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Integrating Fishers' Knowledge Contributions in Marine Science to tackle bycatch in the Bay of Biscay

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Author contribution statement

- C. C. did the bibliographic research and wrote the article.
- J. R. assisted in the writing and literature search.
- A.D. provided assistance with the bibliography.
- C. M. is the research project leader and assisted with the bibliography.

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bycatch, Fishers, knowledge, co-creation, conflict

Abstract

Word count: 337

The issue of bycatch is raising considerable political, mediatic and scientific attention. Bycatch is one of the main causes of at-sea mortality for small cetacean species and for seabirds. Scientists are raising alerts regarding the potential effects on the structure of the ecosystem, increasingly aiming for research-action. Decision-makers are facing a political trade-off, with increasing pressure from the European Commission and international nongovernmental organizations to implement mitigation measures such as space-time closure of the fisheries, which could present a risk of altering the well-being of the fishing industry in the short-term. The process of co-creation of knowledge on bycatch is key to understand better the fishers-species interactions and to develop regulations that are adapted to local specificities, towards an adaptive and inclusive socio-ecosystem-based management of the fisheries. But the knowledge co-creation process is hindered by tensions between the interests of stakeholders, the climate of mistrust, dense media coverage and power asymmetries between actors. In parallel, the fast rate of biodiversity degradation is calling for the rapid development of regulations. Understanding the complex system dynamics highlighted by these conflicts requires an analysis of the socio-political dimension of the interactions between fisheries and marine biodiversity. Based on a series of ethnographic interviews with the different stakeholders involved in the bycatch mitigation projects in the Bay of Biscay, this paper explores how co-creating knowledge through conflict and collaboration between researchers and fishers can generate collective learning for bycatch mitigation policies. We adopt an epistemological approach, with the objective to promote transparency in the exchange between researchers and fishers and to inform decision-making at various scales of governance. We argue that co-creation of knowledge should not aim for consensus. We conclude that acknowledging the presence of conflicts between the stakeholders, and understanding their roots and their impact on the co-design process can allow identifying factors of path-dependency hindering the adaptive capacity of institutions. Moreover, we highlight the key role of the fishers' representative bodies in knowledge co-creation, and the importance to improve our understanding of fishers' perception of their political representation.

Contribution to the field

In this paper, we explore how co-creating knowledge through conflict and collaboration between researchers and fishers can generate collective learning for bycatch mitigation policies. We adopt an epistemological approach, with the objective to promote transparency in the exchange between researchers and fishers and to inform decision making at various scales of governance. We present a diagnosis of the interactions between fishers and scientists with regards to bycatch mitigation projects in the Gulf of Biscay. More specifically, we analyze the political and scientific approaches of integrating fishers in knowledge production and in decision making on bycatch mitigation. How do decision-makers, fishers and researchers interact to evaluate the options to reduce bycatch? How do they analyze and compare the sets of policies, techno-economic and behavioral options to reduce bycatch? We also explore the evolution of the cooperation dynamics between the different stakeholders, and the main sources of tension arising from collaborating on bycatch mitigation projects. We aim to highlight key lessons and research gaps for the future research on bycatch policies.

1 Integrating Fishers' Knowledge Contributions in Marine Science to tackle bycatch in the Bay 2 of Biscay

3

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6

7 **Abstract**

8

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10 causes of at-sea mortality for small cetacean species and for seabirds. Scientists are raising alerts regarding the
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29 institutions. Moreover, we highlight the key role of the fishers' representative bodies in knowledge co-creation, and
30 the importance to improve our understanding of fishers' perception of their political representation.

