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An Assessment of Vulnerability of Fisher's Livelihood to Climate Change in Coastal Odisha, India

SAMBIT PRIYADARSHI, S.N. OJHA* and ARPITA SHARMA

Fisheries Economics, Extension, and Statistics Division, ICAR-CIFE, Mumbai, Maharashtra, India.

Abstract

A study was conducted in Odisha, a state on the east coast of India, with the objective of assessing the vulnerability of fisher's livelihood to climate change. The state was chosen for study since it is considered as one of the most vulnerable states due to climate change. A total of 120 fishers were interviewed from two districts, Balasore and Ganjam, to assess their livelihood vulnerability by considering their exposure, sensitivity and adaptive capacity to climate change. A composite livelihood vulnerability index with minima 0, and maxima 1 was used for the purpose. The composite livelihood vulnerability index approach calculates vulnerability by aggregating data for a set of indicators for the components of vulnerability which include exposure, sensitivity, and adaptive capacity. The aggregated vulnerability score was found to be 0.54 ± 0.04, suggesting that fishers are vulnerable to climate change. For fishers of Balasore the score was 0.56 ± 0.03 and for Ganjam it was 0.5 ± 0.04. Vulnerability score was relatively higher in Baleswar due to higher scores on the exposure and sensitivity parameters overshadowing the higher adaptive capacity. The study shows evidence that marine fishers of Odisha are vulnerable to climate change. Also, it throws light on the location and context specificity of livelihood vulnerability.

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Sensitivity;
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Introduction

Experts opine climate change adversely impacts multiple sectors challenging the livelihood and food security of high natural resource-dependent communities, especially fishing communities and fishery-based livelihoods.[1] Marine fishery is susceptible to a wide range of climate change implications, which range from ecological impacts, like loss of coastal wetlands, coral bleaching, increased acidification of oceanic water, changes in freshwater inflow,[2] to human side impacts, such as increased risk of sea level rise, increased extreme

CONTACT S.N. Ojha snojha@cife.edu.in ICAR-Central Institute of Fisheries Education, Panch Marg, Andheri(W), Mumbai-400061, Maharashtra, India.

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weather events on fishing communities that ocupy low-lying coastal areas.[3] The emerging effects of climate change pose serious risks to coastal ecosystems and fishing communities along with other persistent challenges influencing small-scale fisheries, especially in low-lying areas.[4] Additionaly, extreme weather events disrupt fishing operations and land-based infrastructure, while fluctuations in fisheries production and other natural resources can have an impact on livelihood strategies and outcomes of the fishing communities.[5]

The existing vulnerability profile of India is expected to change due to climate change.[6] Floods and droughts, monsoon depressions and cyclones, heat waves, cold waves, prolonged fog, snowfall, and sea level rise are some of the important climatic events affecting India.[7] The average Sea Surface Temperature (SST) in the Indian sea is predicted to increase by 2 to 3.5 ^{o}C by 2099.[8] In the last century, the frequency of occurrence of cyclonic storms showed an increasing trend over the years in the country.[17] Also, there is an increase in the number of severe cyclonic storms crossing the Indian Coast.[17]

Fisheries have emerged as a key sector of the Indian economy, which is evident from the over-increasing domestic and international demand for fish and fishery products has not only enhanced foreign exchange earnings but also created many employment opportunities in the primary, secondary, and tertiary sectors.[9] People depend on fisheries on full-time or part-time basis to earn their livelihood.[10] However, extreme weather events disrupt fishing operations and cause damage to land-based infrastructure. Moreover, fluctuations in fisheries production and other natural resources exert a negative impact on livelihood strategies and outcomes of the fishing communities.[11]

The vulnerability is defined as “the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes”.[12] The vulnerability is a function of the character, magnitude and rate of climate change to which a system is exposed, its sensitivity, and its adaptive capacity.[12] Exposure is “the nature and degree to which a system is exposed to significant climatic variations”.[13] Sensitivity is “the degree to which a system is affected, either adversely or beneficially, by climate variability or change”.[12] Adaptive capacity is “the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damage, to take advantage of opportunities, or to cope with the consequences”.[13]

The present study was conducted in the state of Odisha, India, aiming to assess the vulnerability of marine fishers' livelihood to climate change. Odisha is a maritime state on the east coast of India. Historically, it has been a state prone to natural calamities, especially coastal districts.[14]

Materials and Methods

Data for the selected variables for measuring the sensitivity and the adaptive capacity components of vulnerabilty were collected from two villages each, from Balasore and Ganjam district. The state has a coastline of 480 km length and continental shelf area of 24,000 Km^2. As per Central Marine Fisheries Research Institute (CMFRI) census (2010)15,out of total 3,288 numbers of marine fisher villages in India, 813 of them (24.7%) are in Odisha with the total marine fisher population of 605,514.

