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Climate change and adaptation to social-ecological change: The case of indigenous people and culture-based fisheries in Sri Lanka

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Abstract: Rural coastal fishery systems in tropical island nations are undergoing rapid change. Using a case study from eastern Sri Lanka, this paper examines the ways in which Indigenous Coastal-Vedda fishers experience and respond to such change. We conducted semi-structured interviews (n=74), focus group discussions (n=17, 98 participants), and key informant interviews (n=38) over a two year period (2016-2019). The changes that most Coastal-Vedda fishers experience are: disturbance from Sri Lankan ethnic war, changes in climate and the frequency and severity of natural disasters, increased frequency of human-elephant conflicts, increasingly unpredictable weather patterns, and transformation of the Coastal-Vedda due to social modernisation. We used a resilience-based conceptual framework focusing on place, human agency, collective action and collaboration, institutions, indigenous and local knowledge systems, and learning to examine fishers' responses to rapid changes. We identified three community-level adaptive strategies used by the Coastal-Vedda: adaptive institutions with a multi-level institutional structure that facilitates collective action and collaboration, the use of culture-based fisheries (CBF), and diversification of livelihoods. We also recognised four place-specific attributes that shaped community adaptations: cultural identity and worldviews, co-management of CBF, flexibility in choosing adaptive options, and indigenous and local knowledge systems and learning. These adaptive strategies and place-specific attributes provide new insights for scientists, policymakers, and communities in the region, enabling them to more effectively work together to support community adaptation.

Keywords: Adaptation, Coastal-Vedda, Culture-based fisheries, Aquaculture, Climate change, Sri Lanka, Resilience

1. Introduction

While environmental change is global, its effects are felt most directly by local communities. Rural Coastal-Vedda communities in Sri Lanka are undergoing complex changes including climate change impacts (e.g., frequent extreme weather events leading to floods and droughts) (Esham and Garforth, 2013, Truelove et al., 2015), civil war (1983-2009) (Aaronson, 2016, Zoysa, 2018), tsunami devastation (2004) (Lehman, 2014), and globalization. These changes have profound impacts on Coastal-Vedda communities, altering their livelihoods, culture, and lifestyle, and creating risks and opportunities (Pelling et al., 2015). Coastal-Vedda communities are also likely to be amongst those most exposed to and impacted by climate change. Identifying ways to reduce, through adaptation, the risks that global and local changes pose is an emerging topic in research on decision-making in natural resource management sectors including fisheries and aquaculture (Cinner et al., 2018, Galappaththi et al., 2019). Understanding how fisheries and aquaculture communities experience and respond to rapid change is essential for supporting adaptation processes.

While empirical assessment of communities' adaptation to change is an increasingly active area of research, little work focuses on indigenous peoples and culture-based fisheries (CBF)[1], particularly climate change in eastern Sri Lanka. Studies do focus on other aspects of CBF (Amarasinghe and Nguyen, 2009, Pushpalatha and Chandrasoma, 2010, Amarasinghe and Wijenayake, 2015, Wijenayake et al., 2016) and climate change impacts (Yamane, 2003, De Silva et al., 2007, Esham and Garforth, 2013) in Sri Lanka. The eastern part of the island has received limited attention due mainly to its three decades of civil unrest (Lehman, 2014). Against this backdrop, we use a case study from the Kunjankalkulam community in eastern Sri Lanka to assess community adaptations to climate change in Coastal-Vedda fisher communities. The paper has two objectives: i) examine how Coastal-Vedda fishers experience change, including climate change; and ii) investigate how Coastal-Vedda fishers respond and adapt to such change. In the next section, we describe Coastal-Vedda within the context of the indigenous populations of Sri Lanka, and the study's conceptual and methodological approach. Following the 'methods' section, we reveal means by which Coastal-Vedda fishers build resilience and minimise vulnerability (i.e. adapt) to the impacts of climate change. Finally, we identify potential community adaptive strategies and attributes that shape community adaptations in a CBF setting.

2. Methods

2.1 Indigenous peoples in Sri Lanka

Sri Lanka's indigenous populations refer to themselves as *Wanniya-laeto*[2] ('people of the forest') (Lund, 2000: 102). Most Sri Lankans use '*Vedda*'[3] to identify the country's indigenous populations (Seligmann and Seligmann, 1911, Lund, 2000, Attanapola and Lund, 2013). This term means 'the person who uses bows and arrows', referring to their practices of shifting cultivation, hunting, and trapping and of collecting forest products (Dharmadasa, 1993). The *Wanniya-laeto* have their own culture, way of life, and personality (Seligmann and Seligmann, 1911). In determining geographical boundaries, they recognise only natural landmarks. They also protect the forest they inhabit, as they believe their ancestors' spirits belong to it (Lund, 2000). However, from ancient times (including the war period), the *Wanniya-laeto* have peacefully co-existed with the island's majority Singhalese and Tamil populations (Seligmann and Seligmann, 1911, Brow, 1978, Dharmadasa, 1993).

