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Adaption planning to climate change in industrial fisheries: Progress in the Basque tropical tuna fishery

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ABSTRACT

Climate change impacts on ocean living organisms and ecosystems have flow-on effects on fisheries and their associated values. Industrial fisheries operate long distance fleets that potentially have the capacity to respond to such impacts by using technology and changing the timing and distribution of fishing effort. However, long-term adaptation to climate change in industrial fisheries entails larger structural changes that include adaptive management and international cooperation, where actors beyond the industry need to be engaged. How industrial fisheries are tackling adaptation to climate change is largely unknown, as is the role that actors in these systems undertake. In this study, we explored the Basque tropical tuna fishery to understand past and projected adaptation actions by each of the main actors in the fishery. We performed in-depth interviews with high-level representatives from 65% of the fishing industry, governments, research bodies, and non-governmental organizations of the Basque tropical tuna freezer purse seine fishery operating in the central-eastern Atlantic Ocean. We found that the fishery system has engaged in adaptation actions that seek to improve fishery sustainability, and that most adaptation actions are undertaken by the fishing industry. We also found that actors promote several types of adaptation actions such as practice change, and capacity building, among others, and that there is a lack of joint adaptation planning. We discuss the challenge in identifying suitable adaptation options to promote resilient and sustainable fisheries and to avoid losing their associated values.

1. Introduction

According to scientific evidence, the planet has already experienced 1 °C ± 0.2 °C of warming above pre-industrial levels [77]. In the marine environment, climate change is already modifying one widely valued marine ecosystem service; fisheries production [3,17]. Impacts include higher risk of at sea operations, the reduction of fishing days [37,87], or the redistribution of fishing effort [82]. It has been projected that catch potential will be redistributed globally, with decreases in tropical regions and increases in poleward areas [15,33]. Poleward latitudinal shifts of catches have been recorded for the three most important species of tropical tuna, i.e., Skipjack tuna *(Katsuwonus pelamis)*, Yellowfin tuna *(Thunnus albacares)* and Bigeye tuna *(Thunnus obesus)* in longline fisheries [64]. Abundance of these species is expected to change in the future, but patterns are mixed; for example, models project an increase of Skipjack global biomass between 2010 and 2050 and a decrease between 2050 and 2095 under a high emission scenario in the Atlantic Ocean (RCP 8.5) [22]. Erauskin-Extramiana et al. [25] project an abundance increase through to 2100 for both Yellowfin and Skipjack, but, newer research from Erauskin-Extramiana et al. [24] point to a general decrease in abundance and body size ratio of Bigeye, Yellowfin and Skipjack tuna stocks in the Atlantic.

Tuna fisheries are highly important since they provide a crucial source of protein and income for many developed and developing countries globally [60]. Tuna and tuna-like species are within the third most highly valuable fish group and among them, Skipjack and Yellowfin tropical tuna alone represented 58% of the total catch in 2018 [28]. A range of fleets, from artisanal to large-scale fisheries, targets these marine resources. Within the large-scale sector, tropical tuna freezer purse seiners funded by Spanish investment, which include Spanish and associated (or convenience) flagged vessels, are responsible for around 10% of the global tropical tuna catch and around two thirds

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of these vessels are supported with Basque capital investment [92,93]. In addition to the nearby Atlantic Ocean, these vessels operate around the world, and come under a range of management and jurisdictional bodies. In the Atlantic Ocean, the International Commission for the Conservation of Atlantic Tunas (ICCAT) is the Regional Fisheries Management Organization (RFMO) responsible for the management and conservation of tuna and tuna-like species. In the period 2013–2017, purse seiners, longliners, bait boats, and handliners accounted for 95% of the tropical tuna catch in the Atlantic, among which purse seiners corresponded to 46% (calculated from [46]). The Spanish flagged purse seine fleet was estimated to account for 18% of the tropical tuna catch in the Atlantic Ocean (calculated from [46,47]). The fleet mainly lands the catch in Abidjan in Ivory Coast and Dakar in Senegal, among other ports (e.g., Tema in Ghana, Mindelo in Cape Verde). Abidjan is the most important port where the highest amount of tuna landings, comprising small individuals and bycatch species, are destined for the local market as the so-called 'faux poisson' [31].

Changes derived from climate change in the oceans will have considerable socio-economic implications for the fishing industry and related sectors [16,17,54]. Fisheries catch potential is expected to decrease as much as 60% for some tropical regions under the most adverse climate scenarios [32]. The compound effects of ocean extreme events [41], together with ongoing impacts from marine species re-distribution [70,76] and productivity change [14], escalate the need for adaptation. Adaptation in social systems is defined as 'the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities.' [77]. Adaptation can be undertaken by individuals, organizations, institutions, and other forms of social entities [62,85]. Adaptation will be key to maintain seafood production and food security [5,32,43,89] and meet the Sustainable Development Goals [12,39,84].

