaceans in Oceania, as well as globally, being classified as data deficient by the International Union for the Conservation of Nature (IUCN) (Polidoro, et al., 2011; Simmonds & Eliott, 2009; Learmonth, et al., 2006; Miller & Prideaux, 2013).

Although we can examine temperature rise, reduction of sea ice and rising sea levels, the nature and degree to which these effects will occur, and the responses of whales as complex ocean organisms, are difficult to predict (Learmonth, et al., 2006). In addition, the parameters that may inform predictive modelling of climate change effects on whales including changes in prey distribution, reduced reproductive capacities, changes in salinity levels, and ever-increasing anthropogenic stressors, are uncertain. Thus, predictions of the effects on marine mammals, their populations, and their responses to climate and ecosystem variations are highly speculative (Learmonth, et al., 2006).

Despite the challenges, continued and increased data collection is vital to informing our understanding and predictive capacities of climate change and its impacts on whales. Additionally, given the geographical scope of PICT waters, collaborative partnerships with the many organisations and researchers addressing these issues is essential to tackling climate change issues. Combined with the precautionary principle, these efforts can guide climate mitigation and adaption strategies that benefit Pacific Island whales and their ocean habitats, and support their well-established cultural and economic roles.

Climate Change and Pacific Island Whales

Impacts of climate change on whales

Islands nations are at the forefront of climate change, and the impacts are not only limited to life on land. Life in the ocean surrounding Pacific islands faces a range of challenges driven by climate change. Whales are not alone in facing direct impacts such as warming oceans and disappearing habitat, but as predatory and migratory animals, they also face indirect effects through changing distributions and availability of prey. Changes in whale behaviour may be subtle or incremental, and not easily attributed to any one cause. The effects of climate change on lower trophic levels are complex and can be amplified at higher trophic levels (Fleming, et al., 2015). Here we outline effects of climate change and how they are expected to affect whale species in PICTs.

- **Ocean Acidification**

Ocean acidification is caused by absorption of CO2 into the ocean, which reduces ocean pH levels (Zeebe, et al., 2008). Ocean acidification can directly affect the activity of some fish as well as, phytoplankton and zooplankton, and coral reef-forming organisms with calcium carbonate skeletons or shells (Doney, et al., 2012). These organisms form the base of food chains for many whales and can provide important habitat for their prey (Fleming, et al., 2015; Doney, et al., 2012; Doney, et al., 2012; Doney, et al., 2012).

- **Warming Oceans**

Sea surface temperature is widely recognised as a direct influence on the distribution of many whale species (Lambert, et al., 2014; Ashford-Hodges & Simmonds, 2014; MacLeod, 2009). Being highly mobile, many whales are expected to exhibit behavioural changes rather than physiological responses, including altering distribution as ocean conditions change (Kaschner, et al., 2011). However, contracted range size, which increases risk of extinction, can be due to various drivers and not necessarily solved through mobility, including geographic barriers, availability of prey or lack of suitable habitat (Parmesan, 2006). Using climate change projections from the IPCC, it is estimated that, by the years 2040-49, 58% of cetacean species would experience range expansion, 2% would experience a stable range size, and 40% would experience range contraction (Kaschner, et al., 2011). Finally, likelihood of illness and disease outbreaks in marine ecosystems may be increased due to expansion of pathogen ranges, host susceptibility due to increased stress, and expansion of vectors of disease (Hoegh-Guldberg & Bruno, 2010).

- **Disrupted Food Chains**

Changes in prey availability due to climate change are already being observed in some regions (Fleming, et al., 2015; Hauser, et al., 2016). Food availability in polar regions is linked to sea ice cover (Hauser, et al., 2016), including humpback prey items such as krill (Kaschner, et al., 2011). Krill population estimates vary greatly, and research into the impact of climate change on krill abundance is ongoing (Clapham, 2016). In response to low krill availability in the North-East Pacific, humpbacks have been recorded switching to anchovy and sardines (Fleming, et al., 2015). Whales that are unable to switch between prey may be forced to use other adaptation strategies, such as range shifts, or face extinction.