Throughout the 19th and 20th centuries, the *Wanniya-laeto* were marginalised and forced to relocate (Lund, 2000: 102) mainly because of (post)colonialism and development activities (Attanapola and Lund, 2013). The Sri Lankan government is primarily responsible for marginalising and disempowering the indigenous population, mainly by weakening the population's knowledge systems and capacities (Lund, 2000, Attanapola and Lund, 2013). Thus, the locals have lost their

[1] CBF are essentially a form of extensive aquaculture, or a farming practice conducted in small water bodies (generally less than 100 ha). These water bodies would not be able to support a capture fishery due to a lack of adequate natural recruitment of suitable species. Artificial water bodies, not built for fishery/aquaculture purposes (such as village tanks) but often built for irrigation purposes, can be used (De Silva et al. 2006: 11).

[2] '*Wanniya-laeto*' is the plural term and '*Wanniya-laeta*' (masculine) or 'Wanniya-laeti' (feminine) is the singular term.

[3] '*Vedda*' is the singular term and '*Veddas*' is the plural.

connection to ancestral lands (Lund, 2000). The *Wanniya-laeto* have rapidly and inconsistently adapted to new social, cultural, and political contexts, including the new administrative structure and market economic system (Lund, 2000, Attanapola and Lund, 2013). They appear to be at a crossroads between traditional and modern systems (Latour, 2012, Attanapola and Lund, 2013).

In this paper, we study 'Coastal-Vedda'[4], a group of *Wanniya-laeto* who migrated to eastern Sri Lanka's coastal areas. Historically, Costal-Vedda moved within the forest in the eastern coastal belt, fishing and cultivating vegetables around their huts and in clearings in the jungle (slash, burn, and shifting to another area)—known as 'Chena cultivation' (Dharmadasa, 1993, Childs, 2017). They cultivated maize, pumpkin, and other easy-to-grow crops. Later, Coastal-Vedda mixed with the Tamil populations in the eastern area[5]. The main livelihood of the Coastal-Veddas living on the seaboard was fishing in the sea or in lagoons (Seligmann and Seligmann, 1911, Dharmadasa, 1993). The others fished in tanks, rivers, and streams, using methods such as emptying water courses, and using poisonous leaves and creepers. They used traditional fishing gear like *karaka* and *kemana*, as well as made their own, such as cast nets, spears, and bifid iron spearheads. Coastal-Vedda also use arrows as harpoons for fishing (Seligmann and Seligmann, 1911).

Currently, Coastal-Vedda live in four villages in the eastern region. They have lived in Kunjankalkulam since the 1960s, after the government built the village tank to promote irrigation (rice farming). The national Coastal-Vedda Chief resides in Kunjankalkulam (population = 193) (Figure 1). The Kunjankalkulam *Wanniya-laeto* population has indigenous cultural practices and values similar to inland *Wanniya-laeto*. Kunjankalkulam is a remote, isolated community accessible only by a gravel road. People use bicycles, motorbikes, and tractors to commute. The inhabitants face unique challenges including food insecurity, a lack of drinking water and infrastructure (roads and housing), and low high school graduation rates (Herath and Joseph, 2016, Gunatilaka, 2017). This region was affected by the Sri Lankan civil war (1983-2009), tsunami devastation (2004), and climate change impacts such as droughts, floods, and tropical storms (De Jong et al., 2002, Yamada et al., 2006, Esham and Garforth, 2013), which increases the complexities of the Coastal-Vedda way of life and the natural environment.

Kunjankalkulam is one of the few Coastal-Vedda communities in the region with a high level of fisheries activity and high non-fisheries livelihood diversity. Coastal-Vedda use a village tank (reservoir) to raise fish (i.e., CBF) as a main community livelihood activity. The community is in a dry climatic zone where CBF is challenging. The north-eastern tropical monsoon and the weather dynamics in the Bay of Bengal influence the region's weather. Eastern Sri Lanka gets rain and high winds between October and January and remains dry for the remaining months (especially May through September). Rice farming is another essential livelihood activity, though unexpected climate changes (mainly extended droughts) do not allow Coastal-Vedda to farm consistently. Human-wild elephant conflicts are common; protecting the rice harvest from elephants is another

[4] 'Coastal-Vedda', refer to themselves as '*Muhudu-Vedda*', meaning '*Wanniya-laeto* of the cost'. The term 'Coastal-Vedda' is the standard translation of '*Muhudu-Vedda'*.

[5] Eastern Sri Lanka used to be a Tamil-dominated area but presently Muslim populations are becoming more dominant in terms of population growth and culture, including building architecture.

challenge facing Coastal-Vedda. Furthermore, Coastal-Vedda use the surrounding forest for livelihood activities such as collecting wild honey, medicinal/edible plants, fruits, and wood for selling, as well as trapping/hunting.