The multi-stage sampling method was employed in the study to collect data. Multistage sampling involves two or more stages of random sampling based on the hierarchical structure of natural clusters within the population.[16] In the study, the ‘stage unit' nomenclature has been used to represent the clusters at different hierarchical levels. There are six coastal districts in Odisha, out of which two districts were selected. All the six coastal districts were considered as the first stage units, In the first stage, from all the six coastal districts of Odisha, Balasore and Ganjam districts were selected based on the number of landing centers in it. The fishing villages with fishlanding centers (FLC) as second stage units, two fishing villages with FLCs from each of the two districts were selected. The fishing villages selected from Ganjam were Golabandha and Sana Arjipalli, and from Balasore, Bahabalapur and Balaramgadi. The rationality behind the selection of villages with FLC was the importance of landing centers, which act as a focal point for various stakeholders involved in marine fisheries. The fisher households in each fishing villages as third stage units, Subsequently, Thirty fisher households from each fishing villages were selected randomly, which made the total number of households studied to 120. The rationale behind taking thirty households from all the coastal villages is to make them statistically comparable.

Selection of Indicators

The incidence of cyclones and the extent of coastal erosion were selected as the indicators for exposure to climate change. The number of cyclonic disturbances in Odisha during the last century (1900-2000) was 260, the highest among all states in the country.[17] The National Centre for Sustainable Coastal Management (NCSCM) report from 2011, suggests that the coastal line of Odisha is exposed to coastal erosion and the extent of erosion is spatially differentiated along the state.[18] On the basis of the above findings, data from secondary sources were collected for the variables of exposure. Information regarding the cyclonic disturbances in the study area was collected from the 2014 report of the *National Cyclone Risk Mitigation Project (NCRMP)*.[17] Information on coastal zone erosion was collected from the Shoreline change assessment report of the NCSCM.[18]

Employment (from fisheries in days per year), income (from fisheries-related activities during the year 2017 in USD), and per capita consumption of fishes per month were selected as indicators for sensitivity. The study assumed the households with a higher dependence on fisheries for income, nutrition, and employments are more sensitive to climate change.[3] As income can be a part of both sensitivity and adaptive capacity, to avoid using the same indicator for both, only the income from fisheries is included as an indicator of sensitivity. Data for all these variables were collected through the household survey. Adaptive capacity of fisher households was determined using the Sustainable Livelihood Approach (SLA framework). Livelihood assets, as explained in the SLA framework, of fishers were used as indicators of adaptive capacity. Human capital is the skills, knowledge, the ability to labor, and good health and physical capability important for the successful pursuit of different livelihood strategies.[19] For the assessment of human capital, in their work we selected experience in fisheries, presence of non - elderly household (< 50), and adult workforce, as used by Sesabo and Tol (2005).[20] Further, educational level of the household was also selected as a variable of human capital.[3]

For determining the status of the financial capital of the household, income from sources other than fisheries (in USD), and the number of income-generating activities of the household were selected as variables. Livelihood diversification was an important adaptation measure to climate change.[21] Physical assets are capital that is created by the economic production process. It refers to the basic infrastructure and producer goods needed to support livelihood.[22] The number of working fishing assets possessed by fishers, quality of the house, and types of fishing crafts were selected as variables to assess the physical capital of the household. Possession of agricultural land and possession of trees giving some financial return are taken as parameters to assess the natural capital of the household. An aggregated index was made for natural capital, whose value ranged from 0 to 2.

Aggregated social capital was measured through selected variables for the purpose. Selected variables were participation in community festival, presence of relatives/friends in the village and outside the village, help from relatives/friends present in/outside the village during adverse climatic condition, membership of cooperatives/Self Help Group, help from these membership during adverse climate, membership of political parties, help from political parties, and possession of identity cards (For enabling social security schemes). Access to livelihood support system was assessed by inquiring about their access to cyclone shelters, source of safe drinking water, sanitation, fish trading facility, bank, cooperative society, panchayat office, fisheries office, educational institution, Non Governmental Organisations (NGO), local political leaders, electricity, loan/Credit, hospital, court, fish processing plant, local community leaders, road transportation, railway station, police station, and research organization.

Mann-Whitney Utest was used to compare vulnerability indices of households of two districts and Kruskal-Wallis H test was used to compare the vulnerability status of fishing villages.