- **Increased Competition**

Climate change could be a significant factor in increasing competition between species whose niches were formerly separated by sea surface temperature (MacLeod, et al., 2007). Species with expanding ranges, or those which are less constrained by water temperature, may encroach upon species with contracting ranges (Ashford-Hodges & Simmonds, 2014; MacLeod, 2009). Climate-forced range overlaps add complexity to established food chains and compound existing threats with increased competition, and can result in exclusion of formerly dominant species from resources (Ashford-Hodges & Simmonds, 2014; MacLeod, et al., 2007). Due to the complex nature of increased competition between species that currently occupy separate spaces, it is difficult to predict the outcomes of such occurrences (MacLeod, 2009).

- **Anthropogenic Activity**

Changes in human behaviour in relation to climate change, called tertiary effects, are likely to result in increased encroachment of human activities upon whale habitats (Alter, et al., 2010). Examples include human migration to coasts and relatively untouched areas that become increasingly habitable as well as increased activities in newly-accessible ocean and polar areas, including shipping, resource extraction and fishing (Alter, et al., 2010). This encroachment and the associated threats are expected to exacerbate the impacts of climate change on whales and their habitats (Alter, et al., 2010).

Consequences for Pacific Island Whales

Ocean acidification is expected to affect all habitats of PICTs whales, from the Antarctic to the tropics (Fabry, et al., 2008; Doney, et al., 2012). Some plant species are expected to increase production in response to acidification, some organisms will respond physiologically, and others may not be affected (Doney, et al., 2012; Kroeker, et al., 2010; Sydeman, et al., 2015). Although whales aren't expected to exhibit any direct physiological responses, they are likely to experience indirect effects, such as those on food webs, which are uncertain but likely irreversible (Doney, et al., 2012; Sydeman, et al., 2015). It is widely reported that reef-forming corals are susceptible to reduced pH, and in future, coral reef ecosystems may support less biodiversity than at present (Doney, et al., 2012; Hoegh-Guldberg & Bruno, 2010; Zeebe, et al., 2008). Some PICTs coral reefs have adapted to naturally acidified waters (Shamberger, et al., 2013), however it is unknown whether these will continue to provide suitable habitat for reef-dependent species in the event of climate-driven acidification.

Ocean warming is expected to bring about changes in the distribution of whales and, without geographical barriers to movement, whales in the Pacific Islands are expected to move towards cooler waters (Kaschner, et al., 2011; Ashford-Hodges & Simmonds, 2014). Models assessing ocean warming over the next 35 years indicate that the Pacific islands may experience a net reduction in the diversity of marine mammal species found in their waters (Kaschner, et al., 2011). While temperature is a key driver behind range shifts, other factors also have a strong influence on whale behaviour (Ashford-Hodges & Simmonds, 2014; Poloczanska, et al., 2013), and whales may face ecological barriers to finding new feeding and breeding grounds (Lambert, et al., 2014).

Reduction in prey availability or changes in prey distribution could be as strong a driver of whale population range shifts as temperature (Kaschner, et al., 2011). Many models attempt to predict marine mammal distribution in response to climate factors (Kaschner et al. 2011, Salvadeo et al. 2015), however few consider the potential and likely significant effects of changing prey distribution. Most baleen whales do not feed in the Pacific Islands waters. Antarctic krill is the principal prey of several baleen whale species that migrate between Pacific islands and Antarctica, as well as forming the basis of the food chain for other whale species (Hofman, 2017). Food availability at feeding grounds in Antarctica is dictated by ice cover and ocean fronts, like the Antarctic convergence, both of which will shrink with warming oceans (Kaschner, et al., 2011; Thomas, et al., 2015). Pacific island whales are

therefore vulnerable to the impact of climate change on krill populations (Clapham, 2016). Because of predicted changes in krill availability, migratory whales are expected to travel an additional 3-5^{o} of latitude further South to find foraging grounds (Thomas, et al., 2015). Thus, migration patterns of Pacific island whales, including length and timing, may be disrupted when feeding and breeding areas are affected by climate change (MacLeod, 2009). Krill abundance could also be reduced due to climate change, which could result in whale malnourishment and population decreases (MacLeod, 2009; Learmonth, et al., 2006).

