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Quantifying climate change induced threats to wetland fisheries: a stakeholder-driven approach

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Abstract Wetlands are biologically sensitive habitats and envisaged as the most impacted systems by climate change. Floodplain wetlands of West Bengal, India, are important fisheries resources and provide tremendous economic and ecological services. There is lack of long-term quantified data to assess the impacts of climate change on floodplain wetlands fisheries in India. The article presents a stakeholder-driven approach to quantify the impacts of climate change on wetland fisheries. A modified Delphi method has been used to accomplish this. The present article discusses the modified methodology and the results obtained thereof. The study identified around seven potential climate change-induced threats on wetland fisheries among which water stress (95% consensus), wetland accretion/sedimentation (85%), aquatic weed proliferation (70%) and loss of wetland connectivity (65%) are high-priority issues demanding immediate management action. These issues are expected to further aggravate in future climatic scenario.

Keywords Perception · Climate change · Floodplain wetlands · Fisheries · Delphi method

1 Introduction

Climate change is one of the leading challenges for sustaining agriculture, fisheries and livelihood of people, especially the farmers who have to continuously respond to climatic variations (Dhanya and Ramachandran 2015; Uddin et al. 2014). Fifth assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) indicated that direct impact and indirect impact of climate change poses several threats to water resources, agriculture, coastal areas and resource-dependent livelihoods, especially in Asian countries (IPCC 2014). Climate change, i.e., changing thermal regime, precipitation pattern and

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frequency of extreme weather events, has both direct and indirect effects on fisheries and aquaculture, associated with loss of existing livelihood in many cases, if not all (Badjeck et al. 2010; Handisyde et al. 2014).

The fisheries and aquaculture sector worldwide employ 43.5 million people directly and 200 million people indirectly (Cochrane et al. 2009). Fisheries activities in wetlands are also an important contributor to this sector, particularly in Southeast Asia. India has a wealth of floodplain wetland ecosystems that support diverse and unique habitats and are spread across 5.54 lakh ha area (Sugunan et al. 2000; Pathak et al. 2014). Wetland fisheries in India comprise of capture fishery (natural stock) and culture-based fisheries. Culture-based fisheries practiced in these floodplain wetlands play an important role in providing livelihood security. A total of 85 fish species belonging to 33 families have been recorded from floodplain wetlands in India. These wetlands are reported to have a potential fisheries yield of 1000–1500 kg/ha/year, if managed scientifically. In particular, the state of West Bengal in India is bestowed with 42081.65 ha of floodplain wetlands of which 51.21% is presently under culture-based fisheries (DoF West Bengal 2016). Studies encompassing climate change-driven modifications in wetland eco-geomorphology (IPCC 2014; Ramsar Convention Secretariat 2013), ecosystem or human vulnerabilities to extreme climatic events (Adger 2006; Hossain 2015) and stakeholder-level adaptations (Dhanya and Ramachandran 2015; Uddin et al. 2014; Hossain et al. 2016) have been prime areas of interest in climate research. Floodplain wetlands, which provide recruitment and nursery grounds for many indigenous fish species, are considered as biologically sensitive habitats, to be most impacted by climate change (Ramsar Convention Secretariat 2013). Climate change is known to threaten the sustainability of the wetland fisheries, the livelihood of financially poor and illiterate fisher folks in developing countries like Bangladesh (Mamun 2007). In plenty of studies, it is mentioned that climate change will most likely impact the fisheries in wetlands (CIFRI 2000; Dudley et al. 2010; Lukasiewicz et al. 2012; Mamun 2007; Pittock and Finlayson 2011; Ramsar Convention Secretariat 2013; Sharma et al. 2015; Thorp et al. 2006; Tonn 1990).

Quantification of climate change-induced threats is essential for the formulation of prudent adaptation and/or mitigation strategies. In developed nations, studies on this aspect are abundant and seem to be quite elaborate due to their long-term data availability from multiple databases (Adeleke et al. 2012; Allison et al. 2005; Allison et al. 2007; Badjeck et al. 2010; Kam and Badjeck 2012; Leiserowitz 2006; Pramova et al. 2013; Roderick 2012; Wandji et al. 2012; Weber 2006; Weber 2010). The developing and under-developed countries, on the contrary, are often plagued with the problems of data deficiency, lack of standard resource-specific research tools and constraints in implementation of models to the local scale. Quantifying the impact of climate change essentially requires future climate scenario that is generally generated by using global circulation models (GCM), but the projected scenario(s) is mostly available in coarse spatial scale. In such a situation, downscaling of the GCM output becomes necessary to project future scenario in a finer spatial scale which often fails due to misspecification of underlying assumptions (Hessami et al. 2008). Moreover, exact replication of the aforementioned quantitative assessment frameworks to the local or subregional scale that too for a specific natural resource like wetland fisheries is extremely difficult to implement (Das et al. 2016) due to the absence of long-term time series data in local scale.

