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Vulnerability of the fisheries sector to climate change impacts in Small Island Developing States and the Wider Caribbean

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Cover photograph: D. O'Garro - impacts of Hurricane Dean (August 2007) on a fishing vessel, St. Vincent and the Grenadines.

CONTENTS

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ACRONYMS

AIMS	Atlantic, Indian, Mediterranean and South China Sea
BPOA	Barbados Programme of Action
CARICOM	Caribbean Community and Common Market
CDEMA	Caribbean Disaster Emergency Management Agency
CCA	Climate Change Adaptation
CCCCC	Caribbean Community Climate Change Centre
CCCFP	Caribbean Community Common Fisheries Policy
CIRP	Caribbean ICT Research Programme
CPUE	Catch Per Unit of Effort
DRM	Disaster Risk Management
EAF	Ecosystem Approach to Fisheries
EEZ	Exclusive Economic Zone
ENSO	El Niño Southern Oscillation
EVI	Economic Vulnerability Index
IUU	Illegal, Unreported and Unregulated
IPCC	Intergovernmental Panel on Climate Change
LDCs	Least Developed Countries
GDP	Gross Domestic Product
GHG	Greenhouse Gas
MPA	Marine Protected Area
MSI	Mauritius Strategy for Further Implementation
ODA	Official Development Assistance
PCA	Principal Component Analysis
SIDS	Small Island Developing States
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UV	Ultraviolet

1 INTRODUCTION

Climate change impacts are becoming increasingly real and adaptation is becoming crucial. Some sectors, regions, nations, communities and people will be more vulnerable to climate change than others. Vulnerability assessments are at the heart of efforts to prioritize and execute adaptation investments from scarce global funding in ways that address those who most need it. They can help guide policy makers to target and implement effective adaptation initiatives by identifying the particular places, people or sectors where climate change impacts are likely to cause the greatest harm. Vulnerability assessments have been receiving increasing attention from policy-makers and academics. Given limited funds for adaptation, the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat has suggested that eligible countries be prioritized for support based on their vulnerability to climate change. Vulnerability is thought to be highest in Least Developed Countries (LDCs) and Small Island Developing States (SIDS) (Guillaumont 2009; UNOHRLLS 2009).

The UNFCCC recognises SIDS and LDCs as country groups most vulnerable to the adverse effects of climate change.[1] LDCs are already considered to be vulnerable to extreme weather events and climate variability and change are expected to exacerbate this. LDCs are also expected to lack the adaptive capacity to respond to climate change due to their fragile economies (Bruckner 2012; Soares, Gagnon, and Doherty 2012). SIDS are considered to be highly vulnerable to climate change as many are low-lying, small, often remote, and economically vulnerable. Moreover, most SIDS are located in the tropics and sub-tropics where changes in weather patterns due to climate change are expected to be most pronounced (Guillotreau, Campling, and Robinson 2012; Nurse et al. 2014).

There is increasing concern over the direct and indirect impacts of climate change and climate variability on marine capture fisheries (Brander 2010; Cheung et al. 2010; Mora 2013). Climate change impacts such as sea surface temperature increases, ocean acidification, increased intensity of storms, and sea level rise are expected to trigger a series of biophysical and socio-economic impacts on national fisheries (Allison et al. 2009; Brander 2007; Cheung et al. 2010; Mahon 2002; Mora 2013; Nurse 2011; Pörtner and Karl 2014). These impacts will however be different for different regions and countries. Understanding where the impacts of climate change on the fisheries sector have greatest social and economic significance is crucial as fisheries are important for food security, livelihoods and employment and the generation of foreign exchange for national governments globally (Allison 2011; Allison et al. 2009).

There have been numerous fisheries vulnerability assessments at the local and community level (Cinner et al. 2013; Cinner et al. 2012; Marshall and Marshall 2007; Park et al. 2012), yet only two have been undertaken at the national-global level (Allison et al. 2009; Barange et al. 2014). The Allison et al. (2009) study followed the commonly applied definition of vulnerability used in the 2001 Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) to build their vulnerability framework. In this interpretation the vulnerability of any sector to climate variability or change is a function of (a) the degree of exposure to the threat; (b) the sector's sensitivity: the degree to which a system is affected (either adversely or beneficially); and (c) the capacity of the sector to cope with or adapt to

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[1] under Articles 4.8 and 4.9

the threat, to take advantage or create opportunities, or to cope with the consequences (Smit and Wandel 2006).[2]

The 51 recognized SIDS are dispersed across the Caribbean region, Pacific Atlantic and Indian Oceans. There are 23 SIDS in the Caribbean, 20 in the Pacific and 9 in the Atlantic, Indian, Mediterranean and South China Sea (AIMS). Climate change is considered as one of the most serious threats facing Caribbean SIDS. Sea-level rise (SLR), sea surface temperature change, ocean acidification and an increasing number and intensity of extreme weather events will all have an effect on Caribbean SIDS as a large part of the population and infrastructure is in the low-lying vulnerable coastal zone and they highly depend on ocean ecosystem services. The vulnerability of Caribbean countries to climate events is evidenced by the impact of events such as hurricanes, tropical storms, and flooding in the region, as well as gradual changes such as erosion due to sea level rise and loss of reefs due to warming. The high dependence in the Caribbean on marine resources (Monnereau et al. 2013; Nurse 2011;) makes Caribbean nations highly vulnerable as there is increasing concern over the consequences of climate change and climate variability for fisheries production and the state of marine ecosystems (Brander 2010; Cheung et al. 2010; Mora et al. 2013). Caribbean countries thus have considerable cause for concern as the threats posed to the region's development prospects are severe, the marine ecosystem itself will be impacted and adaptation will require a sizeable and sustained investment of resources that governments will find very difficult to provide on their own.

In the Caribbean there has been increasing concern for the impacts of climate change on the region. In the 2012 document on "Implementing the CARICOM Regional Framework for Achieving Development Resilient to Climate Change" for Caribbean Community and Common Market (CARICOM) countries (CCCCC, 2012)[3], it is stated that adaptation and capacity-building must be prioritized and a formal and well-financed framework established within and outside the UNFCCC to address the immediate and urgent, as well as long term, adaptation needs of vulnerable countries, particularly SIDS.

SIDS need financial support to enhance their capacities to respond to the challenges brought on by climate change and to access technologies that will be required to undertake needed mitigation actions and to adapt to the adverse impacts of climate change (CCCCC, 2012). The report of the 5Cs highlights five strategic elements of which two are important for this study. They recommend (a) promoting implementation of specific adaptation measures to address key vulnerabilities in the region; and (b) encouraging action to reduce the vulnerability of natural and human systems in CARICOM countries to the impacts of a changing climate. From this standpoint, vulnerability studies and the consequent climate change adaptation pathways for the region are essential. It is crucial for academics and policy makers to know the relative vulnerability of the fisheries sector among regions, country groups and nations, and determine the underlying sub subcomponents of vulnerability. This is important as it is needed to effectively address climate change adaptation pathways.

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[2] In the Fifth IPCC Assessment Report (AR5) the interpretation of vulnerability altered with a new focus on climate change risks (Field et al. 2014). However, during this research the AR5 was not yet available and as we are comparing and building on to the original Allison et al. (2009) framework we have the original framework as discussed in the TAR (2001) and AR4 (2007), which has also been used by a number of other vulnerability assessments (Cinner et al. 2012; Bell et al. 2011).

[3] Caribbean Community Climate Change Centre, Belmopan, Belize. 2012

Although the vulnerability of Caribbean SIDS in the face of climate change is clear from various studies, vulnerability studies have been less evident. Both the Allison et al. (2009) and Barange et al. (2014) national-level studies on fisheries sector vulnerability to climate change and other more general vulnerability assessments (see e.g Brenkert and Malone 2005; Kreft and Eckstein 2013; Peduzzi et al. 2009) identify LDCs as particularly vulnerable to climate change and more so than SIDS. In Allison et al (2009), only 11 of the 52 SIDS (21%) were included while 24 LDCs (49%) were included[4] in the analysis, while Barange et al. (2014) included only three SIDS and 14 LDCs in their analysis of 58 countries. The study by Allison et al (2009), with more than 300 citations at the time of this study, has been influential in both the international policy-making stage and in the redistribution of international funding available to countries for adaptation to climate change. The very limited inclusion of SIDS, and more particularly of Caribbean SIDS in these studies, is a serious shortcoming. The VA outcome for country groups can have large political and financial consequences as the outcome of vulnerability assessments have become increasingly popular for prioritization of climate change adaptation funding.

We therefore set out to examine the vulnerability of the fisheries sectors of Caribbean countries and of Caribbean SIDS in particular building on to the framework developed by Allison et al. (2009). We first set out to examine the outcome of different methodological choices in reference to vulnerability assessments of the fisheries sector to climate change for the three country groups: LDCs, SIDS and other coastal countries.

We further built on to the framework of Allison et al. (2009) by providing an updated version of their assessment that includes nearly all coastal nations with the most recent data and a broader set of indicators. These were used to assess all countries and compare SIDS, LDCs and other countries (Section 3). Using an even larger set of indicators which were considered to be important for SIDS in particular, we compared the vulnerability of the three groupings of SIDS (Section 4). Finally, we focused in more detail on the assessment of Caribbean countries (Section 5). We argue that a more detailed understanding of the factors underlying exposure, sensitivity and adaptive capacity can assist policymakers to make more appropriate choices regarding adaptation to climate change. We aim to identify priority support needs with regard to fisheries sector vulnerability and to identify suitable responses based on the differences among Caribbean nations.

This report is organized into five sections.

Section 2 examines the outcome of different methodological choices in reference to vulnerability assessments of the fisheries sector to climate change for the three country groups: LDCs, SIDS and other coastal countries. We investigate the different vulnerability outcomes for: 1) the use of specific indicators without scaling for differences across countries in human population or land size, 2) the absence or inclusion of particular countries, and 3) the choice of indicators and quantitative analysis. The aim of this chapter is therefore to show how different methodological choices impact the vulnerability outcomes of different country groups.

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[4] UN List of SIDS http://www.un.org/special-rep/ohrlls/ohrlls/allcountries-regions.pdf.The United Nations currently classifies 52 countries and territories as Small Island Developing States (SIDS), with a total population of over 50 million people. In the United Nations system, three major SIDS regions are recognized: the Caribbean with 23 SIDS, the Pacific with 20 SIDS and the Africa, Indian Ocean, Mediterranean and South China Sea (AIMS region**)** with 9 SIDS.

Section 3 examines the underlying differences in fisheries sector vulnerability of LDCs and SIDS. LDCs and SIDS are both considered highly vulnerable to climate change impacts because of high levels of exposure as they are located in sub-tropical and tropical regions which are associated with a high incidence of natural disasters and climate extremes, high levels of sensitivity and low levels of adaptive capacity. However, the particular vulnerability components across the three categories of exposure, sensitivity and adaptive capacity can be expected to differ between LDCs and SIDS. This chapter therefore aims to compare more specifically how the two country groups differ across the three categories of vulnerability: and identify underlying themes within the three categories. As a result we assess which underlying components that explain the variation in terms of vulnerability characteristics of the particular country groups.

Section 4 examines and compares fisheries vulnerability to climate change across three SIDS groups. Climate change impacts will have serious negative effects on all SIDS, especially on socio-economic conditions and bio-physical resources - although impacts will be ameliorated by the extent and effectiveness of adaptation. The 51 SIDS share similar sustainability challenges related to their specific characteristics such as *inter alia* smallness, isolation, remoteness, susceptibility to natural disasters, and concentration of population and infrastructure in the coastal zone. However, they are not homogenous and differences between the three SIDS groups can be expected. The aim of this section is to 1) build on to the framework set out in Section 2 by including 11 more indicators that are particularly tailored to SIDS climate change vulnerability; 2) compare the three different SIDS groups vulnerability scores across the three categories and final vulnerability score; 3) assess which subcomponents explain variation in terms of vulnerability characteristics of the fisheries sector of particular SIDS groups; and 4) examine the difference in impacts of observed and projected climate changes for the three SIDS groups.

Section 5 examines the vulnerability of the fisheries sector to climate change in the Caribbean. The chapter 1) investigates the impacts of methodological choices as described in Section 2 specifically for the Caribbean region; 2) investigates the outcome of the SIDS comparative analysis for the Caribbean region; 3) compares the vulnerability outcome for the three components of vulnerability for the Caribbean countries; 4) investigates the underlying subcomponents of vulnerability; 5) shows the scoring per underlying dimension for each Caribbean country. This aims to help design specific adaptation pathways for the fisheries sector in each Caribbean country in the face of climate change.

2 METHODOLOGICAL CHOICES AFFECT THE OUTCOME OF CLIMATE CHANGE VULNERABILITY ASSESSMENTS: AN EXAMPLE FROM THE GLOBAL FISHERIES SECTOR

2.1 Introduction

There is increasing concern over the direct and indirect impacts of climate change and climate variability on marine capture fisheries (Brander 2010; Cheung et al. 2010; Mora, 2013). Climate change impacts such as sea surface temperature increases, ocean acidification, increased intensity of storms, and sea level rise are expected to trigger a series of biophysical and socio-economic impacts on national fisheries (Allison et al. 2009; Brander 2007; Cheung et al. 2010; Mahon 2002; Mora 2013; Nurse 2011; Pörtner and Karl 2014). Increasing frequency and strength of extreme events such as tropical storms, hurricanes and droughts also pose significant threats to coastal zones, maritime areas and economies. Direct (usually ecological) and indirect (both social and ecological) pathways exist between climate change or variability and the potential impacts on the fisheries sector. The impacts will vary across regions and countries as a result of their exposure, sensitivity and level of adaptive capacity. Understanding where the impacts of climate change on the fisheries sector have greatest social and economic significance is crucial as fisheries are important for food security, livelihoods and employment and the generation of foreign exchange for national governments globally (Allison 2011; Allison et al. 2009). Vulnerability assessments to determine where the impacts of climate change are most severe are therefore very important.

Given the scarcity of funds currently available for adaptation, the UNFCCC Secretariat has suggested that prioritization among eligible countries should be based on their vulnerability to climate change and that a vulnerability index be developed to guide such prioritization (Klein 2009). Vulnerability assessment based on a range of biophysical and socio-economic indicators have become the dominant method to establish who and what is vulnerable to the negative effects of climate change (Klein 2009; Tschakert et al. 2013). They are considered to be particularly relevant now that the impacts of climate change are increasingly being observed (Hinkel 2011). Climate change vulnerability assessments have been receiving increasing attention in policy and academic circles (Hinkel 2011; Khazai et al. 2014; Klein, 2009) and have been used to address fisheries sector vulnerability (Allison et al. 2009; Barange et al. 2014).

A comparative approach using the country or state as the unit of analysis can be used to identify particularly vulnerable groups of countries. These national level vulnerability assessments can help guide appropriate climate change adaptation policies (Allison et al. 2009; Brooks, Adger, and Kelly 2005). The underlying causes of vulnerability are, however, not considered to be climate change alone, but interactions between contextual conditions and multiple processes of change (O’Brien et al. 2007). Indicator studies can be used both to enhance understanding of the causes of vulnerability and to quantify the extent of the problem (O’Brien et al. 2007).

Vulnerability assessments and the ranking of countries can have both political and practical consequences. However, this ranking is partly due to methodological choices and as a result can have serious flaws. The main critiques of many existing indices of vulnerability assessments to climate change relate to conceptual, methodological and empirical weaknesses including lack of focus, lack of sound conceptual framework, methodological flaws, large sensitivity to alternative methods for data aggregation, limited data availability, and hiding of legitimate normative controversies (Fussel 2009; Hinkel 2011; Park, Howden, and Crimp, 2012). Partly as a result of this there is little agreement regarding which countries are the most vulnerable (Eriksen and Kelly 2007).

Given the serious implications for adaptation, in this study we seek to illustrate how simple, yet sound, methodological choices in the implementation of these types of assessments can substantially change the perceptions of which country groups and countries are most vulnerable to climate change. We do this by systematically comparing the vulnerability outcome of three groups of countries, i.e. Small Island Developing States (SIDS), Least Developed Countries (LDCs) and all other coastal countries using six methodological assessments. LDCs and SIDS are recognized to be very vulnerable to the adverse effects of climate change by the UNFCCC. LDCs are considered to be vulnerable to extreme weather events, and climate variability and change are expected to exacerbate this; further these countries are expected to lack the adaptive capacity needed to respond to climate change due to their fragile economies (Bruckner, 2012; Soares et al., 2012). SIDS are also considered to be highly vulnerable to climate change as many are low-lying, small, often remote, and economically vulnerable. Moreover, most SIDS are located in the tropics and sub-tropics where changes in weather patterns due to climate change are expected to be most pronounced (Guillotreau, Campling, and Robinson 2012; Nurse et al. 2014).

In this comparison, we specifically focus on the vulnerability of the fisheries sector to climate change of these three country groups, although the effects of the methodological aspects here highlighted will generally apply to any vulnerability assessment at the national-level. While there have been numerous fisheries vulnerability assessments at the local and community level (Cinner et al. 2013; Cinner et al. 2012; Marshall and Marshall 2007; Park et al. 2012), only Allison et al. (2009) and Barange et al. (2014) have undertaken vulnerability assessments at the national-level. Both these national-level studies on fisheries sector vulnerability to climate change identify LDCs as the most vulnerable country group to climate change. The study by Allison et al. (2009) in particular, with more than 300 citations at the time of this study, has been influential in both the international policy-making stage and in the redistribution of international funding available to countries for adaptation to climate change.

We argue here that all national-level vulnerability assessments, and in particular those dealing with the fisheries sector, seeking to compare the three aforementioned country groups suffer from four main methodological shortcomings. The first is an inconsistent representation of countries belonging to each group, with SIDS in particular being very poorly represented (Table 1). The second is the use of socio-economic indicators that are not scaled to take into account the existing large differences among countries in human population size (Table 1). The third is the use of an overly small number of indicators, raising concerns about the sensitivity of the results to the inclusion or exclusion of any particular indicator. The fourth is the lack of accounting for potential redundancy among indicators, which might lead to a disproportionate effect on the final vulnerability scores by those specific aspects of vulnerability that might be overrepresented with indicators. The sensitivity of vulnerability assessments to methodological choices is rarely examined in studies focusing on climate change. In this study, we assess how the outcome of national-level vulnerability assessments of the fisheries sector to climate change is altered as we overcome the main methodological shortcomings mentioned above. We do this by using the conceptual framework and methodological setting proposed by Allison et al (2009) in their very influential paper as a starting point.

In Table 1 we present a number of studies that face a number of these methodological shortcomings. A number of the assessments presented in Table 1 included indicators based on total national values. Allison et al. (2009) use total national fish catch in mt and total number of fishers without standardizing them to population, while Kreft and Eckstein (2013) use total national number of deaths as a result of natural disasters and economic loss in absolute value. The use of such indicators based on total, rather than relative values, has the potential to dwarf the vulnerability of smaller nations. Of the eight studies, four included indicators that are based on total national numbers and thus potentially impact the final vulnerability score of smaller nations, concealing their true vulnerability. The maximum number of indicators used in these nine studies are 16 (for two studies) while remaining studies had 10 indicators or less. The small number of indicators used could be hypothesized to influence to outcome as one single indicator (and/or an outlying score) can have a large influence on the final vulnerability outcome. Furthermore, in most cases, indicators are weighted equally and so it is not fully clear how the existence of groups of potentially redundant (correlated) indicators might affect the final vulnerability score. Most studies also had a significant larger inclusion of LDCs (as % of total LDCs) in comparison to the inclusion of SIDS (% of total SIDS). This can have consequences for the ranking of country groups.

Table 1 Inclusion of SIDS and LDCs in global climate indices

Topic	**# of 52 SIDS (%)***	**%SIDS of total # countries included**	**# of 49 LDCs (% of total LDCs)**	**% of LDCs of total countries included**	**Total number countries in analysis**	**# absolute indicators/ total number of indicators**	**References**
Fisheries sector vulnerability to climate change	11 (21)	8	24 (49)	18	132	3/10	Allison et al. (2009)
Impacts of climate change on marine ecosystem production	4 (8)	7	14 (49)	24	58**	0/4	Barange et al. (2014)
National-level vulnerability assessment: food security in fisheries	4 (8)	15	7 (14)	26	27	0/10	Hughes et al. (2012)
Vulnerability Risk to climate change	5 (10)	5	16 (33)	16	100	2/16	Brenkert and Malone (2005); Yohe et al. (2006)
Vulnerability-Resilience Indicators Model (VRIM)	14 (27)	9	37 (76)	23	160	2/16	Malone and Brenkert (2009)
Disaster Risk Index	27 (52)	18	36 (73)	24	149	0	Peduzzi et al. (2009)
Global Climate Risk Index	33 (63)	18	46 (94)	25	181	2/4	Kreft and Eckstein (2013)
Disaster Sensitivity Index	46 (88)	23	47 (96)	23	198	0/3	Guha-Sapir and Hoyois (2012)
Commonwealth Vulnerability	31 (60)	28	37 (76)	33	111	0/3	WTO (2002)

Topic	# of 52 SIDS (%)*	%SIDS of total # countries included	# of 49 LDCs (% of total LDCs)	% of LDCs of total countries included	Total number countries in analysis	# absolute indicators/ total number of indicators	References
Index							

* The 12 SIDS that overlap with LDCs have been counted both for LDCs and SIDS groups, ** 67 countries are mentioned in introduction yet only for 58 countries fisheries dependency data is presented

2.2 The national level fisheries sector vulnerability assessment by Allison et al. 2009

The Allison et al. (2009) study followed the commonly applied definition of vulnerability used in the Third Assessment Report of the IPCC (2001) to build their vulnerability framework (see Figure 1). In this interpretation the vulnerability of any sector to climate variability or change is a function of (a) the degree of exposure to the threat; (b) the sector's sensitivity: the degree to which a system is affected (either adversely or beneficially); and (c) the capacity of the sector to cope with or adapt to the threat, to take advantage or create opportunities, or to cope with the consequences (Smit and Wandel 2006).[5]

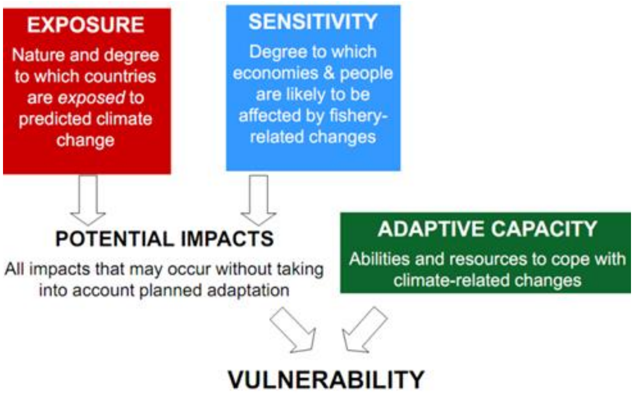

Figure 1 Fisheries sector vulnerability assessment framework

Exposure is defined as the degree of climate stress upon a particular unit of analysis; it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (IPCC 2001). Both slow-onset changes (e.g. sea surface temperatures, ocean acidification) and an increased number of extreme-weather events and intensity thereof are expected to impact fisheries worldwide (Brander 2007). In the Allison et al. (2009) study, the exposure component indicator was limited in number (only one) and thus an overly small number raising concerns about the sensitivity of the results. In addition, the indicator chosen (projected air surface temperature change by 2050) is projected to mostly take place in the higher latitudes and thus gives the impression there is only relatively low impacts of climate change in the lower latitudes (sub-tropical and tropical countries). Other exposure indicators such as sea-level rise, ocean acidification and sea surface temperature change have a more direct link with fisheries sector vulnerability.

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[5] In the Fifth IPCC Assessment report (AR5) the interpretation of vulnerability altered with a new focus on climate change risks (Field et al. 2014). However, during this research the AR5 was not yet available and as we are comparing and building on to the original Allison et al. (2009) framework we have the original framework as discussed in the TAR (2001) and AR4 (2007), which has also been used by a number of other vulnerability assessments (Cinner et al. 2012; Bell et al. 2011).

Sensitivity is usually defined as the degree to which biophysical, social and economic conditions are likely to be influenced by extrinsic stresses or hazards due to climate change, including beneficial and harmful effects. In the Allison et al. (2009) study, sensitivity was regarded as fisheries dependency of a nation for which five socio-economic indicators related to the fisheries sector were used. Out of these five indicators, three were not scaled to take into account the existing large differences among countries in human population size. Using the absolute number of fishers per country or fish catch, for example, conceals the importance of fisheries to smaller nations such as Kiribati in comparison to larger nations such as China.

Adaptive capacity relates to the capacity of a community or country to cope with, and adapt to, a variety of climate change impacts and is strongly influenced by several factors related to economic vulnerability, governance, education, and health. Adaptive capacity is thus context specific, related to both availability of resources, capacity to learn, and government measures (Gupta et al. 2010). Climate-induced shifts in ecosystems and fisheries production will create significant challenges to sustainability and management, particularly for countries with fewer resources and lower adaptive capacity, including many low-latitude and small island nations (Allison et al. 2009; Pörtner and Karl 2014). In the Allison et al. (2009) study, four socio-economic indicators were used of which one was not scaled to take into account the existing large differences among countries in human population size.

Finally, each of the three components of vulnerability was calculated as the mean of the selected indicators, which were equally weighted, and overall vulnerability was calculated as the mean of exposure, sensitivity and adaptive capacity. However, the degree of redundancy among indicators within each component was not examined. Thus, there is a risk that some specific vulnerability subcomponents within each component might have been overrepresented with indicators relative to other similarly important subcomponents, but for which there simply were fewer indicators.

2.3 General approach

The objectives of this research are addressed by comparing the outcome of six vulnerability assessments, the first of which is the original assessment by Allison et al (2009). Figure 2 provides a roadmap of the sequence of changes undertaken, starting from Allison's assessment (A1), which is based on their original data using 10 indicators and 107 coastal countries (excluding landlocked countries that the original authors had included). In A1 and all subsequent assessments, we have opted to rank-transform all the indicators, which is different from the Allison et al. (2009) approach, where either log-transformations or the raw values were used for the indicators. We believe rank-transforming each indicator should yield more robust results as this approach allows for standardizing data across indicators independently of the shape of the distribution of values underlying each indicator, while minimizing the influence of extreme values in a consistent manner across indicators. In any case, rank-transforming all the data or using Allison's selective log-transforming approach made no difference to the results obtained for A1. Assessment two (A2) follows the same methods as A1, but uses indicators scaled to human population size where relevant, and omits an indicator deemed to be inappropriate. Assessment three (A3) uses the same indicators as A2, but is based on a more recent dataset, gathering the most up-to-date information available for the indicators used in A2. Thus, A3 does not imply any methodological change in the assessment sequence. Assessment four (A4) uses the same recent data but incorporates an additional set of 66 countries. Assessment five (A5) adds an additional set of indicators to the vulnerability assessment analyses; we propose that all these new indicators are particularly relevant to assessing the vulnerability of SIDS. For the final vulnerability assessment (A6), we account for potential redundancy among indicators within each vulnerability component (exposure, sensitivity, adaptive capacity) by means of principal component analysis on the ranked-transformed indicator data. This allowed the identification of groups of redundant (correlated) indicators and ensured an equal weighting by each of these groups within each vulnerability component.