Whale species may adapt to climate change at different rates to each other, and to their prey (Ashford-Hodges & Simmonds, 2014; Parmesan, 2006), which can affect the success of range shifts (Ashford-Hodges & Simmonds, 2014; Lambert, et al., 2014). For whales in PICTS, boundaries between habitats, foraging areas, and other spatial and temporal parameters that define the niche for each species are not well documented. Thus, the potential for successful range shifts, increased competition within or between species, or altered diets, and is unknown.

Adding to the complexity, climate-driven impacts will interact with other threats to whales from human activities, and so cannot be considered in isolation (MacLeod, 2009). Climate change is enabling human exploration and industry to expand and to enter new regions of Antarctic waters. As a result, the potential for anthropogenic disturbance to Pacific island whales is consequently increased, including ship strikes, noise and other pollution (Thomas, et al., 2015).

Non-climate stressors

Existing and emerging threats to whales, unrelated to climate change, remain a factor in whales' responses and ability to adapt to change. Because of their life history traits, such as slow growth, reliance on multiple distinct habitats, and lower population densities, whales are at higher risk of extinction than smaller mammals (Schipper, et al., 2008). The IUCN red list classifies almost a fifth of marine mammals in Oceania as threatened (Polidoro, et al., 2011). Accidental whale mortality, through entanglement in fishing gear (bycatch) or ship strikes, is thought to be the most prevalent threat to whales in Oceania and around the world, followed by pollution, including chemicals, plastics and sound (Schipper, et al., 2008; Polidoro, et al., 2011; Thomas, et al., 2015), and the International Whaling Commission includes these activities in its remit (Hofman, 2017).

Krill fisheries are active in the same Antarctic waters as whales that feed on krill, such as humpbacks (Hofman, 2017). As well as increased potential for ship strikes, Pacific islands whales that migrate to Antarctic waters are therefore likely competing for resources with these fisheries (Hofman, 2017). Growing demand for krill and the development of technology that reduces the cost of krill fishing are likely to result in industry pressure for increased catch allowances (Hofman, 2017). Balancing conservation and fisheries activities could diminish the principles of conservation outlined in the CAMLR convention (Hofman, 2017). In the absence of effective management and regulation, krill fisheries have the potential to exacerbate any negative ecological impacts of climate change on krill populations, and thus krill-dependent food chains including humpbacks and other baleen whales (Hofman, 2017).

Role of whales in climate change mitigation

The contribution of whales to ecosystem function has been gaining recognition in scientific literature (Hofman, 2017) and support from members of the IWC (IWC, 2016). Through their unique behaviours, long life spans and large body size, whales directly contribute to the oceans ability to absorb CO_2, a greenhouse gas, and store organic carbon in the ocean (Pershing, et al., 2010; Roman & McCarthy,

2010). Carbon captured and stored by ocean and coastal organisms, such as whales, is termed “blue carbon”.

In oceans where low nutrient availability limits uptake of CO_2 from the atmosphere by photosynthesis, whales that move nutrients can enhance the carbon capture process (Lavery, et al., 2010; Lavery, et al., 2012; Roman & McCarthy, 2010). For example, in the Southern Ocean, sperm whales eat at depth and release faeces containing iron in surface waters, which can then be used by marine plants (Lavery, et al., 2010). Whales also increase nutrient availability by mixing up stratified layers through their movement alone (Lavery, et al., 2012), and deliver nutrients into their breeding grounds through shedding skin and other life processes (Roman, et al., 2014).