Alternatively, in climate change adaptation, planning and policy processes the farmers' perception(s) have gained importance over the years. Makate et al. (2017) had recommended that the adaptation to changing climate should be a social process (rather than a strictly legislative arrangement) which should involve all the stakeholders and also emphasized on the need for equal consideration of farmer perceptions on climate resilience policies. In India, there is a lack of 'effective communication' between policymakers and fisher folk regarding the threat perceptions on climate change which is evident from the lack of interventions made so far to devise resource-specific, farmer-friendly and climate change resilient fisheries/aquaculture strategies (Das et al. 2016; Saha et al. 2015). This situation has led the fish farmers to perceive and adapt to climate change threats on their own (Saha et al. 2015). Therefore, it is worthwhile to develop stakeholder-driven research framework(s) to assess the impact of climate change on wetland fisheries for developing countries like India. Review of literature revealed that there are very few studies on fish farmers' perception on climate change impact in India, mostly of recent origin. Most of the studies conducted so far on stakeholders' perceptions of climate change impacts on fisheries and aquaculture in India are broad, reflect an overall scenario and largely focus on the weather events associated with climate change (Kumaran et al. 2012; Ponnusamy and Swatilakshmi 2012; Saha et al. 2015; Udayasekhar et al. 2012). Fishermen communities who are directly dependent on wetlands perceive the climate change as a threat. This threat perception may build their attitude toward the future, in regard to the viability of wetland fisheries under changing climate. Fishermen perceptions on climate change-related threats to wetland fisheries are based on their practical observations, indigenous knowledge and experiences that may raise certain points, which could serve as core area(s) for future climate change research. Moreover, these perceptions may form an important basis for policymakers in formulating farmer-friendly, climate change resilient policies for managing or ameliorating threats to natural resources like wetlands. The perceived threats and the attitude toward future are important for planning agencies in order to achieve the developmental goals on sustainable wetland fisheries in a changing climatic scenario.

Therefore, in the absence of long-term time series data, a stakeholders' perception-based approach was proposed to quantify the perceived threat of the fishermen community and their attitude toward the future in regard to the wetland fisheries. Accordingly, a sincere effort was made to develop a methodology for ascertaining stakeholders' perceptions with an objective of enlisting, quantifying and prioritizing various threats on the wetland fishery due to climate change.

2 Materials and methods

2.1 Study area

The study area includes four freshwater floodplain wetlands of West Bengal, India, namely Akaipur *beel* (23°5′8.36″N, 88°43′3.80″E), Bhomra *beel* (22°59′14.59″N, 88°37′40.33″E), East Kolkata wetland (22°32′57.53″N, 88°27′5.25″E) and Garapota *baor* (23°8′52.45″N, 88°48′39.81″E) (Table 1).

Four wetlands (Garapota wetland > Akaipur wetland > Bhomra wetland > East Kolkata Wetland) spanning a total linear distance of 125 km and covering three districts (Nadia, North 24 Parganas and Kolkata) of the state West Bengal, India, were strategically selected to obtain perception on climate change threats to wetland fisheries from stakeholders' perspective. The selected study area being part of the floodplain system of lower reaches of the Ganga River basin comprises a large number of small- to medium-sized wetlands covering more than 40% of the total wetland area of the state (CIFRI 2000). Four of the largest wetlands in the area with organized fisheries management regimes (fisheries

Table 1 Details of wetlands studied

S. No.	Name of wetland	Geomorphology	District	Coordinates	Area (approx.) (ha)	Land use pattern
1.	Akaipur *beel*	Closed, ox-bow	North 24 Parganas	23° 5′8.36″N 88°43′3.80″E	32	Agriculture
2.	Bhomra *beel*	Semi-closed, ox-bow	Nadia	22°59′14.59″N 88°37′40.33″E	83	Agriculture
3.	East Kolkata wetland	Open, sewage-fed low land	Kolkata	22°32′57.53″N 88°27′5.25″E	40	Urban establishment
4.	Garapota *baor*	Open, ox-bow	North 24 Parganas	23°8′52.45″N 88°48′39.81″E	122	Agriculture

cooperatives) were purposively selected to serve as representatives of the concentrated numbers of wetlands in the region. The present study has emphasized on the stakeholder-driven approach because a huge number of people depend on these wetlands for agriculture and fisheries or both.

2.2 Stakeholder-driven approach

Stakeholder-driven approach is often used in the climate change research, particularly for vulnerability assessment (McCormick 2016), which is normally applied when quantitative data are poor. This approach elicits the involvement of stakeholders in agreeing upon the main issues, importance and impact of climate change (Malone and Engle 2011). The idea here is to utilize the opinion of stakeholders as alternative sources of information for assessing threats of climate change to wetland fisheries. For the purpose of promoting stakeholder-driven approach, the present study considered fishermen, cooperative managers and fish traders with vast experience and practical knowledge as the sole participants for climate change threat perception extraction. The rationale of this strategy is in line with a recently published study (Diogo et al. 2017) where the authors recommended that fishers' experience and acquired traditional knowledge can be effectively used in the field of fisheries research for evaluating various biological and ecological impacts.

