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

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7

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

27

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

30

31 **1. Introduction**

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

45
46 While empirical assessment of communities' adaptation to change is an increasingly active area
47 of research, little work focuses on indigenous peoples and culture-based fisheries (CBF)¹,
48 particularly climate change in eastern Sri Lanka. Studies do focus on other aspects of CBF
49 (Amarasinghe and Nguyen, 2009, Pushpalatha and Chandrasoma, 2010, Amarasinghe and
50 Wijenayake, 2015, Wijenayake et al., 2016) and climate change impacts (Yamane, 2003, De Silva
51 et al., 2007, Esham and Garforth, 2013) in Sri Lanka. The eastern part of the island has received
52 limited attention due mainly to its three decades of civil unrest (Lehman, 2014). Against this
53 backdrop, we use a case study from the Kunjankalkulam community in eastern Sri Lanka to assess
54 community adaptations to climate change in Coastal-Vedda fisher communities. The paper has
55 two objectives: i) examine how Coastal-Vedda fishers experience change, including climate
56 change; and ii) investigate how Coastal-Vedda fishers respond and adapt to such change. In the
57 next section, we describe Coastal-Vedda within the context of the indigenous populations of Sri
58 Lanka, and the study's conceptual and methodological approach. Following the 'methods' section,
59 we reveal means by which Coastal-Vedda fishers build resilience and minimise vulnerability (i.e.
60 adapt) to the impacts of climate change. Finally, we identify potential community adaptive
61 strategies and attributes that shape community adaptations in a CBF setting.

62

63 2. Methods

64 2.1 Indigenous peoples in Sri Lanka

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

76

77 Throughout the 19th and 20th centuries, the *Wanniya-laeto* were marginalised and forced to relocate
78 (Lund, 2000: 102) mainly because of (post)colonialism and development activities (Attanapola
79 and Lund, 2013). The Sri Lankan government is primarily responsible for marginalising and
80 disempowering the indigenous population, mainly by weakening the population's knowledge
81 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.

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

86

87 In this paper, we study ‘Coastal-Vedda’⁴, a group of *Wanniya-laeto* who migrated to eastern Sri
88 Lanka’s coastal areas. Historically, Coastal-Vedda moved within the forest in the eastern coastal
89 belt, fishing and cultivating vegetables around their huts and in clearings in the jungle (slash, burn,
90 and shifting to another area)—known as ‘Chena cultivation’ (Dharmadasa, 1993, Childs, 2017).
91 They cultivated maize, pumpkin, and other easy-to-grow crops. Later, Coastal-Vedda mixed with
92 the Tamil populations in the eastern area⁵. The main livelihood of the Coastal-Veddas living on
93 the seaboard was fishing in the sea or in lagoons (Seligmann and Seligmann, 1911, Dharmadasa,
94 1993). The others fished in tanks, rivers, and streams, using methods such as emptying water
95 courses, and using poisonous leaves and creepers. They used traditional fishing gear like *karaka*
96 and *kemana*, as well as made their own, such as cast nets, spears, and bifid iron spearheads.
97 Coastal-Vedda also use arrows as harpoons for fishing (Seligmann and Seligmann, 1911).

98

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

111

112 Kunjankalkulam is one of the few Coastal-Vedda communities in the region with a high level of
113 fisheries activity and high non-fisheries livelihood diversity. Coastal-Vedda use a village tank
114 (reservoir) to raise fish (i.e., CBF) as a main community livelihood activity. The community is in
115 a dry climatic zone where CBF is challenging. The north-eastern tropical monsoon and the weather
116 dynamics in the Bay of Bengal influence the region’s weather. Eastern Sri Lanka gets rain and
117 high winds between October and January and remains dry for the remaining months (especially
118 May through September). Rice farming is another essential livelihood activity, though unexpected
119 climate changes (mainly extended droughts) do not allow Coastal-Vedda to farm consistently.
120 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 coast’. 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.

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

124

125 2.2 Conceptual approach

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

136

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

150

151 2.3 Data collection methods

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

160

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

166 about Coastal-Vedda experiences and responses to change. As of March 2019, we had conducted
167 24 weeks of in-field PO during three visits to Kunjankalkulam and the surrounding area. The first
168 visit was in August 2016 and involved reconnaissance, preliminary data collection, and the
169 gathering of community feedback. The second visit was from September-December 2017 and
170 involved the collection of data about the Coastal-Vedda's CBF and how locals cope with the rainy
171 season. The third visit was from April-July 2018 and involved the collection of data about the
172 changes Coastal-Vedda face during the dry season and their adaptations. The researcher's daily-
173 updated field diary helped track PO data. The researcher spent much time with Coastal-Vedda
174 fishers, attending community events, meetings, and community-based institutions. The researcher
175 also made >20 fishing trips to the village reservoir and participated in most activities (e.g., fish
176 stocking, net setting, harvesting, and fish landing site activities).