Whales also contribute to the ocean’s carbon storage capacity (Pershing, et al., 2010). Whales store large amounts of organic carbon, passed along through ocean food chains, in their bodies (Pershing, et al., 2010). As well as storing carbon in the ocean during their long lifespans, when whale carcasses sink, the carbon stored in their biomass can enter sediments (Pershing, et al., 2010). This is one way that carbon is effectively retired from the carbon cycle, and is unlikely to re-emerge as a greenhouse gas for hundreds to thousands of years (Pershing, et al., 2010).

Implications for the Pacific Islands Region

Impacts of climate change on the Whale-Watching Industry

Whale-watching tourism around the world has become more popular as tourists are increasingly seeking authentic experiences in natural habitats. Growth of this sector in the Pacific Island region was estimated at 45% per year during the period between 1998 – 2005 (SPREP, 2013). A 2005 study reported US $7.5 million of direct economic benefit, and US $21 million of total economic benefit to the region (SPREP, 2013). As well as impacts on the whales that tourists pay to see, climate change will also have direct and indirect effects on whale-watching operations.

As a nature-based economy, whale-watching is directly dependent on the health of whale populations and their habitats. Climate change impacts on these will therefore affect whale-watching economies and associated livelihoods. Although many species of dolphins and whales, including blue, sei, fin, sperm and orca, are found in the Pacific Island waters, the whale and dolphin watching tourism industry focuses on the humpback whales. Like most baleen whales, humpbacks in the South Pacific are migratory. They travel to feeding grounds in Antarctica in austral summer, where they forage on a range of small fish and krill species, and migrate to the Pacific Islands during austral winter for breeding and calving (Constantine et al. 2010). Economies based on these whales therefore have a stake in ensuring the long-term protection of food and habitat at Antarctic feeding grounds.

Humpback whales are known for their seasonal site fidelity in certain breeding and feeding locations throughout their range, however some Pacific Island waters are used as corridors (Constantine et al. 2010). Protection remains crucial for this subpopulation of Oceania humpback whales, which is one of only two populations of humpbacks on the planet listed as “endangered”; the other population being in the Arabian Sea (IUCN, 2017). (IUCN 2017). Because whale-watching in the Pacific Islands is focused on humpback whales, although impacts of climate change on other whale species may be implied, this section will concentrate on humpback whales.

- **Seasonal Variances**

Whale-watching in the Pacific islands is a seasonal economy that follows the patterns of migrating humpback whales. The whale season is anywhere between May and November, depending on the island state. Climate change may affect migration phenology resulting in earlier or later humpback whale arrivals and/or departures, with the potential to shorten or lengthen the season. The impact of changes to timing, particularly in the shoulder seasons (i.e. those first and last months when the whales are arriving and departing), may reduce predictability of whale occurrence, which is important for both tourist satisfaction and businesses. For operators and other businesses indirectly benefitting from whale-watching, such as hotels and restaurants, income and staff contracts may be affected. In addition, given the investment of time and money required to travel to PICT countries, ongoing shifts in timing and the corresponding lack of certainty may reduce the attractiveness of the Pacific Islands as a whale-watching destination, both to tourists and businesses.

- **Weather patterns**

Predictability of the weather is expected to be reduced with climate change and inclement weather, including cyclone frequency and severity, is expected to increase (CDKN, 2014). Circumstances in which boats are unable to launch, tourists are unable to view or swim with whales, or are uncomfortable, may increase, leading to loss of revenue. Poor weather conditions may also increase search time on the water, which may both reduce tourist satisfaction and increase fuel expenditure.

- **Abundance**

With protective measures in place, most humpback whale populations around the world have been increasing. However, it is unclear if and to what extent the Oceania subpopulation is following suit, as it remains one of two endangered humpback whale species on the IUCN Red List. Negative impacts of climate change that stall the upward trend or decrease humpback whale abundance will correspondingly increase search time and associated costs to the whale-watching operators, as well as reduce customer satisfaction.