Finally, for each assessment, differences in components and overall vulnerability among country groups (i.e. SIDS, LDCs, others coastal countries) were assessed graphically and quantitatively by means of box-and-whisker plots.

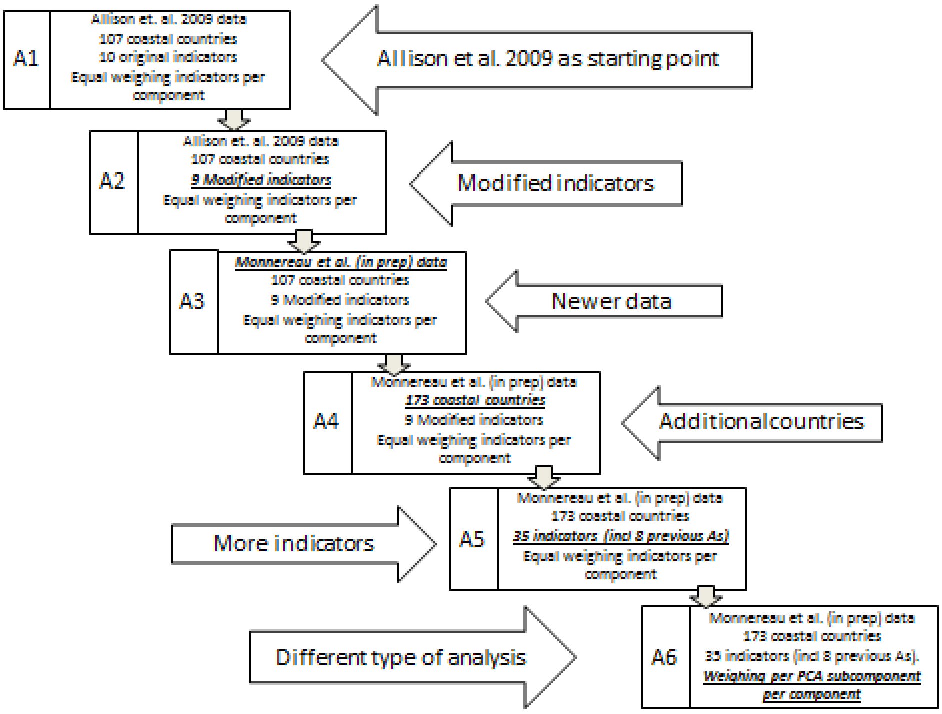

Figure 2 Characteristics of the six different vulnerability assessments used in this study

2.3.1 A1 to A2: use of non-relative numbers

The first methodological comparison is between indicators which are not scaled to take into account the existing large differences among countries in human population size and those which are, as we argue this could make a large difference in vulnerability ranking of country groups. The indicator 'fisherfolk' in total national numbers used in the Allison et al. (2009) study was deleted (see Table 2) in the second analysis. In the Allison et al. (2009) study, there were two indicators related to the number of fisherfolk. One indicator was the absolute number of fisherfolk, the second used the same data but as a percentage of Economic Active Population. As the indicator using the absolute number of fishers per country was not scaled to take into account the existing large differences among countries in human population size we excluded this indicator and kept the second indicator which was scaled to population. The exposure component was unaffected as the indicator remained the same in A1 and A2. Rescaling the indicators altered the pattern of differences among country groups for sensitivity, with SIDS replacing LDCs as the most sensitive country group (see Figure 3a-d). It also accentuated existing differences among groups in adaptive capacity, but it did not have any apparent effect on differences among groups in exposure. However, these changes did not affect the existing pattern of differences among groups in overall vulnerability, with LDCs being the most vulnerable group and ‘others’ the least.

Table 2 Comparison between the indicators used in the Allison et al. (2009) framework (framework 1) and indicators used in assessment 2 (where necessary, indicators were reversed to ensure that high outcomes implied high vulnerability (marked with *).

Components	**Assessment 1 (Allison et al. (2009), 107 coastal countries)**	**Assessment 2 (9 modified indicators: 107 coastal countries)**
Exposure	Air surface temperature change B2 scenario	Air surface temperature change B2 scenario
Sensitivity	Fisherfolk	-
Sensitivity	Fisherfolk/EAP	Fisherfolk (marine)/EAP
Sensitivity	Fish export as % of total export	Fish export as % of total export
Sensitivity	Fish catch (mt)	Fish catch (capture)(mt)/population
Sensitivity	Fish as % animal protein	Fish as % animal protein
Adaptive capacity	Health (HALE)*	Health (HALE)*
Adaptive capacity	Education (Literacy rate and Gross Enrolment Ratio)*	Education (Literacy rate)*
Adaptive capacity	Governance Index*	Governance Index*
Adaptive capacity	GDP*	GDP per capita*

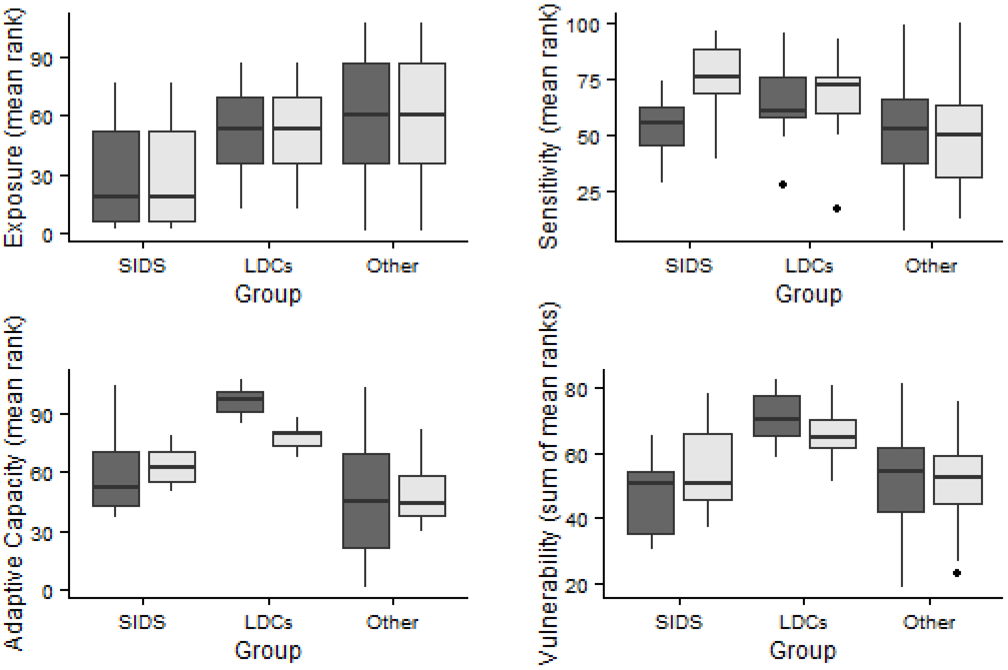

Figure 3a-d Comparison between Assessments 1 (dark grey) and 2 (light grey) for 107 countries for exposure, sensitivity, adaptive capacity and vulnerability

2.3.2 A2 to A3: use of most current data available

In this comparison we examine whether the methodological choice to use more up-to-date data will impact the outcome on country groups rankings. Unlike the previous assessment, updating the datasets did not alter in any substantial way the existing pattern of differences among country groups for any of the components and for overall vulnerability (

Figure 4a-d).

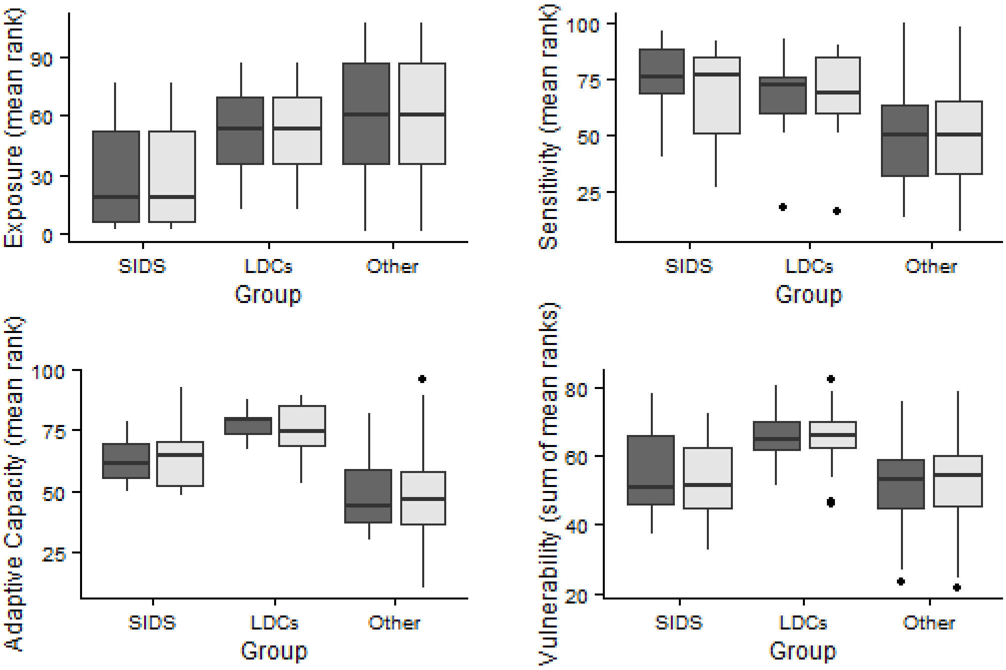

Figure 4a-d Comparison between A2 (dark grey) and A3 (light grey) using newer data for 107 coastal countries for exposure, sensitivity, adaptive capacity and vulnerability

2.3.3 A3 to A4: inclusion of more countries

Inconsistent representation of countries belonging to the country groups LDCs and SIDS could alter the results. SIDS were particularly poorly represented in the Allison et al. (2009) study (see Table 1). Data on SIDS are often excluded as a result of alleged ‘data deficiency’ (Allison et al. 2009; Hughes et al. 2012). In order to partly overcome this we followed various routes. In the case of missing data we would make a thorough search of secondary literature and/or establish direct contact with the countries involved. In some cases proxies were used for countries or missing data was filled with predictions using other datasets, which were correlated with the indicator datasets. Missing values in a given indicator were filled with the median value for that indicator. In A4 we present the results for the assessment including an additional 67 countries compared to A3. Note that the three country groups show a higher vulnerability scoring in A4 (Figure 5a-d). This is the result of scores being calculated as mean rank within the group of countries assessed, whereby the addition of countries to the analysis raises the median scores. Thus, comparisons should focus on relative differences among country groups and not on absolute country group scores. In that regard, a larger representation of countries within the SIDS and LDC groups tended to reinforce the pattern of differences among country groups established in A3 for all three components and the overall vulnerability score.

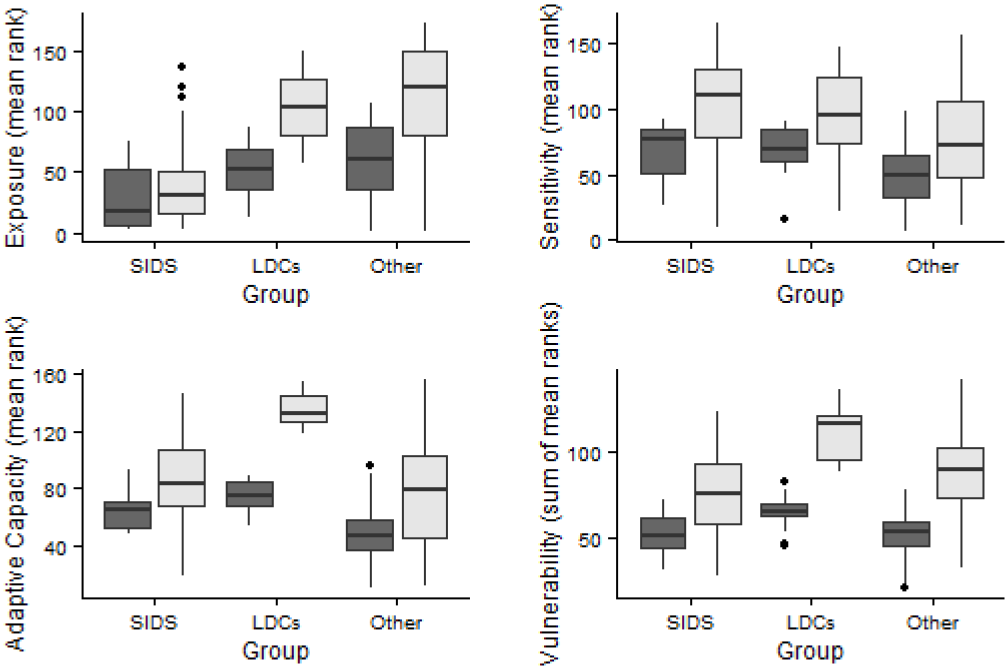

Figure 5a-d Comparison of A3 (dark grey) and A4 (light grey) scores using a larger set of countries for exposure sensitivity, adaptive capacity, and final vulnerability

2.3.4 A4 to A5: using a larger set of indicators.

A5 includes an additional 27 indicators, including indicators thought to be particularly appropriate to assessing vulnerability in SIDS. Based on a literature review we compiled a list of 130 indicators of which we found data for 107 (see Figure 6). We faced several limitations in finding data for the desired indicators at a global scale and many potential indicators identified were not yet available. Of the 107 for which data were available, we excluded 69 from further analysis for the following reasons: >10% missing data (41), redundancy (15) with similar indicators in the analysis covering the same topic, or uncertainty if different datasets covering the same topic gave different results (13) (Figure 6). Of the 33 final indicators included in A5, three were based on projected data (e.g. sea level rise and maximum potential yield change in fisheries by 2050; ‘end-point’ indicators) while the remainder were based on current status (‘start-point’ indicators).

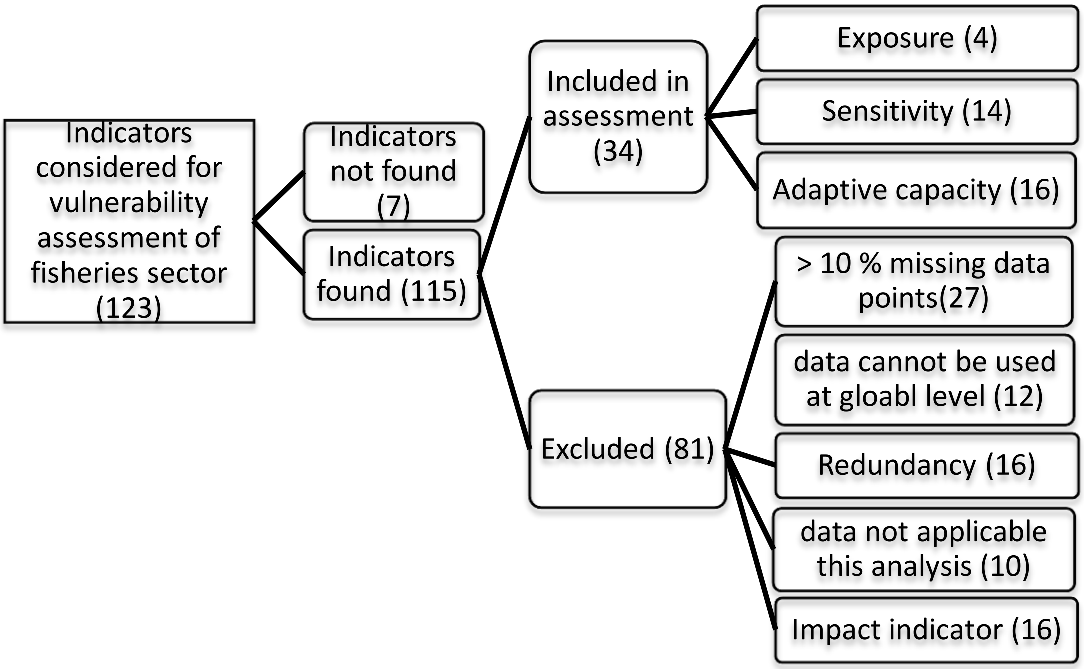

Figure 6 Selection procedure for the final indicators used in Assessments 5 and 6

Expanding on the existing work on vulnerability assessments and the fisheries literature we present a broadened framework for assessing the vulnerability of the fisheries sector to climate change (Figure 7). This means a larger set of indicators which will allow the identification and isolation of interpretable subcomponents within each of three vulnerability components. This should better reflect the complex nature of these components.

There are no objective, independently derived measures of exposure, sensitivity or adaptive capacity, so their relevance and interpretation depend on the scale of analysis, the particular sector under consideration and data availability. For the three key elements of vulnerability the derivation of each indicator is detailed in Appendix 1.

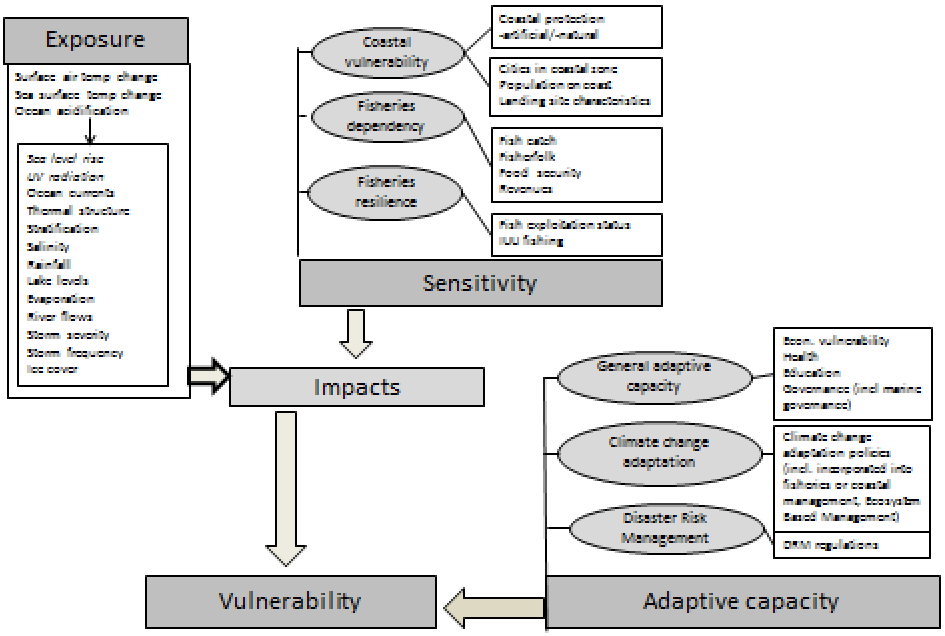

Figure 7 Vulnerability framework of the fisheries sector in the face of climate change

Exposure

In A5 we used four crucial exposure indicators for which data were available at the global scale. We consider these as making up the four main climate stressors affecting fisheries:1) sea surface temperature change; 2) sea level rise; 3) ocean acidification; and 4) UV radiation.

Sensitivity

Sensitivity is usually defined as the degree to which biophysical, social and economic conditions are likely to be influenced by extrinsic stresses or hazards due to climate change, including beneficial and harmful effects. We consider sensitivity to consist of three elements: fisheries dependency; coastal vulnerability and fisheries resilience. *Fisheries dependence* relates to the importance of fisheries to national economies and food security (Allison et al. 2009). It is represented by four indicators comprising: 1) fisheries production per 1,000 people (landings); 2) contribution of fisheries to employment by number of marine fishers as a percentage of total economic population; 3) export income as fish exports as % of total exports; and 4) food security as % of animal protein coming from fish. If a country scores higher on one of these indicators it is assumed the fisheries sector will be more heavily impacted by climate change impacts (positive or negative). *Coastal vulnerability* will be exacerbated by increases in the frequency and severity of extreme events (e.g. storms or floods) damaging infrastructure, homes, health, marine livelihoods and non-marine livelihoods (Pörtner et al. 2013). The population and assets projected to be exposed to coastal risks as well as human pressure on coastal ecosystems will increase significantly in the coming decades due to population growth, economic development, and urbanization (Field et al. 2013). *Fisheries resilience* relates to the ability of fisheries to remain viable in the face of climate-induced changes and to bounce back when these are short-term events. Climate-induced shifts in ecosystems and fisheries production will create significant challenges to sustainability and management, particularly for countries with fewer resources and lower adaptive capacity, including many low-latitude and small island nations (Allison et al. 2009; Pörtner and Karl 2014).

Adaptive capacity

The capacity of a community or a nation to cope with, and adapt to, a variety of climate change impacts is strongly influenced by several factors related to economic vulnerability, governance, education, and health. Adaptive capacity is thus context specific, related to both availability of resources, capacity to learn, and government measures (Gupta et al. 2010). Climate-induced shifts in ecosystems and fisheries production will create significant challenges to sustainability and management, particularly for countries with fewer resources and lower adaptive capacity, including many low-latitude and small island nations (Allison et al. 2009; Pörtner and Karl 2014). In this study adaptive capacity consists of three sub-components*:* general adaptive capacity of a country (e.g. health, education, governance and economic vulnerability); climate change adaptation policies (regulations and implementation, and public and private involvement); and disaster risk management (DRM). For the latter two components, no global comparable data were available. We have therefore built on the four indicators used by Allison et al. (2009) on general adaptive capacity of a country (healthy life expectancy, education, governance and size of economy by means of GDP per capita) and increased the number of indicators to include economic vulnerability, marine governance and fisheries resilience. Economic vulnerability is important as countries with lower economic vulnerability can be expected to have a higher adaptive capacity. Marine governance (fisheries management capacity), marine protected areas (MPAs) and marine resilience are important as successful fisheries management and MPAs have the potential to increase ecosystem resilience (reference needed).

The main differences between assessments A4 and A5 are seen in the exposure component (Figure 8a-d). A4 used only air surface temperature as an indicator of exposure due to lack of global availability for sea surface temperature data per country and used the underlying assumption that warming-related impacts (both positive and negative) upon physical and biological variables affecting fisheries production and fishery operations will be greater in areas where projected air temperature changes are greater (Allison et al. 2009). Geographical patterns of projected atmospheric warming, however, show greatest temperature increases over land (roughly twice the global average temperature increase) and at high northern latitudes, and the least warming over the southern oceans and North Atlantic (Barange and Perry 2009). SIDS therefore showed low levels of exposure in A1 through A4, whereas LDCs and ‘others’ showed much higher levels of vulnerability.

We have argued in the introduction that an overly small number of indicators and the particular choice of indicators can raise concerns about the sensitivity of the results to the inclusion or exclusion of any particular indicator. In A5 we omitted air surface temperature change and used sea level rise, sea surface temperature change, ocean acidification and UV radiation which we expect to have more direct and profound impacts on the fisheries sectors. As a result, SIDS are found to be much more vulnerable, closely followed by LDCs, whereas the median exposure of ‘others’ was the lowest of the three groups. Using a larger and different set of indicators thus altered the pattern of differences among country groups for exposure. It did not alter existing differences among country groups for sensitivity and adaptive capacity. The choice of more indicators in sensitivity and adaptive capacity has thus only slightly altered the ranking of country groups. However, the choice for indicators more suited to explain differences in vulnerability of the fisheries sector for the exposure component have a large influence on ranking of country groups. Due to this change whereas LDCs were ranked most vulnerable in A4, they were classified as having medium vulnerability in A5, and whether SIDS appear to be *least* vulnerable in A4, they actually appear *most* vulnerable in A5.

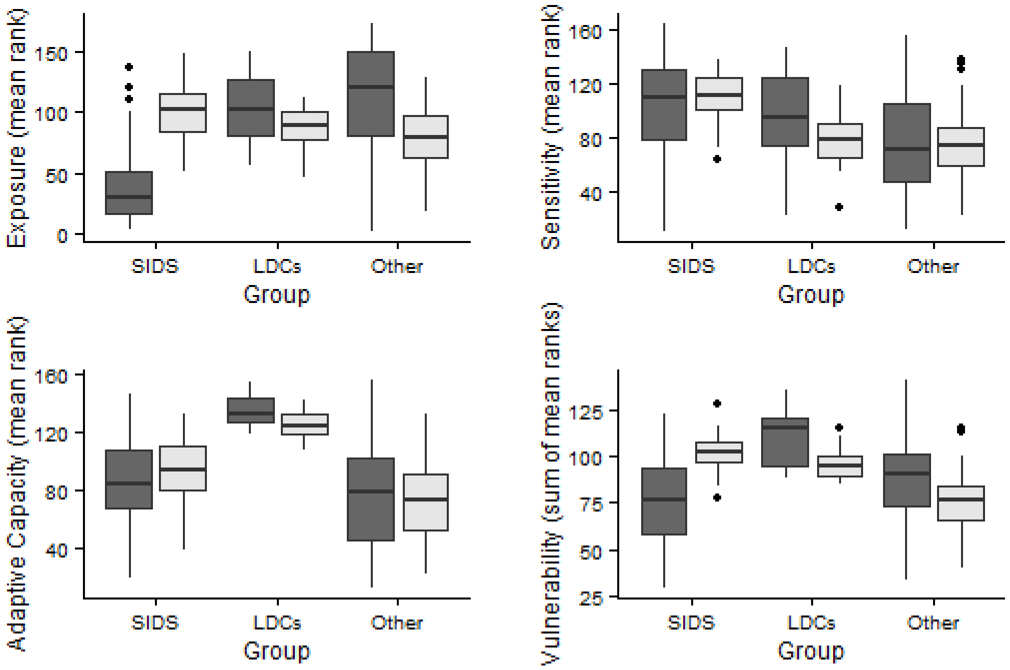

Figure 8a-d Comparison of A4 (dark grey) and A5 (light grey) using a wider set of indicators between SIDS, LDCs and others on exposure, sensitivity, adaptive capacity and vulnerability

2.3.5 A5 to A6: Accounting for potential redundancy among indicators

For the final vulnerability assessment A6, we have first used principal component analysis (PCA) to identify groups of correlated indicators (i.e. subcomponents) within each vulnerability component (exposure, adaptive capacity, sensitivity – one PCA per component). This allowed implementing an equal weighting across subcomponents within a vulnerability component, rather than across all individual indicators. Each PCA was based on a correlation matrix and was followed by varimax rotation of the principal components (PCs) to help interpret indicator loadings. Only principal components (PC) corresponding to eigenvalues ≥1 were retained (Legendre and Legendre 2011). Each PC represented a specific interpretable dimension of a vulnerability component. To interpret each PC, only indicators with relatively high loadings (≥0.6) on that PC were considered. Second, for each vulnerability component, the country scores on the retained PCs were extracted, rank-transformed, and averaged to yield an overall country score for that vulnerability component. Thus, each retained PC contributed equally to the final country score rank for a given vulnerability component, even though the PCs might have differed in the amount of total variance (and number of high loading indicators) that they captured. Finally, the three country scores (one for exposure, one for adaptive capacity, one for sensitivity) were averaged to yield the overall vulnerability score. We believe that this approach is more conceptually sound, although it did not affect the final results in this specific study, with little differences observed between A5 and A6 (fig 1.9a-d).