2.2 Conceptual approach

We took a social-ecological systems (SES) approach to understanding the interconnected but partly distinct nature of integrated 'Coastal-Vedda' and 'Kunjankalkulam' sub-systems (Berkes et al., 1998, Berkes et al., 2003). The SES approach emphasizes neither purely ecosystems nor societies; rather, the SES and the connections between the system's ecological and social components are the focus. Economic systems and markets are not treated separately but as deeply nested in an SES approach, creating understanding of the complexities in Coastal-Vedda aquaculture—what can be termed 'complex adaptive aquaculture systems' (Mahon et al., 2008, Folke, 2016, Arlinghaus et al., 2017). 'Aquaculture systems' refers to the coupled sub-systems of Kunjankalkulam Coastal-Vedda and their forest/land/water and associated socio-economic and cultural aspects related to CBF activities.

We use a resilience-based conceptual framework (Galappaththi et al., 2019) to identify and assess the adaptations of Kunjankalkulam Coastal-Vedda towards stressors of the aquaculture system. The framework has six characteristics that develop an understanding of SES change and human responses to such change: place, human agency, collective action and collaboration, institutions, indigenous and local knowledge (ILK) systems, and learning (Table 1). This framework provides indicators that guide the assessment process. Results are structured around such indicators under each framework characteristic. A unique conceptualisation of resilience (as a function of coping, adapting, and transformative capacities) (Béné et al., 2014, Brown, 2016) permits a macro-level understanding of adaptation with micro-level comprehensive details in fishing communities. This conceptual tool was developed through an integration of resilience thinking and development studies (Galappaththi et al., 2019). We used this framework to assess the community adaptation process in Coastal-Vedda aquaculture systems and obtain insights into adaptation needs and relevant policy.

2.3 Data collection methods

We used a community-based participatory research approach (Magee, 2013) to ensure community engagement in shaping knowledge production. The study received community feedback through the national Coastal-Vedda Chief, informants from local institutions (e.g., NAqDA-National Aquaculture Development Authority, Batticaloa), and research assistants. During field data collection, the researcher relied on five language translators (Tamil/Coastal-Vedda language to English) and three local research assistants. All field data were collected according to the McGill Research Ethics Board Certificate of Ethical Acceptability of Research Involving Humans (file number: 52-0617) as well as under the consensus of the (Coastal) Vedda Chief of Sri Lanka.

We used a qualitative research design for primary data collection to understand how Coastal-Vedda fishers experience and respond to SES change, including climate change, in Kunjankalkulam. Field data were collected using multiple methods: participant observations (PO), semi-structured interviews (SSI), key informant interviews (KII), and focus group discussions (FGD) (Berg, 2016, Laurier, 2016, Longhurst, 2016). PO helped us obtain contextual knowledge

about Coastal-Vedda experiences and responses to change. As of March 2019, we had conducted 24 weeks of in-field PO during three visits to Kunjankalkulam and the surrounding area. The first visit was in August 2016 and involved reconnaissance, preliminary data collection, and the gathering of community feedback. The second visit was from September-December 2017 and involved the collection of data about the Coastal-Vedda's CBF and how locals cope with the rainy season. The third visit was from April-July 2018 and involved the collection of data about the changes Coastal-Vedda face during the dry season and their adaptations. The researcher's daily-updated field diary helped track PO data. The researcher spent much time with Coastal-Vedda fishers, attending community events, meetings, and community-based institutions. The researcher also made >20 fishing trips to the village reservoir and participated in most activities (e.g., fish stocking, net setting, harvesting, and fish landing site activities).

Seventy-four face-to-face semi-structured interviews (SSI) (Longhurst, 2016) were conducted with Coastal-Vedda fishers to document changes in the region and identify/characterize the response to them (Appendix-Table S1-key themes of the interview guide). A snowball sampling technique was used to select participants (3). Initially, the Coastal-Vedda leader introduced the researcher to the community; the researcher made most appointments via cell phones and sometimes by walking in. We recruited participants until saturation, when interviewees provided no new relevant information (Bowen, 2008). These interviews were conducted, audio-recorded, and transcribed in Kunjankalkulam from September 2017 through July 2018 (Appendix-Table S2-sample profiles). The SSI questioning focused on "change" in general to prevent bias and to keep the interviews open-ended, focusing on the issues and changes that Coastal-Vedda viewed as most important. This sample consisted of Coastal-Vedda fishers who permanently live in Kunjankalkulam. SSI obtained richer insights into 'place' and its meanings/attachments (Williams and Patterson, 2008, Kaján, 2014). All the interview questions relating to 'change' referred to "about 30 years back" in Coastal-Vedda's lives.

Thirty-eight key informant interviews (KIIs) were conducted and included questions about Coastal-Vedda, climate change, and CBF. The goal was to examine topics not accessible via PO and SSI, such as the Coastal-Vedda population (national indigenous chief and Ministry of Cultural Affairs to find/verify the Coastal-Vedda community), co-management of CBF (e.g., NAqDA), and adaptive responses (e.g., NGOs—non-governmental organizations) in the community. The researcher conducted interviews with representatives from NAqDA (n=4), the Ministry of Cultural Affairs (n=4), the Department of Fisheries-Batticaloa (n=2), the Divisional Secretariat Office-Vakarai (n=1), the Ministry of *Mahaweli* Development and Environment-Colombo (n=6), the Department of Meteorology-Batticaloa (n=1), the World Vision International Zonal Office-Vakarai (n=1), the *Sabaragamuwa* University of Sri Lanka (n=1), and the University of the Visual and Performing Arts-Colombo (n=1), as well as individuals with knowledge of Coastal-Vedda (n=17). KII helped validate and describe data gathered using other methods.