- **Species Diversity**

Models indicate that, with warming oceans and a lack of geographic barriers to movement, PICTs will experience a net reduction in species diversity (Kaschner, et al., 2011). As whale-watching in PICTs is focused on humpback whales, species diversity is not currently an issue for the industry. However, the continued recovery or at least stability of PICT humpback whale populations is of importance to the health of whale watching economies. Presence of whale species other than humpbacks could diversify whale-watching activities, and may enable year-round whale-watching, potentially creating more economic stability for the industry and thus resilience in a time of unpredictable climate change.

- **Whale Behaviour**

Whale behaviour plays a notable role in the tourism experience with tourists being more satisfied with species, such as humpback whales, that are "more active and gregarious" (Cloke & Perkins, 2005; Orams, 2000). Humpback whales come to the Pacific Islands to breed, calve and sing (Constantine, et al., 2010), making display of these natural behaviours is part of the tourism draw. Climate change has been demonstrated to affect reproductive success of humpbacks (Lambert, et al., 2010), which could affect the number of mother-calf pairs in the PICTs. Whales undernourished or stressed by climate change and anthropogenic stressors may not exhibit these behaviours regularly. Accordingly, supporting a whale-watching economy translates to not only supporting a healthy population of whales, but also an environment which encourages the natural behaviours that are also engaging to customers.

Research Priorities

The IUCN red list classifies more than 50% of marine mammals in Oceania as data deficient, meaning not enough is known to assign a category on their population status (Polidoro, et al., 2011). Few studies focus on climate change and whales in the PICTs, and even in well-studied regions there are gaps in understanding of potential impacts and responses (Sydeman, et al., 2015).

Whale migrations and their drivers are not fully understood, and so the potential impacts of climate change on destination habitats and timing are hard to identify (MacLeod, 2009). Long term monitoring, use of satellite and remote sensing technology, traditional surveys and assessment of relationships between whales and their habitats will help identify the causes of potential range shifts, and estimate their likelihood and outcomes (MacLeod, 2009). Ultimately, when climate change projections are combined with understanding of other threats to whales, conservation and management plans can incorporate proactive measures to address expected conflicts (MacLeod, 2009), reducing stress and thus enhancing resilience of whale populations to climate change.

The value of whales for their ecosystem services is being recognised in international fora (IWC, 2016), however, few studies record and quantify these services (Pershing, et al., 2010). The contribution of whales to ocean productivity, removal of carbon dioxide from the atmosphere and its storage as organic carbon in the PICTs is unknown. Focused research in the PICTs can enable estimates of the carbon-market value of whale conservation (Martin, et al., 2016). Payments to protect natural carbon

storage in coastal ecosystems are already a reality, and benefits shared with communities encourage stewardship of natural resources (T. Locatelli, et al., 2014).

Opportunities for collaborative conservation

Conservation measures in key areas can help to reduce stress from anthropogenic impacts and increase resilience to climate change (Ashford-Hodges & Simmonds, 2014). For whale populations with ranges that cross national borders, international collaboration will help to identify key habitats and establish effective conservation and management measures therein.

Humpback whales are dependent upon Antarctic feeding grounds. Thus, humpbacks are dependent on the effectiveness and success of ecosystem based fisheries management (EBFM) of krill, which aims not only to protect krill resources, but also predator populations and the entire ecosystem (Hinke, et al., 2017). PICTs with humpback whale populations, and particularly those with livelihoods and economies supported by them, have a stake in the ongoing efficacy of these protections. Identification of areas where industry-whale interactions are most likely, and allowance of harvest rates that will not diminish resources for whales, are essential for EBFM to reduce risks to whales (Hinke, et al., 2017). However, at present, there is no formal requirement for management of the krill fishery to consider research into the effects of climate change on krill resources, predator populations, or the broader ecosystem (Hofman, 2017). To enhance the resilience of whales to climate change, PICTs could demonstrate support for the current conservation principles of the CAMLR Convention, and encourage proactive management measures for krill fisheries in Antarctic feeding grounds.