Large-scale fisheries are seen as adaptable to changing conditions [4]; unfortunately, under rapid climate change, even being adaptable might not be sufficient and adaptation planning is required. Recent evidence points out that transformational adaptation will be needed in the fisheries sector in order to effectively address climate change impacts while assuring equity and sustainability in the longer term [10,42,77]. However, adaptation has so far failed to become a priority in fisheries management governance and practice [12,88]. This may be linked to existing knowledge gaps regarding implementation, monitoring, and evaluation of adaptation in the marine domain [9], but growing literature shows that there are steps that could be taken to adapt [6,40,51,57]. For industrial fisheries in particular, evidence of adaptation practice is scarce. One of the few examples in the literature is West African industrial fisheries, which have adapted by expanding fishing grounds at the expense of greater operating costs [4]. Our main goal is to address this gap by exploring what adaptation actions large-scale fisheries have undertaken and plan to implement in the future, and what kind of organizations develop them. This assessment of adaptation options is explored for the Basque tropical tuna fishery.

2. Material and methods

2.1. Case study description

Our case study focuses on the Basque tropical tuna freezer purse seine fishery (hereafter, the Basque fishery) operating in the Atlantic Ocean. Some climate change impacts on the fish and fishery have been documented. Rubio et al. [82] found that purse seine fisheries targeting tropical tunas shifted southward from the equator in the central-eastern Atlantic Ocean over the period 1991–2017. Ocean warming (i.e., an increase in sea surface temperature of 0.82 °C in the fishing area during the study period compared to reference levels), institutional, management and technological factors explained the observed shifts, with management identified as a powerful factor in distributional patterns. In fact, management and technology better explained the effort changes than sea surface temperature [82].

A focus on the Basque fishery in the Atlantic also provides an opportunity to explore how adaptation might relate to the cultural and economic dimensions of this large-scale fishery with more than 60 years of tradition [30] that is site-attached to the Basque territory where fishing company headquarters are located. Basque fishers who commenced their activity in the central-eastern Atlantic in the 1950 s originated from the long-standing small-scale fisheries activity of the Basque Country, whose historical documented roots date from the 14th century when fishermen guilds already existed [80]. Fishers exploring the central-eastern Atlantic obtained profitable catches, and a few decades later they expanded to the Indian and Pacific oceans and the industry developed to the current one based on highly technological freezer purse seine vessels [90].

Between 2013 and 2018, the Atlantic was the second most important ocean after the Indian, accounting on average for 33% of the Spanish and associated flagged vessels' catches (calculated from [93]). Here, we focus on the Atlantic Ocean, where the Basque fishery started its activity. Since its inception, the fishery has experienced important changes such as a shift in fishing mode from free school fishing to use of fish aggregating devices (FADs) (see main changes in Table 1) and a structural characteristic of the fleet is that it is highly mobile (see fishing area in Fig. 1).

2.2. Methodological approach

A range of organizational representatives are interviewed to investigate past and future adaptation actions in the Basque tropical tuna fishery. By means of in-depth interviews with high level representatives, we collect information on climate change perceptions and engagement in adaptation actions at the organizations level. The results illustrate the pathways for informing future implementation of adaptation actions in industrial fisheries.

We designed a questionnaire (available in the Appendix) for in-depth, semi-structured interviews with representative stakeholders of the Basque fishery operating in the Atlantic Ocean (Fig. 1). We used the social-ecological systems (SES) framework developed by Elinor Ostrom [61,68] to define all the potential organizations involved in the Basque fishery (Fig. 1 in [81]). In this regard, the fishery is understood as a system that includes the organizations and institutions involved in the fishery governance (hereafter 'organizations'). SES categories that helped identify organizations include 'resource users' (i.e., private companies, who perform direct harvest of tropical tunas in the Atlantic Ocean by means of freezer purse seiners, and their representative organizations) and the 'governance system' (i.e., governments, research bodies, non-governmental organizations (NGOs), and other non-profit organizations). We then classified these organizations into four types: fishing industry, research, government, and NGOs and others (i.e., other non-profit organizations).

As the objective of this article is to study adaptation actions performed by the fishery organizations, we interviewed one representative per organization. Thus, selected interviewees were high-level representatives, as they are most knowledgeable about their organization and the adaptation actions implemented, have the agency to implement the adaptation measures and have a role in designing and/or deciding future adaptation options. Potential representatives for the interviews were identified through the authors' professional networks and 'snowballing interview technique', where interviewees nominated other potential representatives from their network based on their experience and knowledge [11]. In total, 20 specific organizations were identified, which correspond to all the specific organizations directly related to the Basque fishery but excludes national governments at the international scale due to lack of access to representatives of these governments. Representatives from the ICCAT and the European regional level were contacted but did not agree to take part in the interview process. Participation was voluntary in order to comply with EU-H2020 Ethic

Table 1
Important changes experienced by the Basque fishery in the Atlantic Ocean since its inception.