One of the widely used stakeholder-driven approaches is the Delphi method (Dalkey and Helmer 1963; Linstone and Turoff 1975). The methodology applied in the present study is based on the original Delphi, which is a systematic combination of individual judgment/opinion for forecasting or finding reasonable solution(s). Mukherjee et al. (2015) provided excellent guidelines for application of Delphi technique in the contexts of ecology and biological conservation. In line with Mukherjee et al. (2015), the implementation of Delphi method in the present study involved four steps: (i) selection of participants, (ii) interview process, (iii) interpretation and (iv) discussion (graphically represented in Fig. 1). The purpose of the present study was to uphold the stakeholders' perceptions on climate change threats on wetland fisheries and to quantify these perceptible threats employing modified Delphi method as discussed below.

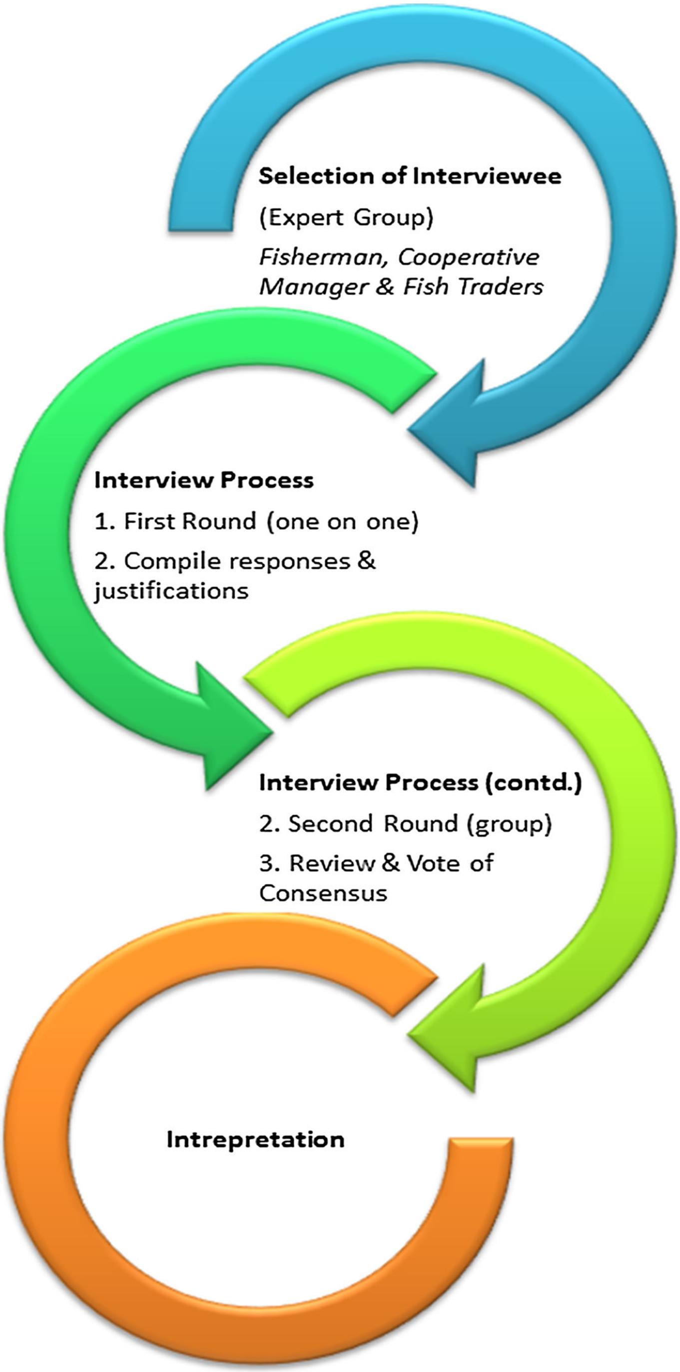

Fig. 1 Schematic diagram of the proposed methodology

2.2.1 Selection of participant

Unlike in the original Delphi method where the academic qualifications and career achievements of an individual are considered for selecting participants, in our study experience was the sole criteria for selecting the participants due to their poor or non-existent academic backgrounds. Traditional stakeholders (fishermen, cooperative managers and fish traders) who have been directly involved with fisheries activities in their respective wetlands for more than 10 years and have seen their previous generation being involved in the same profession were selected as the participants. A total of 20 participants in each wetland were selected which included cooperative manager (1), associated fishermen (7) and local fish traders (12). Details of participants considered for the study are given in Table 2.