Issues related to climate change, industry, ocean ecosystems and whales could be included in environmental assessment, planning and management, or other mechanisms considering and regulating the impacts of industry. Collaborative partnerships between industry, government, research and NGOs can look together to address the issues that face each of these entities.

Half of Pacific Island region's ocean area falls within one of the PICT exclusive economic zones, leaving the other half, 16 million km^2 of ocean in total (Polidoro, et al., 2011), falling into areas beyond national jurisdiction. In 2015, the United Nations General Assembly adopted a resolution to develop an agreement addressing the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction. The process is currently underway, and provides an opportunity for the region to unite with other like-minded organizations, states or regions to be a strong voice for whales in the high seas.

Conclusions and recommendations

Conservation and management strategies, such as marine protected areas, will need to address both climate and non-climate related threats to be successful (Hoegh-Guldberg & Bruno, 2010). Climate change will affect the feeding behaviour, distribution and migration patterns of whale species that are able to adapt. Non-climate related threats will exacerbate climate impacts on availability of prey and habitat, as well as causing direct mortality. Despite this interconnection, current international conservation action and policy does not account for potential impacts of climate change (Lambert, et al., 2014). Collaboration between Governments could promote and encourage a more holistic approach to whale conservation and management throughout their range, including national territorial waters, Antarctic areas governed by the CAMLR Convention, and areas beyond national jurisdiction. In PICTS, marine management practices that incorporate climate change adaptive measures could be encouraged and formalised through customary and introduced law.

Since restoration of whale populations could help mitigate global warming (Clapham, 2016), it is worth considering that activities that negatively impact whale populations also limit their mitigation potential. Climate adaptation discussions, plans and frameworks could tap into the potential of whales and their blue carbon services, while research and projects that aim to preserve and restore healthy whale populations for their carbon sequestration services would have co-benefits for the whale-watching economy.

Economies based on whale-watching tourism are dependent on continued presence of whales and positive tourist experiences. Collaborative research in the PICTs region would improve understanding of large scale processes, identify likely range shifts and other behavioural changes, and inform proactive policies and management decisions, including priority areas and actions (Kaschner, Tittensor, Ready, Gerrodette, & Worm, 2011). Traditional knowledge could help increase understanding and protection of whale species, and insights could be gathered from researchers, fishers and boat-based tourism operators on trends and anecdotal observations on the water.

The geography of many PICTs is well-suited for land-based whale-watching, which could relieve boat-based stress on the currently endangered population of humpback whales, and provide an economical and comfortable option for those who do not fare well on the sea. If weather patterns intensify as predicted, and reduce the number of days that boats can launch, alternative land-based infrastructure would provide an adaptive measure for the industry to continue to provide touristic experiences to view whales.

While further research is needed to target priority actions and areas, formal recognition of the necessity of addressing the impacts of climate change on whales alongside other threats, and support for action, can enable development of management plans. In turn, these actions can feed in to advocacy for policy and financial support to international bodies.

References

Alter, S., Simmonds, M. & Brandon, J., 2010. Forecasting the consequences of climate-driven shifts in human behavior on cetaceans. *Marine Policy,* pp. 34:943-54.

Ashford-Hodges, N. & Simmonds, M., 2014. *Climate change and cetaceans: an update.,* Cambridge: International Whaling Commission.

CDKN, 2014. *The IPCC's Fifth Assessment Report: What's in it for Small Island Developing States,* s.l.: Climate & Development Knowledge Network (CDKN).

Clapham, P. J., 2016. Managing leviathan: Conservation challenges for the great whales in a post-whaling world.. *Oceanography,* pp. 29(3), http://dx.doi.org/10.5670/ oceanog.2016.70..