Seventeen focus group discussions (FGD) (Carey and Asbury, 2016) were undertaken with 98 respondents to build thematic areas related to changes that Coastal-Vedda fishers experience (e.g., climate extremes, unpredictable weather patterns, increased human-elephant conflicts during the post-war period) and to identify how Coastal-Vedda respond to such changes (e.g., collective action and collaborations, community-based institutions, knowledge systems, and aquaculture). Coastal-Vedda groups of four to eight individuals participated in the FGD, organised throughout

212 the data collection process (Appendix-Table S3-Details of FGDs). Further, FGD validated the data
213 collected using other methods.
214
215 2.4 Data analysis
216 Qualitative interview data were translated into English and transcribed, then analysed using
217 content analysis (Yow, 2014, Hancock and Algozzine, 2015, Berg, 2016, Clifford et al., 2016).
218 The key techniques were manifest and latent content analysis (Vaismoradi et al., 2016,
219 Krippendorff, 2018) supplemented with critical discourse analysis (Van Dijk, 2015, Wodak and
220 Meyer, 2015) to develop themes and patterns related to Coastal-Vedda's experience and response
221 to change. We also used direct quotations to support the results. We used Microsoft Excel 2013 to
222 create descriptive statistics (e.g., percentages, mean values, standard deviations). Percentages in
223 the text refer to the number of respondents from the immediately mentioned sub-sample who made
224 that statement. Initially, the study recorded 16 types of changes that Coastal-Vedda fishers
225 experienced. We selected the five most-recorded areas of change (based on the data frequency) for
226 further analysis. The results were supplemented with selected quotes (from SSI/KII) based on the
227 latent content analysis. We identified links among the selected changes using data from PO and
228 SSI and validated them through KII and FGD. Data relating to Coastal-Vedda fishers' response to
229 change were mostly fed through the PO data (research diary, photos, and the researcher's first-
230 hand experience), supplemented with SSI and KII.
231
232 **3. Results**
233
234 3.1 Experiencing SES change
235 Coastal-Vedda experience change in many ways. Key changes are: continued disturbances
236 resulting from the civil war, extreme weather and natural disasters (e.g., cyclones, floods, drought),
237 increased human-elephant conflicts, increasingly unpredictable weather patterns, social pressure
238 from transformations towards modernization, materialistic values, and wellbeing. Some changes
239 (e.g., human-elephant conflicts (Fernando et al., 2005, Santiapillai et al., 2010)) are more widely
240 documented than others, yet certain changes are described as more important than others. These
241 are profiled in Table 2.
242
243 3.2 Responding to SES change
244 This section examines how Coastal-Vedda respond to identified changes using the resilience-based
245 conceptual framework. It is structured around the themes of place, human agency, collective
246 action, institutions, knowledge systems, and learning (Galappaththi et al., 2019).
247
248 3.2.1 Place
249 Place-specific conditions such as water availability for aquaculture, climatic conditions, and
250 wildlife threats to livelihood activities can influence community adaptive capacity and processes
251 (Amundsen, 2015, Adger, 2016). CBF supplies food for Kunjankalkulam year-round and is a key
252 source of protein. This minor-non-perennial[6] reservoir (110 ha) was built during the 1960s to meet
253 the demand for water to cultivate rice but currently is used primarily for CBF activities. This

[6] Most of the reservoirs used for CBF/aquaculture are minor-non-perennial reservoirs (50-200 ha at full water supply level) in Sri Lanka.

reservoir can no longer accommodate the seasonal water demand for rice farming due to extended droughts. The reservoir is close to village housing and rice farms. With the support of the government, fisheries and aquaculture institutions, and NGOs, an annual stock of eight varieties of fish fingerlings (Appendix-Table S4-aquaculture species) grows in the natural reservoir system. In 2017 this reservoir was stocked with 250k-300k fish fingerlings (tilapia, carp, and indigenous fish) and 100k-150k freshwater prawn postlarvae. The estimated harvest for the year was 5-7k MT fish and prawns. The peak season for fish harvesting is March-September; the offseason begins with the heavy rains in October. In 2018 this reservoir received a pen culture system stocked with 100k fish fingerlings.

Coastal-Vedda practice two types of fishing activities. During the day, fisherwomen enter the water to fish using rods (Appendix-Figure S1-photos). They fish mainly for subsistence purposes. These locations change based on the reservoir water levels, which themselves depend on weather conditions. The most commonly caught fish are tilapia and indigenous fish. During the day, fishermen rest or engage in other livelihood activities. Fishermen go fishing in the early morning (2-3 am) in deep areas of the reservoir, using canoes and gill nets. They look for commercial species (e.g., freshwater prawns, well-grown carp and tilapia). They use some of the harvest (small fish) for food purposes while selling large, high-quality fish to fish collectors (i.e., middlepersons who collect fish every morning and supply it to large markets in urban areas).