177
178 Seventy-four face-to-face semi-structured interviews (SSI) (Longhurst, 2016) were conducted
179 with Coastal-Vedda fishers to document changes in the region and identify/characterize the
180 response to them (Appendix-Table S1-key themes of the interview guide). A snowball sampling
181 technique was used to select participants (3). Initially, the Coastal-Vedda leader introduced the
182 researcher to the community; the researcher made most appointments via cell phones and
183 sometimes by walking in. We recruited participants until saturation, when interviewees provided
184 no new relevant information (Bowen, 2008). These interviews were conducted, audio-recorded,
185 and transcribed in Kunjankalkulam from September 2017 through July 2018 (Appendix-Table S2-
186 sample profiles). The SSI questioning focused on "change" in general to prevent bias and to keep
187 the interviews open-ended, focusing on the issues and changes that Coastal-Vedda viewed as most
188 important. This sample consisted of Coastal-Vedda fishers who permanently live in
189 Kunjankalkulam. SSI obtained richer insights into 'place' and its meanings/attachments (Williams
190 and Patterson, 2008, Kaján, 2014). All the interview questions relating to 'change' referred to
191 "about 30 years back" in Coastal-Vedda's lives.

192
193 Thirty-eight key informant interviews (KIIs) were conducted and included questions about
194 Coastal-Vedda, climate change, and CBF. The goal was to examine topics not accessible via PO
195 and SSI, such as the Coastal-Vedda population (national indigenous chief and Ministry of Cultural
196 Affairs to find/verify the Coastal-Vedda community), co-management of CBF (e.g., NAqDA), and
197 adaptive responses (e.g., NGOs—non-governmental organizations) in the community. The
198 researcher conducted interviews with representatives from NAqDA (n=4), the Ministry of Cultural
199 Affairs (n=4), the Department of Fisheries-Batticaloa (n=2), the Divisional Secretariat Office-
200 Vakarai (n=1), the Ministry of *Mahaweli* Development and Environment-Colombo (n=6), the
201 Department of Meteorology-Batticaloa (n=1), the World Vision International Zonal Office-
202 Vakarai (n=1), the *Sabaragamuwa* University of Sri Lanka (n=1), and the University of the Visual
203 and Performing Arts-Colombo (n=1), as well as individuals with knowledge of Coastal-Vedda
204 (n=17). KII helped validate and describe data gathered using other methods.

205
206 Seventeen focus group discussions (FGD) (Carey and Asbury, 2016) were undertaken with 98
207 respondents to build thematic areas related to changes that Coastal-Vedda fishers experience (e.g.,
208 climate extremes, unpredictable weather patterns, increased human-elephant conflicts during the
209 post-war period) and to identify how Coastal-Vedda respond to such changes (e.g., collective
210 action and collaborations, community-based institutions, knowledge systems, and aquaculture).
211 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-perennial⁶ 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.

254 reservoir can no longer accommodate the seasonal water demand for rice farming due to extended
255 droughts. The reservoir is close to village housing and rice farms. With the support of the
256 government, fisheries and aquaculture institutions, and NGOs, an annual stock of eight varieties
257 of fish fingerlings (Appendix-Table S4-aquaculture species) grows in the natural reservoir system.
258 In 2017 this reservoir was stocked with 250k-300k fish fingerlings (tilapia, carp, and indigenous
259 fish) and 100k-150k freshwater prawn postlarvae. The estimated harvest for the year was 5-7k MT
260 fish and prawns. The peak season for fish harvesting is March-September; the offseason begins
261 with the heavy rains in October. In 2018 this reservoir received a pen culture system stocked with
262 100k fish fingerlings.

263
264 Coastal-Vedda practice two types of fishing activities. During the day, fisherwomen enter the
265 water to fish using rods (Appendix-Figure S1-photos). They fish mainly for subsistence purposes.
266 These locations change based on the reservoir water levels, which themselves depend on weather
267 conditions. The most commonly caught fish are tilapia and indigenous fish. During the day,
268 fishermen rest or engage in other livelihood activities. Fishermen go fishing in the early morning
269 (2-3 am) in deep areas of the reservoir, using canoes and gill nets. They look for commercial
270 species (e.g., freshwater prawns, well-grown carp and tilapia). They use some of the harvest (small
271 fish) for food purposes while selling large, high-quality fish to fish collectors (i.e., middlepersons
272 who collect fish every morning and supply it to large markets in urban areas).