Cloke, P. & Perkins, H., 2005. Cetacean performance and tourism in Kaikoura, New Zealand. *Environment and Planning D: Society and Space,* pp. 23:903-24.

Constantine, R. et al., 2010. *Abundance and interchange of humpback whales in Oceania based on fluke photo-identification and DNA profiling,* s.l.: Paper SC/62/SH18 presented to the IWC Scientific Committee.

Doney, S. M. R. J. D. J. B. F. C. C. E. H. G. J. G. A. H. et al., 2012. Cimate change impacts on marine ecosystems. *Annual Review of Marine Science,* pp. 4:11-37.

Fabry, V. J., Seibel, B. A., Feely, R. A. & Orr, J. C., 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science,* p. 65: 414–32.

Fleming, A., Clark, C. T., Calambokidis, J. & Barlow, J., 2015. Humpback whale dietsrespond to variance in ocean climate and ecosystem conditions in the California Current.. *Global Change Biology 22,* pp. 1214-1224.

Hauser, D. D. W. et al., 2016. Decadal shifts in autumn migration timing by Pacific Arctic beluga whales are related to delayed annual sea ice formation. *Global Change Biology,* p. doi: 10.1111 /gcb.13564.

Hinke, J. et al., 2017. Identifying Risk: Concurrent Overlap of the Antarctic Krill Fishery with Krill-Dependent Predators in the Scotia Sea. *PLoS ONE,* p. 12(1): e0170132. doi:10.1371/journal.pone.0170132.

Hoegh-Guldberg, O. & Bruno, J., 2010. The impact of climate change on the world's marine ecosystems. *Science,* pp. 328: 1523-28.

Hofman, R. J., 2017. Sealing, whaling and krill fishing in the Southern Ocean: past and possible future effects on catch regulations.. *Polar Record,* pp. 53 (268): 88-99 .

IUCN, 2017. *IUCN Red List.* [Online]
Available at: http://www.iucnredlist.org/details/132832/0
[Accessed 28 March 2017].

IWC, 2016. *IWC/66/15Rev3 - Draft Resolution on Cetaceans and Their Contribution to Ecosystem.* [Online]
Available at:
https://archive.iwc.int/pages/view.php?ref=6185&search=%21collection24471&order_by=relevance

&sort=DESC&offset=0&archive=0&k=&curpos=15&restypes=
[Accessed 28 March 2017].

Kaschner, K. et al., 2011. Current and Future Patterns of Global Marine Mammal Diversity. *PLoSOne,* pp. 6(5):1-13.

Kroeker, K. J., Kordas, R. L., Crim, R. N. & Singh, G. G., 2010. Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. *Ecology Letters,* p. 13: 1419–1434 .

Lambert, E., Hunter, C., Pierce, G. & MacLeod, C., 2010. Sustainable whale-watching tourism and climate change: towards a framework of resilience. *Journal of Sustainable Tourism,* pp. 18(3): 409-27.

Lambert, E. et al., 2014. Cetacean range and climate in the eastern North Atlantic: future predictions and implications for conservation. *Global Change Biology,* p. DOI: 10.1111/gcb.12560.

Lavery, T. J. et al., 2010. Iron defecation by sperm whales stimulates carbon export in the Southern Ocean. *Proceedings of the Royal Society B,* p. 277: 3527–3531 doi:10.1098/rspb.2010.0863.

Lavery, T. J. et al., 2012. Can whales mix the ocean?. *Biogeosciences Discuss,* pp. 9: 8387–8403 doi:10.5194/bgd-9-8387-2012.

Learmonth, J. A. et al., 2006. Potential Effects of Climate Change on Marine Mammals. *Oceanography and Marine Biology: An Annual Review,* pp. 44: 431-64.

MacLeod, C. D., 2009. Global climate change, range changes and potential implications for the conservation of marine cetaceans: a review and synthesis. *Endangered Species Research,* pp. 7: 125-136.

