Tropentag 2018, Ghent, Germany September 17-19, 2018

Conference on International Research on Food Security, Natural Resource Management and Rural Development organised by Ghent University, Ghent

Modeling the vulnerability of fisheries and aquaculture to climate change impact in Africa

[1]John Emeka Ogbonna, [2]Gebriele Hörstgen Schwark

[1]Georg-August Universität Göttingen, Dept. of Animal Sciences, Germany
[2]Georg-August Universität Göttingen, Dept. of Animal Sciences, Germany

Abstract

Climate change as result of global warming remains one of the major threats to Aquaculture, fisheries and dependent communities worldwide. Vulnerability of Aquaculture and fisheries to climate change is a function of exposure, sensitivity, and adaptive capacity of the community in question. Vulnerability of fish farmers is largely determined by the differences in socio-economic conditions among communities. This study aims to determine factors influencing the vulnerability of fishers and fish farmers to climate change impact in Africa. The objectives are twofold: first, to develop indicators influencing vulnerability and to determine how they influence vulnerability, secondly, to compare the vulnerability of fishers and fish farmers in different regions of Africa. Using the most recent data, Twenty-six countries in Africa were evaluated using seventeen indicators, which are allocated into the three component of vulnerability; the exposure, sensitivity and adaptive capacity. Results show that vulnerability is driven by poverty and that the most vulnerable regions in Africa are the west, central, East and North Africa regions. The southern regions of Africa tend to be less vulnerable to climate change impact on fisheries and aquaculture. This is as a result of high exposure and high sensitivity of the vulnerable region with a very low adaptive capacity. Our result show that establishment of marine protected area will decrease vulnerability. The findings allow for formulation of policy recommendations to help strengthen the livelihoods of small-scale fisheries and aquaculture in Africa.

Keywords: Aquaculture, climate change, Fisheries
* Corresponding author Email: emekaogbonna.johm@stud.uni-goettingen.de

Introduction

Natural climate variability has always been a challenge to human livelihoods such as fisheries and aquaculture. Human induced climate change has given a complex new dimension to this challenge. Evidences show that the natural climatic variability, compounded with climate change will adversely affect millions of livelihoods around the world (Weatherdon et al., 2016). The rural communities in the developing countries of the world are expected to be affected more due to their extensive dependence on climate sensitive livelihood options, and limited adaptive capacity to adapt to the changes (Badjeck, 2009). Africa, with its fragile geography, predominantly natural resource dependent livelihoods, and low level of adaptive capacity due to higher rate of poverty, is placed among the most vulnerable region to climate change (IPCC, 2014). Within the Africa region, fishers and fish farmers are poor and marginalized and have the least capacity to cope with climate-related disasters. Small-scale fisheries provide food for millions of people along tropical coastlines and hence play an important role in the food security of a large number of countries (Mcclanahan et al., 2015; Pauly and Charles, 2015).

This research conducts an in-depth analysis of the regional level vulnerabilities of fisheries and aquaculture to climate change impact by integrating quantitative analysis with qualitative information obtained from different sources.

Methodology

A comprehensive vulnerability assessment methodology (CVAM) approach was used in this study to assess relative exposure, sensitivity, and adaptive capacity of fishers and fish farmers. This methodology computes vulnerability indices by aggregating data for a set of indicators. An indicator represents a characteristic or a parameter of a system and it is an empirical, observable measure of a concept. Several common principles in the climate change vulnerability literature were considered when building our CVAM. One principle is that loss of habitat due to warming is a major determinant of fisheries and aquaculture vulnerability (Hollowed et al., 2013). A second principle is that poor regions of the world are often the most vulnerable to environmental change due to lack of capacities to adapt (Blasiac et al, 2017). Thirdly, areas that are already prone to natural disaster are likely to be more impacted by climate change and have less capacity to adapt their fisheries and aquaculture to climate change (Planque et al., 2010). Lastly, we assume that vulnerability cannot be characterized by only one or two socioeconomics, biological or habitat-based indicators.

Data

All data were collected from secondary sources. A priority for data selection was availability for a broad a range of countries in Africa as possible to allow comparisons across the continent. This, in turn limits the range, and hence resolution of data available for use. Extreme events, climate variables and population were represented at various higher resolutions, while the rest of the data (social, economic and political) were represented at the national level. We considered an indicator as "data-limited" if no data could be found to obtain scores for said indicator for more than 25% of our study countries. Indicators were given a level of importance between 0 and 2, where 2 was applied to the most important indicator with strong data, 1 was applied to indicator of medium importance or highly important data-limited indicator, and 0 was applied to the least important indicator or data-limited indicators of medium importance. This 0-2 method applied in this context allowed us to weight our indicators relative to each other to ensure the effect of each indicator on the outcome of the model reflected this relative importance. The number of indicators for each component was limited from 4 to 8 for simplicity and to focus on the most salient indicators for each component in the context of climate change.