31

32

33 **Introduction**

34

35 The impact of bycatch, or the incidental capture of non-targeted species in commercial and recreational fisheries
36 (Rouby et al., 2022) raises concerns regarding biodiversity conservation (Hall et al., 2000). Bycatch is one of the
37 main causes of at-sea mortality for small cetacean species, such as the common dolphin (*Delphinus delphis*) and
38 the harbour porpoise (*Phocoena phocoena*), but also for seabird species (Dias et al., 2019; Rouby et al., 2022).
39 The socio-genesis of bycatch as a political issue in France can be traced back to the emergence of whistleblowers
40 in the 1970s, as scientific concerns grew on marine biodiversity degradation. Prior to this, the interactions between
41 fishers and the marine megafauna were only considered by most actors as competition for the same food
42 resources, and cetaceans were sometimes hunted and consumed (Fishou and Levasseur, 2004). The cetacean
43 strandings have started to be recorded as statistical data by the *Réseau National Échouage* (RNE), a participatory
44 science program created in 1972, forming a network of 350 correspondents, which documents the spatio-temporal
45 trends in stranding numbers. The RNE is steered by a committee of scientists, managers and correspondents
46 elected within the network, and it is coordinated by the Pelagis observatory, a research unit whose main missions
47 are to support research in marine megafauna ecology and public conservation policies (Dars et al., 2020). From
48 1970 to 1993, 4,627 cetacean strandings were reported on the French Atlantic and Mediterranean coast (Collet
49 and Mison, 1995). It was not until 1989 that researchers, noticing a significant increase in the number of cetacean
50 strandings, became interested in the correlation with accidental captures (idem). This correlation was later
51 confirmed by the Pelagis observatory, which concluded that 60% and, during peaks of strandings, up to 90% of the
52 animals autopsied have traces of fishing gear (Peltier et al., 2019). In the Bay of Biscay, dolphin stranding increased
53 significantly from 2016 onward, most of them with evidence of having been bycaught. The size of the bodies, the
54 contemporary western cultural significance of the species, and the communication work of marine conservation

55 organizations such as Sea Shepherd contributed to make the strandings a visible impact of fisheries on marine
56 biodiversity.

57
58 The scientific concerns regarding the bycatch of seabird in France emerged in the French Southern and Antarctic
59 Territories (TAAF) with the shift from bottom trawls to longlines for the fishing of the Patagonian toothfish in the
60 1990s, which led to a significant increase in the bycatch of three species of albatrosses and four species of petrels
61 (Cherel et al., 1996 ; Tuck et al., 2003). The strong presence of scientists on the territories since the 1960s
62 contributed, among other factors, to the estimation of the long and short-term trends in the species populations and
63 to the identification of the vessels responsible for bycatch (Rolland, Weimerskirch and Barbraud, 2010 ;
64 Weimerskirch, 2018). In the Atlantic coast, the first scientific projects to study the interactions between fishing
65 activities and protected seabird species only started around 2010, thus little is known yet about the bycatch of
66 seabirds in the area.

67
68 A normative framework aimed at mitigating bycatch was established at the European level and then at the national
69 level in French law (Figure 1). In 1992, when concerns arose regarding the impact of driftnets on dolphin and
70 seabird populations, the Commission of the European Communities decided to prohibit "any vessel from carrying
71 on board or engaging in fishing activities with one or more driftnets whose individual or cumulative length exceeds
72 2.5 kilometers" (OJEC, 1992). This ban met a lot of resistance from the fishers and led to unintended
73 consequences. Once driftnets were banned, fishing activity was shifted offshore by long-lining, where other species
74 such as albatrosses and petrels started to be affected by bycatch (Euzen et al., 2017). Another European regulation
75 was implemented in 1997 to ban the use of driftnets for the capture of certain migratory fishes such as albacore
76 (*Thunnus alalunga*) and bluefin tuna (*Thunnus thynnus*) starting from 2002 (OJEC, 1997). It was not until 2011 that
77 French law transposed the European driftnet regulations (JORF, 2011a). Another ministerial order was issued in
78 2011, to determine the list of marine mammals protected on the national territory and the modalities of their
79 protection (JORF, 2011b). In 2019, a bycatch reporting requirement for fishers was introduced, requiring ship
80 captains to report protected marine mammal specimens caught accidentally in fishing gear (JORF, 2018). The
81 information provided by fishers is intended to advance research into the understanding and characterization of
82 incidental catches, with the aim of preventing them. This declaration can be made through a digital declaration for
83 vessels of more than 12 meters equipped with an electronic fishing logbook, while smaller vessels can use fishing
84 paper's sheets (Ministry of Agriculture, 2022). Finally, from 26 December 2019, fishers have the obligation to equip
85 pelagic trawls with acoustic deterrent devices, also called pingers, in the Bay of Biscay (JORF, 2019).