The Coastal-Vedda fisheries system has place-specific vulnerabilities. Wild elephant attacks affect the community's fishing activities and peak during rainy seasons. To repel elephants, fishers use special firecrackers and create fires. The community also has an inoperable electrified fence. The need to spend time and energy on wild elephants affects nighttime commercial fishing activities.

3.2.2 Human agency

A high level of human agency can indicate a high adaptive capacity to change (Cinner et al., 2015, Galappaththi et al., 2019). This section uses livelihood diversification, access to credit, occupational multiplicity, access to assets, fishing gear diversity, and occupational mobility to understand the adaptive capacities of Coastal-Vedda fishers (Table 3).

Coastal-Vedda fishers engage in many livelihood activities to increase their income options in adverse conditions (Figure 2). Some activities were historically practiced (*collecting* wild honey/fruits/wood, hunting/trapping, chena/rice cultivation), while others are recent additions (aquaculture, beach seine fishing, *selling* wild honey/fruits/wood, income support). These activities reduce Coastal-Vedda reliance on CBF (or one specific livelihood activity) for food security. Livelihood diversification decreases the opportunity cost of Coastal-Vedda's dependence on CBF for food. Almost all (100%) the respondents were involved in CBF; 62% engaged in fishing for commercial aquaculture and 38% were involved in subsistence aquaculture. Almost all fishers involved in subsistence aquaculture were female. Gender roles are clearly set among Coastal-Vedda; women are not directly involved in commercial activities including night-time CBF.

> …now we [Coastal-Vedda] save money, and women even have saving clubs … learnt that [saving money] from an NGO program…—Young Coastal-Vedda

> It's hard during dry season and flood season, but we do multiple activities [livelihoods] … I go fishing early morning and garden during the daytime … sometimes going to forest [to collect honey, fruits, or wood] instead [of gardening] … sometimes we buy rice or meat from town and make a vegetable and fish curry … I have options [livelihoods] now and I don't need to miss any meals anymore…—Elder Coastal-Vedda

We observed limited or no modern or advanced technology in CBF operations among Coastal-Vedda. However, particularly after the war, Coastal-Vedda have been undergoing rapid social modernisation (Latour, 2012), including the use of money (cash economy), modern clothing, cement housing, a non-mobile lifestyle, cell phone use, aquaculture, and fish selling activities (Childs, 2017, Ranasinghe and Cheng, 2018). Coastal-Vedda have limited access to credit (personal loans) for CBF activities but can borrow money from informal money lenders. Coastal-Vedda's CBF operation doesn't involve major expenses, with the exception of fish fingerling stocking, which is funded by RFO, NGOs, and the government. Furthermore, through fisher compensation programs, Coastal-Vedda can obtain low-cost canoes and fishing gear.

3.2.3 Collective action and collaboration

Collective action and collaboration shape community adaptation by improving community cohesion and unity, which helps members cope with common changes through enhanced collective adaptive capacity (Adger, 2003, Armitage, 2005, Pelling et al., 2008). Collective action is embedded in Coastal-Vedda's way of life. An example is fisherwomen's daytime subsistence fishing operation. All the fish are collected into one sack and distributed equally among the families. This fishing operation is led by the village first-lady (spouse of the Coastal-Vedda chief). A rotational system determines who fishes on a particular day (similar to the *Padu* system (Lobe and Berkes, 2004) but in this case, the catch is shared). The fishing time can vary from two to five hours depending on the fishing spot and the community's needs. Fisherwomen usually remain in one fishing area for at least five days. This routine changes due to weather, the need to engage in other livelihood activities, or cultural priorities.

Also, groups of two to four Coastal-Vedda fishermen gather at night for commercial fishing operations; they set their nets and share their income. A majority (over 90%) of fishermen said they don't share large fish (of marketable size); however, they share small fish for food purposes. Most fishermen (52%) will not share their fishing gear (gillnets, canoe). Only 15% of fishermen said they would share. Within the sample of fisherwomen, 64% said they would share their gear (fishing rods), while 25% said they would not.

Coastal-Vedda use informal social networks to share important information about CBF activities. People—especially women—gather around the water well and drinking water tank to share daily updates, including fisheries-related information (e.g., the quality of the fish harvest, who went fishing/is planning to fish, and changes in fish prices) and non-fisheries-related information (e.g., alerts about wild animals). People also use informal social networks to share information about extreme weather events. Most (89%) fishermen have cell phones. Among fisherwomen, 46% use cell phones for communication. Informal social networks allow Coastal-Vedda to spread information more quickly than formal methods of information sharing (e.g., monthly fisheries

cooperative meetings). Such information can be less precise but useful for a small society that does not rely on the internet.