Pre-selection of indicators

We carried out an indicator selection; to do this we conducted a principal component analysis to avoid bias in selection of indicators. These indicators were allocated into the components of exposure, sensitivity and adaptive capacity. Selected countries within the Africa region were given a score for each indicator by using the available data and weighting. Some factors related to these common principles are also present in other recently developed vulnerability assessment literatures (Blasiak et al., 2016 and Gaichas et al., 2014). Some indicators influence vulnerability more strongly than others for this reason, indicators were weighted by their importance as reported in the literature, as well as by data availability, so as to limit the impact of uncertainty on the outcomes of the model.

Results and Discussion

This study identifies regions of Africa whose fisheries and aquaculture are potentially the most vulnerable to future climate change impacts. Classification of indicators found that on average 30% of the indicators used in this methodology are socioeconomics, 29% to the Land/coastal and marine Ecosystem, 17% to the economics, 15% to the Fishing community, 6% to the natural environment and 3% were other indices. Although warming will be most prominent at high latitudes, the countries with economies most vulnerable to warming-related effects on fisheries are in the tropics. This is obviously because of the poor economic conditions of the people living in the tropics (Table 1). Low latitude fin fisheries, or small-scale fisheries, provide food for millions of people along tropical coastlines and hence play an important role in the food security of a large number of countries (Mcclanahan et al., 2015; Pauly and Charles, 2015). In many cases, populations are heavily dependent on fisheries as a source of protein given the lack of alternatives (Cinner et al., 2012, 2016; Pendleton et al., 2016). Our findings indicates that vulnerability is driven by poverty, many artisanal fishers and small scale fish farmers are extremely poor and even in cases where they earn more than other rural people, they are habitually, socially and politically marginalized and can afford only limited access to health care, education and other public services (Allison et al., 2009). Corruption, conflict, political and social marginalization leaves many small-scale and migrant fishers with slight capacity to adapt, and makes them highly vulnerable to climate change impacts affecting the natural capital they heavily depend on for their livelihoods. Two-thirds of the most vulnerable countries are in tropical Africa, where fisheries and aquaculture form the means of livelihood of the poor people and fishery and aquaculture production are closely dependent on climate variability. Our vulnerability index in Central, East, West, North and Southern Africa are 0.69, 0.72, 0.56, 0.53, and 0.52 respectively.

Table 1. Analysis of Vulnerability of Fisheries and Aquaculture to Climate Change Impact

Indicator	Component	No.	Coefficient	Standard error	P-value	r
Average Monthly Temperature (^{0}C)	Exposure	300	0.0885	0.0586	0.1697	0.24
CO_2 Emission/Capita	Exposure	300	0.0289	0.1016	0.7835	-0.04
Number of threatened species	Sensitivity	52	0.1180	0.0671	0.1168	0.16
Marine protected area (%)	Adaptive Capacity	52	-0.2050	0.0669	0.0155*	-0.39
Literacy rate (%)	Sensitivity	52	0.0006	0.0012	0.6601	-0.07
Poverty line (%)	Sensitivity	52	0.2891	0.0593	0.0012 **	0.57
Human development Index	Adaptive Capacity	52	-0.3329	0.1500	0.0458*	-0.22
Fish protein as percentage of animal protein	Sensitivity	52	0.1165	0.0435	0.0281 *	0.03

****, *, Indicating significance at 0.01% and 0.05% respectively, Note: r = correlation, No. = number of observation**

Previous findings indicate that climate related stresses affecting finfish are producing a number of challenges for small-scale fisheries based on these species (Bell et al., 2017; Kittinger, 2013; Pauly and Charles, 2015). The Coast of Sahelian and sub-Saharan Africa have large coastal populations that depend upon exploitation of rich marine surge fisheries and landings from which are largely driven by uncertain climate conditions. These climatic and hydrological fluctuations are revealed by changes in fishing activity and catches. Recent literatures has continued to outline growing threats from the rapid shifts in the biogeography of key species (Burrows et al., 2014; Poloczanska et al., 2013, 2016) and the ongoing rapid degradation of key habitats such as coral reefs, sea grass and mangroves. As these changes have accelerated, so have the risks to the food and livelihoods associated with small-scale fisheries (Cheung et al., 2010). These risks have compounded with non-climate stresses (e.g. pollution, overfishing, unsustainable coastal development) to drive many small-scale fisheries well below the sustainable harvesting levels required to keep these resources functioning as a source of food (Mcclanahan et al., 2015; Pendleton et al., 2016). Our results show the significance impact of fish protein intake in this assessment (Table 1). Regions that are highly dependent on fish protein have significantly higher vulnerability to climate change impact on fisheries. As a result, projections of climate change and the growth in human populations increasingly predict shortages of fish protein for many regions e.g. Pacific (Bell et al., 2017), Indian Ocean (McClanahan et al., 2015). Mitigation of these risks involves marine spatial planning and marine protected area, fisheries repair, sustainable aquaculture, and the development of alternative livelihoods (Kittinger, 2013; Mcclanahan et al., 2015; Song and Chuenpagdee, 2015; Weatherdon et al., 2016). The lower the marine protected area the more vulnerable the more vulnerable the region (Table 1).