Finally, the data were collected from a total of 80 participants from 4 floodplain wetlands of West Bengal, over 10 months of repeated and multi-round surveys (April 2015–January 2016) discussed below. The number of participants in Delphi method does not require statistically representative sample (Powell 2003), and the same may range from 2 to 184 (Mukherjee et al. 2015). In the present study, the selected number of participants is well within the recommended range.

2.2.2 Strategy for eliciting response

In order to bypass some limitations and field-level constraints faced during working with the aforementioned participant groups, implementation strategy of the original Delphi method (Dalkey and Helmer 1963) has been slightly modified to quantify the threat perception of the participants and their attitude toward future. Traditionally, the Delphi method seeks to achieve a consensus among group members through a series of questionnaires. The series of questionnaires are sent by either mail or electronic media, to a pre-selected group of participants. The answers received are summarized and sent back to the group members along with the next questionnaire for arriving at a consensus. However, this approach is not suitable when dealing with fishermen or fisheries stakeholders in wetlands due to their illiteracy and ordinary communication skills. Therefore, modifications in the original method were made to serve the purpose of this research. Instead of mailing the questionnaires on paper and receiving the written replies in return, personal interviews were conducted face to face with the same set of questions, which were asked by the interviewer in different ways depending upon the individual attitude and behavior of the participants.

Table 2 Details of participants considered for perception-based study

S. No.	Group	Criteria for selection	Number of participants in each wetland
1.	Fisherman	Engaged in the fishing activity for at least 15 years or above	12
2.	Cooperative manager	Managed/have been managing a cooperative for at least 10 years or above	1
3.	Fish marketer	Involved in fish marketing for at least 10 years or above	7

Anonymity of participants and their responses in the initial rounds of the survey were strictly maintained followed by a group discussion to avoid the power of persuasion of prestigious individuals in shaping a group opinion, vulnerabilities of group dynamics to manipulation and prevention of the bandwagon effect of a majority opinion. Additionally, in order to avoid the difficulty in maintaining participant enthusiasm throughout process as in the original Delphi method, repeated multi-round surveys were conducted keeping gaps of a month or more between subsequent rounds. This resulted in 'memory reboot' of the participants, refreshed participatory enthusiasm, helped obtaining filtered responses that were persistent in their head and also excluded the responses that were vague or tempted. The above-mentioned modifications on the original method were adapted to suit field conditions after thorough consultation of the process of the Delphi technique, its variants, use in threat perception research, strengths, limitations, comparison with other methods and possibility of refinements scientifically outlined in Mukherjee et al. (2015).

2.2.3 Climate data analysis

Climatic data (mean air temperature and total annual rainfall) of the studied districts (North 24 Parganas, Nadia and Kolkata) were collected from Indian Meteorological Department (IMD) for the last three and half decades (1980–2015). In order to provide an overall picture of the climate change trend over the region where the selected wetlands exist, the climate dataset for individual districts was merged keeping in view the nearness of the districts to each other. The analyses were based on the annual mean air temperature and total annual rainfall representing climatic variables in the dataset. The climatic trend obtained was cross-checked with the perception of fisher folk interviewed to assess their level of awareness on changing climate.

3 Results and discussion

Systematic interview process was followed after selection of the participants.

3.1 Interview process

The interview strategy consisted of two rounds as summarized below.

3.1.1 First round

Fifty percent of most knowledgeable ['knowledgeable' implies practical experience and acquired traditional or indigenous knowledge, see Diogo et al. (2017)] participants of each wetland were identified in the first round, which is crucial for framing of issues on climatic threats. Participants were interviewed in person. The interviewer made sure that no other individual except the concerned participant was present during the interview. The interview was strictly confidential, was interrogative in nature and focused around some predecided points of interest. No information was provided to the participant regarding the purpose of the interview and possibility of occurrence of a second follow-up round. Moreover, the identity of the participant was kept anonymous.

After the interview, the interviewer compiled the responses and justifications obtained from the participants into an anonymous report. The identified issues were tabulated for the ease of discussion in the second round.

3.1.2 Second round

Second round was conducted after 1 or 2 month(s) of the first round. All the participants, excluding those who participated in the first round, were included in this round. A heterogeneous group comprising individuals from all the participant groups was gathered for the purpose of discussions. The interviewer gradually revealed the anonymous report issue by issue. Each issue was reviewed by the group members with the objective of arriving at a consensus.

The issues identified from the first round were subjected to testing (corrections, additions or deletions) in this round. It was made sure that in no way whatsoever the identities of the first round participants were revealed at any stage. At the end, the degree of consensus against each identified issue was calculated through voting.