3.2.4 Institutions

Local institutions can boost a community's adaptive capacity by engaging with fishery resource management approaches and collaborating with stakeholder institutions to minimize vulnerabilities in the use of natural resources. Kunjankalkulam's CBF is co-managed by a multi-level institutional structure with diverse stakeholder organizations that manage stress and change by sharing knowledge, identifying barriers, and learning from each other (Figure 3). RFO (Rural Fisheries Organisation) is the key fisheries institution managing community-level CBF. It has annually appointed officers: a (vice) president, a secretary, and a treasurer appointed by RFO members (i.e., Coastal-Vedda fishers). The treasurer has the only paid full-time job. He must visit the landing site twice daily and record the number of canoes that entered the reservoir as well as how many fish was brought to the landing-site (landing-site management). Every commercial fisher must pay a fee to RFO based on their catch. Occasionally, RFO buys all the fish from the fishers and sells it back to the local market/vendors, depending on prevailing market prices. Currently, Kunjankalkulam RFO is one of 22 RFOs in the region (eastern fisheries division).

The Inland Fisheries Federation (IFF) is the regional-level aquaculture industry organisation. IFF has significant control over the inland fish market price. The organization consists of leaders from 22 RFOs (e.g., the president). IFF charges RFOs a membership fee based on the reservoir size (Sri Lankan Rupee equivalent to C$23 for minor, C$38 for medium, and C$76 for major). IFF also has annually appointed leadership positions: (vice) president, secretary, and treasurer. The president is part of the National Fisheries Federation (NFF), which oversees national-level fisheries and aquaculture concerns.

The Batticaloa regional center of the National Aquaculture Development Authority of Sri Lanka (NAqDA) directly supports the community adaptation process through co-management of CBF. NAqDA is the national-level government institution for inland fisheries and aquaculture management. Extension officers of NAqDA work closely with RFOs to ensure that fishers follow regulations and procedures. The extension officers attend most RFO meetings and offer administrative support. For example, fishers must meet three key requirements to become involved in commercial CBF: a) obtain an 'operating licence' from NAqDA (with no fees) for recording purposes so that NAqDA will know who the full-time fishers are (those who fish three or more times per week), b) register their canoe (number) with the Department of Fisheries, Batticaloa, and c) obtain fisher insurance (C$8/year) from Ceylinco General Insurance Limited to mitigate fishers' health-related risks such as hospital bills and death during fishing-related activities.

NGOs play a key role in funding the CBF co-management process. The fish fingerling stocking process is partly funded through various NGOs (e.g., World Vision, FAO, Care, and USAID) and the government. RFO also contributes. For example, in 2018 Coastal-Vedda started an experimental pen culture project in the reservoir to increase the community's annual fish production. Furthermore, in 2017 Kunjankalkulam RFO received fishing gear and canoes as NGO donations. Additionally, Coastal-Vedda use many non-fisheries/aquaculture-related community-

based institutions to cope with common challenges (Appendix box S1). Each institution is led by different Coastal-Vedda, which allows for collective leadership at the community level, improving the community's adaptive capacity.

Figure 3 shows the multi-level institutional structure of vertically integrated fisheries associations and government and non-governmental organisations (NGOs). Multi-level fisheries associations are horizontally integrated with government institutions primarily for fisheries and aquaculture management-related aspects (solid-line arrows) and with NGOs for specific project financing aspects (dotted-line arrows). RFO is the key community institution representing Costal-Vedda with respect to CBF.

> Now village reservoir is our main way of living … we are planning to further increase our fish production with the help of NAqDA and … local NGOs … I am glad they [NAqDA] help and consult us with technical expertise … Today … […] NGO donate five canoes and gillnets for our fishers, they [NGO] have being helping us over the last year…—Coastal-Vedda chief

3.2.5 ILK systems

ILK systems are a source of resilience and a means of measuring the understanding of adaptations in a fisheries and aquaculture setting (Folke et al., 2003, Galappaththi et al., 2018, Galappaththi et al., 2019). This section describes Coastal-Vedda applications of ILK, the combining of different types of knowledge, and the weakening of ILK systems throughout SES change.

Coastal-Vedda use various types of knowledge to cope with SES change. Table S5 in the appendix illustrates selected types of knowledge that Coastal-Vedda fishers use. We have identified various knowledge systems surrounding fishing spots, CBF operation, weather predictions, collective action, and climate adaptation responses. Furthermore, we have recognised essential knowledge for surviving in the 'place', such as knowledge about wild elephants and disaster/emergency practices. All acknowledged types of knowledge are currently practiced by Coastal-Vedda fishers and have been developed over the past three decades. Specific types of knowledge developed due to Coastal-Vedda's exposure to long-term stresses such as climate change impacts (adaptation knowledge) and war conditions (knowledge about disaster or emergency situations). Another sub-set of knowledge (weather predictions) has been used and is evolving.

Moreover, Coastal-Vedda believe that aspects of their ILK system are weakening, partly due to ethnic conflict and social modernization. Coastal-Vedda still possess specific knowledge that they have gained over the generations but do not often practice it. For example, a lack of traditional fishing and hunting activities results in weakened knowledge about making/using traditional weapons (e.g., bow and arrow, spear). However, new knowledge about aquaculture can mitigate the livelihood impacts of weakened knowledge, enhancing Coastal-Vedda's capacity to adapt to SES change.