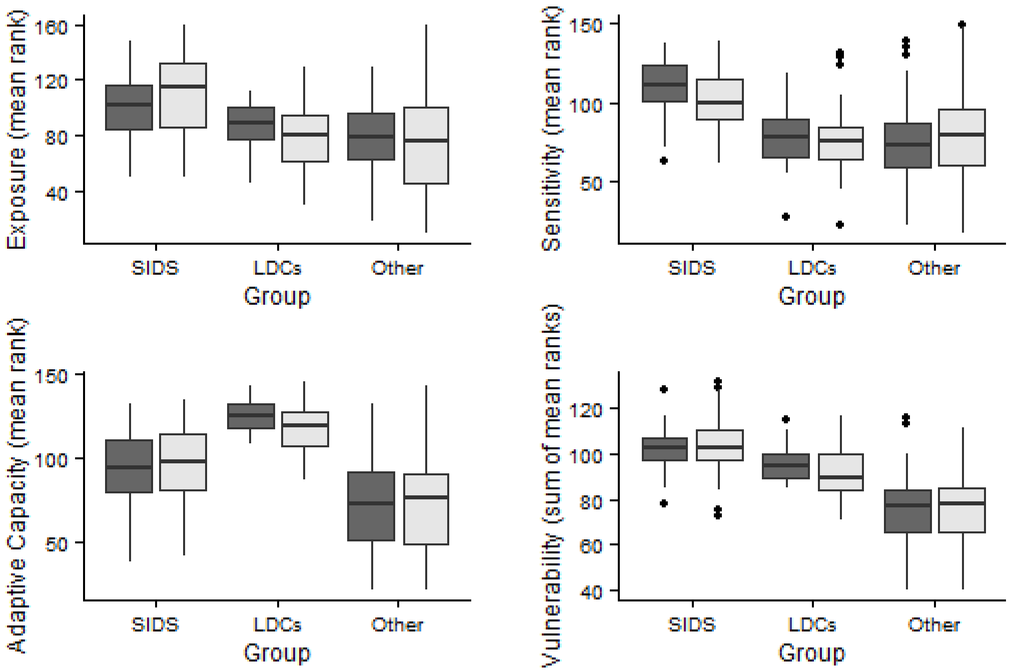

Figure 9a-d Comparison of A5 (dark grey) and A6 (light grey) between SIDS, LDCs and others on exposure, sensitivity, adaptive capacity and vulnerability

2.4 Maps of global coastal nation's fishery sector vulnerability by assessment

In Figure 10a-f we show in maps how individual countries would score according to the six assessments. Each map shows the level of vulnerability of each coastal nation whereby we have coloured each country's EEZ rather than landmass to make small islands and nations more visible.

The maps of the six assessments show the changing representation of vulnerability of the countries involved. The general pattern of change is that tropical and subtropical countries, including SIDS, are shown to be highly vulnerable in the latter analyses in comparison to the initial assessments. This is clearly illustrated in Figure 10g, which shows the change in ranks between A1 and A6 for all countries included in both assessments (n=107). The results show that particularly Australia and islands in the Pacific Ocean, the Caribbean, Chili, northern Europe, the Middle East and some islands in the Indian Ocean became much more vulnerable in A6 while North America, Russia, and parts of Asia and Africa became less vulnerable. This figure only shows the change for the initial 107 countries in Allison et al. (2009) and therefore does not include the majority of SIDS.

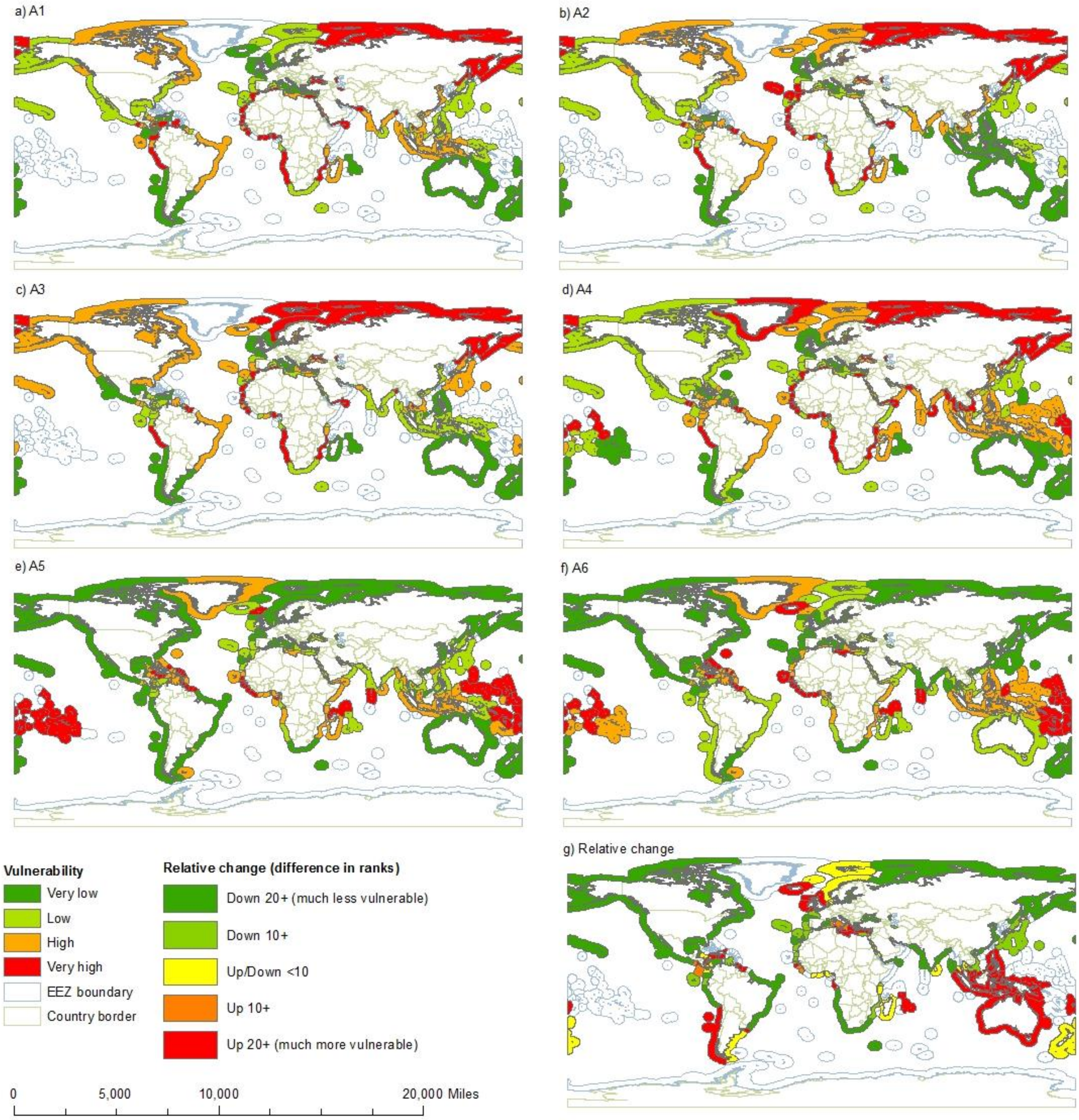

Figure 10a-g The outcome of the six vulnerability assessments of national fisheries sector to the climate change (integrating exposure, sensitivity and adaptive capacity) per coastal country. [Shading in maps a-f represent quartiles with red for upper quartile, dark orange for third quartile, orange for second quartile and yellow for lowest quartile (see vulnerability legend). Shading in map f illustrates the change in ranks between A1 and A6 for all countries included in both assessments (n=107) (see relative change legend)].

2.5 Discussion and conclusion

Climate change vulnerability assessments of different sectors and at different scales have been gaining ground in academia and policy circles. At the national level, different country groups can be expected to express differences in vulnerability due to their level of exposure, sensitivity and capacity to adapt. SIDS and LDCs are both expected to be highly vulnerable to climate change, yet assessments to date have suggested that LDCs are most vulnerable. We have argued, however, that the underlying reasons for this conclusion can partly be found in methodological choices that are made when assessing vulnerability of different nations. The outcomes of indicator-based vulnerability assessments are unavoidably affected by methodological choices and we argue that these choices should be made more transparent because these studies are well known to drive policy and have clear socio-economic implications for adaptation.

This is the first study to have systematically analyzed the effect of differences in methodological choices in vulnerability of the fisheries sector to climate change between SIDS, LDCs and other coastal nations. Based on earlier work (Allison et al. 2009) in which vulnerability of the fisheries sector in the face of climate change was seen as a function of exposure, sensitivity and adaptive capacity, we developed a six-step methodological approach to show how different methodological choices can lead to different outcomes between SIDS, LDCs and other coastal countries. In this section we have shown the changes in vulnerability ranking according to four main methodological shortcomings. These are: an inconsistent representation of countries belonging to each group, with SIDS in particular being very poorly represented; the use of socio-economic indicators that are not scaled to take into account the existing large differences among countries in human population size; the use of an overly small number of indicators, raising concerns about the sensitivity of the results to the inclusion or exclusion of any particular indicator; and the lack of accounting for potential redundancy among indicators, which might lead to a disproportionate effect on the final vulnerability scores by those specific aspects of vulnerability that are overrepresented with indicators

Changes between each assessment were carried out sequentially so which methodological choices contributed the most to alter the final difference between the first and last assessment are difficult to identify, yet we can draw some overall conclusions. In line with the thinking of other research, our study shows that the choice of vulnerability indicators used in the analysis will lead to different conclusions (see Eakin and Luers 2006). Rescaling the indicators altered the pattern of differences among country groups for sensitivity, with SIDS replacing LDCs as the most sensitive country group. Updating the datasets with most up-to-date data did not alter in any substantial way the existing pattern of differences among country groups for any of the components and for overall vulnerability. Using more recent data or giving equal weight to underlying themes rather than individual indicators also had very little impact on the final outcome. When including a much later set of countries, the differences between the country groups is accentuated in exposure and adaptive capacity, yet there is little difference in sensitivity and vulnerability score. Using a large set of indicators and particularly the choice for different exposure indicators which are most suitable to assessing fisheries sector vulnerability have accentuated the differences in final vulnerability outcome more strongly, increasing the relative vulnerability outcome of SIDS. We have noted that the results for exposure were radically different as a result of the choice of indicators with SIDS being the last vulnerable in the first analysis to most vulnerable in the last. These results between A4 and A5 also show that despite adding 27 indicators across the components of sensitivity and adaptive capacity the ranking of SIDS and LDCs differ only marginally. This suggests that the original indicators chosen by Allison et al. (2009) for sensitivity and adaptive capacity are robust; yet, due to the small number of indicators in their study adding or subtracting one indicator can be expected to make a large difference. For the final vulnerability assessment A6 we have combined the indicators in each of the subcomponents using principal component analysis and thus accounting for potential redundancy among indicators, which might lead to a disproportionate effect on the final vulnerability scores by those specific aspects of vulnerability that are overrepresented with indicators. Our results show very little difference in vulnerability outcome between the different country groups. However, it should be noted that even when the results do not show apparent differences between country groups for a choice of method individual countries within that group could still be strongly affected by choice.

When examining the results of the relative change in ranking of vulnerability between the various assessments, Australia and islands in the Pacific Ocean, the Caribbean, Chile, some countries in Northern Europe, the Middle East and some islands in the Indian Ocean are assessed as being much more vulnerable, going up in rank by at least 20 ranks, while North America, Russia, and parts of Asia and Africa are assessed as being less vulnerable and dropped over 20 ranks.

Our results show that although SIDS were least vulnerable in the initial assessments they were most vulnerable in the later assessments. Methodological choices thus have a large-scale impact on the vulnerability outcome of countries and country groups and these choices, and we argue that the potential impact on the outcome should be made much more explicit in vulnerability assessments. These results emphasize the importance of methodological choices in vulnerability studies beyond the fisheries sector as well. Our study also argues for a more adequate inclusion of SIDS in fisheries sector climate change vulnerability analyses as their exclusion has concealed their actual vulnerability. The under-representation of SIDS in previous vulnerability assessments can have widespread consequences for SIDS in the climate change debate, given that the results of national level vulnerability assessments are used to help determine the allocation of adaptation resources under various international governance mechanisms.

3 KEY DRIVERS OF CLIMATE CHANGE VULNERABILITY IN THE FISHERIES SECTOR IN SMALL ISLAND DEVELOPING STATES AND LEAST DEVELOPED COUNTRIES

3.1 Introduction

The adverse impacts of climate change are a major obstacle to the achievement of sustainable development goals for Small Island Developing States (SIDS) and Least Developed Countries (LDCs) (Bruckner 2012; UN, 2005). SIDS and LDCs are recognized as being the most vulnerable groups to the adverse effects of climate change by the UNFCCC.[6] The country groups have both been recognized by the UN as groups with distinct characteristics and vulnerabilities. Vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt (Adger, 2006). In the IPCC definition of vulnerability, therefore, the key parameters of vulnerability are the stress to which a system is exposed, its sensitivity, and its adaptive capacity (Smit and et al. 2001.). In the light of scarce funds currently available for adaptation some Parties to the UNFCCC have suggested a prioritization among eligible countries on the basis of their vulnerability to climate change and the development of a vulnerability index to guide such prioritization (Klein 2009).

Climate change vulnerability assessments of different sectors and at different scales have been gaining ground in academia and policy circles. At the national level, different country groups can be expected to express differences in vulnerability due to their level of exposure, sensitivity and capacity to adapt. SIDS and LDCS are both expected to be highly vulnerable to climate change, yet assessments to date have suggested that LDCs are most vulnerable. We have argued, however, in Section 2 that the underlying reasons for this conclusion can partly be found in methodological choices that are made when assessing vulnerability of different nations. Our results show that although SIDS were least vulnerable in the initial assessment by Allison et al. (2009), in comparison to LDCs and other coastal nations, they were most vulnerable in the later assessments. Methodological choices thus have a large-scale impact on the vulnerability outcome of countries and country groups. We have argued that methodological choices in vulnerability assessments should be made more transparent because these studies are well known to drive policy and have clear socio-economic implications for adaptation.

Section 2 has shown that the fisheries sector in SIDS is most vulnerable to climate change, yet, closely followed by LDCs. Their underlying vulnerability, however, can be expected to be different between the two groups. LDCs and SIDS contribute very little to greenhouse gas (GHG) emissions yet they are expected to suffer significantly from the adverse impacts of climate change (Adgeret al. 2003; Guillotreau, Campling, and Robinson, 2012; Huq et al. 2003). LDCs and SIDS are both considered vulnerable because of high levels of exposure as they are located in sub-tropical and tropical regions which are associated with a high incidence of natural disasters and climate extremes (Bruckner 2012; Nurse et al. 2014). The particular vulnerability components across the three categories, that are expected to be exacerbated by climate change, can be expected to be different however in LDCs or SIDS. Building on to the vulnerability assessment developed in Section 2, this section aims to compare more specifically how the two country groups differ across the three categories of

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[6] under Articles 4.8 and 4.9

vulnerability: exposure, sensitivity and adaptive capacity of the fisheries sector. In Section 2 we have modified and expanded the vulnerability indicators used by Allison et al. (2009). Based on an assessment using 33 indicators, of which 8 were also used by Allison et al. 2009 (see Appendix 1), we here identify underlying themes in the three categories and assess which subcomponents explain the largest variety among country groups.

LDCs were first officially recognized as a separate group by the United Nations in 1971. Currently there are 48 LDCs of which 34 are coastal nations. Of these 34 coastal LDCs, 12 are also SIDS. They are a group of the world's poorest countries and thus can be expected to have the least capacity to adapt to climate changes. LDCs have been classified by the United Nations as least developed on the basis of their low Gross Domestic Product (GDP) per capita, weak human assets, and high degree of economic vulnerability. The original criteria used to determine LDCs have since 1971 been modified and expanded. Since 2011 the UN criteria for determining LDCs are based on Gross National Income per capita, Human Asset Index based on four indicators on health and education, and the Economic Vulnerability Index (EVI) based on 8 indicators. Specific thresholds for each component are used to include or exclude countries (UNFCCC 2011). LDCs are already considered to be vulnerable to extreme weather events and it is expected that this condition will be exacerbated by climate change and climate variability. These countries with the lowest indicators of socio-economic development are expected to lack the adaptive capacity to respond to climate change due to their fragile economies (Bruckner 2012; Soares et al. 2012). They lack many key elements of the adaptive capacity to respond to climate change, including e.g. a stable and prosperous economy, a high degree of access to technology or human capital, and robust information dissemination systems and equitable access to resources (UNFCCC 2011)

Small Island Developing States are small island or low-lying coastal countries located in the tropical and sub-tropical regions (partly) surrounded by oceans (Boto and Biasca 2012). SIDS were first formally recognized as a distinct group by the United Nations in 1992 at the Conference on Environment and Development held in Rio de Janeiro in Brazil (Boto and Biasca 2012). Unlike LDCs where inclusion of countries is based on precise thresholds for specific indicators, SIDS constitute a more loose component of countries. There is no common accepted definition of what constitutes SIDS (Boto and Biasca 2012; Polido, João, and Ramos 2014) and the exact countries will vary depending on the criteria used (Boto and Biasca 2012; Crowards 2002). A classification of SIDS based on size of population, land or size of economy, for example, will each create a different set of countries (although with overlaps) (Crowards 2002). The UN recognizes 51 SIDS of which 14 are non-members of the UN and in this study we follow their classification of SIDS. SIDS are considered a separate group by the UN as they share similar sustainability challenges related to their specific characteristics such as smallness, isolation, remoteness, susceptibility to natural disasters, vulnerability to external shocks, concentration of population and infrastructure in the coastal zone, high dependence on a limited number of resources including marine resources and excessive dependence on international trade (Guillotreau et al. 2012; Mimura et al. 2007; Nurse et al. 2014; Polido, João, and Ramos 2014).[7]

The aim of this section is threefold. First, the relative vulnerability of the fisheries sector of coastal LDCs, SIDS and other coastal nations is assessed, based on the three indices of exposure, sensitivity and adaptive capacity. Secondly, it evaluates which groups of indicators of the three components explain the largest variety among country groups. Third, the chapter

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[7] See also www.sids.org

seeks to determine which group of subcomponents of exposure, sensitivity and adaptive capacity best characterizes the three country groups. As far as the authors are aware, this is the first study to carry out a rigorous in-depth comparison of vulnerability scoring of the fisheries sector of LDCs and SIDS. We argue that a more detailed understanding of the factors underlying exposure, sensitivity and adaptive capacity would assist policymakers in making more appropriate adaptation choices in the face of climate change.

3.2 Methods

The choice of indicators used in this assessment is based on the vulnerability framework described in Section 2 (see sub-section 2.2.4). We have used 33 indicators that are derived from an original much larger set of indicators (see Appendix 1 for indicators used). We used eight indicators used by Allison et al. (2009) across the categories of sensitivity and adaptive capacity. In addition, we have added a new set of 27 indicators. Based on a literature review we compiled a list of 130 indicators of which we found data for 107. Several challenges were encountered in finding global scale data for some of the desired indicators. Ultimately, some indicators were excluded due to >10% missing data (41), redundancy (15) with similar indicators in the analysis covering the same topic, or uncertainty if different datasets covering the same topic gave different results (13).

This study includes 50 out of 52 SIDS that are officially recognized by the UN[8] and an additional eight overseas territories located in tropical or sub-tropical areas. All coastal LDCs (24 countries) are included (see Appendix 2 for a list of all countries included per group). The twelve LDCs that are also SIDS have been grouped under SIDS, since their characteristics are similar to those in this group. Missing values for a given indicator were filled with the median value for that indicator and each indicator was subsequently rank-transformed. This approach allowed for standardizing data across indicators independently of the shape of the distribution of values underlying each indicator, while minimizing the influence of extreme values in a consistent manner across indicators.

3.2.1 Principal Component Analysis

A principal component analysis (PCA) was conducted separately for each group of ranked-transformed indicators representing a vulnerability component. Each PCA was based on a correlation matrix and was followed by varimax rotation of the principal components (PCs) to help interpret indicator loadings. Only principal components (PC) corresponding to eigenvalues ≥1 were retained (Legendre and Legendre 2011). To help interpret each PC, only indicators with relatively high loadings (≥0.6) on that PC were considered. Finally, the country scores on the retained PCs of each vulnerability component (exposure, sensitivity, adaptive capacity) were extracted and rank-transformed. For each PC retained, the score ranks for the countries were used to assess potential differences among country groups (i.e. Others, SIDS, LDCs) graphically and quantitatively by means of box-and-whisker plots.

The rank-transformed country scores on the retained PCs were averaged across PCs within each vulnerability component to yield a single average score rank for each country for each vulnerability component. This implies that each retained PC contributed equally to the final country score rank for a given vulnerability component, even though such PCs differed in the amount of total variance (and number of high loading indicators) that they captured. In order

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[8] http://unohrlls.org/about-sids/

to integrate vulnerability component scores into overall vulnerability, the final average score ranks for each country for each vulnerability component were averaged to yield a single final vulnerability score.

3.3 Results

Scores for the three vulnerability indices and the composite vulnerability scores all show significantly different results for the three country groups (see Figure 11a-d). The figure accentuates SIDS are more vulnerable than LDCs under the exposure component, while other coastal countries are the least vulnerable in this component (Figure 11a). For sensitivity, SIDS are the most vulnerable group, yet the relative difference with other coastal nations and LDCs is small (Figure 11b). With respect to adaptive capacity the LDCs are the most vulnerable group, followed by SIDS and other coastal nations, respectively (Figure 11c). The composite vulnerability scores rank the fisheries sector in SIDS as the most vulnerable to climate change, ahead of LDCs and other coastal nations (Others) (Figure 11d).

Variation among countries within each country group is substantial and a more detailed look at the results per component for individual countries is shown in figures Figure 12a-d. The Exclusive Economic Zone (EEZ) of a country is coloured rather than landmass to make smaller nations more visible.

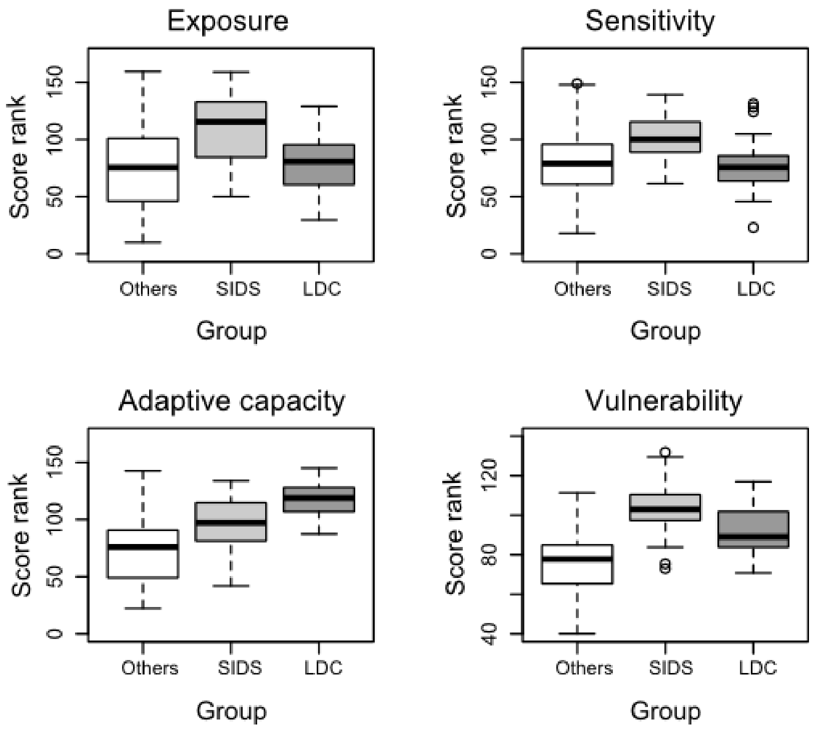

Figure 11a-d: Comparison of SIDS, LDCs and Others on exposure, sensitivity, adaptive capacity and composite vulnerability scores

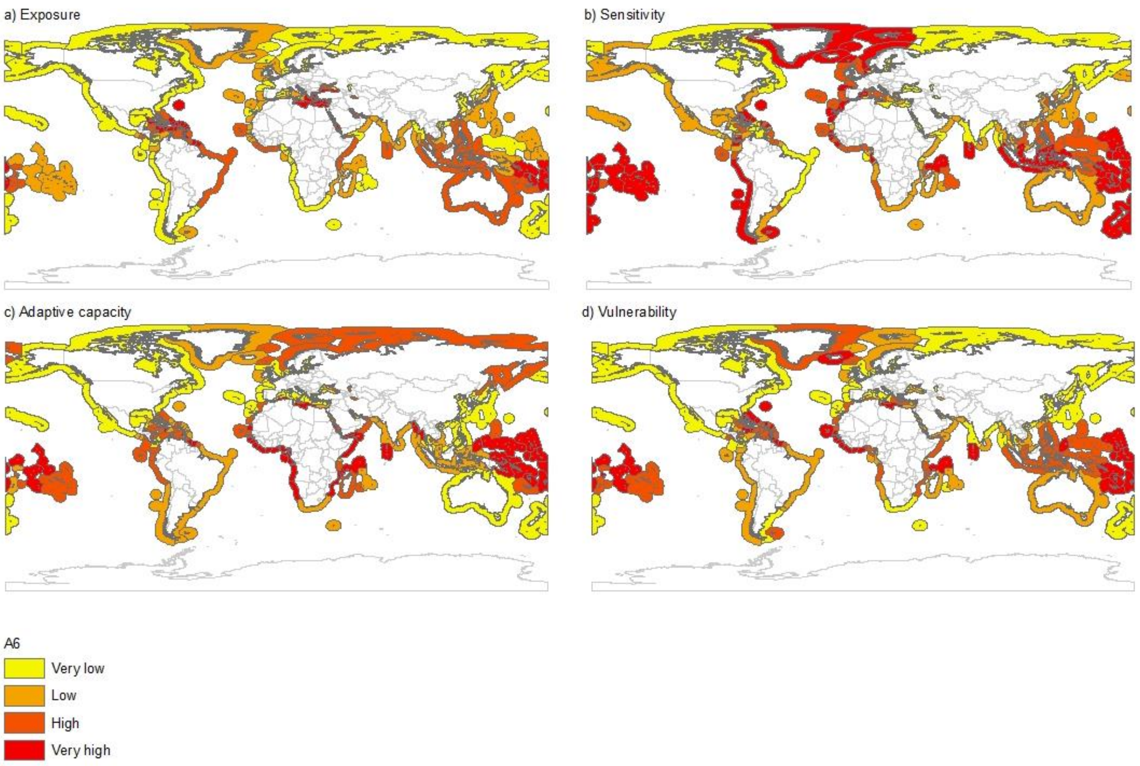

Figure 12a-d: Results on exposure, sensitivity, adaptive capacity and composite vulnerability scores per individual country (divided in quartiles)

3.3.1 Subcomponents by component

The PCA identified 13 subcomponents across the three categories: two for exposure, four for sensitivity and three for adaptive capacity. PCA results have successfully identified coherent groups of indicators within the three categories that explained relatively high amounts of variation in the data. For exposure, the two subcomponents explain 63.4% of the variation (Table 3). The first subcomponent represents sea surface properties (ocean acidification and sea surface temperature change); the second subcomponent is UV radiation. For sensitivity, the four subcomponents explain 68.1% of the variation (see Table 3). The first subcomponent, coastal vulnerability, explains 34.5% of the variation. Then, fishery dependence, habitat health and fishery resilience explain 14.9%, 11.1% and 7.6% of the variation, respectively.