3.2 Interpretation

The combined results of first and second round are presented in Table 4. As perceived by the stakeholders, a total of seven threats, namely (a) water stress, (b) wetland accretion/sedimentation, (c) aquatic weed proliferation, (d) loss of wetland connectivity, (e) periodic recruitment failure of small indigenous fishes (SIF), (f) epizootic ulcerative syndrome and other ulcer-like fish diseases and (g) enhanced toxicity of fishes to agricultural pesticide run-offs, were identified in the first round. Possible climate-related influencing factors on these issues were also identified in the first round. Subsequently, final selection of influencing factors was made by the consensus of stakeholders in the second round (Table 4). Degree of consensus (Table 4) on individual issue was expressed in terms of percent of stakeholders in favor of the identified issues in the first round. The level of confidence on a particular issue (response and justification) was assigned depending on the degree of consensus achieved. The inception of this particular classification scheme was adapted from IPCC (2014). Inference on the issue was drawn from the level of confidence (Table 3).

Table 3 Criteria for interpretation

S. No.	Degree of Consensus (%)	Level of Confidence	Impact prediction	Priority scale (for management)
1.	Above 90	Very high	Most certain	High-priority issue
2.	81–90	High	Certain	
3.	71–80	Medium	Most likely	Medium-priority issue
4.	61–70	Medium	Likely	
5.	40–60	Low	Biased	Low-priority issue
6.	Below 40	Very low	Not under consideration	Zero-priority issue

Threat-wise, water stress and wetland accretion/sedimentation registered very high level of confidence to the tune of 95 and 85%, respectively, as perceived by the stakeholders. According to the IPCC (2014) impact classification scheme, these two threats will have the 'most certain impact' on wetland fisheries. Similarly, aquatic weed proliferation and loss of wetland connectivity were perceived as 'likely impact' owing to medium level of confidence (Table 4). The remaining three issues fell within 'low' to 'very low' confidence category (Table 4). Among the seven issues identified, two were assigned as 'high-priority issues' for management, two as 'medium-priority' and the rest as either 'low-priority' issues or 'not given any consideration' for management (Table 4). The problems like water stress, wetland accretion/sedimentation, aquatic weed proliferation and loss of wetland connectivity in floodplain need to be tackled immediately 'on priority', as threat perception levels associated with these issues indicate they will impede the sustainability of wetland fisheries in the long run under a continuously changing climate. Stakeholders also possess low adaptive capacities to tackle these issues as they are already giving up on these issues due to underlying climate change influence, which seems inevitable to them. Stakeholders perceived that these issues will further exaggerate in the future climate scenario.

For validation of the results, at least partly, we provided evidences through survey of published literature from secondary sources ($n = 35$). It revealed several scientific evidences in conformity with the threats perceived by the stakeholders in the present study. Table 5 shows the meta-analysis of the literature reviewed after completion of field survey. Majority (18) of the literature was related to freshwater wetlands, while rest (13) either intended to discuss wetlands in general (irrespective of subtypes) or aquatic ecosystems as a whole; only a few (4) was reported exclusively for saltwater wetlands. Although our post-survey literature review was not exhaustive in nature, we observed some general trends of the identified issues. Among all the threats identified by the stakeholders, the literature related to the first three issues (water stress, wetland accretion and aquatic weed proliferation; Table 4) was fairly abundant, while for the rest, published literature was scanty. Studies on the issue of 'aquatic weed proliferation' in relation to climate change were relatively more abundant than the rest of the issues. Another interesting observation was regarding 'wetland accretion–climate change' relationship, which appears to have been studied more exclusively in coastal tidal wetlands (saltwater). The review yielded a generalized picture of similar or relevant reports, concerns, suggestions or hypotheses identified by other authors, preferably for or from wetland ecosystem (irrespective of types). It was beyond the purview of the present study to dig deeper into the intricacies of ecosystem functioning and responses of different types of wetlands in relation to climate change. There will be differences in underlying ecosystem processes and responses against each of the identified threats between saltwater and freshwater ecosystems, but we hypothesize that some degree of similarities may still be identifiable as the parent nature of the ecosystem remains same (*i.e.*, wetland).

Apart from those studies (NATCOM-UNFCCC 2004; IPCC 2014; Day et al. 2008; Christensen et al. 2007; Tsai et al. 2007; Kolker et al. 2010; Close et al. 2012; Milton 2004; Hussner 2009), which quantified threats in future climatic scenario using long-term climatic data, most of the literature has reported those threats and corresponding influencing factors based on authors' expert knowledge and review of the related literature. There are a number of considerations to be taken into account for quantifying the impact of climate change with the estimate of uncertainty in wetland fisheries due to inherent complex interaction between atmospheric climate and its manifestations in wetland ecosystem functioning. To address this issue 'weight-of-evidence' approach is often applied to quantify the level of confidence (Wrona et al. 2006). This approach uses historical data,

Table 4 Climate change-related threats to wetland fisheries in floodplain wetlands of West Bengal, India—perception of the fishermen community