Topic	Changes	References
Fish Aggregating Devices (FADs)	Shift of fishing mode from free schools to FADs since the 1990 s. During the 2013-2017 period around 80%* of the catch by the Spanish fleet in the Atlantic was on FADs. The main changes have been: • Increase in number of FADs and support vessels and associated environmental problems (e.g., marine life entanglement). • Fishing area expansion. • Permanent improvements in the FAD technology and associated knowledge adjustments by the fishing industry.	[34]; Lopez et al.[53]; Maufroy et al.[58]; Moreno et al.[65]; Murillas-Maza et al.[66]; Zudaire et al.[96]; *calculated from Pascual-Alayón et al.[69]
Technology	Technological advances occur in the fishery through digitalization and high-tech products are developed by the private sector (software development for route optimizations, catch zones detection, etc.).	Granado et al.[38]; Erauskin-Extramiana et al.[24]; Marine Instruments (2023); Maxar[59]
Economic Exclusive Zones (EEZs) and fishing agreements	Tuna catches in coastal EEZs have always been important for the fishery. During the 2013-2018 period around 58%* of the catch by the Spanish fleet in the Atlantic was within EEZs. Public (European Fisheries Partnership Agreements) or private agreements are negotiated to access foreign EEZs. The European Economic Community concluded one of its first bilateral agreements to access Senegal's EEZ in 1979. The adoption of the United Nations Convention of the Law of the Sea in 1982 established sovereignty of coastal countries over their EEZs.	European Commission,[26]; *calculated from ICCAT[47]
Associated flags	European rules limit the fishing capacity of all its fishing fleets so fishing companies use associated flags (vessel registration in other countries) to increase their fleet capacity. These arrangements also offer greater flexibility to access waters that European vessels cannot.	European Commission[27]
Management and reporting obligations	The ICCAT Recommendation 21-01 and others regulate the management of tropical tunas in the Atlantic Ocean. The reporting obligation and level of fleet control has increased in the last decades.	ICCAT[45]
Risks	Reputation, piracy, and overexploitation, among others, are pressing risks that did not exist or were less pressing at the beginning of the fishery. Efforts to improve sustainability are being made by the fleet (e.g., BIOFAD project, Fishery Improvement Project with the World Wildlife Fund for the East Atlantic Ocean tuna in 2017, Code of Good Practices including 100% observer coverage on vessels since 2012).	AZTI[1]; POSEIDON[78]; Ugalde and de la Peña[91]; Zudaire et al.[96]

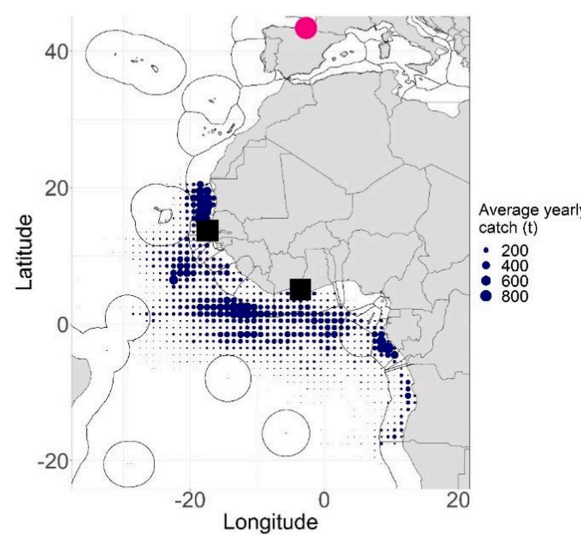

Fig. 1. Fishing area of the Basque fleet in the central-eastern Atlantic. Blue dots represent the average annual catch (metric tons) of the Spanish flagged fleet in the region from 1991 to 2018 [47], used as a proxy to know where the Basque fleet operates. Black squares represent the main landing ports (Dakar in Senegal and Abidjan in Ivory Coast) and the pink dot indicate the Basque region.

requirements.

After pre-testing the survey instrument with a small group of scientists and fishery experts, the in-depth interviews were conducted in a one-to-one fashion, in Spanish and with a duration of 1.5 h on average from January to April 2019. Each interview included two questions about perceptions of environmental change and attribution to climate change. First, respondents were asked about observed changes in the last 10 years regarding tropical tuna stock abundance, distribution and other risks associated with the fishery (e.g., weather risks, storms), which are or will be affected by climate change. Then, respondents were asked whether they attributed the previous three impacts to climate change using a 5-category Likert scale, ranging from 'not at all attributed to climate change' to 'extremely attributed to climate change' with an additional option of 'do not know'. These questions provide insight about their knowledge on general environmental phenomena and specific climate change.