Table 3 PCA subcomponents for LDCs, SIDS and other comparison

Indicators per component	**Subcomponents**			
Exposure	**E1 Sea surface properties (35.8%)**	**E2 UV radiation (27.6%)**		
Sea surface temperature change	.878			
Ocean acidification	.605			
UV radiation		.929		
Sensitivity	**S1 Coastal vulnerability (36.7%)**	**S2 Fishery dependence (15.9%)**	**S3 Habitat health (11.8%)**	**S4 Fisheries resilience (7.9%)**
% pop 10 km coastline	.904			

Indicators per component	**Subcomponents**			
% land 10 km coastline	.903			
% land within 5 m above sea level	.880			
% cities in coastal zone	.850			
% pop within 5 m above sea level	.746			
Fisherfolk		.795		
Fish nutrition		.761		
Fish catch		.757		
Habitat status			.962	
Biodiversity status			.972	
Species resilience				.713
Fisheries overexploitation			.	-.804
Adaptive capacity	**AC 1: Socio-economic development (48%)**	**AC 2: Ocean space and protection (11%)**	**AC3: Trade vulnerability (8%)**	
GDP per capita	.917			
Governance	.876			
Infant mortality	.858			
Health	.844			
Fisheries resilience	.824			
Access to clean sanitation	.820			
Nightlight Development Index	.785			
Education	.767			
Livelihood resilience	.502			
EEZ/coastline		.771		
MPAs/EEZ		.749		
Terms of trade			-.723	
Concentration of exports			.684	

For adaptive capacity, the three subcomponents identified explain 67% of the variation (see Table 3). The subcomponent representing socio-economic development explains 48% of the variation whereas ocean space protection and trade vulnerability represent the second and third subcomponents, with 11% and 8% of the variance explained.

3.3.2 Country groups ranked by subcomponent

The country group scores vary significantly across the different PCA subcomponents. SIDS rank as the most vulnerable group for both subcomponents of exposure (Figure 13). LDCs are shown to have particularly low vulnerability with respect to sea surface properties (SST and ocean acidification (see Figure 13).

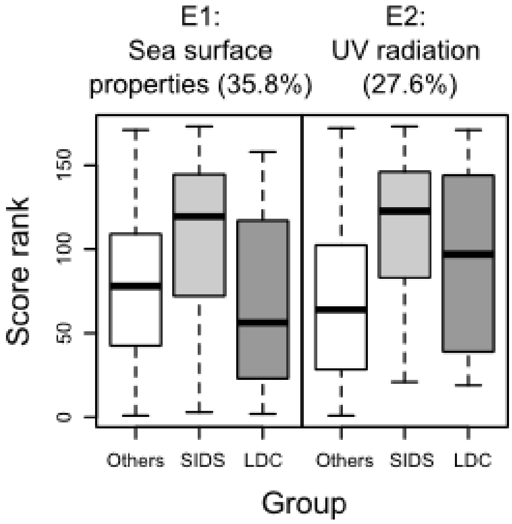

Figure 13 Scores of three country groups ranked by subcomponents of exposure

The sensitivity component only accentuated minor differences between country groups (Figure 14). Although SIDS emerged as the most vulnerable group for this component overall, the difference with LDCs and others was marginal. Yet, when we examine the four subcomponents there are clear differences among country groups (Figure 14). SIDS are highly vulnerable with respect to 'coastal vulnerability', while other coastal states and LDCs are assigned much lower scores under this subcomponent of sensitivity. In the second component, sensitivity, there are four subcomponents: 'coastal vulnerability'; 'fisheries dependency'; 'habitat health', and 'fishery resilience'. For 'coastal vulnerability' SIDS score very high while LDCs and Others have low vulnerability in this subcomponent. For 'fisheries dependence' LDCs are the most vulnerable, although closely followed by SIDS. In 'habitat health' LDCs score most vulnerable as a group but when considering the median SIDS and Others have near identical scores. Others and SIDS have nearly identical high vulnerability scores for the subcomponent 'fisheries resilience', while LDCs are considerably less vulnerable. The ranking shows that actually 'Others' are considered to be more vulnerable than SIDS and LDCs when considering fisheries resilience.

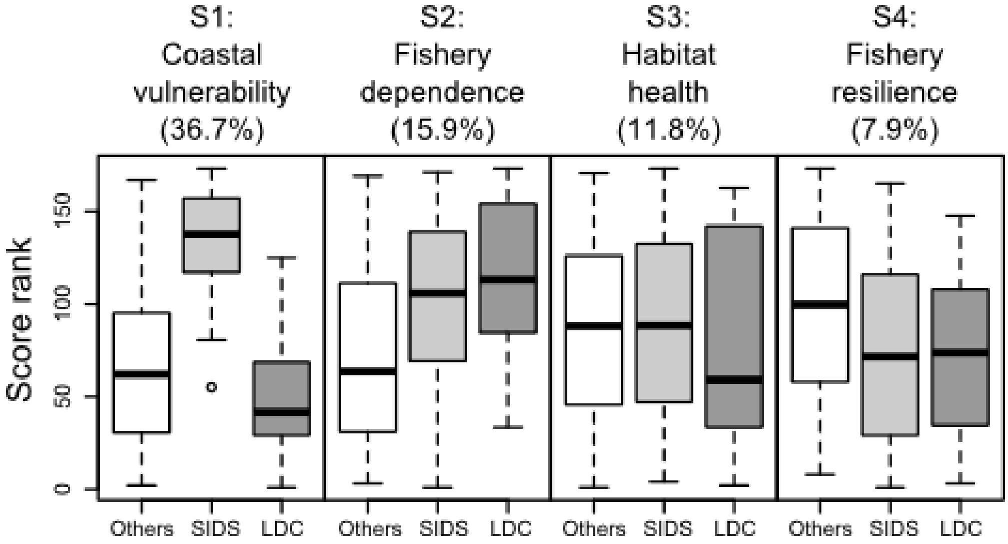

Figure 14 Scores of the three country groups ranked by subcomponent of sensitivity

With respect to adaptive capacity, there is great variation in the rankings among the three country groups across the three subcomponents (Figure 15). LDCs are ranked as extremely vulnerable for the subcomponent 'socio-economic development', while SIDS and Others have similarly ranking and have a low vulnerability. SIDS vulnerability is most pronounced with respect to 'ocean space and protection' which refers to the magnitude of the EEZ in comparison to as well as the % of EEZ designated as a protected area.

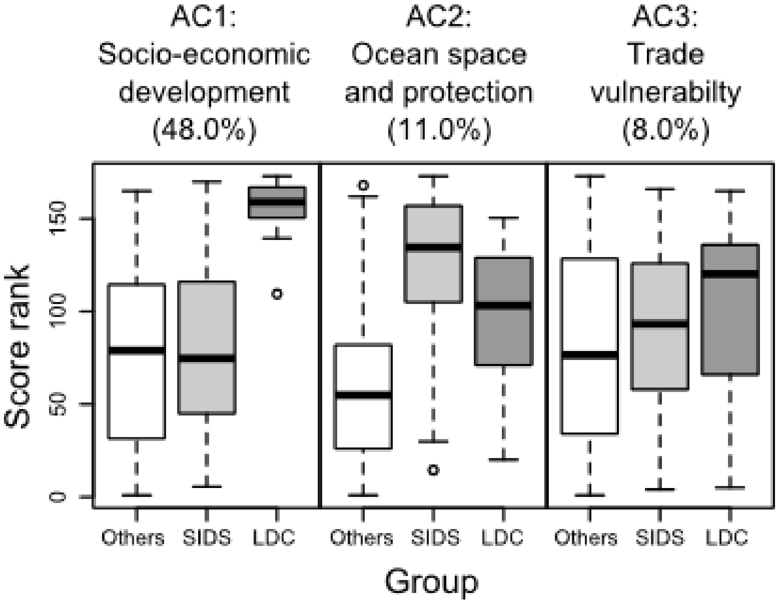

Figure 15 Scores of the three country groups ranked by subcomponent of adaptive capacity

We have found that the two sub-components that show the largest variety between the three country groups are S1: *coastal vulnerability* and AC1: *socio-economic development.* The biplot in Figure 16 represents the score location of the three country groups. SIDS are ranked as highly vulnerable on coastal vulnerability in the plot, while LDCs are highly vulnerable in the socio-economic development subcomponent. These results support previous conclusions about SIDS with respect to coastal vulnerability (Mimura et al. 2007; Nurse et al. 2014) and the low adaptive capacity of LDCs (Bruckner 2012; Soares et al. 2012).

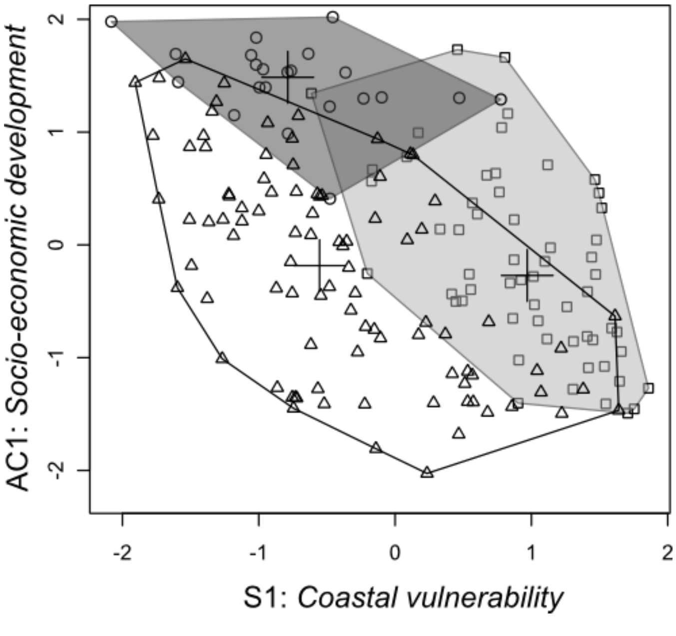

Figure 16 Two subcomponents explaining largest variation between SIDS (dark grey), LDCs (light grey) and others (no color).

3.4 Discussion and conclusion

This section has shown SIDS are considered to be most vulnerable in the composite vulnerability rankings, followed by LDCs in comparison to other countries. Thus, these results reinforce the view that SIDS and LDCs are among the most vulnerable states, when compared to other nations. However, despite SIDS and LDCs showing similar high levels of final vulnerability ranking of their fisheries' sector to climate change, our results suggest there are great differences in vulnerability in terms of the underlying subcomponents of vulnerability. When we examined the differences of vulnerability ranking between the three country groups per component, exposure, sensitivity and adaptive capacity, our results suggest SIDS are most vulnerable in the sensitivity component, while for LDCs the area of greatest vulnerability lies in their low adaptive capacity.

We have identified underlying dimensions for the three components of vulnerability, and have identified those which explain the largest variety of rankings in vulnerability of country groups. The two components explaining the largest variety among the three groups are sensitivity and adaptive capacity and the two subcomponents are (socio-economic development and coastal vulnerability) of vulnerability. The analysis shows that the LDCs are highly vulnerable with regard to the socio-economic development subcomponent of adaptive capacity. Contrastingly, SIDS are the most vulnerable group with respect to ocean space and the large EEZ they have to manage and protect, factors that underscore the difficult task they face in adequately governing their fisheries.

Our results indicate that exposure is a highly complex and heterogeneous dimension that cannot be easily captured in a single aggregated value. The complexity partly results from the fact that the four indicators have three underlying principal components: ocean acidification and sea surface temperature, UV radiation and sea level rise, and each indicator shows a different result. Given the complexity of the exposure component, it was felt that assessment of regional and country level differences should therefore form a critical element of the analysis. In addition, using exposure indicators that already incorporate the projected impacts on marine potential yield as a result of climate change (e.g. work by Barange et al. 2014 or Cheung et al. 2010) could improve the current framework and should be considered in future research.

These results thus highlight the issue of heterogeneity within each component. While SIDS and LDCs can have similar ranks for a component, they can have fundamentally different patterns of variation across the sub-components of that component. This has implications for policy and adaptation actions as implies that in order to develop adequate adaptation measures to climate change it is crucial to look at the ranking on underlying components and not on the ranking on the component per se.

As we do not know the precise impacts of climate change and the large differences in country groups, we need to take a pre-cautionary approach and focus on adaptation. In SIDS and LDCs fisheries governance will only be improved by employing a range of strategies, including the application of ecosystem-based approaches, wide stakeholder engagement, institutional building of fisheries administrations and stricter application of international fishery agreements to accommodate and support climate change related activities. We stress the importance of enhancing emergency preparedness and response, and development of insurance and social safety schemes in the fisheries sectors for both SIDS and LDCs, in order to enhance their adaptive capacity.

This research has identified some of these underlying drivers. However, in order to offer the most effective adaptation recommendations one would need to refine these results at an even more regional and local scale. The wide boxplots for LDCs and SIDS for all subcomponents except two (coastal vulnerability and socio-economic development) indicate a large variation in scores within these two groups. Further analysis, for example investigation of the differences that exist among the three SIDS groups, i.e. the Pacific, Atlantic, Indian, Mediterranean and South China Sea (AIMS) and Caribbean SIDS, would help to highlight more precisely the nature of the differences within the groups. Section 4 will further explore the differences between these three different SIDS groups.

4 ARE ALL SIDS THE SAME: COMPARING FISHERIES VULNERABILITY TO CLIMATE CHANGE ACROSS THREE SIDS GROUPS

4.1 Introduction

Although SIDS produce only 0.6%[9] of global greenhouse gases (Monnereau et al., 2013), they are expected to be disproportionally affected by the threats of climate change (Mimura et al., 2014; Nurse et al., 2014). SIDS are small island or low-lying coastal countries located in the tropical and subtropical regions (partly) surrounded by oceans (Boto and Biasca, 2012), which have been banded together under the United Nations to address common sustainability challenges. Small islands will be most at risk as a result of sea-level rise, tropical and extra-tropical cyclones, increasing air and sea surface temperatures, and changing rainfall patterns (Nurse et al., 2014). It has been suggested that the very existence of some atoll nations are threathened by rising sea levels associated with climate change. Although this scenario is not applicable to all SIDS, it is without a doubt that climate change impacts overall will have serious negative effects on SIDS especially on socio-economic conditions and bio-physical resources-although impacts will be ameliorated by the extent and effectiveness of adapatation (Nurse et al., 2014).

SIDS were first formally recognized as a distinct group by the United Nations in 1992 at the Conference on Environment and Development held in Rio de Janeiro in Brazil (Boto and Biasca, 2012). The UN recognizes 51 SIDS of which 14 are non-members of the UN. SIDS are considered a separate group by the UN as they share similar sustainability challenges related to their specific characteristics such as smallness, isolation, remoteness, susceptibility to natural disasters, vulnerability to external shocks, concentration of population and infrastructure in the coastal zone, high dependence on a limited number of resources including marine resources; excessive dependence on international trade high import dependency and dependency on global markets; and geopolitical weakness (Boto and Biasca, 2012; Briguglio, 2003; Easter, 1999; Guillotreau et al., 2012; Mimura et al., 2007; Nurse et al., 2014; Polido, João, and Ramos, 2014).[10] Climate change impacts can be expected to exacerbate this vulnerability because SIDS are mostly low-lying islands with vulnerable coastlines with a high percentage of population and vital infrastructure located in the coastal zone. SIDS are also highly dependent on marine resources, which are expected to be negatively affected by climate change. Furthermore, SIDS are located in the sub-tropical and tropical region where an increasing number and intensity of storms and hurricanes are projected.

In Section 2 we have seen that as a country group, the fisheries sector in SIDS is considered most vulnerable to climate change in comparison to LDCs and other coastal nations. Despite SIDS and LDCs showing similar high levels of final vulnerability ranking of their fisheries' sector to climate change our results in Section 3 suggest there are great differences in vulnerability in terms of the underlying subcomponents of vulnerability. When we examined the differences of vulnerability ranking between the three country groups per component,

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[9] This percentage is based on our calculations of SIDS' carbon production in 2009 from the Carbon Dioxide Information Analysis Center. See http://cdiac.ornl.gov/trends/emis/meth_reg.html (accessed July 23rd 2013). All SIDS are included in this analysis except for: American Samoa; Guam; Puerto Rico; Tuvalu; and the US Virgin Islands (due to lack of data).

[10] See also www.sids.org

exposure, sensitivity and adaptive capacity, our results suggest SIDS are most vulnerable in the sensitivity component, while for LDCs the area of greatest vulnerability lies in their low adaptive capacity.

We found that of the 10 subcomponents the two that best explain the variation between the three country groups are *coastal vulnerability* and *socio-economic development.* SIDS are ranked as highly vulnerable on coastal vulnerability, while LDCs are highly vulnerable in the socio-economic development subcomponent. However, the wide boxplots for LDCs and SIDS for all subcomponents except two (coastal vulnerability and socio-economic development) indicate a large variation in scores within these two groups (Figure 11). Large differences *within* the SIDS and LDCs can therefore be expected.

The 51 recognized SIDS are dispersed across the Caribbean region, Pacific, Atlantic and Indian Oceans. There are 23 SIDS in the Caribbean, 20 in the Pacific and 9 in the Atlantic, Indian, Mediterranean and South China Sea (AIMS) (see

Figure 17). Understanding the differences in vulnerability between the three SIDS groups is important as this can help determine adequate pathways for fisheries sector adaptation in the face of climate change. We argue that the special characteristics of SIDS needs to be further explored by using a broader set of indicators developed and described in Sections 2 and 3. The aim of this section is to 1) build on to the assessment developed in Section 2 by including indicators that are particularly tailored to SIDS climate change vulnerability; 2) comparing the three different SIDS groups vulnerability scores across the three categories and final vulnerability score; and 3) assess which subcomponents (group of indicators) explain the largest vulnerability in terms of vulnerability characteristics of the fisheries sector of particular SIDS groups.

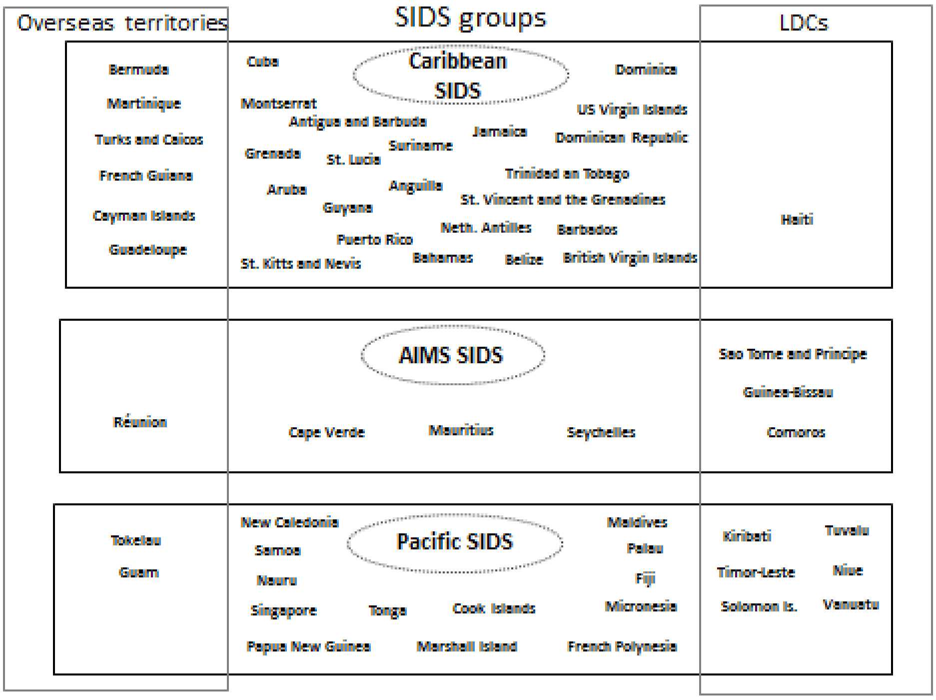

Figure 17 The countries per SIDS groups included in this study (incl. division for overseas territories and LDCs)

4.2 Vulnerability of SIDS

The unique and particular vulnerabilities of SIDS have been acknowledged by the international community since the United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil, in 1992 through to the most recent UN Small Island Developing States conference held in 2014 in Samoa (seeFigure 18). The first UN Global Conference on the Sustainable Development of SIDS in 1992 in Barbados adopted the Barbados Programme of Action (BPOA) which identified 14 priority areas for SIDS, including areas such as climate change and sea- level rise; natural and environmental disasters; management of wastes; and coastal and marine resources.[11] In 2005 the Mauritius Strategy for Further Implementation of the Programme of Action for Sustainable Development of SIDS (MSI) was adopted identifying further critical areas in the BPOA and new emerging issues (Boto and Biasca 2012). The MSI strengthened the social and economic subcomponents of the BPOA further by placing more emphasis on matters such as health, culture, knowledge management, education for sustainable development, and consumption and production. After two previous conferences in 1994 and 2001 on SIDS, in September 2014, the Third United Nations (UN) Confernce on Small Island Developing States was held in Apia, Samoa (see Figure 18)[12]

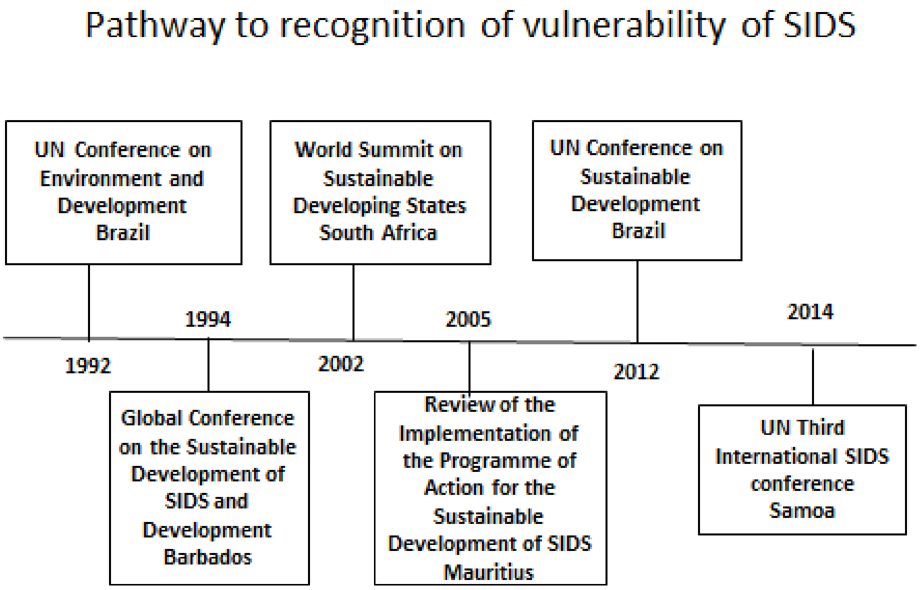

Figure 18 Timeline to recognition of vulnerability of SIDS (1992-2014)

SIDS share several common characteristics and there has been a tendency to generalize about the potential impacts of climate change on SIDS and their adaptive capacity (Nurse et al. 2014). Table 4 presents a number of vulnerability characteristics of SIDS in general found in the literature and the additional vulnerability pressures climate change is expected to exacerbate.

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[11] Priority areas are: climate change and sea- level rise; natural and environmental disasters; management of wastes; coastal and marine resources; freshwater resources; land resources; energy resources; tourism resources; biodiversity resources; national institutions and administrative capacity; regional institutions and technical cooperation; transport and communication; science and technology; human resource development

[12] See also www.sids2014.org

Table 4 Vulnerability characteristics of SIDS

Vulnerability categories of SIDS	**General vulnerability characteristics**	**Climate change vulnerability**
Smallness	• High competition between land use, spatial concentration of population, infrastructure and other productive assets in coastal zone • large % population concentrated in one centre in the coastal zone • SIDS are often comprised of a number of small islands	• Located in tropical and sub-tropical region and (partly) surrounded by ocean and thus prone to natural disaster and climate change affects such as sea-level rise, increased intensity and frequency of ENSO events, sea surface temperature rise, and ocean acidification. • Sea level rise and increased intensity and frequency of ENSO events can lead to flooding in the coastal zones where most population infrastructure and other productive assets are located • Often single-town islands where flooding and damage to main city will shut down civil services • Small population often means limited institutional capacity in the public and private sectors. Government departments and private firms are relatively small, affecting their capacity and competitiveness. Governments have less capacity to deal with climate change issues and provision of public services is limited. • Sources of revenue are limited with many small islands relying heavily on tariffs for a substantial proportion of public revenue • They tend to be free in trade while largely depending on trade. Yet external capital is limited and many small states are dependent on Official Development Assistance (ODA)
Insularity and remoteness	• High external transport costs time delays • high costs in accessing import goods delays and reduced quality in information flows • High freight costs and reduced competitiveness • Geopolitically weak • Heavy reliance on limited number of natural resources (high reliance on coastal and marine resources)	• Accessing material needed to improve adaptation (building sea defences) are limited and costly • Limited number of natural resources are expected to be disproportionally affected by climate change impacts • Remoteness entails dependence on transport providers and high transport costs, which are already higher for smaller volumes.
Environmental factors	• Located in tropical and sub-tropical regions • High reliance on marine resources to meet protein needs • High dependence on fish for livelihood and employment and exports • Limited freshwater resources • Small size, isolation and fragility of island ecosystems creates biodiversity threat	• High level of exposure to natural disasters and climate change impacts such as sea level rise, increased intensity and frequency of ENSO events, sea surface temperature rise and ocean acidification due to geographical location of SIDS in tropical and subtropical regions • Climate change impacts expected to increase threat to biodiversity; cause coral reef degradation; mangrove destruction • High concentration of population and infrastructure in coastal zone with large chance impacted by natural disasters; and sea level rise • Affect saline intrusion • Coastal erosion
Economic factors	• Small economies (small internal market) • Limited resource base	• Loss of land and flooding will lead to destruction of existing economic infrastructure and human settlements

Vulnerability categories of SIDS	**General vulnerability characteristics**	**Climate change vulnerability**
	• Dependence on external finance • Dependence on narrow range of export product • High import content (particularly of strategic imports such as food and fuel) • Susceptible to volatility of international trade • High use of foreign exchange for energy imports • High costs of energy inhibits development of particular new economic sectors • GDP per capita often higher than cut-off for ODA so limited access to concessionary resources • High dependence remittances (not secure and is volatile)	• Exports and imports depend on ports which can be affected by climate change impacts such as increased frequency and intensity of storms • High dependence on foreign aid and remittances which makes economy volatile while demand for financial aid for climate change adaptation will only increase this dependency • Limited resource base makes SIDS vulnerable for natural disasters as there is the chance it will wipe out/affect the supply of key resources for the whole country
Demographic factors	• Small population (limited human resource base; costly public administration and infrastructure; limited institutional capacity) • High population density which increases pressure on already limited resources • Small economies (high per capita costs for infrastructure and services	• Limited human capacity for climate change adaptation • High costs of infrastructural adaptation
Governance	• Large EEZ to manage in comparison to landarea • Limited human, financial and technical capacity to adapt	• Loss of land and disappearance of low-lying island and atolls will lead to loss of EEZs as maritime boundaries will shift • Climate change adaptation requires high level of human, financial and technical capacity and expertise which is often not or only available to a limited degree in SIDS • EEZ difficult to manage as large in comparison to land area
Disaster mitigation capacity	• Limited hazard forecasting ability, complacency, little insurance cover	• Increased intensity and frequency of natural disasters such as floods, hurricanes and storms will be further intensified by the limited forecasting ability of SIDS

Sources: (Briguglio 1995, 2003; Guillaumont 2009; Guillotreau et al. 2012; Nurse et al. 2014; Von Tigerstrom 2005).