Livelihood Vulnerability Index

In the present study, the status of the vulnerability of fisher's livelihood was assessed by employing a composite Livelihood Vulnerability Index. The Livelihood Vulnerability Index (LVI) uses the IPCC (Intergovernmental Panel on Climate change) framework of vulnerability.[23] Vulnerability, as explained by IPCC, has three subcomponents i.e. exposure, sensitivity, and adaptive capacity. The composite livelihood vulnerability index approach calculates vulnerability by aggregating data for a set of indicators

In the present study, all the selected variables of the exposure, sensitivity and adaptive capacity components of vulnerability, were equally weighted to calculate the overall index. The advantage of unweighted indicators is that it can be scaled up more confidently.[24] At the same time, it is criticized at the point that all the components of vulnerability may not equally affect a community. As each indicatorwas measured on different scales, so it was normalized to an index with a value ranging from 0 to1. The Min-Max method was employed for normalising[25]:

$$Index_{SI} = (S_V - S_{min}) / (S_{max} - S_{min})$$

$Index_{si}$ is the normalized value of a particular indicator for a particular household. S_V is the actual value of the indicator of that household, S_{max} is the maximum observed value of that indicator in the data set, and S_{min} is the minimum value observed for that indicator in the data set. After normalizing each value of the indicators under the exposure, sensitivity, and adaptive capacity components of vulnerability, the index values of the components are calculated by using the following formula:

$$SC_{VJ} = \sum^{n}_{i=0} index_{svi} / n$$

Where SC_{VJ} is the sub-index value of the component *J* for household *V*; $index_{svi}$ represents the value of indicators indexed byi, for the component *J*, and n is the number of indicators in each component. Further, index values of subcomponents are combined to find vulnerability by using the additive approach,[3] and were used to calculate the final vulnerability index of the household. Vulnerability indices of all households were averaged to get the vulnerability index of a particular fishing village. Subsequently, vulnerability indices of villages were averaged to get the index for a particular district.

$$V_{HH} = \{E + S + (1\text{-}AC)\} / 3 \text{ (Additive Approach)}$$

Where E = Exposure, S = Sensitivity and AC = Adaptive capacity

Table 1: Incidence of cyclonic events and coastal erosion in theBalasore and Ganjam districts of Odisha, India

Cyclonic disturbances	Balasore	Ganjam	Source
Depression	66	22	
Storm	23	6	
Severe storm	8	6	
Total	97	34	NCRMP, 2014
Coastal erosion (%)	26.82	32.39	Shore line change assessment report, NCSCM

Table 2: Index values of all the components of Composite Livelihood Vulnerability Index

Variables	Balasore	Ganjam	Overall
Cyclonic disturbances	0.97	0.34	0.65
Coastal erosion	0.51	0.61	0.56
Exposure**	**0.74**	**0.47**	**0.6**
Income from fisheries	0.24	0.1	0.17
Consumption	0.37	0.52	0.44
Employment	0.69	0.68	0.68
Sensitivity**	**0.43**	**0.43**	**0.43**
Human Capital	0.49	0.44	0.46
Physical Capital	0.41	0.28	0.34
Financial Capital	0.16	0.09	0.12
Natural Capital	0.3	0.02	0.16
Social Capital	0.77	0.69	0.73
Access to livelihood support system	0.9	0.87	0.88
Adaptive Capacity**	**0.47**	**0.37**	**0.42**
Vulnerability**	**0.56**	**0.51**	**0.54**

** Significant at 1% level of significance based on Kruskal Wallis test

Results and Discussion

Exposure

The overall exposure level (average) of the studied fisher households remained at 0.505 + 0.283. The exposure sub-index for Balasore (0.79) was higher as compared to Ganjam (0.22). Among all the coastal districts of Odisha, the highest incidence of cyclones was in Balasore. Not only the cyclones but also the number of incidence of depressions, storms and severe storms were also higher in Balasore, compared to Ganjam during the last century (1900 - 2000). However, the coastal erosion is lower for Balasore compared to all the coastal districts of Odisha. This is due to the presence of dense mangrove vegetation and the riprap structure, which is protecting the coastline along the district of Balasore from erosion.[18]

Sensitivity

The overall sensitivity of Balasore, 0.431, is slightly lower than the Ganjam,0.434. This difference is mainly due to the higher consumption of marine fishes by the fisher households of Ganjam (3.91 kg / month) as compared to Balasore (2.77 kg / month). During the study, it is also found that members of the Fisher family consume fishes of lower quality (both in terms of taste and nutritional value). It is in correspondence with the lower income of fishers of Ganjam, which make them to sell high valued and nutritionally rich fishes and to consume fishes that remain unsold. It erodes the health status of the fishers and subsequently makes them less capable of adapting to climate change. However, the higher sensitivity of Ganjam overshadows the fact that the income from fisheries and employment from fisheries were more in Balasore as compared to Ganjam. The mean income from fisheries of the households of Balasore ($3006.14 USD) was more than the Ganjam ($1317.79 USD). In Balasore, almost 253 days were invested by a fisher household in fisheries, whereas the number was 247 days for Ganjam. It shows the higher dependence of fisher households of Balasore on fisheries for employment, which in turn make them more sensitive to climate change. In this context, livelihood diversification can be an effective tool. Linking fishing households to new occupational sectors can effectively reduce employment dependency of fishers.[26]