Next, respondents were provided a list of potential adaptation actions, identified from the literature as specific adaptation responses to climate impacts on fisheries [4,18,50,73,74,95]. A total of 35 actions were identified (Table 2). This list of potential actions was classified in relation to the three previously defined impacts and linked to

Table 2
List of all adaptation actions identified from the literature and actions added during the interview process.

Action from literature	Action from interview
1. Stimulating domestic demand for a broader range of products (e.g. media campaigns)	1. Adapting to the reality of ICCAT limitations
2. Signing new private agreements	2. Improve scientific knowledge on fisheries, climate change, sustainability, etc.
3. Co-management between RFMO, governments and fishing actors	3. Assess, inform or define guidelines for the revision of fishing rights allocation
4. Investment in private research to improve the fishing sustainability	4. Include climate change considerations in the certification process in the future
5. Contracting insurances	5. Improve fishery's sustainability (certification, fishery improvement projects, etc.)
6. Spreading risk through cooperatives and alternative forms of financing	6. Improving RFMO management
7. Adaptive fishery management	7. Improving national management
8. Evaluate management strategies against (or not) climate scenarios	8. Financial support to promote sustainable fishing practices
9. Revise fishing rights allocation	9. Bycatch commercialisation
10. Pre-agreements, side payments, or transferable quotas among nations	
11. Climate adaptation fund creation	
12. Improving communication and information sharing on climate change and fisheries adaptation	
13. Spatial stock assessments	
14. Temporary moratorium on target species shifting into a new region	
15. Prioritize new target species for research (species shifting into a new region)	
16. Create Fisheries reserves (or networks)	
17. Re-evaluate and potentially move stock boundaries	
18. Weather warning system	
19. Permit or vessel buybacks, subsidy and other incentives reductions, other means of reducing overcapacity	
20. Programs to encourage accessing higher value markets, diversification of markets	
21. Information services for anticipation of market prices	
22. Programs to encourage and assist in diversifying livelihoods	
23. Developing projects and/or courses intended to foster fisheries adaptation and decrease social vulnerability to climate change	
24. Signing new Sustainable Fisheries Partnership Agreements	
25. Economic incentives to switch target species or use other gear. Which ones?	
26. Support for existing local management institutions (e.g. influx of new fishers)	
27. Diversification of markets and products	
28. Improve product quality and life	
29. Reduce costs to increase efficiency	
30. Switch to new target species (e.g. changing gear)	
31. Fish more quantities of other species (excluding BET, SKJ, YFT)	
32. Change fishing period	
33. Travelling further	
34. Fishing area expansion	
35. Searching for new ports (or helping to search)	

organization types so each respondent was confronted with actions that their organization could develop in practice as a response to defined impacts (Appendix Question 4). The option of selecting 'other' was always included to record any additional action suggested, which identified 9 new actions (Table 2). Two questions were formulated to record past and future adaptation actions depending on when each action was developed. First, respondents were asked about actions that their organization developed over the last 10 years in order to assess each of the impacts on the fishery (i.e., tropical tuna stock abundance, tuna distribution and other risks associated with the fishery). The words 'climate change' and 'adaptation' were not used at this stage of the interview to avoid response bias. Second, and using the same set of actions, respondents were asked to identify those that their organization will implement over the next 5 years, i.e., future actions. After choosing the set of actions already in place or to be implemented in the future, respondents were asked whether any of the actions were planned as a response to climate change. A final question on adaptation actions sought information about future potential adaptation options. Respondents were asked to select, from the complete list, the three most important adaptation actions to keep fishing activity sustainable in the future. These questions were recorded at the organization level, since representatives are knowledgeable about actions implemented by their organizations.

To summarise adaptation responses from each interview, we classified past and future adaptation actions based on Pecl et al. [71] and Biagini et al. [8]. We selected the four relevant adaptation behaviour categories applicable to our case study: capacity building (human or social resources or capital), financing (adaptation related financial strategies), practice change (changes in or expansion of practice or behaviour), and management and planning (governance and institutional management and planning) [8].

Finally, in order to better understand the implications of this industrial fishery's adaptation, we asked interviewees about which economic and cultural values they perceive the fishery generates. We used five cultural services categories for fisheries used by the [29] from an ecosystem services perspective (de Groot et al., 2012), and two separate economic options that are important within the case study [90]. The FAO cultural options were: 1) recreational activities; 2) tourism, as an enjoyment of nature, landscapes, villages etc. benefiting visitors; 3) inspiration for culture art and design; 4) traditional knowledge and associated customs (e.g., festivals, culinary traditions, proverbs); and 5) sense of belonging and individual identity. The two general economic options potentially generated by the fishery are job positions and private business (i.e., private companies). The cultural and economic options were provided to respondents as a list so they could value the generation of each of them in the fishery, according to a qualitative 5-category Likert scale that ranged from 'not generated at all' to 'extremely generated'.