Despite these common characteristics SIDS are by no means homogenous and they vary by geography, physical, climatic, social, political, cultural, and ethnic character as well as level of economic development (Nurse et al. 2001). Table 5 shows some clear differences between the three SIDS groups. The average population per island is much higher in the Caribbean than in the other two SIDS groups. The land area is much smaller in AIMS SIDS in comparison to Caribbean and Pacific SIDS. GDP per capita is lowest in Pacific SIDS, although closely followed by AIMS. Caribbean SIDS have an average GDP per capita more than double that of Pacific SIDS. The average EEZ is highest for Pacific SIDS with an average of 1,430,636 km^2, while Caribbean SIDS have a small EEZ of only 127,420 km^2.

The three different SIDS groups (Caribbean, Pacific and AIMS SIDS) can be thus expected to score differently in vulnerability assessments.

Table 5 General characteristics of the three SIDS groups and other coastal nations

Characteristics(averages per group)	**AIMS SIDS**	**Caribbean SIDS**	**Pacific SIDS**	**Other coastal nations in the world**
Population (average per group)[13]	757,351	1,839,885	594,189	55,525,137
Landarea km^2 [(14)]	6,244	25,988	30,966	959,720
GDP per capita[15]	8,433	15,370	7,024	21,108
EEZ[16]	639,638	127,420	1,430,636	878,629
EEZ/landarea[17]	664	133	3,871	437
% population 10 km from coastline[18]	84	79	89	32

4.3 Methodology

For this study we have examined 58 small islands. We have analysed the data of 50 out of the 51 recognized SIDS and eight overseas territories (see Appendix 2). Of the 50 SIDS, nine are LDCs as well (see

Figure 17).This section expands on the work presented in sections 2 and 3. In this section we use the 35 indicators used in the global analysis and an additional set of 11 indicators, bringing a final set of 46 indicators. The 46 indicators used in the analysis are a combination of projected or 'end-point' indicators and 'starting point' indicators. A number of indicators within exposure are based on projected data (e.g. sea level rise and maximum potential yield change in fisheries by 2050) while all the indicators for sensitivity and adaptive capacity are based on the current state of affairs (see Appendix 2 for a list of the 46 indicators). The 11 new indicators used in this section in comparison to the set used for the global analysis in sections 2 and 3 for the three components are:

- Exposure: thermal stress. Thermal stress by 2050 are projections on the number of times over that period the coral bleaching threshold will be reached.
- Sensitivity: coral reef health; coastal development threat; and natural coastal protection status. These are particularly important for SIDS which are highly dependent on coral reefs and their related ecosystem services.
- Adaptive capacity: official aid as % of GDP, foreign direct investment, remittances (% GDP), dependence on tourism (% of GDP direct and indirect), shipping line connectivity (relating to remoteness of islands), and oil imports.

In our analysis we have assigned an equal weight to each subcomponent which is an arbitrary decision made by the authors. This decision means that the amount of variance explained by the different subcomponents is not taken into account in the overall scores in the boxplots, explaining some of the discrepancies between boxplots and biplots. Other weighting schemes would lead to different results and relates back to section 2 where we discussed the impacts of different methodological choices.

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[13] CIA factbook 2012
[14] WorldBank 2011
[15] Worldbank 2011
[16] www.seaaroundus.org
[17] See footnote 7 and 9
[18] CIESIN 2010

4.4 Data analysis

The 46 indicators were rank-transformed to ensure standardization and minimize the influence of extreme values, given that no single alternative transformation was found to achieve a normal distribution of values for all indicators. Within each vulnerability component (exposure, sensitivity and adaptive capacity), a Principal Component Analysis on its corresponding set of rank-transformed indicators was used to identify coherent groups of correlated indicators explaining relatively high amounts of variation in the data. Missing values in indicators were replaced by the median value of the indicator.

The PCA identified 17 subcomponents across the three components: three for exposure, seven for sensitivity, and six in adaptive capacity. These 17 subcomponents represented coherent and interpretable groups of indicators that explained relatively high amounts of variation in the data. For each component (exposure, sensitivity and adaptive capacity), we compared the country scores of the PCA subcomponents among the three SIDS groups.. Boxplots were used to visually assess the median score and distribution of values within each vulnerability component (exposure, sensitivity, and adaptive capacity), and for the final vulnerability score across the three SIDS groups.

4.5 Component comparison of the three SIDS groups

The three components and final vulnerability rankings show differences among the three SIDS groups. The results accentuate Caribbean SIDS are more vulnerable in terms of exposure with the Pacific SIDS coming out as least vulnerable (see Figure 19). Pacific SIDS are the most vulnerable in sensitivity, followed by Caribbean SIDS and lastly AIMS SIDS. In adaptive capacity AIMS SIDS are most vulnerable, followed by Pacific SIDS SIDS, while the Caribbean SIDS are least vulnerable. As a result of these differences across the three categories per SIDS group the final vulnerability rankings Caribbean SIDS are most vulnerable, followed by Pacific SIDA while AIMS SIDS are least vulnerable.

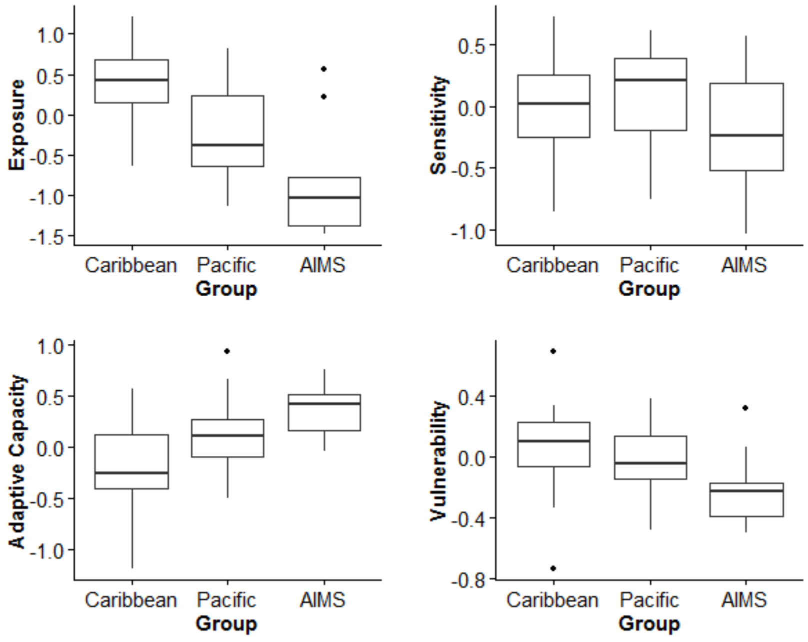

Figure 19 Scores per component and final vulnerability of the three SIDS groups

4.5.1 Subcomponents of the three categories

Each component (exposure, sensitivity, and adaptive capacity) has several subcomponents that explain the variance in the data. Table 6 presents the different subcomponents per component and their % contribution to the variance of that component.

Table 6 Subcomponents per component used for boxplots and bi-plots and their per cent contribution to variance (in brackets)

	PCA 1	**PCA 2**	**PCA 3**	**PCA 4**	**PCA 5**
Exposure	Ocean acidification and thermal stress (31)	Sea level rise and sea surface temperature (27)			
Sensitivity	Coastal vulnerability 10 km coastline and cities (17)	Coastal health (17)	Coastal vulnerability within 5 m above sea level (13)	Fisheries dependence (13)	Species health (10)
Adaptive Capacity	Socio-economic vulnerability (31)	Extent EEZ and MPA (10)	Export diversity and concentration (10)	FDI, remittances and fisheries management (8)	Terms of trade and oil imports (9)

We use the two main subcomponents to look at the scoring of the different country groups. We first present the tables of the first two dimensions and their respective indicators per component (Table 7). The two exposure dimensions explain 55% of the variance (only factors > 0.6 are shown in Table 7). Table 7 shows that dimension one represents high values for ocean acidification while dimension two has high scores for sea level rise but with low numbers on sea surface temperature change. Sensitivity is mainly determined by coastal health and coastal vulnerability. The two dimensions each explain 20% of the variance and thus 40% of the total variance. Adaptive capacity is mainly determined by the two dimensions of socio-economic vulnerability and the extent of EEZ, MPA and remoteness. Together they account for 50% of the variance with the first dimension responsible for 39%. Dimension one relates to socio-economic indicators such as GDP per capita, education, governance and health and thus relates to the indicators chosen by Allison et al. 2009. The second dimension relates the extent of EEZ, the magnitude of MPAs in this EEZ and remoteness. In our results fisheries sector related indicators (e.g. fisherfolk as % Economic Active Population, fish nutrition, fish exports, fish catch, management of fisheries) do not come out in these first two PCs for each component.

Table 7 Scoring of indicators on the first two subcomponents of exposure, sensitivity and adaptive capacity

EXPOSURE	**Dimension 1: ocean acidification and thermal stress (31%)**	**Dimension 2: sea level rise and sea surface temperature (27%)**
Sea surface temperature change		0.76
Ocean acidification	0.92	
Sea level rise		-0.83
Future thermal stress	-0.77	
SENSITIVITY	**Dimension 2: coastal vulnerability (17%)**	**Dimension 1: coastal health (17%)**

habitat status		0.92
biodiversity status		0.92
natural coastal protection		0.83
% land 10 km coastline	0.83	
% pop 10 km coastline	0.83	
% cities coastal zone	0.66	
fish nutrition	0.61	
ADAPTIVE CAPACITY	**Dimension 1: socio-economic vulnerability (31%)**	**Dimension 2: Extent EEZ, and MPA and remoteness (10)**
GDP per capita	0.89	
Agriculture % GDP	0.89	
Infant mortality	0.82	
Governance	0.80	
Healthy life expectancy	0.79	
Nigh Light Development Index	0.78	
Sanitation	0.76	
Fisheries resilience	0.68	
Official AID	0.63	
Education	0.59	
EEZ per coastline		0.84
MPA (%of EEZ)		0.65

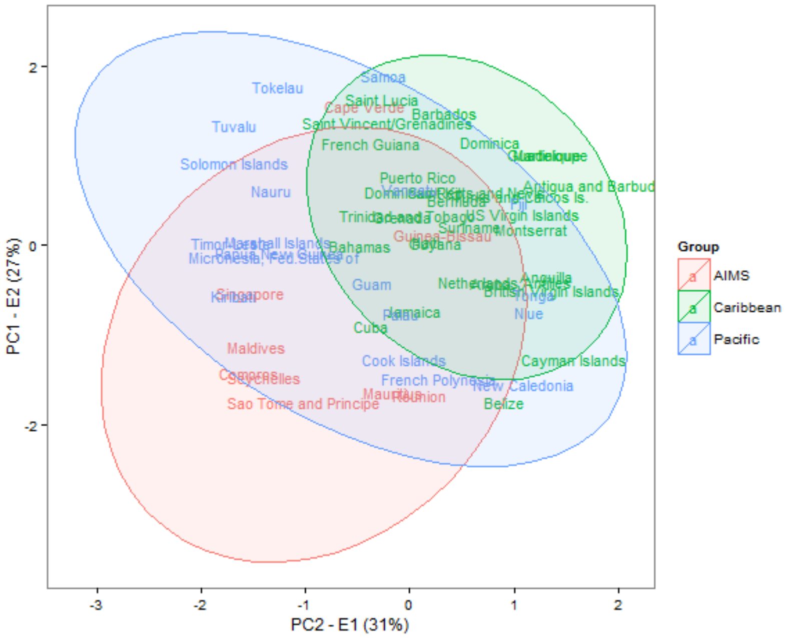

Figure 20a Plotting of three SIDS groups along first two PCA components for exposure

The Caribbean SIDS have very distinct scorings on the first two subcomponent of exposure (E1= ocean acidification and E2= sea surface properties) while Pacific and AIMS SIDS show mixed results (see Figure 20a). Caribbean SIDS generally score high on the dimension of ocean acidification but with mixed results on sea level rise and sea surface temperature. Caribbean scores tend to be on the positive quadrant, whereas AIMS tend to be on the negative quadrant with the Pacific SIDS somewhere in between. This is consistent with the results of the boxplots.

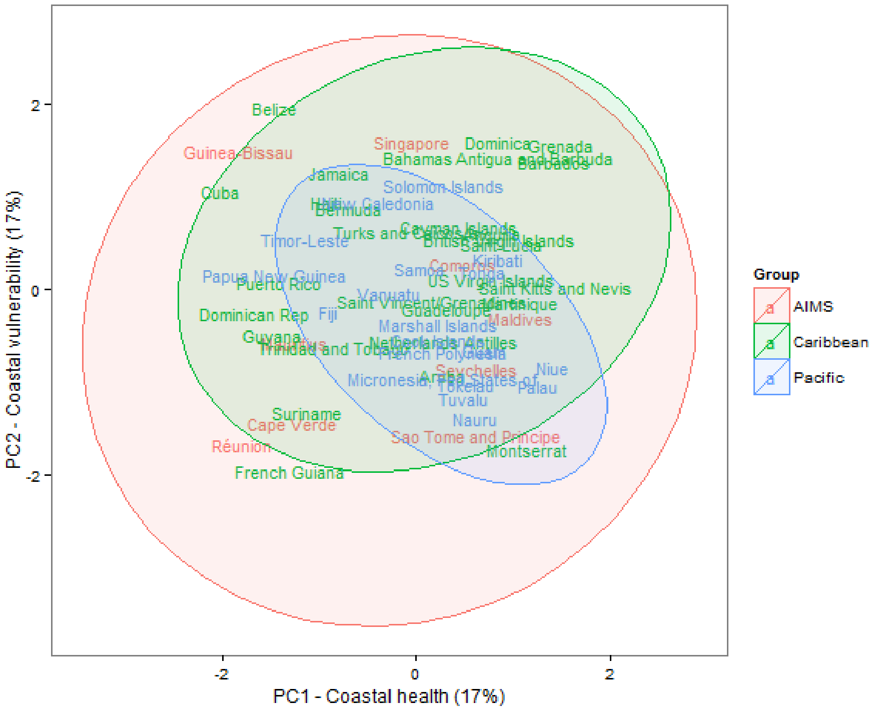

Figure 20b Plotting of three SIDS groups along first two PCA components for sensitivity

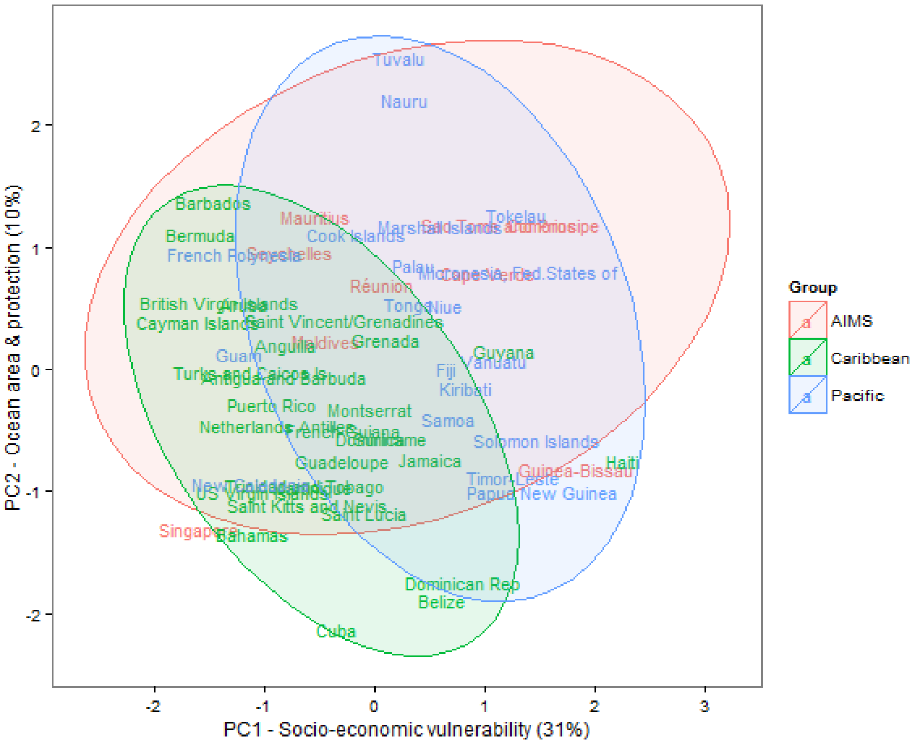

Figure 20c Plotting of the three SIDS groups along first two PCA components for adaptive capacity

For sensitivity the scoring of the three groups of countries tend to be centred around the centre, thus explaining why there is no apparent very strong differences in the previous boxplots (see Figure 20b). The trend towards a lower vulnerability in the boxplot for AIMS SIDS probably reflects the influence of the other 3 subcomponents (which are equally weighted). For adaptive capacity Caribbean SIDS score on the negative quadrant, implying a low vulnerability for adaptive capacity (see Figure 20c). Pacific and AIMS SIDS are more or less centered around zero which is broadly consistent with the low ranking of Caribbean SIDS in boxplots. The results are not so much in line with the ranking of AIMS nor Pacific SIDS in the boxplots as the take into account all other subcomponents, not just the two major ones, which have a different result.

4.6 Discussion and conclusion

This chapter has examined the similarities and differences in the vulnerability of the fisheries sector of SIDS in the face of climate change. SIDS vulnerability in the face of climate change in general has often been marked, however, a rigorous quantitative comparison of the differences in fisheries sector vulnerability in SIDS has to date not been carried out. This chapter builds on to the assessment developed in chapter 1 by including 11 new indicators that are particularly tailored to SIDS climate change vulnerability; 2) compared the three different SIDS groups vulnerability scores across the three categories and final vulnerability score; 3) assessed which subcomponents explain the largest variety in terms of vulnerability characteristics of the fisheries sector of particular SIDS groups in the face of climate change for the three categories.

Examining the rankings of the three different SIDS groups on final vulnerability we have found that the Caribbean SIDS are most vulnerable. When taking a closer look at the differences between the three components we find contrasting results of exposure and adaptive capacity in the boxplot group comparison. These results highlight opposing patterns that might cancel each other out when averaged for final vulnerability. The final result is thus the outcome of Caribbean SIDS being most vulnerable overall, mediated by the weak trend of aims being less vulnerable to sensitivity. This speaks of the fundamentally different nature of the underlying vulnerability separating the country groups. Using final vulnerability scores for allocation of funds, for example for climate change adaptation, is therefore too crude. A more detailed examination on the areas of vulnerability per SIDS group to assess the true areas of vulnerability of each SIDS group is therefore detrimental.

We examined the underlying subcomponents of vulnerability per groups and found some distinct patterns which are expressed in the biplots of the first two subcomponents per component. Although this analysis compares the vulnerability outcome between the three SIDS groups we need to keep in mind the analysis does not indicate whether the SIDS group as a whole is already vulnerable beyond a sustainable threshold. Thus, while, for example, a particular group of SIDS might not appear to be vulnerable to ocean acidification in comparison to the other two groups, it is possible that the entire region might already be beyond a sustainable threshold with respect to this underlying dimension.

This research has shown that some distinct patterns in vulnerability can be seen between and within Caribbean and Pacific SIDS while AIMS SIDS, except for adaptive capacity, do not stand out as a distinct group. Despite the patterns we cannot overlook the fact diversity within each SIDS group can be expected and in order to look at particular adaptation measures we will need to examine each group more closely. In Section 5 we will take a regional approach by taking a detailed look on the vulnerability across individual Caribbean SIDS.

5 VULNERABILITY OF THE CARIBBEAN FISHERIES SECTOR TO CLIMATE CHANGE

5.1 Introduction

Climate change is one of the most serious threats facing Caribbean countries. Sea-level rise (SLR), sea surface temperature change, ocean acidification and an increasing number and intensity of extreme weather events will all have an effect on Caribbean countries as they highly depend on ocean ecosystem services and a large part of the population and infrastructure is in the low-lying vulnerable coastal zone. Projections for the Caribbean region by The Caribbean Community Climate Change Centre (CCCCC) and the recent AR5 report of the IPCC in 2014[19] are:

1. Sea levels are likely to continue to rise on average during the century around the small islands of the Caribbean Sea (see Figure 22). However, projections are not precise as there are few long-term sea level records available for individual Small Island Developing States (SIDS) such as the Caribbean SIDS. Thus, detecting variation caused by climate change, rather than temporary conditions such as storm waves and surges, deep ocean swell and tidal cycles, is very difficult.
2. All Caribbean islands are very likely to warm up during this century. Downscaled projections for the Caribbean regions indicate an increase in temperature of 1–4C[20].
3. The warming is likely to be somewhat smaller than the global annual mean warming in all seasons.
4. These projections also show increasing rainfall during the latter part of the wet season in the northern Caribbean and drier conditions in the southern Caribbean, with drying in the traditional wet season. Lengthening of seasonal dry periods and increasing frequency of drought are expected to increase demand for water across the region.
5. It is likely that intense tropical cyclone activity will increase (but tracks and the global distribution are uncertain).
6. Short term variability in rainfall patterns (e.g. as caused by ENSO events) will likely continue. The prevailing warmer conditions may make the convection associated with the short lived events more intense. In general, climate change will produce a warmer, dryer (in the mean) region with more intense hurricanes, and possibly more variability.

The 23 Caribbean SIDS share similar sustainability challenges related to their specific characteristics such as smallness, susceptibility to natural disasters and climate change, vulnerability to external shocks, concentration of population and infrastructure in the coastal zone, high dependence on limited number of resources including marine resources; and excessive dependence on international trade (Guillotreau et al., 2012; Mimura et al., 2007; Nurse et al., 2014; Polido, João, and Ramos, 2014).[21] Such vulnerabilities, which place the states at risk to economic and environmental conditions, stem from intrinsic features of these states, and are not related to governance of the countries involved (Nurse et al., 2014). One of the problems associated with climate change adaptation for SIDS is that adaptation to climate change can involve infrastructural works. This generally requires large up-front overhead

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[19] What is in it for Small Island Developing States? IPCC AR 5 2014

[20] These projections are made under the emissions scenarios used in the previous IPCC *Fourth Assessment Report* (SRES A2 and B2, which are respectively relatively high- and low- emissions scenarios)

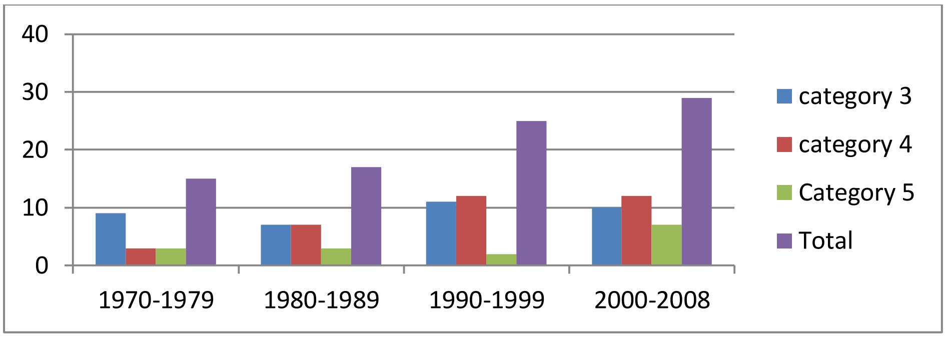
[21] See also www.sids.org

costs, which in the case of small islands cannot be easily downscaled in proportion to the size of the population or territory (Nurse et al. 2014).

Both slow-onset changes (e.g. sea surface temperatures) and increased extreme-weather events are expected to impact fisheries worldwide directly and indirectly (Brander, 2010; Cheung et al., 2010; Mora, 2013). Climate change impacts such as sea surface temperature increases, ocean acidification, increased intensity of storms, and sea level rise are expected to trigger a series of biophysical and socio-economic impacts on national fisheries (Allison et al., 2009; Mahon, 2002).

The key findings of the Intergovernmental Panel on Climate Change Fifth Assessment Report (2014) in relation to climate change impacts on fisheries and aquaculture show that the projections are that climate change will negatively affect the fisheries sector on a global scale. These changes include (but are not limited to); fish redistribution: fish populations are shifting away from tropical latitudes; high local extinction rates in the tropics and semi-enclosed seas; fish size changes: large fish will have a smaller maximum body size due to reduced oxygen capacity of seawater; coral bleaching events affecting fisheries biomass of coral reefs, abundance and productivity; and harmful algal blooms could cause mass die-offs of wild and farmed fish. Although its effects on marine organisms have not been fully explored, ocean acidification is expected to be a limiting factor in the development of corals, as well as other organisms with calcium carbonate shells and exoskeletons (Nurse, 2011). As climate change intensifies, increasing ocean acidification and thermal stress affect coral reefs and lead to coral bleaching. Coral reef ecosystems form a vital economic part of the economy in Caribbean countries. As food, as a main form of coastal protection and as a basis for tourism, people in the Caribbean are dependent on the services that the reefs provide. In projections by Cheung et al. 2010 on maximum potential yield change by 2050 due to climate change, the global map shows maximum potential yield change for the Caribbean region will decline in some areas with 50% to 100% (Cheung et al., 2010). The impact is likely to be exacerbated, as global fisheries are already under pressure from stressors including overfishing, loss of habitat, pollution, disturbance of coral reefs, and introduced species (Allison et al., 2009; Brander, 2010; Hoegh-Guldberg et al., 2007). The fisheries sector production in the Caribbean region has declined some 40% over the last two decades. A FAO assessment of the exploitation levels of commercially harvested fish stocks revealed that the Western Central Atlantic region, to which the Eastern Caribbean islands belong, is the most overexploited region in the world in terms of fisheries exploitation levels. Some 55% of the commercially harvested fisheries stocks in this region are overexploited or depleted and an estimated 41% of the stocks are fully exploited at present. The problems are compounded by the high levels of illegal, unreported and unregulated fishing (IUU) activities. There is therefore increasing concern over the consequences of climate change and climate variability for fisheries production and the state of marine ecosystems in the Caribbean.