Table 3: Results of Mann-Whitney test between Livelihood Vulnerability Index (LVI) for Balasore and Ganjam

Districts	N	Mean rank	U	z	P
Balasore	60	90.37	8	- 9.406	< 0.001
Ganjam	60	30.63			

Adaptive Capacity

Human capital is the most important component of adaptive capacity, which facilitates the access of the household to other livelihood assets.[27] The experience of households in fishing and allied activities was higher in Ganjam as compared to Balasore. Higher experience helped fishers to better adapt to climate change by learning from the experience. Educational level of fishers at Balasore (4.71 ± 0.31 years) was higher, helping them to better adapt to the climate change as compared fishers of Ganjam (1.88 ± 0.23 years) district. The overall average of educational level of fishers household was found to be (3.29 ± 2.58) years. The higher educational level opens up avenues for income. In contrast, limited education can constrain their ability to understand weather warning information, rendering them to be more vulnerable. Lower educational level and experience make fishers more vulnerable to climate change.[28] Further, the average adult workforce per household was higher in Balasore (2.93) than the Ganjam with (2.53). Adult work force implies the number of adult members in the family, who are earning and contributing for the maintenance of the family.

The overall natural capital of fisher households of Balasore was higherthan Ganjam, which was possible due to the higher possession of agricultural land and possession of trees, which gave them some financial return. The geographical location of the fishing villages of Ganjam, located mostly in the sandy beach area, makes the village inappropriate for agriculture. Fisher households of Balasore possessed more fishing assets (1.07 ± 1.21) compared to Ganjam (0.52 ± 0.91), which enable fishers to get more catch or to process the catch. However, the higher standard deviation in both the cases reveals the inequality in possession of fishing assets among fishers. For both districts, more than half households possess houses of good

(Pucca / Semi-pucca) quality. A lower proportion of households in both the districts live in kuccha houses.

In Ganjam, almost 75 % of the studied households do not possess craft. Fishers here used borrowed boats for their fishing activities. Further, the catch of the boat trip is shared between boat owners and fishers. In Balasore, fishers with no boat work in trawlers as fish workers or involved in allied fisheries activities, such as net mending, icing, etc. Information on the possession of mechanized crafts in both districts was found to be concomitant with the CMFRI-Marine Fisheries Census (2010),[12] showing a higher number of mechanized craft operating along the Balasore's coast than the Ganjam's.

Income from other sources than fisheries was higher in Balasore as compared to Ganjam. The income generated by other activities was also higher in Balasore as compared to fisher households of Ganjam. The higher financial capital of fishers of Balasore makes them to better adapt to the impact of climate change, as the financial capital provides greater access to other livelihood assets and play a key role in adaptation.[29]

Social capital enhances the capacity of the individual to deal with the negative impact of climate change effectively.[30] Fisher households of Balasore possess higher social capital, compared to Ganjam. Higher social capital supported by higher connectedness help people by enhancing their adaptive capacity. Further, an assessment of fisher households' access to livelihood support system revealed that the access of fishers of Balasore to livelihood support system is higher to the fisher households of Ganjam.

Vulnerability

Vulnerability of fisher households of Balasore district (0.57 ± 0.03) was higher ($Z = -9.406$; $p = < 0.01$) than the fisher households of Ganjam district (0.51 ± 0.03). A higher vulnerability of fisher households of Balasore district was due to the higher exposure of the Balasore district to the impact of climate change. However, there was a little difference in the sensitivity sub-index between Balasore and Ganjam. Though the adaptive capacity of the fishers of Balasore was higher compared to Ganjam, because of their higher index scores in livelihood capitals, yet it had a little mitigative impact on the overall vulnerability index score of Balasore. It is also evident from the study that, a higher level of exposure and sensitivity requires a higher adaptive capacity to reduce the vulnerability.

Conclusion

From the study, we conclude that adaptation and mitigation measures in regard to climate change should not be generic in nature. Rather, they should be location-specific and considering exposure, sensitivity, and adaptive capacity of the target population of the area in consideration. On a similar line, in marine fisheries is recommended to have location-specific climate change management plans for lowering the vulnerability of fishers to the climate change.

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