Responses to all the questions described above were tabulated using the R Environment for Statistical Computing [79] in 2019. Some qualitative information provided during interviews is included in the discussion as 'personal communication' with the intention of enriching the results. The scripts for data analysis and visualization are available in GitHub, which were last updated in 2023 (see data availability statement).

3. Results

A total of 13 in-depth interviews (11 in person and 2 video calls) were carried out with organization representatives from the Basque fishery (Table 3). This constitutes 65% of the institutions that conform the case study fishery system (see Fig. 1 from [81]). All participants were male between 35 and 64 years old and their mean level of experience in the Basque fishery was 15 years.

Perceptions about changes occurring in the fishery during the last 10 years covered all possible answers and varied by organization type

Table 3
Organization representatives interviewed by social-ecological system (SES) category [61,68], organization type (with number of specific organizations identified within the SES), and position (with number of representatives for each position).

SES Category	Organization type (number identified)	Position of representative (number interviewed)
Governance system	Government (4)	Division director (2)
	Research (2)	Coordinator of research area (1)
		Principal researcher (1)
	NGO, others (8)	Division vice president (1)
		Fisheries area coordinator (2)
Users	Fishing industry (6)	Managing director (4)
		Deputy director (1)
		Area director (1)

(Fig. 2). At least half of the respondents stated that they did not know if changes in stock distribution have happened for the tropical tuna fishery, and the remaining respondents either stated that there has been natural variability or a latitudinal spatial shift. Most respondents agreed on a general decrease and natural variability in stock abundance. One respondent stated that an abundance increase had occurred (fishing industry), one had not perceived any changes (fishing industry) and a third one did not know (NGO, others). Perceptions on the risks associated with the fishery varied greatly and were almost equally distributed for all options (Fig. 2).

When asked to consider whether the observed impacts (i.e., fishery risks, stock abundance and distribution) can be attributed to climate change (Fig. 3), most respondents perceived stock distribution changes as caused by climate change. Attribution to climate change of stock abundance and risks in the fishery activity varied broadly across respondents. While some respondents in the fishing industry attributed stock abundance changes 'very much' or 'extremely' to climate change, researchers only reported a 'moderate' attribution (Fig. 3).

From the 35 adaptation actions identified in the literature, the system has implemented a total of 20 different actions in the past (Table 4), from which 10 have been done only by the fishing industry. Most of these actions were included in the 'practice change' category, which accounts for 11 out of 20 actions. The remaining actions fall within the categories of 'financing', 'capacity building' and 'management and planning'. As explained in the Methods, each respondent received a list that only included actions that their organization could perform (e.g., NGOs were not given the option of expanding the fishing area) (see Appendix Question 4 list), and therefore few respondents chose the same actions in Table 4.

Regarding the extent to which these adaptation actions have been or are part of adaptation planning, results show that the vast majority of actions correspond to autonomous adaptation [71], since only one action was consciously planned taking into account climate change, i.e., *improving scientific knowledge on fisheries, climate change, sustainability,* etc., by research organizations.

All organizations in the fishery will implement adaptation actions in the next five years (Table 5) that differ from the actions applied in the past. From these six new planned actions, only two are consciously conceived and planned in response to climate change. The organizations

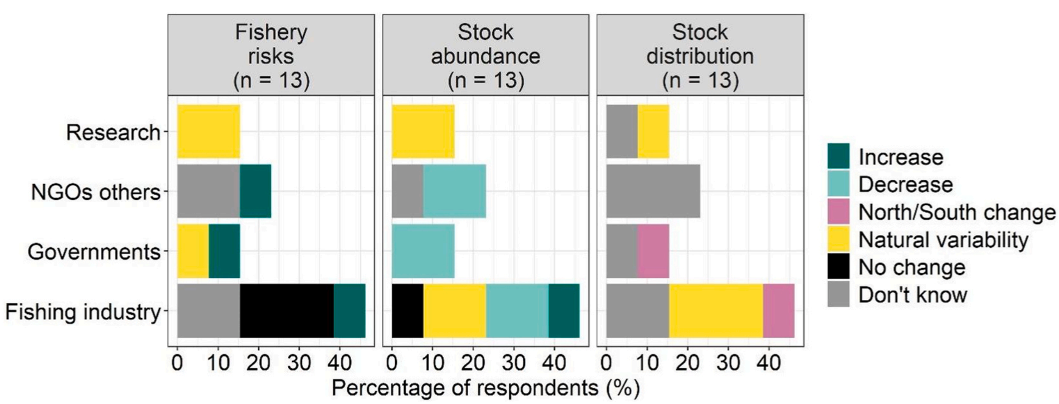

Fig. 2. Perceived changes of the fishery risks (e.g., weather risks, storms), tropical tuna stock abundance and stock distribution over the last 10 years by organization type. Six response options were available: impact increase, impact decrease, natural variability of changes, north/south change of stock distribution, no change observed and do not know if changes have occurred. An additional east/west option was available for stock distribution change but no respondent selected it.