> Now everything [has] changed. It is hard to predict weather, animals, even forest … but we need to live. The government and NGOs [are] giving us new knowledge that help to develop aquaculture—Elder Coastal-Vedda

3.2.6 Learning

Learning is a key characteristic of community adaptation (Galappaththi et al., 2019). This section describes how Coastal-Vedda practice learning-by-doing in their fishing way of life, the available learning opportunities, and the ways Coastal-Vedda co-learning supports the local adaptation process.

Coastal-Vedda have various opportunities to learn and adapt to change (Appendix-Table S6). Identified learning opportunities are: learning-by-doing (65%), local institutions such as RFO (53%), external stakeholders such as NGOs (32%), and parents and elders (28%). In FGDs, all respondents agreed that by combining all learning opportunities, Coastal-Vedda co-learn in the context of CBF. 'Learning-by-doing' is a common application across multiple learning opportunities (e.g., RFO and NGO settings). Collective action and collaboration are key mechanisms for co-learning. Local institutions and community-based organizations facilitate Coastal-Vedda's co-learning process. Co-learning could lead to new knowledge such as aquaculture technology (e.g., pen culture to increase fish production).

Coastal-Vedda have access to formal education through a public-school system. Coastal-Vedda children attend the nearest primary school (up to grade three) in nearby communities. Over the last three decades, ethnic conflicts have disturbed Coastal-Vedda education. Because they live in a geographically isolated rural fishing community, Coastal-Vedda fishers concentrate on identified opportunities for learning.

> This effort [the co-management of CBF] is teamwork, we tried many aquaculture activities over the last years …we need patience ... and especially learning from our past mistakes is important to strongly face this change—Elder Coastal-Vedda

4. Discussion

We assessed Coastal-Vedda community adaptation by examining how Coastal-Vedda experience and respond to change in a small-scale aquaculture context (i.e., CBF). We illustrated five key stressors and shocks: the Sri Lankan ethnic war; extreme weather and natural disasters including cyclones, floods, and droughts; human-elephant conflicts; an increase in unpredictable weather patterns; and social pressure from modernization (Latour, 2012). Compared to other small-scale fisheries systems (Arimi, 2014, Paprocki and Cons, 2014, Khan et al., 2018), Coastal-Vedda have experienced a unique combination of changes over the last three decades. We discovered four characteristics of how Coastal-Vedda fishers experience change: (i) Coastal-Vedda's culture-based fisheries systems are undergoing multiple stressors, indicating that change is non-linear; (ii) climate change is perceived as one of many changes with mixed/interconnected implications for Coastal-Vedda fisheries; (iii) Coastal-Vedda themselves (culture, economy, lifestyle) are transforming within the SES change over time; and (iv) responding to identified changes over a long period has made Coastal-Vedda more resilient to SES change.

Table 4 illustrates the implications of specific changes that Coastal-Vedda fishers experience, their potential outcomes, and community responses to them. Furthermore, Table 4 describes the

conceptual link between the listed implication of change and the respective community responses. To advance the understanding of adaptive responses, we must investigate how Coastal-Vedda address the implications of changes differently from other documented small-scale fisheries systems. An aquaculture-centered livelihood equipped with multi-level mixed governance institutions is the collective strategy that fosters community adaptation.

We identified three key adaptive strategies of Kunjankalkulam Coastal-Vedda that construct the community responses to SES change. First, we recognised CBF (or aquaculture) itself as an adaptation strategy. Coastal-Vedda once had wild capture fisheries and engaged in chena cultivation and rice farming; now they are involved primarily in CBF (De Silva et al., 2006, Amarasinghe and Nguyen, 2009). This aquaculture is the best fit for the changes surrounding Coastal-Vedda's SES, such as climate (e.g., cyclones, floods, and droughts) and way of life (e.g., non-mobile lifestyle). CBF can build more resilience among Coastal-Vedda than can other livelihoods, as it: (i) reduces food insecurity by supplying consistent protein sources (Amarasinghe and Nguyen, 2009), (ii) does not involve major investments (compared to intensive large-scale aquaculture operations), with the cost of fingerling stocking borne by multiple funders (RFO, NGOs, government) (Chandrasoma and Pushpalatha, 2018), and (iii) creates opportunities to collaborate and co-learn with external information/knowledge sources. Globally, aquaculture is identified as an adaptive strategy for climate change impacts and is included in some countries' national natural resources strategies (e.g., Solomon Islands, Vanuatu, Timor-Leste, Fiji, and Vietnam) (Bosma et al., 2012, Dey et al., 2016a, Dey et al., 2016b, Rosegrant et al., 2016).

Second, adaptive institutions with a multi-level institutional structure are the heart of community adaptation. The key features of Coastal-Vedda adaptive institutions (Boyd and Folke, 2012, Galappaththi et al., 2018) are: (i) RFO is the key community institution for CBF, representing all Coastal-Vedda fishers, (ii) the presence of multi-level institutions (RFO—community, IFF—regional, NFF—national) (Galappaththi and Berkes, 2014), (iii) the existence of mixed regimes of community, government, and NGOs to fund culture-based fisheries systems (Galappaththi and Berkes, 2015a), (iv) the bottom-up nature of functioning (feedback escalated from the community level to the national level) (Galappaththi and Berkes, 2014), and (v) adaptive nature—multi-level industry association structure collaborates/links with various stakeholder organizations (NAqDA, Department of Fisheries, NGOs) based on need (e.g., connect with NAqDA for general aquaculture management, with the Department of Fisheries for canoe licensing, and with NGOs for funding community projects).