In the Caribbean region between 1980 and 2007, nearly 98% of disasters, 99% of casualties and 99% of economic losses related to natural hazards were caused by recurrent meteorological, hydrological and climate-related events, primarily tropical cyclones and storm surges, floods, droughts and extreme temperatures. These natural disasters are all expected to be further exacerbated as a result of climate change (WMO 2011). This can already be observed in the increasing frequency and severity of extreme weather events experienced since 1970 (Collymore 2011). See Figure 21.



Source: Collymore, 2011

Figure 21 Major hurricanes in the Caribbean by decade (1970-2009)

The natural hazards[22] in Caribbean SIDS are mainly storms and hurricanes. The region experiences regular annual losses due to natural hazard events in the order of USD 3 billion. More than 68%t of these losses are in the social and productive sector. Additionally 60% of the population of the region resides in the coastal zone while 70% of all economic activity takes place within two miles of the coastline. Hurricanes and storms thus have caused major economic loss and damage to the economy of Caribbean SIDS as a whole and pose particular threats to the fishing sector. Extreme weather events (e.g. hurricanes) associated with abnormally high sea surface temperatures are damaging coastal ecosystems as they damage and remove corals from a reef through direct wave action, or cause indirect damage through abrasion by sediment and rubble and by depositing sediment which smothers the corals and blocks light. They also cause loss or degradation of fishing sites and infrastructure, destruction of gear, boats and economic losses in terms of lost fishing days and pose increasing risk to fishers' safety at sea. In 2010 Hurricane Earl, for example, caused a total damage of USD 122,000 in Antigua and Barbuda to the fishing sector in terms of loss and damages of boats, gears destruction and loss of gear in Antigua and Barbuda. This extreme event also impacted infrastructure ranging from landing sites to post-harvest facilities and transport routes which is not included in this figure.

Due to the high dependence in the Caribbean on marine resources (Monnereau et al. 2013; Nurse 2011) and the high vulnerability of fisherfolk and fisheries infrastructure in the coastal zone, increasing intensity of extreme-weather events, and the negative impacts on the marine ecosystem impairing fish yields, there is increasing concern over the consequences of climate change and climate variability for the fisheries sector in the region. Consequently, effective adaptation measures for the fisheries sector are particularly critical for sustainable livelihoods, improved food security and protection of marine resources.

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[22] International Disaster Database http://www.emdat.be/database

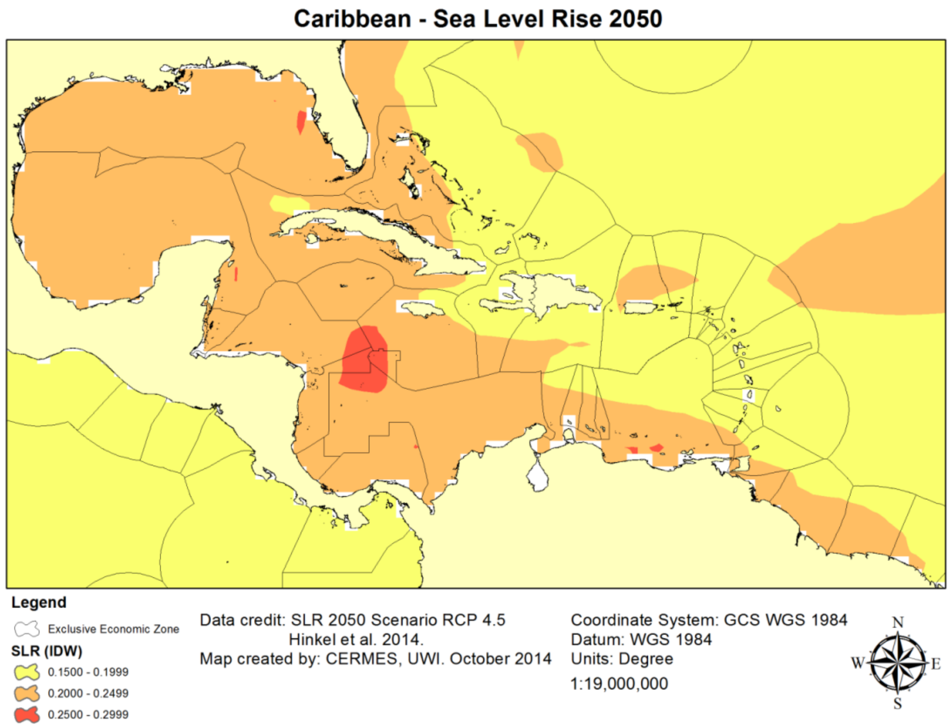

Figure 22 Sea level projections by 2050 for the Wider Caribbean Region

As a result, in the Caribbean, there has been increasing concern for the impacts of climate change throughout the region. The regional policy context is set out primarily in the "Regional Framework for Achieving Development Resilient to Climate Change" (the Regional Framework) (CCCCC 2009) which articulates the strategy of the Caribbean Community (CARICOM) on climate change. CARICOM Heads of Government endorsed the Regional Framework at their July 2009 meeting in Guyana and issued the Liliendaal Declaration, which sets out key climate change related interests and aims of CARICOM Member States. The Implementation Plan (IP) (CCCCC 2012) for the Regional Framework is based on the Liliendaal Declaration. It is entitled "Delivering transformational change 2011–21" and incorporates several global and regional instruments concerning climate change and variability. In the IP it is stated that adaptation and capacity-building must be prioritized and a formal and well-financed framework established within and outside the UN Framework Convention on Climate Change to address the immediate and urgent, as well as long-term, adaptation needs of vulnerable countries, particularly SIDS. In the Liliendaal Declaration it was also recognized that SIDS need financial support to enhance their capacities to respond to the challenges posed by climate change. Within their strategic approach they highlight five strategic elements of which two are important for this study. They recommend (a) promotion of the implementation of specific adaptation measures to address key vulnerabilities in the region; and (b) encouraging action to reduce the vulnerability of natural and human systems in CARICOM countries to the impacts of a changing climate. It is recognized that fisheries and aquaculture initiatives in the CARICOM region should be integrated into the IP. To address the key vulnerabilities in the region and encourage action to reduce vulnerability in the fisheries sector one needs to have an understanding of the key vulnerabilities of the sector and the differences between the different countries in the region.

We have seen in the preceding chapters Caribbean SIDS are highly vulnerable to climate change across the components of exposure, sensitivity and adaptive capacity. Our results have also shown that despite overlaps, differences in vulnerability of the fisheries sector across the Caribbean exist which is why a more detailed study on vulnerability of the fisheries sector in the region is considered necessary.

Vulnerability assessments have become the dominant method to establish who and what is vulnerable to the negative effects of climate change (Klein 2009; Tschakert et al. 2013) and are considered to be particularly relevant now that the impacts of climate change are increasingly being observed (Hinkel 2011). This work builds on the framework developed by Allison et al. (2009) who followed the commonly applied definition of vulnerability used in the Third Assessment Report of the IPCC (2001) to build their vulnerability framework (see Figure 23). In this interpretation the vulnerability of any sector to climate variability or change is a function of (a) the degree of exposure to the threat; (b) the sector's sensitivity: the degree to which a system is affected (either adversely or beneficially); and (c) the capacity of the sector to cope with or adapt to the threat, to take advantage or create opportunities, or to cope with the consequences (Smit and Wandel 2006).

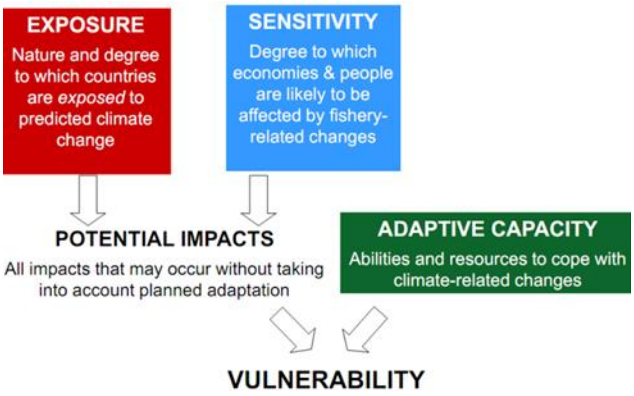

Figure 23 Fisheries sector vulnerability assessment framework

In Section 2 we have seen that due to methodological choices in the vulnerability assessment by Allison et al. (2009), the high vulnerability of the fisheries sector in SIDS was concealed. In Section 3 we have shown that SIDS are most vulnerable to climate change in comparison to LDCs and other coastal countries yet differences between the two groups were marginal. The analysis also showed that there was a large disparity within the vulnerability component scores of the three SIDS groups. A more detailed examination of the three different SIDS was carried out and distinct differences among, and within, the three SIDS groups could be established. However, our results indicated the Caribbean region showed a diversity of scores, particularly for the sensitivity component. Therefore, in order to fine tune interventions aimed at adapting to climate change in the Caribbean region, it is important to examine the differences in vulnerability across the individual Caribbean SIDS in greater detail.

This section therefore examines the vulnerability of the fisheries sector to climate change in the Caribbean. The section 1) investigates the impacts of methodological choices as described in Section 2 specifically for the Caribbean region; 2) investigates the outcome of the SIDS comparative analysis for the Caribbean region; 3) compares the vulnerability outcome for the three components of vulnerability for the Caribbean countries; 4) investigates the underlying dimensions of vulnerability; and 5) shows the scoring of the underlying dimension of the principal component analysis for each Caribbean country.

5.2 Results

5.2.1 Implications of methodological choices

The objectives of this research are addressed by comparing the vulnerability outcomes of six vulnerability assessments the first of which is the original assessment by Allison et al (2009) and the remaining five of which include modifications and improvements to that original assessment (see Figure 24 also presented in Section 2).

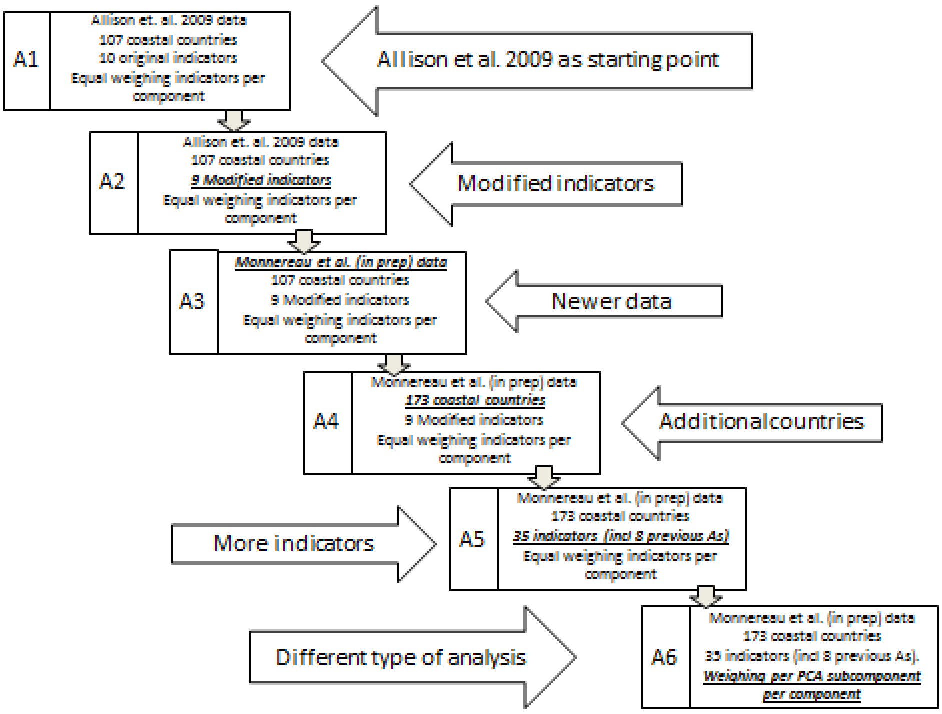

Figure 24 Characteristics of the six different vulnerability assessments used in this study

The original framework by Allison et al. (2009) is called assessment one (A1) and is based on their original data using 10 indicators and for 107 coastal countries (excluding landlocked countries). Assessment two (A2) builds on the framework developed by Allison et al. (2009) by using their original data but with modifications to nine of the indicators. Comparing A1 and A2 will show how the results change when the three original indicators that were based on absolute national numbers are rescaled to per capita values. Assessment three (A3) uses the same indicators as A2 but is based on a more recent dataset. Comparing A2 and A3 thus shows the difference in results between the dataset by Allison et al. (2009) and most recent data. Assessment four (A4) uses the most recent data but includes an additional 66 countries making 173 countries in total. In this assessment LDCs increase in number from 24 to 36, while SIDS increase from 11 to 50 including an additional eight overseas territories. For this section the Caribbean region includes the 23 Caribbean SIDS nations plus two groups of overseas territories (British and French overseas territories).

For the Caribbean region the differences in results for the six assessments are quite striking. In A1 the Caribbean region was largely excluded (see Figure 25a-f). The Lesser and Greater Antilles, for example, were largely excluded from the analysis. The most vulnerable countries were the coastal Caribbean countries. These were assessed to be less vulnerable in A2 and A3 as modified indicators and newer data were used. In A4 a large number of countries was added and the entire Caribbean region including overseas territories were included. In A5 a much broader set of indicators was used which indicated the region to be much more vulnerable overall than in the previous analyses. A principal components analysis highlighted the vulnerability of the Greater Antilles. When the final vulnerability scores for the Caribbean in the global assessment (A6) are examined, it can be seen that the region’s fisheries sector is in fact highly vulnerable when compared to other regions (see Figure 26).

Figure 25a-f shows that successive analyses from A1 to A6 include a much larger set of countries. When the Lesser and Greater Antilles are included (from A4 onwards) and the assessment includes more indicators, those two country groups are assessed to be highly vulnerable, based on the application of principal component analysis.

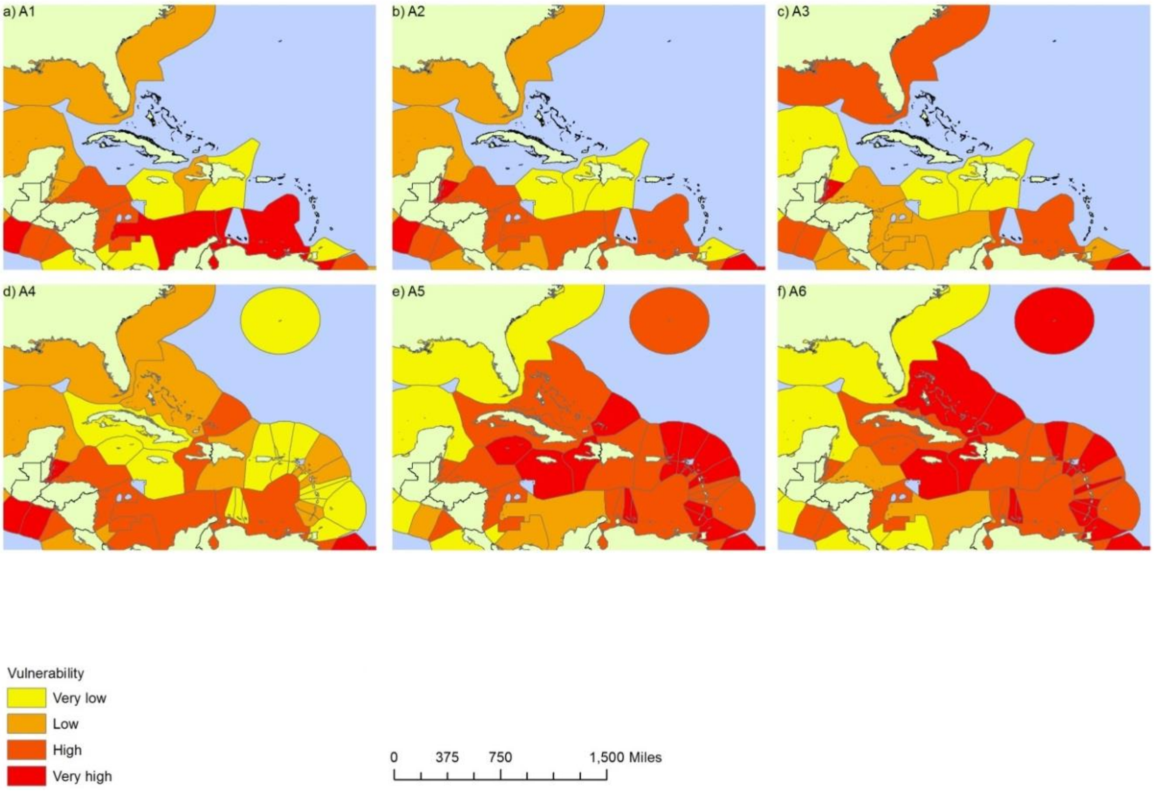

Figure 25a-f Vulnerability outcome per vulnerability assessment for Caribbean SIDS

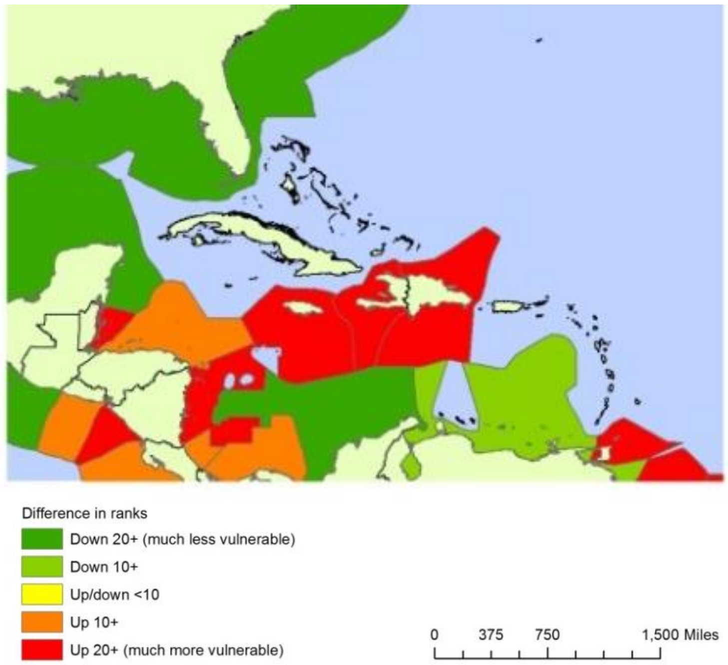

Figure 26 Relative change of country ranking between A1 and A6

Figure 26 illustrates the change in ranks between A1 and A6 for all Caribbean countries included in assessments A1-A6 yet only for those who were included in the initial analysis by Allison et al. (2009), i.e. n=107. This therefore excludes a large number of Caribbean SIDS. The figure shows for those that were included in the original assessments the coastal countries of Central America in particular become less vulnerable in vulnerability ranking (green), while the Caribbean islands (such as Jamaica, the Dominican Republic and Haiti) included in the analysis become increasingly vulnerable. Their vulnerability rank goes up by more than 20 between the first and last assessment.

5.2.2 Caribbean SIDS in the comparative SIDS analysis

In Section 4 we have seen that when we compared the final vulnerability (as a result of summing the mean of exposure, sensitivity and adaptive capacity) the Caribbean SIDS are considered most vulnerable (see Figure 27). Our results show the region is particularly vulnerable in the exposure component. When looking at the spread of Caribbean countries across the two underlying principal components (ocean acidification and sea surface temperature change) the Caribbean countries were as a group highly vulnerable to both dimensions. For the sensitivity component the Caribbean scored high but scores were similar for the Pacific and AIMS SIDS. There was a large diversity, however, in vulnerability ranking of the different Caribbean countries. Adaptive capacity is the only indicator for which the Caribbean is assessed to be less vulnerable than the other SIDS regions.

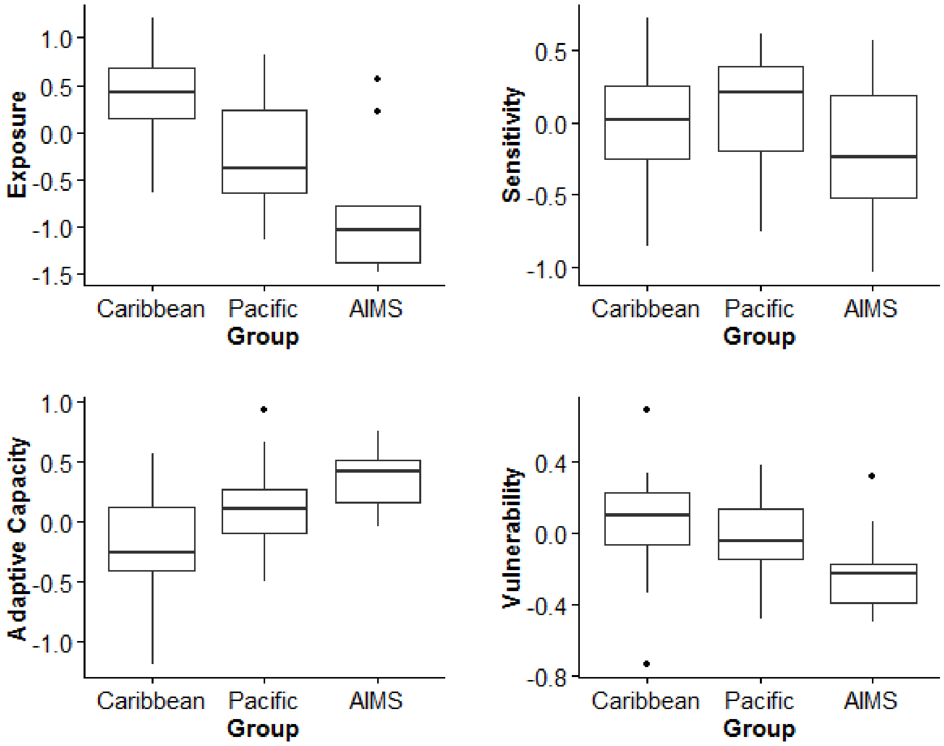

Figure 27 Scores per component and final vulnerability of the three SIDS groups

It is therefore clear that Caribbean SIDS fisheries sector is highly vulnerable to climate change in comparison to the other two SIDS groups. This is particularly so in the case of the exposure component, with Caribbean SIDS ranked as highly vulnerable to ocean acidification and sea surface temperature in comparison to the other two SIDS groups. Our results also indicated this (see Section 4 for further details).

5.2.3 Caribbean vulnerability to climate change per component

Vulnerability in our assessment is comprised of exposure, sensitivity and adaptive capacity. Examination of the three components for all Caribbean SIDS shows (see Figure 28) that the Lesser Antilles and Greater Antilles are extremely vulnerable in exposure, yet their vulnerability in sensitivity show mixed results. For adaptive capacity, except for Haiti and Grenada, most Caribbean SIDS are not vulnerable in the adaptive capacity component.[23] For the cumulative vulnerability score our results show that the fisheries sector in the Greater Antilles and Lesser Antilles are particularly vulnerable to climate change. The Central American countries are somewhat less vulnerable to climate change in comparison.

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[23] Where necessary, indicators were reversed to ensure that high outcomes in adaptive capacity also implies high vulnerability

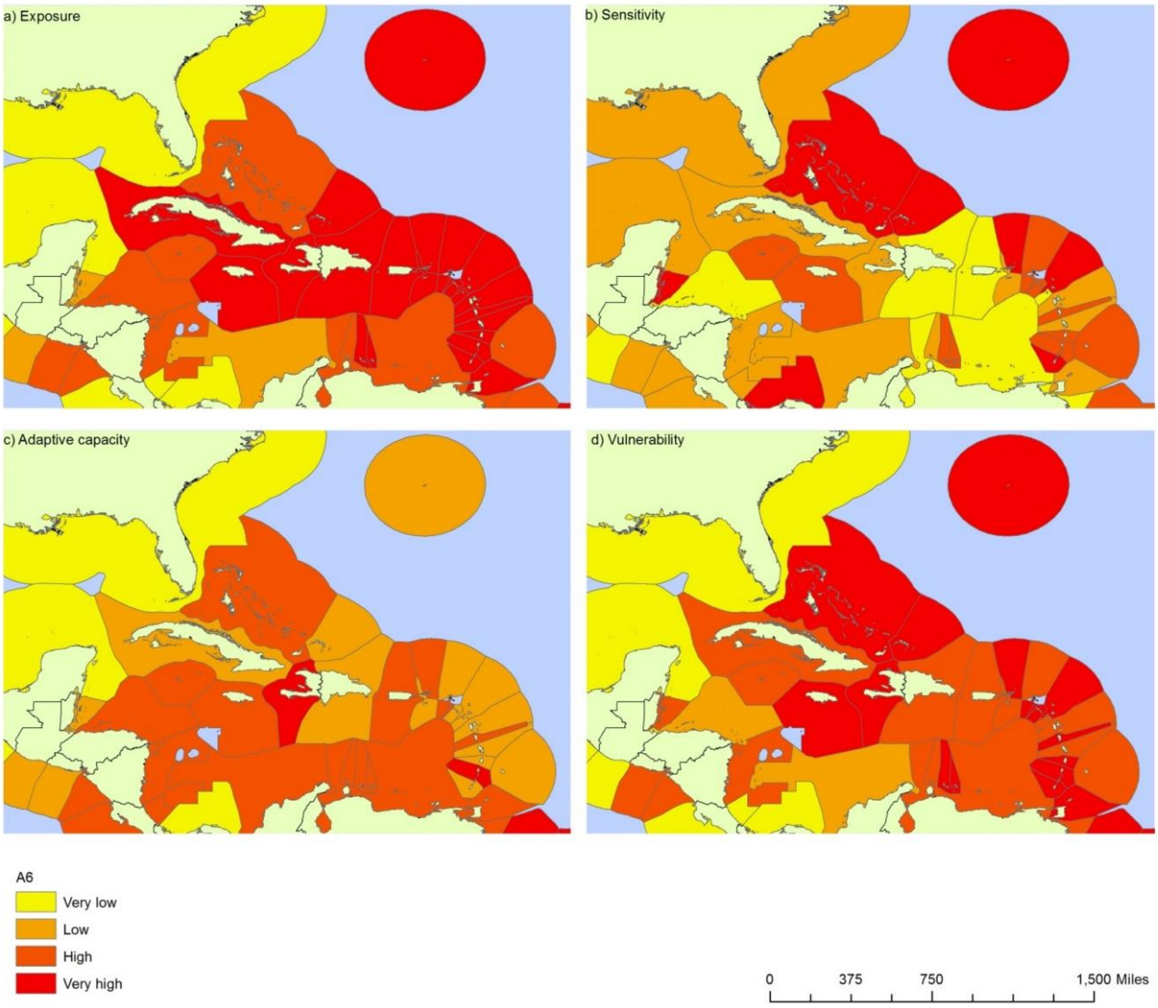

Figure 28 Vulnerability of the fisheries sector of Caribbean SIDS in exposure, sensitivity, adaptive capacity and final vulnerability

5.2.4 Principal component analysis and clustering among Caribbean SIDS

The data were rank-transformed to ensure standardization in order to minimize the influence of extreme values, given that no single alternative transformation was found to achieve a normal distribution of values for all indicators. A number of indicators used reversed values to ensure that high outcomes implied high vulnerability. A Principal Component Analysis (PCA) on the 46 rank-transformed indicators was used to (1) identify coherent groups of indicators within the three categories (exposure, sensitivity and adaptive capacity), in which indicators were correlated with one another but not with indicators from other groups, and (2) to identify groups of indicators explaining relatively high amounts of variation in the data. Missing values in indicators were replaced by the median value of the indicator.