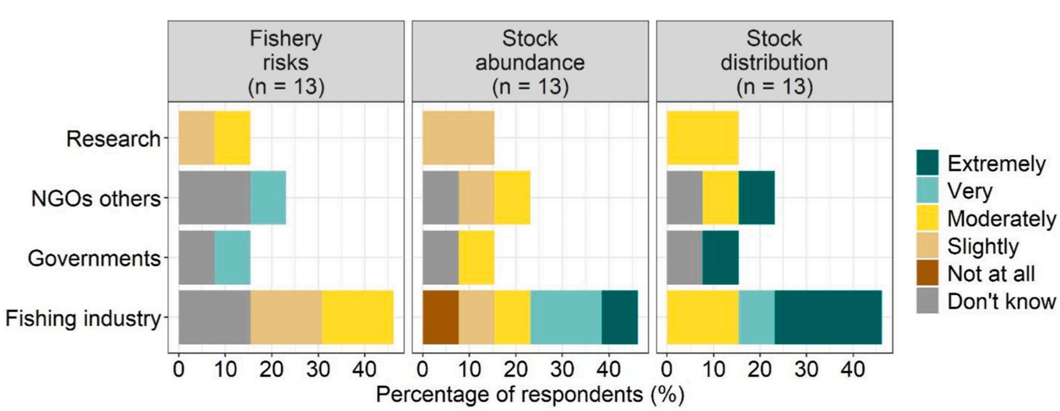

Fig. 3. Degree of climate change attribution of changes in fishery risks, stock abundance and distribution to climate change by organization type. Six response options were available from 'not at all attributed to climate change' to 'extremely attributed to climate change' with an additional option of 'do not know' if the perceived impact was attributed to climate change.

Table 4
List of past adaptation actions undertaken by organization groups in the fishery by type of adaptation (grey cells). Numbers within cells indicate the percentage of respondents in a group having planned an action. Starred cells indicate actions that were designed to address climate change impacts.

Form of adaptation behaviour	Action	Fishing industry	Government	Research	NGO, others
Practice change	Stimulating domestic demand for a broader range of products (e.g., media campaigns)	17 %			
	Signing new private agreements	67 %			
	Investment in private research to improve the fishing sustainability	100 %			
	Diversification of markets and products	67 %			
	Improve product quality and life	50 %			
	Reduce costs to increase efficiency	50 %			
	Bycatch commercialization	17 %			
	Travelling further	33 %			
	Fishing area expansion	50 %			
	Searching for new ports	50 %			
	Improve fishery's sustainability (certification, fishery improvement projects, etc.)	100 %			67 %
Financing	Contracting insurances	33 %			
	Financial support to promote sustainable fishing practices		50 %		
Management and planning	Permit or vessel buybacks, subsidy and other incentives reductions, other means of reducing overcapacity		50 %		
	Signing new Sustainable Fisheries Partnership Agreements		50 %		
	Evaluate management strategies against (or not) climate scenarios			50 %	33 %
	Spatial stock assessments			100 %	33 %
Capacity building	Assess, inform or define guidelines for the revision of fishing rights allocation			100 %	67 %
	Improve scientific knowledge on fisheries, climate change, sustainability, etc.			100 %*	
	Support for existing local management institutions		50 %		

Table 5
List of future adaptation actions planned by organization groups in the fishery by type of adaptation (grey cells). Numbers within cells indicate the percentage of respondents whose organizations have planned an action. Starred cells indicate actions that are designed to adapt to climate change.

Form of adaptation behaviour	Action	Fishing industry	Government	Research	NGO, others
Practice change	Change fishing period	17 %			
	Reduce costs to increase efficiency	17 %			
	Adapting to the reality of ICCAT limitations	17 %			
	Include climate change considerations in the certification process in the future				33 %*
Management and planning	Revise fishing rights allocation		50 %		
	Preagreements, side payments, or transferable quotas among nations		50 %		
Capacity building	Improving communication and information sharing on climate change and fisheries adaptation			50 %*	

engaged in these actions are research, NGO, and other non-profit organizations, and the specific actions are to *include climate considerations in the certification process* (NGO and other non-profits), and to *improve communication and information sharing on climate change and fisheries adaptation* (research organizations).

Responses about cultural and economic values generated by the fishery are included in Fig. 4. According to the respondents, the Basque fishery generates traditional knowledge and associated customs (e.g., festivals, culinary traditions, proverbs), as well as sense of belonging and individual identity. Inspiration for culture, art and design spanned from 'slightly' generated to 'very' much generated, but most respondents nominated this option as 'moderate' or 'slightly'. Recreational activities and tourism were generally seen as services that are not generated by the fishery. All respondents clearly agreed that jobs and private business are highly generated by the fishery, and in most cases they valued these contributions over the cultural services.