273
274 The Coastal-Vedda fisheries system has place-specific vulnerabilities. Wild elephant attacks affect
275 the community's fishing activities and peak during rainy seasons. To repel elephants, fishers use
276 special firecrackers and create fires. The community also has an inoperable electrified fence. The
277 need to spend time and energy on wild elephants affects nighttime commercial fishing activities.

278 279 3.2.2 Human agency

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

284
285 Coastal-Vedda fishers engage in many livelihood activities to increase their income options in
286 adverse conditions (Figure 2). Some activities were historically practiced (*collecting* wild
287 honey/fruits/wood, hunting/trapping, chena/rice cultivation), while others are recent additions
288 (aquaculture, beach seine fishing, *selling* wild honey/fruits/wood, income support). These
289 activities reduce Coastal-Vedda reliance on CBF (or one specific livelihood activity) for food
290 security. Livelihood diversification decreases the opportunity cost of Coastal-Vedda's dependence
291 on CBF for food. Almost all (100%) the respondents were involved in CBF; 62% engaged in
292 fishing for commercial aquaculture and 38% were involved in subsistence aquaculture. Almost all
293 fishers involved in subsistence aquaculture were female. Gender roles are clearly set among
294 Coastal-Vedda; women are not directly involved in commercial activities including night-time
295 CBF.

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

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

303
304 We observed limited or no modern or advanced technology in CBF operations among Coastal-
305 Vedda. However, particularly after the war, Coastal-Vedda have been undergoing rapid social
306 modernisation (Latour, 2012), including the use of money (cash economy), modern clothing,
307 cement housing, a non-mobile lifestyle, cell phone use, aquaculture, and fish selling activities
308 (Childs, 2017, Ranasinghe and Cheng, 2018). Coastal-Vedda have limited access to credit
309 (personal loans) for CBF activities but can borrow money from informal money lenders. Coastal-
310 Vedda's CBF operation doesn't involve major expenses, with the exception of fish fingerling
311 stocking, which is funded by RFO, NGOs, and the government. Furthermore, through fisher
312 compensation programs, Coastal-Vedda can obtain low-cost canoes and fishing gear.

313 314 3.2.3 Collective action and collaboration

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

326
327 Also, groups of two to four Coastal-Vedda fishermen gather at night for commercial fishing
328 operations; they set their nets and share their income. A majority (over 90%) of fishermen said
329 they don't share large fish (of marketable size); however, they share small fish for food purposes.
330 Most fishermen (52%) will not share their fishing gear (gillnets, canoe). Only 15% of fishermen
331 said they would share. Within the sample of fisherwomen, 64% said they would share their gear
332 (fishing rods), while 25% said they would not.

333
334 Coastal-Vedda use informal social networks to share important information about CBF activities.
335 People—especially women—gather around the water well and drinking water tank to share daily
336 updates, including fisheries-related information (e.g., the quality of the fish harvest, who went
337 fishing/is planning to fish, and changes in fish prices) and non-fisheries-related information (e.g.,
338 alerts about wild animals). People also use informal social networks to share information about
339 extreme weather events. Most (89%) fishermen have cell phones. Among fisherwomen, 46% use
340 cell phones for communication. Informal social networks allow Coastal-Vedda to spread
341 information more quickly than formal methods of information sharing (e.g., monthly fisheries

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

344

345 3.2.4 Institutions

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

359

360 The Inland Fisheries Federation (IFF) is the regional-level aquaculture industry organisation. IFF
361 has significant control over the inland fish market price. The organization consists of leaders from
362 22 RFOs (e.g., the president). IFF charges RFOs a membership fee based on the reservoir size (Sri
363 Lankan Rupee equivalent to C\$23 for minor, C\$38 for medium, and C\$76 for major). IFF also has
364 annually appointed leadership positions: (vice) president, secretary, and treasurer. The president is
365 part of the National Fisheries Federation (NFF), which oversees national-level fisheries and
366 aquaculture concerns.

367

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

379

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

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

389
390 Figure 3 shows the multi-level institutional structure of vertically integrated fisheries associations
391 and government and non-governmental organisations (NGOs). Multi-level fisheries associations
392 are horizontally integrated with government institutions primarily for fisheries and aquaculture
393 management-related aspects (solid-line arrows) and with NGOs for specific project financing
394 aspects (dotted-line arrows). RFO is the key community institution representing Coastal-Vedda
395 with respect to CBF.