S. No.	Threats	Pooled degree of consensus (%)	Level of confidence	Impact prediction	Priority of issue (for management)	Climate-related inducing factors (from 1st and 2nd round of interview)
1.	Water stress	95	Very high	Most certain	High	Poor rainfall during actual monsoon months and delaying (staggering) of monsoon proper to July–October Elevated temperatures throughout the year Intense summer
2.	Wetland accretion	85	High	Certain	High	Flash flood or cloud burst rains Short-duration, high-intensity rainfall Frequent drought–flood cycle (accelerated hydro-cycle) loosening top soil; more prone to erosion/run-off Increase in intensity and frequency of non-seasonal rains when agricultural lands are often left fallow after harvest, thus bringing in more sediments through run-offs
3.	Aquatic weed proliferation	70	Medium	Likely	Medium	Elevated temperatures throughout the year, especially warmer winters Prolonged summer resulting in longer persistence of concentrated nutrients in limited volumes of water (summer eutrophication) Frequent or high-intensity extreme weather events like storm surges and floods bringing in plants, seeds and spores of aquatic weeds

Table 4 continued

S. No.	Threats	Pooled degree of consensus (%)	Level of confidence	Impact prediction	Priority of issue (for management)	Climate-related inducing factors (from 1st and 2nd round of interview)
4.	Loss of wetland connectivity	65	Medium	Likely	Medium	Water stress Influx and deposition of sediments during monsoon Sediment trapping by increased mass of floating, emergent and submerged aquatic weeds throughout the year Repeated flooding and drying up
5.	Periodic recruitment failure of SIFs	45	Low	Biased	Low	Delayed arrival of monsoon rains Absence of pre-monsoon rains Absence or Low occurrences or late onset of western disturbances, locally known as '*kalbaishakhi*' (pre-monsoon storm surge and rain) during peak summer Flash rains resulting in flash floods results in smothering (blanketing) of fish eggs with silt/mud
6.	Epizootic ulcerative syndrome and other ulcer-like diseases	30	Very low	Not under consideration	Zero	Warmer winter temperatures Non-seasonal heavy rains Intense summer heat and resulting water stress to fishes Water quality issues (pungency of water, poor odor, low DO, acidic pH, blooms of blue green algae) lowering tolerance limits of fish

Table 4 continued

S. No.	Threats	Pooled degree of consensus (%)	Level of confidence	Impact prediction	Priority of issue (for management)	Climate-related inducing factors (from 1st and 2nd round of interview)
7.	Enhanced toxicity to agricultural pesticide run-offs	20	Very low	Not under consideration	Zero	Warmer winter temperatures Intense summer heat and resulting water stress to fishes Water quality issues Flash floods resulting from low-duration high-intensity rains suddenly accumulating active ingredients of agricultural pesticides in water that become concentrated during dry months and kill fish

information of published literature, model projection and most importantly the expert judgment of the authors. In contrast, we could achieve similar results along with quantified degree of confidence quite easily by the judgment of the 'experienced' stakeholders.

The present study failed to quantify the effect of identified influencing climate-related factors on the threat perceptions. The present method also failed to achieve high degree of consensus on three issues i.e., periodic recruitment failure of small indigenous fishes (SIFs) in the wetlands, frequent occurrence of epizootic ulcerative syndrome/other ulcer-like diseases in fishes and enhanced toxicity of fishes to agricultural pesticide run-offs. This might be due to complex nature of the relationship among fish biology, aquatic environment and climatic variability that are beyond the expertise and perception level of the stakeholders. This is one of the shortfalls of the proposed methodology. Therefore, recommendations on those issues have not been emphasized. Detailed studies on those issues are required based on data-driven approach. This will also help to understand the 'cause–effect' relationships between those issues and the climate change.

3.3 Climate change trends over the region

Analysis of the IMD data on mean air temperature has revealed a unanimous warming trend and decreasing rainfall in the studied districts (North 24 Parganas, Nadia and Kolkata) of West Bengal. During the period of 1980–2015, the mean air temperature has increased in the range of 0.18–0.28 °C (mean 0.22 °C) (Fig. 2). It was also observed that the total annual rainfall during the same period has decreased in the range of

Table 5 Breakdown of 'post-survey literature review' matching the indigenous threat perceptions of wetland stakeholders