Fig. 4. Degree of generation of cultural and economic values in the Basque fishery by organization type. Five response options were available from 'not generated at all' to 'extremely generated' by the fishery.

Finally, respondents chose the three most important adaptation actions in order to keep the fishery in the future. Table 6 shows future potential pathways in the fishery by illustrating these preferred adaptation actions. *Co-management between RFMO, governments and fishing actors* was the most chosen action; almost all respondents (77%) agreed that this action was important to sustain the fishery in the long term. Then, *investment in private research to improve the fishing sustainability* (38% of respondents*); adaptive fishery management* (23%) and *evaluation of management strategies against (or not) climate scenarios* (23%) were rated next in importance.

4. Discussion

Based on in-depth interviews with high-level representatives of the Basque fishery in the Atlantic Ocean, this study shows that the fishery system is currently undertaking many of the adaptation actions reported in the climate change literature. In fact, since its inception the fishery has been adjusting to changes in the environment, such as where the fleet fishes, increasing fishing pressure, responding to management changes, implementing technological improvements and a move to FAD dominance [49,53]. However, very few adaptation actions were found to be designed via adaptation planning; the fishery is undertaking autonomous adaptation.

Table 6
List of adaptation actions seen as most important for the fishery ordered by frequency of selection. Three actions per respondent were selected; the total number of actions is 39 but only actions selected more than once are shown here (see complete table in Appendix Table 1). The action starred was omitted from Table 4 even if selected as past adaptation action because of discrepancies about its meaning among respondents (see interpretation in the Discussion section).

Action	Organization type who chose the action	Percentage of respondents who chose the action (n = 13)
Co-management between RFMO, governments and fishing actors*	Governments; Research; Fishing industry; NGOs others	77%
Investment in private research to improve the fishing sustainability	Fishing industry	38%
Adaptive fishery management	Research; NGOs others	23%
Evaluate management strategies against (or not) climate scenarios	NGOs others; Research	23%
Signing new private agreements	Fishing industry	15%
Spatial stock assessments	NGOs others	15%
Signing new Sustainable Fisheries Partnership Agreements	Governments; Fishing industry	15%
Reduce costs to increase efficiency	Fishing industry	15%

Adaptation planning has been only undertaken by research bodies, NGOs and other non-profit organizations. Governments and the fishing industry have initiated many adaptation actions as autonomous adaptation [44]. According to Smit and Wandel [85], it is extremely unlikely for adaptation actions to be taken in light of climate change alone, which is consistent with this study. Nevertheless, this is recently changing, with growing examples of adaptation planning in other fisheries to directly tackle climate change (e.g. [56]). Few adaptation planning in the Basque fishery might be explained by the existing uncertainties in the knowledge about impacts of climate change in tropical tunas. While various changes in distribution and abundance have been observed and projected [22,24,25], a lack of consistency between studies may limit the use of this information by fishery organizations seeking to develop adaptation strategies. Báez et al. [2] point out a deficit of information on the potential effects of climate change on tropical tunas in the Atlantic Ocean. In fact, our interviews showed that perceived impacts differed for organization representatives. For example, one representative perceived that the stock abundance had increased over the last 10 years, while others perceived a decrease. In addition, more than half of the organization representatives did not know if stocks are shifting their distribution in the Atlantic Ocean. The few existing articles addressing ecological to social impacts and implications of climate change for tropical tunas in the Atlantic Ocean are relatively recent, from 2014 to 2023 (i.e., [21,22,24,82]). In addition, organizations can check or be informed by annual scientific reports of the ICCAT, where information on stock assessments and status is gathered (e.g., [48]). A question that arises is whether scientific results are being efficiently spread among organizations. Many scientific bodies are already advancing knowledge on climate change and fisheries sustainability, and plan additional efforts to disseminate information about climate change to the general public, which could help improve awareness (e.g., [52]), and to the organizations [88]. This information transfer will be key for future adaptation in this particular fishery.

Additional actions may emerge in the future, such as revising the allocation of fishing rights as abundance or distribution of the target species changes [32,67]. The fishing industry might be at risk if it is not capable of adapting to new management rules from the ICCAT, which are becoming more restrictive through time seeking sustainability of tuna fisheries [94]. In the past, stakeholder involvement has been limited in the ICCAT [72], where decision-making comes from agreement of participating nations, who, in turn, need to enforce the international rules on the fishing industry [7]. Thus, when perceptions of the local industry differ from the international view, scale mismatches might affect adaptation success. This mismatch could be overcome by means of management strategy evaluation (MSE), which is amenable to stakeholder involvement [35]. The ICCAT is putting efforts on a MSE work plan [35]. This approach will allow evaluation of harvest control rules and effectiveness of alternative harvest strategies. Holistic strategies and stakeholder diversity is seen as key to implementing inclusive climate adaptation strategies [55,83], which is a challenge in international fisheries [35]. Importantly, the majority of the organization representatives in the Basque fishery do think co-management is the most important adaptation action for the future of the fishery. Interviews revealed that co-management might partially exist at local to national scales (or connections allowing to develop it are already established), and organizations are willing to take part in collaborative approaches. However, more effort is needed at the international scale for stakeholder involvement to become a reality. In this regard, one organization representative was very sceptical about co-management being possible in international fisheries. The involvement of the RFMO and regional level governments in this study (or others), which is its biggest limitation, could have enlightened and enriched this discussion.