Closer examination of the first three principal components (PCs) shows that countries score differently across these PCs. Table 8shows the first two PCs per vulnerability component (exposure, sensitivity, and adaptive capacity) and their percentage contribution to the variance. For the 3D graph (see Figure 29) for each component the respective overall ranks for each of the three components as x, y and z coordinates per country were used (sigmaplot version 10.0).

Table 8 PCs per component (and their contribution to variance) for the Caribbean region

EXPOSURE	**PC 1: ocean acidification (36%)**	**PC 2: sea level rise and sea surface temperature (25%)**
Sea level change		0.89
Sea surface temperature change		-0.69
Ocean acidification	0.92	
SENSITIVITY	**PC 1: coastal vulnerability (18%)**	**PC 2: coastal health (18%)**
% land 5 m > sea level	0.90	
%pop 5 m> sea level	0.83	
% land 10 km coastline	0.62	
% pop 10 km coastline	0.61	
biodiversity status		0.93
habitat status		0.91
natural coastal protection		0.84
ADAPTIVE CAPACITY	**PC 1: socio-economic vulnerability (31%)**	**PC 2: Extent EEZ and MPA (10%)**
Agriculture % GDP	0.89	
GDP per capita	0.89	
Infant mortality	0.82	
Governance	0.80	
Healthy life expectancy	0.79	
Nigh Light Development Index	0.78	
Sanitation	0.72	
Fisheries resilience	0.68	
Official AID	0.63	
Education	0.61	
EZ per coastline		0.84
Tourism direct		0.65

We first present two PCs and the associated indicators in each vulnerability component. The two exposure dimensions explain 61% of the variance per component (only factors > 0.6 are shown; Table 8). Table 8 shows that PC 1 represents high values for ocean acidification while dimension reflects high values for sea level rise and low values for sea surface temperature change. Variation in sensitivity is mainly determined by coastal health and coastal vulnerability. Each of the two dimensions explains 18% of the variance and thus 36% of the total variance. Adaptive capacity is mainly determined by the two dimensions of socio-economic vulnerability, the extent of EEZ and MPA extent. Together they account for 41% of the variance with the first dimension responsible for 31% (see Table 9).

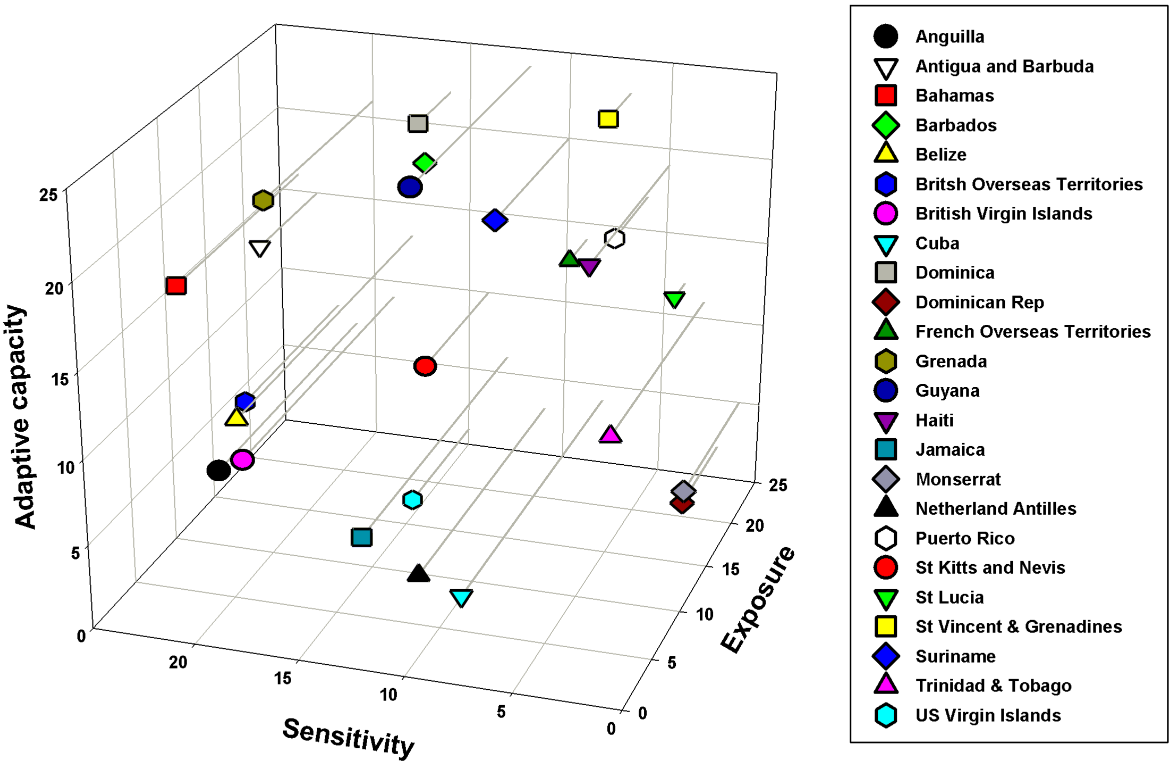

Figure 29 Caribbean SIDS plotted across the three components of exposure, sensitivity and adaptive capacity

Subsequently we examined the ranking of all Caribbean SIDS for the three components to see whether distinguishable patterns could be observed. Figure 29 shows that there is a large diversity of scores across the different countries yet one grouping across countries can be seen. One grouping can be hypothesized to be based on geographical location (Anguilla, British Overseas territories and British Virgin Islands) or similarities in socio-economic conditions. Within this grouping Belize is the odd one out. Further analysis of the Caribbean data was undertaken to identify whether 'clusters' of countries with similar characteristics exist. Despite using different methods to detect clustering and applying them to the final vulnerability outcome as well as the three underlying components, no distinct grouping emerged. The fact that the cluster analysis did not reveal any distinct groupings of Caribbean countries is an indication that interventions to promote adaptation will need to be at the national level and/or programmed to include sets of countries that exhibit particular aspects of vulnerability. As no particular clusters within the Caribbean SIDS could be established we further examined in more detail how each individual Caribbean country ranked across the various underlying dimensions per component that came out of the principal component analysis.

Caribbean SIDS show a high diversity in ranking across the different PCA components (see Table 9). Each component shows the relative vulnerability (green to red) in comparison to other countries in the region. The scores for the countries for each PCA, however, does not examine the critical levels of the different subcomponents. Thermal stress and UV radiation might be beyond an ecologically sustainable threshold level for all countries involved, but values shaded green imply that these countries are less vulnerable than those whose values appear in red. The PCA subcomponents show where each country faces higher and lower vulnerability which can help design adequate adaptation policies. However, national level conclusions need to be made with caution due to coarse resolution of the data. Policy recommendations with respect to each component of vulnerability, are offered for consideration in the ensuing section.

Table 9 Rankings for Caribbean SIDS by PCA subcomponent

Country	Exposure		Sensitivity					Adaptive capacity				
	Thermal stress and UV radiation (-)	SST and SLR (-)	Coastal vulnerability	Coastal health and protection	Coastal development threat	Fisheries dependency	Fisheries overexploitation	Governance and NLDI and (-) EEZ magnitude	MPA protection	Foreign Direct Investment	Fisheries management	Remittances
Anguilla	-1.09	0.64	1.10	0.23	1.19	0.11	0.13	-1.34	0.77	0.08	-0.40	1.01
Antigua and Barbuda	-0.32	-0.41	0.70	0.83	0.93	0.85	0.86	-0.91	-0.25	-1.47	1.16	-0.06
Aruba	0.97	0.81	0.95	-1.17	0.08	-0.69	-1.16	-1.05	0.95	0.63	-0.71	-0.38
Bahamas	-0.57	0.49	0.04	0.57	0.57	1.55	-1.63	-0.23	-0.84	-1.23	-0.82	0.35
Barbados	-0.37	-1.40	0.35	1.29	0.58	0.28	2.16	-1.26	1.06	-0.75	0.60	-1.68
Belize	-0.68	1.18	-1.46	1.83	-0.70	1.03	-1.32	1.60	-1.31	-1.53	-0.22	1.05
Bermuda	-0.25	0.21	0.43	0.82	1.63	-1.11	-1.31	-2.09	1.10	1.08	-0.55	1.29
British Virgin Islands	-1.00	0.86	1.17	-0.08	1.18	-0.40	-0.53	-0.41	0.46	0.55	-0.79	-1.09
Cayman Islands	-0.72	1.51	0.74	0.25	0.80	-0.20	-0.13	-1.45	-0.04	0.00	-0.67	0.02
Cuba	0.53	1.57	-1.16	1.22	-0.59	-1.57	-1.07	0.96	-1.32	1.50	-1.96	-0.42
Dominica	-0.36	-1.81	0.63	1.75	-0.26	-0.25	1.44	1.01	0.69	-0.40	-0.35	-0.51
Dominican Rep	-1.13	0.38	-1.33	0.16	-0.87	-1.60	-0.06	0.39	-1.34	1.07	0.79	0.77
French Guiana	0.19	-1.08	-1.86	-1.88	0.94	0.19	0.60	-0.58	-0.93	-1.13	0.93	1.40
Grenada	1.97	-0.20	0.33	0.49	-0.92	2.10	-0.19	0.92	1.17	-0.49	1.50	-1.31
Guadeloupe	-1.03	-1.40	-0.04	-0.82	0.52	-0.38	0.59	-0.08	0.45	-0.14	-0.46	1.20
Guyana	1.56	-0.09	-2.01	-0.93	0.62	1.27	0.43	1.26	1.56	0.32	1.57	1.08
Haiti	0.35	1.20	-0.94	0.98	-0.97	-0.73	0.97	1.49	0.32	1.77	0.83	1.70
Jamaica	1.01	1.27	-0.67	1.39	0.18	-0.75	0.94	-0.34	-1.06	1.19	1.18	0.92
Martinique	-1.03	-1.40	0.38	-0.86	0.29	-0.52	1.57	0.75	0.33	0.36	-1.36	-0.73
Montserrat	-1.34	0.06	1.46	-1.34	-1.19	0.01	1.03	0.87	1.79	0.27	-0.63	0.55
Netherlands Antilles	0.23	0.53	0.34	-0.38	0.00	0.07	-0.86	-0.21	-0.45	0.57	-0.98	-0.51
Puerto Rico	-0.39	0.35	-0.70	-0.81	-0.50	-1.46	-0.60	-0.87	-0.83	0.32	0.63	-0.33
Saint Kitts and Nevis	0.06	-0.86	0.98	-0.55	-1.05	1.31	-0.07	1.19	-0.54	-1.60	-1.25	0.05

Country	Exposure		Sensitivity					Adaptive capacity				
	Thermal stress and UV radiation (-)	SST and SLR (-)	Coastal vulnerability	Coastal health and protection	Coastal development threat	Fisheries dependency	Fisheries overexploitation	Governance and NLDI and (-) EEZ magnitude	MPA protection	Foreign Direct Investment	Fisheries management	Remittances
Saint Lucia	0.86	-1.49	0.69	0.08	-2.23	0.07	0.69	1.30	1.03	-0.53	-0.77	-0.60
Saint Vincent & Grenadines	1.14	-1.37	0.24	-0.61	-1.82	1.18	-0.95	0.12	0.66	-1.34	1.46	-0.68
Suriname	1.00	0.59	-1.47	-1.12	1.40	1.14	0.78	0.00	-0.91	1.29	1.54	-1.10
Trinidad and Tobago	2.12	-0.29	-0.51	-0.99	-1.06	-0.68	-0.51	0.31	-0.86	1.24	0.51	-2.26
Turks and Caicos Is.	-1.52	-0.37	0.37	0.43	1.04	0.55	-1.33	-0.71	0.27	-0.73	-0.75	0.62
US Virgin Islands	-0.21	0.52	1.29	-0.77	0.23	-1.36	-0.47	-0.63	-1.93	-0.89	-0.01	-0.36

5.3 Policy recommendations for the Caribbean fisheries sector

The challenges of sustainable development in the Caribbean region are numerous and diverse. The fisheries sector presents real opportunities for further economic growth, wealth creation and food security through diversification, innovation, market access, conservation and regional cooperation (CRFM 2014)[24]. Caribbean fisheries, however, are under pressure from stressors including overfishing, loss of habitat, pollution, disturbance of coral reefs, and introduced species while climate change is expected to exacerbate this situation. The contribution of fisheries to social and economic growth and development can be enhanced through appropriate policy interventions and cooperative actions by Caribbean countries. Climate change impacts on the fisheries sector and the most important pathways for adaptation need to be incorporated at the national level to mitigate climate change impacts.

The recommendations that follow are based primarily on the insights and interpretations of the information provided by the PCA. Countries may wish to consider these suggestions as part of a package of adaptation strategies that could enhance resilience in the fisheries sector to the adverse effects of climate change. The different recommendations provided might have overlapping characteristic as some subcomponents are interrelated.

5.3.1 Exposure

PCA E1 Thermal stress

- Use NOAA’s Coral Reef Watch program's satellite data which provides current reef environmental conditions to quickly identify areas at risk for coral bleaching.
- Improve of coral reef ecosystem health to build resilience to combat coral bleaching by means of coral reef restoration programs and improvement of water quality.
- Develop local and national expertise for better management of coral reef ecosystems through training of resource managers and decision-makers.

PCA E2: Sea surface temperature change

- Monitor sea surface temperature continuously at the regional level provides researchers and stakeholders with tools to understand and better manage the complex interactions leading to coral bleaching.
- Strengthen the science-policy interface in order to support evidence based decision-making by building on existing available statistics and indicators and developing downscaled models for the Caribbean region.
- Develop downscaled data on sea surface temperature change projections to assess the impacts thereof on key fish species in the Caribbean region is crucial as the data generated by global assessments is too coarse to be used a regional or national scale.

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[24] Caribbean Community Common Fisheries Policy

5.3.2 Sensitivity

PCA S1: Coastal vulnerability

- Develop downscaled local models on impact projections of extreme weather events (e.g. flooding, coastal erosion) on coastal zones to help determine most the vulnerable areas or communities.
- Build climate proof critical infrastructure or relocate crucial infrastructure (roads for example can be redesigned to withstand the heavier rainfall and higher sea levels).
- Build harbors with boat hauling equipment so in case of extreme weather boats can be safely stored and/or create safe harbours with mooring facilities for fishing boats.
- Assess coastal vulnerability at the local/community level as some coastal communities will face more significant challenges in achieving potential successful adaptation than others.
- Enhance the natural defences provided by wetlands, barrier islands and reefs to control natural processes such as coastal erosion and longshore drift and provide protection from storm surges and floods.Develop engineering solutions to decrease coastal vulnerability whereby soft engineering projects are considered less expensive than hard engineering options, usually more long term and more environmentally sustainable. However, there are circumstances that will necessitate ‘hard’ engineering solutions.

PCA S2: Coastal health and protection

- Restore coastal wetlands as this great potential to minimize the impacts on coastal communities of stronger hurricanes associated with climate change.
- Rehabilitate and protect ecosystems, such as mangrove forests, wetlands, seagrass beds and salt marshes by limiting fishing therein and banning the use of damaging fishing techniques.
- Apply for funding from agencies working on so called ‘carbon sinks’ also called ‘blue carbon’ to help restore and improve mangroves, seagrass beds and salt marshes (e.g. IUCN, GRID-ARENAL, and UNEP).
- Implement good marine practices to restrict dumping of waste at sea and the clearing of ballast waters in accordance with international protocols.

PCA S3: Coastal development threat

- Apply a human-centered approach to integrated coastal area management in an effort to balance economic development, social needs and environmental protection.
- Incorporate the rights and concerns of local fishing communities when approving new development projects (e.g. guarantee access to beaches for fishing access).
- Develop ports, airports, cities and other crucial infrastructure in the coastal zone in an environmentally sustainable manner by for example using renewable energy technologies

PCA S4: Fisheries dependency

- Improving the welfare and livelihoods of fishers and fishing communities and promote small scale fisheries as they provide more spin-off benefits to fisherfolk and coastal communities.
- Improve the post-harvest value chain to cut down the high post-harvest losses currently seen in the fisheries sector in the Caribbean region to improve food security.

PCA 4: Fisheries overexploitation

- Improve data collection and stock assessments as a constantly reassessed, scientifically determined, limit on the total number of fish caught and landed by a fishery will help decrease fisheries overexploitation.
- Enhance monitoring of fish populations as this will be necessary so that commercial fishing regulations can be adjusted as populations are affected by changing climate conditions.
- Apply the Ecosystem Approach to Fisheries incorporating a multi-species fishery approach by for example designing marine reserves that have a wide range of habitats that support the various development stages of the various species while enhancing available biomass.
- Implement temporal restrictions to define fishing seasons, while appropriate gear restrictions could include limits on size and type characteristics as development of these fishing control measures, when properly enforced, can help decrease or prevent fisheries overexploitation.
- Combat Illegal, unreported and unregulated (IUU) fishing which is common in the Caribbean region masking overexploitation as a large part of the catch taken goes unreported.
- Ensure effective Monitoring, Control and Surveillance (MCS) with respect to fishing activities as this is often poor in the Caribbean region and the coast guards and fisheries officers often lack the necessary human, financial and technical capacity.

5.3.3 Adaptive capacity[25]

PCA 2: Marine protected areas

- Expand Marine Protected Areas (MPAs) and improve their management effectiveness in safeguarding coral reef ecosystem health. Improving the area of MPAs and/or enhancing the functioning of existing MPAs are crucial. MPAs provide a range of benefits for fisheries, local economies and the marine environment including, conservation of biodiversity and ecosystems. They can help to reverse the global and local decline in fish populations and productivity by protecting critical breeding, nursery and feeding habits

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[25] There were five pcas in adaptive capacity that came out in the analysis (see table 4.3). For our recommendations we will focus on pcas 2 (Marine Protected Areas) and 4 (Fisheries Management) as recommendations for the other three pcas go beyond the scope of the fisheries sector.

PCA 4: Fisheries management

- Apply an Ecosystem-based Approach to Fisheries as it's an approach to fisheries management and development that strives to balance diverse societal objectives by taking into account knowledge and uncertainties regarding biotic, abiotic and human components of ecosystems and their interactions.
- Apply the precautionary approach as the functioning of the marine ecosystems is only partially understood.
- Improve early warning systems (to storms and hurricanes) for the fisheries sector by means of for example improved technology used by fishers can contribute to the achievement of this objective.
- Acknowledge the limits of centralized fisheries governance efforts and the necessary move towards co-management, a governance approach in which a partnership is created between regulating officials and fishing communities through fisherfolk organizations and other civil society organizations.
- Develop harmonized measures for sustainable fisheries management as fisheries are often transboundary and the resource shared.
- Build capacity of the fisheries divisions as the national fisheries management framework needs to equip the responsible agencies with a range of expertise to support the participatory approach and the demands of good governance.
- Integrate environmental, coastal and marine management considerations into fisheries policy so as to safeguard fisheries and associated ecosystems from anthropogenic threats and to diminish the impacts of climate change and natural disasters.
- Mainstream climate change into fisheries policies and legislation following the regional protocol for integrating climate change adaptation (CCA) and disaster risk management (DRM) into the Caribbean Community Common Fisheries Policy (CCCFP) which is being developed.

5.4 Discussion and conclusion

This assessment has shown that at the global level the fisheries sector in the Caribbean region is highly vulnerable to climate change. Previous vulnerability assessments of the fisheries sector to climate change only included a small number of Caribbean SIDS and underestimated the region's vulnerability. This section demonstrates that the number and choice of countries and indicators, as well as the type of quantitative analysis applied can significantly influence the vulnerability ranking of the fisheries sector to climate change at the global and regional level. Our analysis suggests the fisheries sector of Caribbean SIDS is more vulnerable relative to the other groupings of SIDS (Pacific and AIMS). In comparison with the other two groups it is particularly vulnerable in exposure (ocean acidification and sea surface temperature change). For the sensitivity component the Caribbean showed more diversity and Caribbean SIDS ranked as having higher adaptive capacity than the other two SIDS groups.

This section shows the underlying dimensions of the Caribbean countries' vulnerability to climate change. The analysis does not indicate, however, whether the group as a whole is already vulnerable beyond a sustainable threshold. Thus, while for example a particular country might not appear to be vulnerable to ocean acidification in comparison to other Caribbean states, it is possible that the entire region might already be beyond a sustainable threshold with respect to this indicator. In addition, while the vulnerability scores for some indicators were low, (such as sea level rise), it is widely acknowledged that sea level rise will pose serious consequences for Caribbean SIDS. Similarly, the indicators of adaptive capacity, education, health and GDP per capita were not assigned high scores in the analysis. However, conventional wisdom suggests that these indicators strongly influence a country's adaptive capacity.

Within the region the Greater and Lesser Antilles are most vulnerable in exposure and also more vulnerable in sensitivity than other Caribbean countries. However, cluster analysis revealed that no distinct patterns could be determined among the Caribbean SIDS. This implies that adaptation measures and actions need to devised and implemented in a manner that is appropriate and specific to the individual country. The results from the PCA may also provide some useful guidance about the vulnerability components and indicators on which each Caribbean SIDS may wish to focus when developing their adaptation policies, strategies and measures. The recommendations offered in the previous section may be helpful in this context. The recommendations are in line with the Liliendaal Declaration which promotes the implementation of specific adaptation measures to address key vulnerabilities in the region, and encourages action to reduce the vulnerability of natural and human systems in CARICOM countries to the impacts of a changing climate.

This analysis does not take into account the local level differentiation within and between countries (for example, characteristics of landing sites, poverty, access to resources needed to make changes to fishing gear). Coastal vulnerability in Jamaica is, for example, less high in comparison to other countries in the region. At the same time it is evident that some communities at the local level are still extremely vulnerable, as seen by the devastation caused with the passage of Hurricane Ivan in 2004. An understanding of these types of differences at the local level are therefore crucial in designing appropriate, location-specific climate change adaptation strategies. There is, however, no regional framework for assessing climate change vulnerability of the fisheries sector at the local level which can be implemented and allows for comparison of fishing communities across the region. Development of such a regional model and implementation thereof across fisheries communities will provide valuable inputs for further adaptation strategies of the fisheries sector.

6 CONCLUSIONS

Climate change is a serious threat facing Caribbean countries. Sea-level rise, higher sea surface temperature, ocean acidification and a projected increase in the intensity of extreme weather events are likely to have an adverse effect on Caribbean countries. These countries are small, economically vulnerable and highly dependent on ocean ecosystem services while a large part of their population and infrastructure is located in the low-lying vulnerable coastal zone. Caribbean countries thus have considerable cause for concern as the threats posed to the region's development prospects are potentially severe and adaptation will require a sizeable and sustained investment of resources that governments will find very difficult to provide on their own. The allocation of funds for adaptation programs is often prioritized on the basis of donors' perception of countries with the largest needs. This prioritization is often based on vulnerability assessments. Caribbean countries were largely excluded, however, from the global analysis of fisheries sector vulnerability by Allison et al. (2009). This study was therefore deemed inadequate for an examination of the vulnerability of the fisheries sector of the Caribbean region, individual countries and the underlying dimensions of their vulnerability to help guide policy interventions to adapt to climate change.

In this study we have sought to develop and apply an approach different from that used by Allison et al (2009) to examine the vulnerability of the fisheries sector of SIDS as a group, with a more detailed analysis of the vulnerability of Caribbean SIDS. We argue that a more detailed understanding of the factors underlying exposure, sensitivity and adaptive capacity can assist policymakers in making appropriate climate change adaptation choices. The analysis sought to identify priority support needs with regard to fisheries sector vulnerability and identifies potential responses that Caribbean SIDS may wish to consider. This study will also contribute to the enhancement of our general understanding of climate change vulnerability of the fisheries sector globally. In this analysis we adopt the definition of vulnerability used in the Allison et al. (2009) framework. The Allison et al. (2009) study applied the definition of vulnerability used in the Third Assessment Report of the IPCC (2001) to build their vulnerability framework. In this interpretation the vulnerability of any sector to climate variability or change is a function of (a) the degree of exposure to the threat, (b) the sector's sensitivity: the degree to which a system is affected (either adversely or beneficially), and (c) the capacity of the sector to cope with or adapt to the threat, to take advantage or create opportunities, or to cope with the consequences (Smit and Wandel 2006).

In **Section 2** we have shown that the outcome of vulnerability assessments is very dependent on the methodological choices. Based on earlier work (Allison et al. 2009) in which vulnerability of the fisheries sector in the face of climate change was seen as a function of exposure, sensitivity and adaptive capacity, we developed a six-step methodological approach to show how different methodological choices can lead to different outcomes among SIDS, LDCs and other coastal countries. This is the first study to have systematically analyzed the differences in vulnerability components and indicators of the fisheries sector to climate change among SIDS, LDCs and other coastal nations.

Our results show that although SIDS were reported to be the least vulnerable in the initial assessments they have been shown to be the most vulnerable in the later assessments. Methodological choices thus have a significant impact on the vulnerability rankings of individual countries and groups of countries, a conclusion that we have emphasized in this work. From this section we can conclude that the absence or inclusion of particular countries, the use of indicators based on total versus relative numbers, and the choice of indicators is crucial to the outcome of vulnerability rankings for particular country groups in fisheries sector vulnerability assessments. These factors can conceal or highlight the relative vulnerability of particular country groups. The use of more recent data and omitting potential redundancy among indicators by means of principal component analysis we found to have had very little impact on the final outcome. The under-representation of SIDS in previous vulnerability assessments may be disadvantageous to SIDS, given that the results of national level vulnerability assessments are used to help determine the allocation of adaptation resources under various international governance mechanisms.