These adaptive institutions facilitate the co-management of CBF and allow Coastal-Vedda to co-learn with each other by practicing collective action and collaboration. Table S9 in the appendix highlights the characteristics of the co-management process of the Coastal-Vedda's CBF and the ways in which it advances adaptation. Furthermore, these local institutions create social space for the co-production of knowledge (Armitage et al., 2011) and the emergence of collective leadership (Lichtenstein and Plowman, 2009, Friedrich et al., 2016) required for community adaptation. Moreover, these adaptive institution levels and institutional robustness are similar to those found in other reservoirs in Sri Lanka where farmer organizations (small village reservoirs of under the

519 jurisdiction of Agrarian Development Department; (Kularatne et al., 2009)) and perennial
520 reservoirs (Kulatilake et al., 2010). The present study based on a resilience-based conceptual
521 framework indicates the uniqueness of the Vedda communities, whose norms are based on their
522 traditional culture, which are rapidly disappearing due to external forces.
523
524 Third, diversification is a common strategy across Coastal-Vedda responses in the aquaculture and
525 fisheries setting, livelihoods, institutions, knowledge systems, and learning opportunities. (Table
526 S8 in the appendix explains how types of diversification advance adaptation.) For example, in
527 broader developing context, households diversify income sources for two reasons: (a) people are
528 too poor (finances, power, skills, innovations) to specialize, and (b) people are wealthy enough to
529 invest and expand their portfolio of income (O. T. Coomes, pers. comm.). However, Coastal-
530 Vedda transformation in the face of livelihood distractions, social-marginalization, and
531 disempowerment due to governmental mega development projects and civil war hints at the
532 complexity of reasons for livelihood diversification. Also, diversification is a broad application
533 known to be a source of systems resilience and a means of adaptation in the context of climate
534 change impacts (e.g., small-scale shrimp farmers in northwestern Sri Lanka) (Galappaththi et al.,
535 2018). Nurturing diversity in a changing SES can increase creativity and adaptive capacity as well
536 as set the system for reorganization and renewal (Folke et al., 2003, Folke, 2016). We identified
537 diversification as an adaptive strategy used in combination with other strategies in a Coastal-Vedda
538 fisheries and aquaculture setting.
539
540 In addition to the three identified community adaptive strategies, we identified four place-specific
541 attributes that support adaptive strategies and shape community adaptation: Coastal-Vedda's
542 cultural identity and worldviews (Escobar, 2008), co-management of CBF (Galappaththi and
543 Berkes, 2015b), flexibility towards adaptation (Cinner et al., 2018), and ILK systems and learning
544 (Rodríguez et al., 2019) (Appendix—Table S10). Each attribute can support adaptation under the
545 given circumstances; e.g., Coastal-Vedda's cultural identity and flexibility in working with diverse
546 aquaculture stakeholders help support community CBF. Combined, these four attributes will
547 reduce systems' vulnerability and build the Coastal-Vedda fisheries system's resilience by
548 increasing adaptive capacity. Four attributes, together or in combination with identified adaptive
549 strategies, collectively influence the community's process of adaptation to change. For instance,
550 during the rainy season, Coastal-Vedda incur more damage from wild elephants, which can be
551 addressed in part by a broad range of adaptive responses such as: more reliance on CBF (for food),
552 the use of saved money to buy food, and the earning of money from other identified livelihood
553 activities.
554
555 **4. Conclusion**
556 In this paper, we examine how indigenous fishers experience and respond to environmental and
557 social stressors, including climate change, socio-economic change, and political change, by
558 assessing community adaptations of the rural Coastal-Vedda population in Sri Lanka. Coastal-
559 Vedda have multiple responses that help them adapt to these stressors. Our findings highlight three
560 adaptive strategies (adaptive multi-level institutional structure, aquaculture/CBF, and
561 diversification) as well as four place-specific attributes (worldviews, co-management, flexibility,

and ILK/learning) that shape community adaptation. Our study provides key insights for communities, scientists, and policymakers to improve community adaptation to increasing rates of global change: (1) Understanding how tropical indigenous fishers experience and respond to change is essential to improving adaptation; we suggest that such assessments can be carried out using the six characteristics of the resilience-based conceptual framework (place, human agency, collective action, institutions, ILK, and learning) that we developed. (2) Recognizing information required to link community adaptation realities to government plans (e.g., the National Adaptation Plan of Sri Lanka) can result in the development of a better fisheries adaptation policy (e.g., multi-level institutional structure) under the co-management of the CBF setting. (3) Understanding community adaptations can enable communities to self-evaluate their adaptation and adjust as needed. This may be particularly important for indigenous populations undergoing social transformation. Overall, the case study helps fill the empirical knowledge gap in climate change adaptation in the context of rural indigenous people and their small-scale aquaculture systems, as well as in how they respond to SES change until they find their new system equilibrium.

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