A hot topic for international large-scale fisheries is the access to EEZs of countries that differ from flag countries. The Basque fishing industry has already negotiated private agreements and institutions have signed public ones, which have been recorded as adaptation actions. However, we do not know if the flexibility of these agreements is enough to follow shifting stocks. For that purpose, adaptable agreements between countries will be a necessity [62,74,75]. Usually, governments and the fishing industry make large economic investments to access foreign waters (e.g., [26]). Thus, countries that might lose the fish, might also lose agreements and hence economic and social benefits if fleets shift to other countries. In general terms, opportunities might arise for other countries and then conflict over the fishing access could emerge [20,86].

Apart from the economic and local livelihood risks, food security and social aspects might be also affected if fish move, and interactions between long-distance fisheries and local communities within certain EEZs might be lost. In Abidjan for example, the Spanish fleet (and thereafter the Basque fleet) has landed an average of 6635 annual tons of small tunas since 1991 [31]. Part of this ‘faux-poisson’ is directed to other cities in Ivory Coast, or to other countries like Burkina Faso or Mali for local consumption [23,63]. The ‘faux-poisson’ landed in Abidjan is mainly used by restaurants which sell a national food called ‘garba’ (cassava semolina and fried tuna), that generates between six and nine thousand jobs accessible to almost all the population and contributes to food security [63]. Other relations between the Basque fishery and, for example, a local association of fish processing women in Abidjan, the African Confederation of Artisanal Fisheries Organizations (CAOPA), and the Dakar maritime school (fishing industry, personal communication), would also be at risk. These and other interactions between foreign and local fleets and markets at the EEZ level are less known in the scientific literature and should be further explored in the context of climate change adaptation; ad further analysis could not only include the fishery system where the industry is based, but the broader system with the inclusion of third countries where the fishery operates.

The importance of marine resources in sustaining human well-being at local scales [71] is also supported by our results. Apart from the economic value and jobs the Basque fishery generates [36,90], the fishery actors perceive social and cultural benefits, based on traditional knowledge and associated customs (e.g., festivals, culinary traditions, proverbs) and sense of belonging and individual identity in the region where fishing companies are based. The project Bermeo Tuna World Capital [13] is an example of how the fishery promotes social values. These social values might be very localised in Bermeo town where the majority of the fishery activity is promoted, as opposed to the rest of the Basque country where tuna products (e.g., cans) are generally bought without knowledge of the fishery - an impersonal product of a globalised market.

Finally, a concern arising from this study is what adaptation actions would be suitable for industrial fisheries. Adaptation options should be compatible across multiple scales to promote resilient and sustainable fisheries, which is a challenge in international fisheries where many organizations at different levels play a role. Inclusiveness across stakeholder groups involved in the management and decision-making process should be sought when seeking the best adaptation actions. The case study approach illustrates a concern about attaining co-management in industrial fisheries, which requires integration of stakeholders and scientific advice. We argue that economic and cultural values associated with these fisheries also need to be considered when developing adaptation actions, with the goal of avoiding total transformation or disappearance of a fishery and its associated values due to climate change impacts. This engagement process will depend on the region of focus and the associated impacts for the fishing community as well as the related impacts to other affected communities elsewhere.

5. Conclusion

Evidence of adaptation practice is still scarce in many ocean regions, and this study shows the efforts underway in an industrial fishery that can be used to understand why progress may be slow. Climate change is an additional threat alongside other economic and social changes that fisheries currently confront, and given the uncertainty in climate impacts, it is not surprising that we found few adaptation planning in the Basque tropical tuna fishery. However, many adaptation actions were ongoing, consistent with a fishery that has been adjusting to many changes over time. Given the rate of ongoing climate change, it was encouraging that some adaptation actions seeking a sustainable fishery were found for all organization types.

CRediT authorship contribution statement

All authors have accepted responsibility for the entire content of this manuscript and approved its submission. All authors made a significant contribution to the conception, design, execution and interpretation of the study.

Declaration of Competing Interest

None.

Data availability

The data and code that support the findings of this study are available in ‘tropituna_adaptation’ at https://github.com/irrubio/tropituna_adaptation and https://zenodo.org/record/8083597.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2023.106001.

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