When examining the results of the relative change in ranking of vulnerability between the six various assessments, Australia and islands in the Pacific Ocean, the Caribbean, Chile, some countries in Northern Europe, the Middle East and some islands in the Indian Ocean are assessed as being much more vulnerable, going up in rank of vulnerability by at least 20 countries, while North America, Russia, and parts of Asia and Africa are assessed as being less vulnerable and dropped over 20 ranks in vulnerability on the total list of countries. This emphasizes the importance of choice of indicators, their aggregation and the impact this has on the final ranking of particular countries and country groups.

We identified a set of indicators that builds on existing work but incorporates a more comprehensive list of variables for assessing the vulnerability of the fisheries sectors of SIDS and LDCs, in the face of climate change. The results show distinctive characteristics in the vulnerability profiles of the different country groupings. Although SIDS ranked as most vulnerable, the ranking for LDCs was not noticeably different.

Section 3 shows that in line with the general literature, the fisheries sectors of SIDS and LDCs are more vulnerable to climate change than those of other countries. Compared to developed and other developing states, LDCs and SIDS are responsible for very small volumes of global greenhouse gas emissions, and thus contribute little to anthropogenic climate change, yet the fisheries sectors of the two groups are highly vulnerable to climate change. The results presented here suggest that the SIDS considered in the analysis are most vulnerable in the sensitivity component, while for LDCs the area of greatest vulnerability lies in their low adaptive capacity.

We have examined critical underlying factors for the three components of vulnerability, and have identified those subcomponents which explain the largest amount of variation in of country groups. SIDS rank highest with respect to the two exposure subcomponents, while LDCs score particularly low in vulnerability to sea surface properties (sea surface temperature change and ocean acidification). The subcomponents, coastal vulnerability and fisheries dependence appear to explain the largest variety among country groups for assessing sensitivity. This suggests that it is important to consider variables other than fishery dependence indicators, in order to achieve a broader understanding of the vulnerability of the fisheries sector to climate change and climate variability. The aggregate scores for the different subcomponents show very little variation across the three groups. However, the scores for individual subcomponents show that SIDS are ranked as extremely vulnerable with respect to coastal vulnerability, although the differences across the other subcomponents (except one) while significant, are less extreme.

We need, however, to be aware of the implications of using quantitative analysis to examine vulnerability. The indicator sea-level rise, for example, did not emerge as an important subcomponent in the analysis as it explains only a small part of the variation between SIDS groups. However, this does not imply that SLR is not of crucial importance or that it will not pose a significant threat to the fisheries sector and those living in coastal communities in the future. Our results indicate that exposure is a highly complex and heterogeneous dimension that cannot be easily captured in a single aggregated value. Given the complexity of the exposure component, it was felt that assessment of regional and country level differences should therefore form a critical element of the analysis. In addition, using exposure indicators that already incorporate the projected impacts on marine potential yield as a result of climate change (e.g. work by Barange et al. 2014; Cheung et al. 2010) could improve the current framework and should be considered in future research.

The boxplots for LDCs and SIDS for all subcomponents except two (coastal vulnerability and socio-economic development) indicate a large variation in scores within these two country groups. Further analysis across the three different SIDS groups, i.e. the Pacific, Atlantic, Indian, Mediterranean and South China Sea (AIMS) and Caribbean SIDS – will help to highlight more precisely the nature of the differences within the groups. Section 4 further explores the differences between these three different SIDS groups.

In **Section 4** the vulnerability of the fisheries sector in the three SIDS groups- Caribbean, Pacific, and Atlantic, Indian, Mediterranean and South China Sea (AIMS) are examined. They are considered a separate group by the UN as they share similar sustainability challenges related to their specific characteristics such as smallness, isolation, susceptibility to natural disasters, vulnerability to external shocks, concentration of population and infrastructure in the coastal zone, high dependence on a limited number of resources. Our results in Section 4 show that in fact they share similarities regarding vulnerability to climate change, however, our results also show that there is a large diversity among the three groups in terms of underlying dimensions of vulnerability. Our examination of the underlying dimensions for the fisheries sector vulnerability across the three SIDS groups revealed the Caribbean region was the most vulnerable of the three groups. It is particularly vulnerable in the exposure component, and especially vulnerable to ocean acidification. For the sensitivity component the Caribbean scored high but scores were similar to the Pacific and AIMS SIDS. In adaptive capacity the Caribbean scored low, which implies higher adaptive capacity than other SIDS regions.

In **Section 5** we examined the vulnerability of the fisheries sector in Caribbean SIDS in more detail. Section 4 has shown the fisheries sector in the region is highly vulnerable yet it also showed a large diversity in scores among the different countries. This section has shown that previous vulnerability assessments of the fisheries sector to climate change only included a small number of Caribbean SIDS and underestimated the region’s vulnerability. The six-step methodological assessment carried out in Section 2 has widespread implications for vulnerability scoring of Caribbean SIDS as we have shown in this section. Inclusion of countries, choice of indicators and number of indicators as well as the type of statistical analysis all have explicit consequences for the vulnerability ranking of the fisheries sector in Caribbean SIDS.

Our analysis suggests the fisheries sector of Caribbean SIDS is extremely vulnerable relative to the other groupings of SIDS (Pacific and AIMS). When we compare the Caribbean SIDS to the other two SIDS groups we see the Caribbean is the most vulnerable to climate change. In comparison with the other two groups it has particularly high levels of vulnerability in exposure in relation to ocean acidification. For the sensitivity component the Caribbean scored high but scores were similar to the Pacific and AIMS SIDS. In adaptive capacity the Caribbean scored low, which implies a high adaptive capacity.

This section continued to show the underlying dimensions of the Caribbean countries' vulnerability to climate change. This analysis compares the Caribbean SIDS with each other and thus focusses on the interregional differences. As a result, this does not indicate whether the group as a whole is already vulnerable beyond a sustainable threshold level. Thus, a country might appear not vulnerable to ocean acidification in comparison to other Caribbean countries while in reality all countries might already be beyond a sustainable threshold. In addition, the region's vulnerability ranking was not high for some indicators (such as sea level rise), yet in reality we know that sea level rise will pose serious consequences for Caribbean SIDS. Similarly, for adaptive capacity, Caribbean vulnerability with respect to the indicators education, health, and GDP per capita was relatively low. However, it is acknowledged in the literature that the Caribbean must also focus on these indicators if higher levels of adaptive capacity are to be achieved.

Within the region we find that the Greater and Lesser Antilles are most vulnerable in exposure and also more vulnerable in sensitivity than other Caribbean countries. However, cluster analysis revealed that no distinct patterns could be determined among the Caribbean SIDS. This implies that adaptation measures and actions still need to be location-specific to achieve maximum effectiveness. Our results on the underlying dimensions of the PCA for Caribbean SIDS provides information on what each Caribbean SIDS should focus on in developing their adaptation policies, strategies and measures. We have therefore provided a set of recommendations based on the PCA subcomponents to help steer this process in Section 5. Our recommendations are in line with the Liliendaal Declaration which promoted the implementation of specific adaptation measures to address key vulnerabilities in the region, and encourages action to reduce the vulnerability of natural and human systems in CARICOM countries to the impacts of a changing climate.

6.1 Way forward

- Our results show that although SIDS were *least* vulnerable in the initial assessments they were *most* vulnerable in the later assessments. Methodological choices thus have a large-scale impact on the vulnerability outcome of countries and country groups. We argue that the methodological choices and potential impact on the outcome should be made much more explicit in vulnerability assessments and that these results go beyond the fisheries sector as well. Our study also argues for a more adequate inclusion of SIDS in fisheries sector climate change vulnerability analyses as their exclusion has concealed their actual vulnerability. Providing a platform where data related to climate change vulnerability of the Caribbean countries can be accessed would support future inclusion in vulnerability assessments.

- Exposure of the fisheries sector to climate change impacts will be enhanced by many different routes including changes in ocean currents, salinity levels, sea surface temperature, ocean acidification as well as intensity of tropical cyclones. The consequent impacts on various marine ecosystems and for example, their production and species distribution are still largely unknown. The exposure component showed the largest level of complexity in our analysis as; only a small number of indicators could be used due to lack of comparable data at the global scale. In addition, the indicators (and consequent PCAs) showed very different results for different countries. Using exposure indicators that already incorporate the projected impacts on marine potential yield as a result of climate change could improve the current framework. However, the data generated by these types of global assessments projecting the impacts of sea surface temperature change on maximum potential yield of fisheries (e.g. Barange et al. 2014; Cheung et al. 2010) is too coarse to be used at a regional or national scale. Development of downscaled data on sea surface temperature change projections to assess the impacts thereof on key fish species in the Caribbean region is therefore crucial.

- We have shown that LDCs should focus on improving their adaptive capacity while SIDS are most vulnerable in sensitivity and should therefore focus their attention on building resilience in this component. However, to adequately adapt to climate change we need more downscaled information on vulnerability. Our results in Section 5 on the underlying vulnerabilities for Caribbean SIDS provides information on what each Caribbean SIDS should focus on in developing their adaptation policies, strategies and measures. The set of recommendations based on the underlying vulnerabilities help steer this process. These recommendations need to be further refined and implemented at the national and local level as our vulnerability assessment has shown some remarkable differences among countries. However, there is neither a regional framework to assess fisheries sector vulnerability at the local level nor is the data available. We therefore argue for development of a regional framework on assessing local level vulnerability of the fisheries sector. However, this also implies the need for local level data as data that is regarded as crucial (for example on landing site vulnerability characteristics such as the availability of boat hauling equipment or safe harbours) as this is currently not available. The objective of further vulnerability assessment at the local level is to understand the various sources of vulnerabilities affecting fisheries-dependent communities and activities, and also the factors influencing their adaptive capacity.

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APPENDIX 1: INDICATORS CHARACTERISTICS FOR GLOBAL ASSESSMENT

Component (# countries data)	**Indicator**	**Source of data and year**	**Relevance**
Exposure (173)	Sea Surface Temperature observed 1985-2005	Halpern et al. (2012)	Poleward shifts in plankton and fished species; changes in timing of phytoplankton blooms; changing zooplankton composition; changes in fish distribution
Exposure (165)	Sea level Rise projections (SLR) 2050 (RCP 4.5)	Hinkel et al. (2012)	Sea level rise results in coastal inundation and habitat loss. Storm surges and coastal flooding can lead to death, injury, ill-health or disrupted livelihoods in low-lying coastal zones. Increased storm frequency and intensity may also imply more days at sea lost to unfavourable weather and increased risk of accidents and decrease of safety at sea for fishers (Daw, Adger, and Brown, 2009; Mahon, 2002). High flood risks affect the fishing infrastructure, e.g. landing and market sites, boats, processing plants in these areas.. SLR will also alter fisheries habitats, such as seagrasses, mangroves and salt marshes (Morris, Sundareshwar, Nietch, Kjerfve, and Cahoon, 2002).
Exposure (173)	Ocean acidification 1870-2000	Halpern et al. (2012)	Ocean acidification results in reduced growth and survival of commercially valuable shellfish and other calcifiers, e.g. reef building corals and calcareous red algae (Burkett et al. 2013).
Exposure (163)	UV radiation observed 1996-2004	Ocean Health Index (NASA) (2012)	Recent results continue to support the general consensus that ozone-related increases in UV-B radiation can negatively influence many aquatic species and aquatic ecosystems (Häder, Kumar, Smith, and Worrest, 2007). Solar UV radiation penetrates to ecologically significant depths in aquatic systems and can affect both marine and freshwater systems from major biomass producers (phytoplankton) to consumers (e.g., zooplankton, fish, etc.) higher in the food web (Häder et al., 2007).
Sensitivity (173)	Percentage of population living on land below 5 m above sea level	CIESIN (2010)	Threats from sea level rise, floods and storms are higher if large cities (or the majority of all cities), ports and airports are located in coastal zone, and where coastal population pressure is high. Increased risk of flooding of houses and infrastructure will impact the lives of fishers, fishing communities and

			related industries when the majority of people live only a few meters above sea level. These high flood risks also affect the fishing infrastructure in these areas such as e.g. landing sites, boats, processing plants.
Sensitivity (169)	Percentage of population 10 km from the coast	CIESIN (2010)	Countries that do not have a large area of land or population in 5 meters above sealevel but have a large population and land within first 10 km of the coastline are also extremely vulnerable in their coastal zone in case of flooding, damages due to extreme evens etc. These high flood risks also affect the fishing infrastructure in these areas such as e.g. landing sites, boats, processing plants.
Sensitivity (169)	Coastal land below 5m as percentage of total landarea	CIESIN (2010)	Threats from sea level rise, floods and storms are higher if large part of the land are located in land area within 5 meters above sea level. If a country is small and a large percentage of their land is within 5 meters below sea level this will make it extremely vulnerable.
Sensitivity (169)	Percentage of land 10 km from coastline as percentage of total landarea	CIESIN (2010)	Threats from sea level rise, floods and storms are higher if large part of the land are located in land area within 10 km from the coast. If a country is small and a large percentage of their land is within 10 km from the coast this will make it extremely vulnerable.
Sensitivity (166)	Cities in low lying coastal zone	McGranahan et al. (CIESIN) (2007)	Countries are seeing increasing rates of urbanization. Cities are crucial for housing, employment and public and private services. Cities located in the low lying coastal zone are more prone to threats from sea level rise, floods and storms.
Sensitivity (173)	Population largest city (%)	World Development Indicators (2009)	Countries where a large part of the population, infrastructure, governing and financial institutions are located in one city are more vulnerable than countries where this is more spread out.
Sensitivity (171)	Biodiversity*	Ocean Health index (2013)	Healthy biodiversity is crucial in ecosystem health
Sensitivity (172)	Habitat*	Ocean Health Index (2013)	Habitats evaluates the condition of key habitats that support high number of species
Sensitivity (171)	Species*	Ocean Health Index (2013)	Species evaluates the conservation status of marine species
Sensitivity (173)	Exploitation status of fished stock*	Ocean Health Index (2013)	Climate change impacts on a fishery will be less severe if a fishery is sustainably harvested. A healthy fishery will be less

			vulnerable and more resilient to climate change impacts
Sensitivity (173)	Fisheries employment	Monnereau et al. (2013)	Countries with higher contributions of fisheries to employment are more likely to be impacted (positively or negatively) by warming-related changes in the whole fishery productions systems of that nation (Allison et al. 2009;)
Sensitivity (173)	Fisheries exports	FAO (2009)	Countries with higher contributions of fisheries to export income, and thus deliver foreign exchange to a nation, are more likely to be impacted (positively or negatively) by warming-related changes in the whole fishery productions systems of that nation.
Sensitivity (173)	Fish catch	FAO (2010)	Fish catches contribute to employment and food security. Countries with higher fish catches are more likely to be impacted (positively or negatively) by warming-related changes in the whole fishery productions systems of that nation.
Sensitivity (173)	Fish nutrition	FAO (2005-2009)	Nutritional dependency identifies countries reliant on fish as a primary source of animal protein. This is expressed by fish protein as the percentage of all animal protein per capita per day in grams. This assumes that countries with higher dietary protein of fish are more likely to be impacted (positively or negatively) by warming-related changes.
Ad. capacity (173)	Healthy life expectancy*	United Nations Healthy Life Expectancy (2007)	Life expectancy provides a useful indicator of the overall health effects of environmental and other risk factors in a given population according to the World Health Organization. The link between health and climate protection is one of opportunity cost. Countries with significant public health problems are likely to find it socially and politically difficult to allocate resources to climate protection.
Ad. capacity (158)	Health: access to sanitation*	Worldbank (2009-2011)	Access to basic sanitation includes safety and privacy in the use of these services. Coverage is the proportion of people using improved sanitation facilities. Countries with significant public health problems are likely to find it socially and politically difficult to allocate resources to climate protection.
Ad. capacity (159)	Health infant mortality*	World Health Organisation	Infant mortality rate (IMR) is the number of deaths of children less

		(2010-2015)	than one year of age per 1000 live births. Countries with significant public health problems are likely to find it socially and politically difficult to allocate resources to climate protection.
Ad. capacity (173)	Education*	CIA factbook (2000-2010)	Countries with higher levels of education are likely to have higher adaptive capacity. Low levels of literacy, and education in general, can impede the economic development of a country in the current rapidly changing technology-driven world. Higher education signifies more skilled staff to undertake important functions related to climate protection, including skills for implementing adaptation programs, information management systems, and an array of other activities.
Ad. capacity (173)	Woldwide Governance*	Worldbank (2011)	The level of governance is relevant to the adaptive capacity of a country. Countries with a higher level of governance are likely to have a higher level of adaptive capacity. Lower levels can impede the effectiveness of dealing with climate change.
Ad. capacity (166)	Fisheries management capacity	Mora et al. (via OHI) (2008)	Marine governance (fisheries management capacity), marine protected areas (MPAs) and marine resilience are important as successful fisheries management and MPAs have the potential to increase ecosystem resilience. Countries with a higher level of fisheries management capacity are likely to have higher adaptive capacity. Lower levels can impede the effectiveness of dealing with climate change.
Ad. capacity (172)	Fisheries management capacity: MPAs*	Environment Performance Index (2012)	MPAs are considered a tool for fisheries management and increase fisheries productivity. Higher levels of MPAs (area % of EEZ) can be considered to make fisheries less vulnerable to climate change
Ad. capacity (171)	EEZ by coastline	Coastline Hinrichsen (2011), EEZ seaaroundus.org	A larger EEZ to coastline implies a larger area a country needs to manage which can impede effectiveness of management. A smaller EEZ/coast ration implies a smaller area to manage which could result in more effective management. More effective fisheries management (high levels of Monitoring, Control and Surveillance, lower levels of Illegal Unreported and Unregulated

			fishing) will enhance resilience of the fishery.
Ad. capacity (170)	Resilience Marine livelihood*	Ocean Health Index (2013)	Resilience of a fishery is important in adaptive capacity as a more resilient fishery is expected to be less vulnerable to climate change impacts.
Ad. capacity (170)	Resilience Wildfish caught*	Ocean Health Index (2013)	Climate change impacts on a fishery will be less severe if a fishery is sustainably harvested. A healthy fishery will be less vulnerable and more resilient to climate change impacts
Ad. capacity (173)	Gross Domestic Product per capita*	Worldbank (2011)	Higher levels of economic power by residents and the country as a whole will enforce the adaptive capacity of the nation in the face of impacts of climate change. GDP per capita (ppp) is not a specific indicator of coastal protection or exposure. However, in the absence of more specific information it has been used as a proxy for coastal protection levels in other global studies of coastal vulnerability to sea-level rise (Hinkel, 2008).
Ad. capacity (168)	Nigh Light Development Index (NLDI)*	NOAA (2012)	Economic vulnerability is important as countries with lower economic vulnerability can be expected to have a higher adaptive capacity. NLDI is considered a measure of economic development.
Ad. capacity (161)	Terms of trade*	UNCTAD (2010-2011)	Economic vulnerability is important as countries with lower economic vulnerability can be expected to have a higher adaptive capacity.
Ad. capacity (166)	Concentration of exports	UNCTAD (2013)	Economic vulnerability is important as countries with lower economic vulnerability can be expected to have a higher adaptive capacity. The concentration index shows how exports and imports of individual countries or group of countries are concentrated on several products or otherwise distributed in a more homogeneous manner among a series of products.
Ad. capacity (166)	Diversification of exports	UNCTAD (2013)	Economic vulnerability is important as countries with lower economic vulnerability can be expected to have a higher adaptive capacity. The diversification index signals whether the structure of exports or imports by product of a given country or group of countries differ from the structure of product of the world.

APPENDIX 2: COUNTRIES INCLUDED A1-A3 AND A4-A6

Countries	**SIDS**	**LDCs**	**Other coastal countries**	***Other coastal countries continued***
A1-A3	Belize Dominican Rep Fiji Guinea-Bissau Guyana Haiti Jamaica Mauritius Papua New Guinea Suriname Trinidad and Tobago	Angola Bangladesh Cambodia Congo, Dem Rep Gambia Guinea Madagascar Mauritania Mozambique Senegal Sierra Leone Sudan Tanzania, United Rep Togo Yemen	Albania Algeria Argentina Australia Belgium Bosnia and Herzegovina Brazil Bulgaria Cameroon Canada Chile China Colombia Congo Costa Rica Croatia Cyprus Côte d'Ivoire Denmark Ecuador Egypt El Salvador Estonia Finland France Gabon Georgia Germany Ghana Greece Guatemala Honduras Iceland India Indonesia Iran, Islamic Rep Ireland Israel Italy Japan	Jordan Kenya Kuwait Latvia Lebanon Libya Lithuania Malaysia Malta Mexico Morocco Namibia Netherlands New Zealand Nicaragua Nigeria Norway Pakistan Panama Peru Philippines Poland Portugal Romania Russian Federation Saudi Arabia Slovenia South Africa Spain Sri Lanka Sweden Syrian Arab Rep Thailand Tunisia Turkey Ukraine United Kingdom United States Uruguay Venezuela VietNam
A4-A6	Anguilla Antigua and Barbuda Aruba	Angola Bangladesh Benin	Albania Algeria Argentina	Japan Jordan Kenya

Countries	SIDS	LDCs	Other coastal countries	*Other coastal countries continued*
	Bahamas Bahrain Barbados Belize Bermuda British Virgin Islands Cape Verde Cayman Islands Comoros Cook Islands Cuba Dominica Dominican Rep Fiji French Guiana French Polynesia Grenada Guadeloupe Guam Guinea-Bissau Guyana Haiti Jamaica Kiribati Maldives Marshall Islands Martinique Mauritius Micronesia, Fed.States of Montserrat Nauru Netherlands Antilles New Caledonia Niue Palau Papua New Guinea Puerto Rico Réunion Saint Kitts and Nevis Saint Lucia Saint Vincent/Grenadines Samoa Sao Tome and Principe Seychelles	Cambodia Congo, Dem Rep Djibouti Equatorial Guinea Eritrea Gambia Guinea Liberia Madagascar Mauritania Mozambique Myanmar Senegal Sierra Leone Somalia Sudan Tanzania, United Rep Togo Yemen	Australia Belgium Bosnia and Herzegovina Brazil Brunei Darussalam Bulgaria Cameroon Canada Chile China China, Hong Kong Colombia Congo Costa Rica Côte d'Ivoire Croatia Cyprus Denmark Ecuador Egypt El Salvador Estonia Faeroe Islands Falkland Is.(Malvinas) Finland France Gabon Georgia Germany Ghana Greece Greenland Guatemala Honduras Iceland India Indonesia Iran, Islamic Rep Iraq Ireland Israel Italy	Korea, Dem People's Rep Korea, Rep Kuwait Latvia Mexico Morocco Namibia Netherlands New Zealand Nicaragua Nigeria Norway Oman Pakistan Panama Peru Philippines Poland Portugal Qatar Romania Russian Federation Saudi Arabia Slovenia South Africa Spain Sri Lanka Sweden Syrian Arab Rep Taiwan Thailand Tunisia Turkey Ukraine United Arab Emirates United Kingdom United States Uruguay Venezuela VietNam

Countries	**SIDS**	**LDCs**	**Other coastal countries**	***Other coastal countries continued***
	Singapore Solomon Islands Suriname Timor-Leste Tokelau Tonga Trinidad and Tobago Turks and Caicos Is. Tuvalu US Virgin Islands Vanuatu			

APPENDIX 3: INDICATORS USED FOR ANALYSIS IN SECTIONS 4 AND 5

Component	**Indicator**	**Source of data**	**Component**	**Indicator**	**Source of data**
Exposure	Sea Surface Temperature observed 1985-2005	Halpern et al. (2012)	Adaptive capacity	Healthy life expectancy	United Nations Healthy Life Expectancy (2007)
Exposure	Sea level Rise projections 2050	Hinkel et al. (2014)	Adaptive capacity	Health: sanitation	Worldbank (2011)
Exposure	Ocean acidification 1870-2000	Halpern et al. (2012)	Adaptive capacity	Health: infant mortality rate	Worldbank (2011)
Exposure	Thermal Stress (sea surface temperature prediction impacts on coral reefs) by 2050	Burke et al. (2011)	Adaptive capacity	Education	CIA factbook (2000-2010)
Exposure	UV radiation observed 1996-2004	Ocean Health Index (NASA) (2012)	Adaptive capacity	Woldwide Governance	Woldbank (2011)
Sensitivity	% of population living on land below 5 m above sealevel	CIESIN (2010)	Adaptive capacity	Fisheries management capacity	Mora et al. (via OHI) (2008)
Sensitivity	% of population 10 km from the coast	CIESIN (2010)	Adaptive capacity	Fisheries management capacity: MPAs	Environment Performance Index (2012)
Sensitivity	% of land below 5 m above sealevel	CIESIN (2010)	Adaptive capacity	EEZ by coastline	Coastline is Hinrichsen, EEZ seaaroundus.org
Sensitivity	% of land 10 km from the coast	CIESIN (2010)	Adaptive capacity	Resilience Marine livelihood	Ocean Health Index (2013)
Sensitivity	Cities in coastal zone	McGranahan et al. (CIESIN) (2007)	Adaptive capacity	Resilience Wildfish caught	Ocean Health Index (2013)
Sensitivity	Population largest city (%)	World Development Indicators (2009)	Adaptive capacity	Tourism direct (real and norm)	Worldbank (2013)
Sensitivity	Biodiversity	Ocean Health index (2013)	Adaptive capacity	Tourism total (real and norm)	Worldbank (2013)
Sensitivity	Habitat	Ocean Health Index (2013)	Adaptive capacity	liner shipping connectivitity	Worldbank (2009-2013)
Sensitivity	Species	Ocean Health Index (2013)	Adaptive capacity	Agriculture % GDP	Worldbank (2008-2010)
Sensitivity	coral reef health	Ocean Health Index (2013)	Adaptive capacity	Oilimports as % total oil consumption	U.S. Energy Information Administration (2009-2010)
Sensitivity	Coastal development threat	Burke et al. 2011 (2011)	Adaptive capacity	FDI%GDP	Worldbank (2007-2011)
Sensitivity	natural coastal protection status	Ocean Health index (2013)	Adaptive capacity	OAD%GDP	Worldbank (2009-2011)
Sensitivity	Exploitation status of f ished stock	Ocean Health Index (2013)	Adaptive capacity	remittances	Worldbank (2008-2011)
Sensitivity	Fisheries employment	Monnereau et al. (2013)	Adaptive capacity	Gross Domestic	Worldbank (2011)

Component	Indicator	Source of data	Component	Indicator	Source of data
				Product per capita	
Sensitivity	Coastal livelihoods and economies	Ocean Health Index (2013)	Adaptive capacity	Nigh Light Development Index	NOAA (2012)
Sensitivity	Fisheries exports	FAO (2009)	Adaptive capacity	Terms of trade	UNCTAD (2010-2011)
Sensitivity	Fish catch	FAO (2010)	Adaptive capacity	Concentration of exports	UNCTAD (2013)
Sensitivity	Fish nutrition	FAO (2005-2009)	Adaptive capacity	Diversification of exports	UNCTAD (2013)