S. No.	Supporting literature	Background of supporting literature reviewed			Matching issues identified in the present study[d]
		Freshwater wetlands[a]	Saltwater wetlands[b]	Wetlands and other aquatic systems (in general)[c]	
1.	Bowes and Salvucci (1989)			√	3
2.	Brock and Vierssen (1992)	√			3
3.	Callaway et al. (2012)		√		2
4.	Christensen et al. (2007)			√	2
5.	CIFRI (2016)	√			1, 5
6.	Close et al. (2012)	√			3
7.	Cochrane et al. (2009)			√	6, 7
8.	Day et al. (2008)		√		2
9.	Debusk et al. (1983)	√			1
10.	Dukes (2000)			√	3
11.	Ficke et al. (2007)	√			6, 7
12.	Hossain (2014)	√			5
13.	Hussner (2009)	√			3
14.	IPCC (2014)			√	1, 2
15.	IWAC (2009)	√			2
16.	Kairu (2001)	√			4
17.	Kassenga (1997)	√			4
18.	Kolker et al. (2010)		√		2
19.	Kusler (2005)			√	2
20.	Lallana et al. (1987)	√			1
21.	Lonsdale (1993)	√			3
22.	Low (2012)	√			3
23.	Marcogliese (2008)			√	6, 7
24.	Milton (2004)			√	3
25.	Mohanty et al. (2010)			√	6, 7

Table 5 continued

S. No.	Supporting literature	Background of supporting literature reviewed			Matching issues identified in the present study[d]
		Freshwater wetlands[a]	Saltwater wetlands[b]	Wetlands and other aquatic systems (in general)[c]	
26.	NATCOM-UNFCC (2004)			√	1
27.	Ndimele et al. (2011)	√			1
28.	Ojala et al. (2002)	√			3
29.	Roldan and Ruiz (2001)			√	4
30.	Ross and Adam (2013)		√		6
31.	Roy (2016)	√			4
32.	Saha et al. (2015)			√	1
33.	Sharma et al. (2015)	√			1
34.	Tsai et al. (2007)	√			2
35.	US EPA (2008)			√	3

[a] Number of studies exclusively from freshwater wetlands = 18 (51.43%)

[b] Number of studies exclusively from saltwater wetlands = 4 (11.43%)

[c] Number of studies from wetlands and/or other aquatic systems in general = 13 (37.14%)

[d] Identified issues: 1 = water stress; 2 = wetland accretion; 3 = aquatic weed proliferation; 4 = loss of wetland connectivity; 5 = periodic recruitment failure of SIFs; 6 = epizootic ulcerative syndrome and other ulcer-like diseases; 7 = enhanced toxicity to agricultural pesticide run-offs

135.6–257 mm (mean 192.5 mm) (Fig. 3). These changes are in agreement with the previous reports that mentioned changing climate in the state of West Bengal (Sharma et al, 2015). Cross-validation revealed that about 90–100% of the participants interviewed during the present study were aware of this warming climate and decreasing precipitation regime. Saha et al. (2015) had also reported a high level of climate change awareness among fisheries stakeholders.

Though the present approach could successfully identify climate-induced threats to wetland fisheries effectively, it is pertinent to mention the advantages and limitations as delineated below. This will be useful for replication of the assessment framework in other areas.

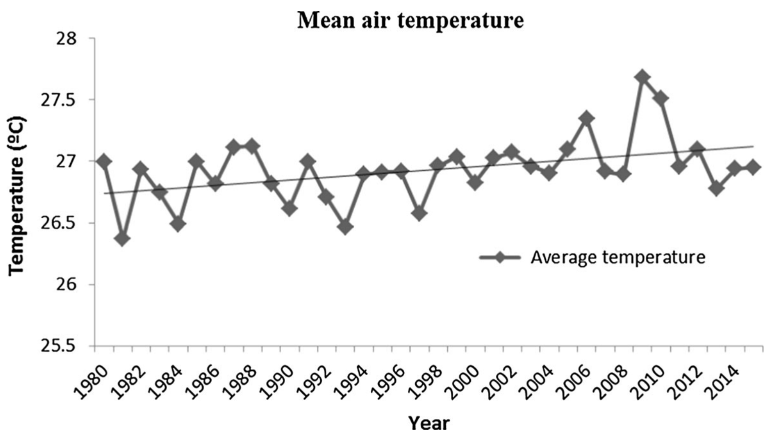

Fig. 2 Trend of increasing mean air temperature in the studied districts (North 24 Parganas, Nadia and Kolkata) of West Bengal, India

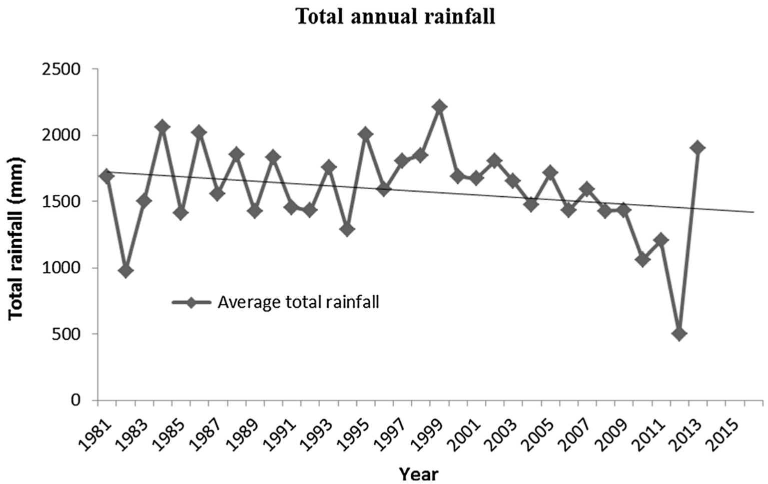

Fig. 3 Trend of decreasing total annual rainfall in the studied districts (North 24 Parganas, Nadia and Kolkata) of West Bengal, India