396
397 Now village reservoir is our main way of living ... we are planning to further increase our fish production
398 with the help of NAqDA and ... local NGOs ... I am glad they [NAqDA] help and consult us with
399 technical expertise ... Today ... [...] NGO donate five canoes and gillnets for our fishers, they [NGO] have
400 being helping us over the last year...—Coastal-Vedda chief

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402

403 3.2.5 ILK systems

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

408
409 Coastal-Vedda use various types of knowledge to cope with SES change. Table S5 in the appendix
410 illustrates selected types of knowledge that Coastal-Vedda fishers use. We have identified various
411 knowledge systems surrounding fishing spots, CBF operation, weather predictions, collective
412 action, and climate adaptation responses. Furthermore, we have recognised essential knowledge
413 for surviving in the 'place', such as knowledge about wild elephants and disaster/emergency
414 practices. All acknowledged types of knowledge are currently practiced by Coastal-Vedda fishers
415 and have been developed over the past three decades. Specific types of knowledge developed due
416 to Coastal-Vedda's exposure to long-term stresses such as climate change impacts (adaptation
417 knowledge) and war conditions (knowledge about disaster or emergency situations). Another sub-
418 set of knowledge (weather predictions) has been used and is evolving.

419
420 Moreover, Coastal-Vedda believe that aspects of their ILK system are weakening, partly due to
421 ethnic conflict and social modernization. Coastal-Vedda still possess specific knowledge that they
422 have gained over the generations but do not often practice it. For example, a lack of traditional
423 fishing and hunting activities results in weakened knowledge about making/using traditional
424 weapons (e.g., bow and arrow, spear). However, new knowledge about aquaculture can mitigate
425 the livelihood impacts of weakened knowledge, enhancing Coastal-Vedda's capacity to adapt to
426 SES change.

427
428 Now everything [has] changed. It is hard to predict weather, animals, even forest ... but we need to live.
429 The government and NGOs [are] giving us new knowledge that help to develop aquaculture—Elder
430 Coastal-Vedda

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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

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

481
482 We identified three key adaptive strategies of Kunjankalkulam Coastal-Vedda that construct the
483 community responses to SES change. First, we recognised CBF (or aquaculture) itself as an
484 adaptation strategy. Coastal-Vedda once had wild capture fisheries and engaged in chena
485 cultivation and rice farming; now they are involved primarily in CBF (De Silva et al., 2006,
486 Amarasinghe and Nguyen, 2009). This aquaculture is the best fit for the changes surrounding
487 Coastal-Vedda's SES, such as climate (e.g., cyclones, floods, and droughts) and way of life (e.g.,
488 non-mobile lifestyle). CBF can build more resilience among Coastal-Vedda than can other
489 livelihoods, as it: (i) reduces food insecurity by supplying consistent protein sources (Amarasinghe
490 and Nguyen, 2009), (ii) does not involve major investments (compared to intensive large-scale
491 aquaculture operations), with the cost of fingerling stocking borne by multiple funders (RFO,
492 NGOs, government) (Chandrasoma and Pushpalatha, 2018), and (iii) creates opportunities to
493 collaborate and co-learn with external information/knowledge sources. Globally, aquaculture is
494 identified as an adaptive strategy for climate change impacts and is included in some countries'
495 national natural resources strategies (e.g., Solomon Islands, Vanuatu, Timor-Leste, Fiji, and
496 Vietnam) (Bosma et al., 2012, Dey et al., 2016a, Dey et al., 2016b, Rosegrant et al., 2016).

497
498 Second, adaptive institutions with a multi-level institutional structure are the heart of community
499 adaptation. The key features of Coastal-Vedda adaptive institutions (Boyd and Folke, 2012,
500 Galappaththi et al., 2018) are: (i) RFO is the key community institution for CBF, representing all
501 Coastal-Vedda fishers, (ii) the presence of multi-level institutions (RFO—community, IFF—
502 regional, NFF—national) (Galappaththi and Berkes, 2014), (iii) the existence of mixed regimes of
503 community, government, and NGOs to fund culture-based fisheries systems (Galappaththi and
504 Berkes, 2015a), (iv) the bottom-up nature of functioning (feedback escalated from the community
505 level to the national level) (Galappaththi and Berkes, 2014), and (v) adaptive nature—multi-level
506 industry association structure collaborates/links with various stakeholder organizations (NAqDA,
507 Department of Fisheries, NGOs) based on need (e.g., connect with NAqDA for general aquaculture
508 management, with the Department of Fisheries for canoe licensing, and with NGOs for funding
509 community projects).

510
511 These adaptive institutions facilitate the co-management of CBF and allow Coastal-Vedda to co-
512 learn with each other by practicing collective action and collaboration. Table S9 in the appendix
513 highlights the characteristics of the co-management process of the Coastal-Vedda's CBF and the
514 ways in which it advances adaptation. Furthermore, these local institutions create social space for
515 the co-production of knowledge (Armitage et al., 2011) and the emergence of collective leadership
516 (Lichtenstein and Plowman, 2009, Friedrich et al., 2016) required for community adaptation.
517 Moreover, these adaptive institution levels and institutional robustness are similar to those found
518 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,

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

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