MacLeod, C. D., Weir, C. R., Pierpoint, C. & Harland, E. J., 2007. The habitat preferences of marine mammals west of Scotland (UK). *Journal of the Marine Biological Association of the United Kingdom,* pp. 87, 157–164.

Martin, S. L., T.Ballance, L. & Groves, T., 2016. An Ecosystem Services Perspective for the Oceanic Eastern Tropical Pacific: Commercial Fisheries, Carbon Storage, Recreational Fishing, and Biodiversity. *Frontiers in Marine Science,* p. 3:50. doi: 10.3389/fmars.2016.00050.

Miller, C. & Prideaux, M., 2013. Protective Cetacean Conservation in the Midst of 'Data Deficiency': Progress of the Convention on Migratory Species Cetacean Agreement in the Pacific Islands Region. *Journal of International Wildlife Law & Policy,* pp. 16(1), 45-56.

Orams, M., 2000. Tourists getting close to whales, is it what whale-watching is all about?. *Tourism Management,* pp. 21:561-69.

Parmesan, C., 2006. Ecological and Evolutionary Responses to Recent Climate Change. *The Annual Review of Ecology, Evolution, and Systematics,* p. 37:637–69.

Pershing, A. J. et al., 2010. The Impact of Whaling on the Ocean Carbon Cycle: Why Bigger Was Better. *PLoS ONE,* p. 5(8): e12444. doi:10.1371/journal.pone.0012444.

Polidoro, B. A. et al., 2011. Conservation Status of Marine Biodiversity in Oceania: An Analysis ofMarine Species on the IUCN Red List of Threatened Species. *Journal of Marine Biology,* p. doi:10.1155/2011/247030.

Poloczanska, E. S. et al., 2013. Global imprint of climate change on marine life. *Nat. Clim. Chang.,* p. 3: 919–925. doi:Doi 10.1038/Nclimate1958.

Roman, J. et al., 2014. Whales as marine ecosystem engineers. *Frontiers in Ecology and the Environment,* pp. 12: 377-385.

Roman, J. & McCarthy, J. J., 2010. The Whale Pump: Marine Mammals Enhance Primary Productivity in a Coastal Basin. *PLoS ONE,* p. 5(10): e13255. doi:10.1371/journal.pone.0013255.

Schipper, J. et al., 2008. The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge. *Science,* p. 322: 225–230.

Shamberger, .. E. F. et al., 2013. Diverse coral communities in naturally acidified waters of a Western Pacific reef. *Geophysical Research Letters,* pp. 41: 499–504, doi:10.1002/2013GL058489.

Simmonds, M. & Eliott, W., 2009. Climate change and cetaceans: concerns and recent developments. *Journal of the Marine Biological Association of the United Kingdom,* pp. 89(1): 203-10.

SPREP, 2013. *Pacific Islands Regional Marine Species Programme,* Apia: Secretariat of the Pacific Regional Environment Programme (SPREP).

SPREP, 2017. *SPREP Climate Change Overview.* [Online]
Available at: http://www.sprep.org/Climate-Change/climate-change-overview
[Accessed 26 March 2017].

Sydeman, W. J., Poloczanska, E. S., Reed, T. E. & Thompson, S. A., 2015. Climate change and marine vertebrates. *Science,* pp. (80-.). 350: 171–193..

T. Locatelli, et al., 2014. Turning the Tide: How Blue Carbon and Payments for Ecosystem Services (PES) Might Help Save Mangrove Forests. *AMBIO,* pp. 43: 981. doi:10.1007/s13280-014-0530-y.

Thomas, P., Reeves, R. & Brownell Jr, R., 2015. Status of the world's baleen whales. *Marine Mammal Science,* p. http://dx.doi.org/10.1111/ mms.12281.

Zeebe, R. E., Zachos, J. C., Caldeira, K. & Tyrrell, T., 2008. Carbon Emissions and Acidification. *Science,* pp. 321: 51-52.

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