4 Advantages of using the methodology

i. Holistic approach.
ii. Less probability of being biased (interviewer or researcher).
iii. Identifies key issues with ease within short period of time.
iv. Classifies the key issues under various degrees of priority for management action.
v. Efficiently extracts the past records from human memory.
vi. The techniques eliminate irrelevant information and unjustified statements and refine the findings gradually through each stage of the iterative process.
vii. Maintains the anonymity of the individual responder and safeguards social status as well.

viii. Bold responses can be expected due to the provision of anonymous identity.
ix. The issues are also discussed upon, irrespective of its source or informer.
x. Takes the experience of the responder into account for providing authentic results.

5 Limitations of the methodology

- The present methodology is most suitable for those water bodies where organized fishery exists through cooperative management and/or self-help groups, for easy selection of expert groups (participants).
- It is a time-consuming technique due to its dependency on the availability of participants. Fishermen and local fish traders remain engaged to their livelihood activities on individual basis, on a daily basis for long duration, often making it hard to coordinate a survey, especially the round on group discussion.
- Low response rate of the most knowledgeable participants in the first round and/or lower turnout of participants in the second round might be a constraint in reaching consensus.
- Biased selection of participants can mislead the results. Hence, background check by the interviewer or self-introductions of participants prior to interview is necessary.
- It is not possible to quantify the individual effect of climate-related factors on the perceived threats. So the relative importance of factors cannot be ranked.

Further modification, improvement and standardization of the present approach may be needed, in spite of its noteworthy merits.

6 Conclusions

In the face of long-term data deficiency and complexities involved in quantifying climate-induced threats in future climatic scenario, an assessment framework based on stakeholders' perception was demonstrated in the present study on wetland fisheries. The approach adopted here effectively quantified the climate-induced threats and identified influencing factors on those threats to wetland fisheries, circumventing data-intensive and complex climate change modeling approach. The results obtained from stakeholders' perception in this study are similar to findings available in the published literature, some of which are based on long-term data and complicated modeling approach.

So, we conclude that to some extent, this stakeholder-driven approach can be an alternative to data-driven approach for quantifying climate-induced threats to wetland fisheries. The assessment framework presented in the study can easily be recalibrated and replicated in other areas where long-term research data are not available. However, adoption data-driven approach is always recommended wherever long-term data are available. Similar studies adopting this methodology need to be undertaken on a wider spatial scale which may raise certain points that could be the core area for future climate change research and also influence policymakers' decisions to formulate climate change resilient fishery policies.

A major limitation in the current engagement with climate change and its impacts on fisheries and fishing communities is that it is based mainly on technical studies. The perceptions and proposals of fishing communities themselves have received scant attention. In India, there is no specific focus on wetland fisheries in the national- and state-level action plans on climate change. As a result, fishers will not only be able to benefit from the measures proposed, but will also increasingly find themselves further marginalized and become more vulnerable to the impacts of climate change. In fact, in the fisheries sector, climate change is not a new problem. Probably, fishers have been experiencing its impacts since before the term 'climate change' itself acquired popularity. It is often not possible to differentiate climate change issues from other factors affecting fisheries, as climate change itself is the cumulative outcome of several complex processes at different levels within and beyond the fisheries sector. Consequently, in the present study, the stakeholder could only identify the possible influencing factors on the threats and did not attain a consensus on some of the issues. The estimation of the effect of climate-related factor(s) on the identified threats was not accomplished in this study. Nevertheless, it can very well be contemplated that climate change may further aggravate these threats. In this context, the key findings obtained in this study have significance in prioritizing management actions and future research as described below.

- Problems like water stress, wetland accretion/sedimentation, aquatic weed proliferation, loss of wetland connectivity to river are high-priority issues which need to be addressed immediately. These problems are expected to further exaggerate with time in future climate scenario. Stakeholders also possess low adaptive and mitigative capacities to tackle these issues as they have already given up on these issues due to the underlying climate change influence which seems inevitable to them.
- The small indigenous fishes (SIFs) present in the wetlands cater to nutritional security of the fisherman owing to their rich nutrient profile and cheap price. Recruitment failure of SIFs in wetlands can be an important researchable topic in context of climate change and its impact on recruitment of resident fish species.

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