Conclusion

The high vulnerability in each of five regions in Africa reflects different combinations of climate exposure, sensitivity and adaptive capacity. Understanding how these various components combine to influence vulnerability provides a useful starting point for directing future research and climate change adaptation and mitigation initiatives in Africa.

References

Allison, E.H, Perry, P.L, Badjeck, M-C, Adger, W.N, Brown K, Conway, D, Halls, A.S, Pilling M.P, Reynolds, J.D , Andrew, N.L, Dulvy, N.K (2009). Vulnerability of national economies to the impacts of climate change on fisheries. First published: 11 May 2009 https://doi.org/10.1111/j.1467 2979.2008.00310.x

Badjeck M.C, Allison E.H, Halls S.A, Dulvy N.K. Impacts of climate variability and change on fishery- based livelihoods. Marine Policy (2009), doi:10.1016/j.marpol.2009.08.007

Bell, J. D., Cisneros-Montemayor, A., Hanich, Q., Johnson, J. E., Lehodey, P., Moore, B. R., et al. (2017). Adaptations to maintain the contributions of small-scale fisheries to food security in the Pacific Islands. Marine Policy . doi:10.1016/j.marpol.2017.05.019.

Blasiak R, Spijkers J, Tokunaga K, Pittman J, Yagi N,OÈ sterblom H (2017) Climate change and marine fisheries: Least developed countries top global index of vulnerability. PLoS ONE 12(6): e0179632. https://doi.org/10.1371/journal.pone.0179632

Burrows, M. T., Schoeman, D. S., Richardson, A. J., Molinos, J. G., Hoffmann, A., Buckley, L. B., et al. (2014). Geographical limits to species-range shifts are suggested by climate velocity. Nature 507, 492– 495. doi:10.1038/nature12976.

Cheung, W. W. L., Watson, R., and Pauly, D. (2013). Signature of ocean warming in global fisheries catch. Nature 497, 365– 368. doi:10.1038/nature12156. García Molinos, J., Halpern, B. S.,

Cinner, J. E., McClanahan, T. R., Graham, N. A. J., Daw, T. M., Maina, J., Stead, S. M., et al. (2012). Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Global Environmental Change 22, 12– 20. doi:10.1016/j.gloenvcha.2011.09.018.

Hollowed, A. B., Barange, M., Beamish, R. J., Brander, K., Cochrane, K., Drinkwater, K., et al. (2013). Projected impacts of climate change on marine fish and fisheries. ICES Journal of Marine Science 70, 1023– 1037. doi:10.1093/icesjms/fst081.

IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts,Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

Kittinger, J. N. (2013). Human Dimensions of Small-Scale and Traditional Fisheries in the Asia-Pacific Region. Pacific Science 67, 315– 325. doi:10.2984/67.3.1.

Mcclanahan, T., Allison, E. H., and Cinner, J. E. (2015). Managing fisheries for human and food security. Fish and Fisheries 16, 78– 103. doi:10.1111/faf.12045.

Pauly, D., and Charles, A. (2015). Counting on small-scale fisheries. Science 347, 242– 243. doi:10.1126/science.347.6219.242-b.

Pendleton, L., Comte, A., Langdon, C., Ekstrom, J. A., Cooley, S. R., Suatoni, L., et al. (2016). Coral reefs and people in a high-CO2 world: Where can science make a difference to people? PLoS ONE 11, 1– 21. doi:10.1371/journal.pone.0164699.

Planque, B., and C. J. Fox, 1998: Interannual variability in temperature and the recruitment of Irish Sea cod. Mar. Ecol. Prog. Ser., 172, 101–105.

Poloczanska, E., Brown, C., and Sydeman, W. (2013). Global imprint of climate change on marine life. Nature Climate Change 3, 919– 925.

Schoeman, D. S., Brown, C. J., Kiessling, W., Moore, P. J., et al. (2015). Climate velocity and the future global redistribution of marine biodiversity. Nature Climate Change 6, 83–88. doi:10.1038/nclimate2769.

Song, A. M., and Chuenpagdee, R. (2015). Interactive Governance for Fisheries. Interactive Governance for Small-Scale Fisheries 5, 435– 456. doi:10.1007/978-3-319-17034-3.

Weatherdon, L. V., Magnan, A. K., Rogers, A. D., Sumaila, U. R., and Cheung, W. W. L. (2016). Observed and Projected Impacts of Climate Change on Marine Fisheries, Aquaculture, Coastal Tourism, and Human Health: An Update. Frontiers in Marine Science 3, 48. doi:10.3389/fmars.2016.00048.