86
87 **Figure 1 : Evolution of European and national policies regarding the incidental capture of seabirds and**
88 **cetaceans**

89
90 Despite the measures taken, the bodies of small cetaceans are regularly washed ashore, most of them with
91 evidence of having been bycaught, and decision-making authorities are pressured by the European Commission
92 to accelerate the mitigation of bycatch through the regulation of fishing practices. On 2 July 2020, the European
93 Commission issued letters of formal notice to Sweden, Spain and France for failing to correctly transpose the
94 obligations related to the Habitats Directive regarding the establishment of a coherent monitoring scheme of
95 cetacean bycatch and the subsequent taking of conservation measures (Autier et al., 2021). On 15 July 2022,
96 considering that France and Spain had not taken the necessary measures since their letter of formal notice, the
97 European Commission sent them a reasoned opinion requesting that the two countries take the necessary
98 measures to "prevent the incidental catch of dolphins and other protected species" within two months (European
99 Commission, 2022). If France is still considered to fail to comply with its obligations after this date, the Commission
100 may decide to refer the matter to the Court of Justice, a process which may entail financial sanctions, which can
101 be a lump sum and/or a penalty payment, in case of sustained failure to comply with the European regulations.

102
103 The bycatch of seabirds in the Bay of Biscay are subject to significantly less legislative and political attention. Since
104 the Bird Directive was established in 1979, there are no hard laws intended to reduce seabird bycatch in France,
105 except the regulations regarding the use of driftnets. Fishers are not required to declare the catches of marine bird
106 species nor to equip their vessels with repellent devices.

107
108 The main policy options to improve the selectivity of the fisheries operations are the implementation of technical
109 measures, and the adjustment of when and where the fishing effort takes place (Calderwood et al., 2021), such as
110 through space-time closure of fisheries, or through the closure of an area in a fishery to one or more gears for a
111 temporary period when a bycatch threshold is reached (Dunn, Boustany, and Halpin, 2010). Technical measures
entail the deployment of repellents on other vessels than the pelagic trawls and the change of fishing practices.

112 The measures are evaluated according to numerous factors such as estimated impact, management complexity,
113 socio-economic impact, and financial investment.

114 The technical devices tested showed mitigated results. The effectiveness of the pingers was demonstrated for
115 pelagic trawls (Morizur et al., 2012). The Necessity project showed a decrease in yearly common dolphin bycatches
116 of about 70%, but the number of observations had to be doubled to hope to show a significant difference in the
117 confidence intervals (Morizur et al., 2008). The PIC project showed a significant reduction in common dolphins
118 bycatch of around 65% (Le Gall, 2020). The devices were first set up voluntarily and then made mandatory.
119 Numerous projects were implemented by the fishers' representatives in partnership with scientists to test pingers
120 on nets, but the repellents tested did not yet demonstrate their effectiveness (Morizur et al., 2009). In some cases,
121 pingers on gillnets even present the risk to attract marine mammals such as the gray seal, who learn to associate
122 the pinger sound with the fishing gear and easily accessible food resource, an unintended consequence that is
123 called the "dinner bell effect" (Carretta and Barlow, 2011). Pingers can also increase the risk of excluding harbor
124 porpoise from their feeding areas (Olesiuk et al., 2002). The effectiveness of techniques for birds, such as the
125 weighting of lines was proven but is difficult to quantify (Jiménez et al., 2018; Santos et al., 2019).

126 Time-area closures are recommended by the International Council for the Exploration of the Sea (ICES) to limit
127 cetacean bycatch, and they are considered to be the only effective measure according to the Pelagis observatory
128 (Peltier et al, 2019). Environmental protection NGOs also advocate for time-area closures to achieve biodiversity
129 conservation objectives. However, there is a risk that the measure triggers a shift of the fishing effort in the
130 surrounding areas. Moreover, the closures are considered neither actionable nor acceptable by professional actors
131 and their representatives because the large range of gears associated with bycatch makes its socio-economic
132 application difficult. Time-area closures would entail a restriction of fishers' activities, who would be financially
133 compensated by the State (by temporary cessation for example). This measure can require short-term losses,
134 induced by the lost economic opportunity (Smith et al., 2020), but they have the potential to produce long-term net
135 economic gains, depending on the distribution of benefits and costs among the fishing communities (Armsworth et
136 al., 2010).

137
138 The economic condition of the fisheries in the European Atlantic coast is tense. The significant decrease in the size
139 of coastal fishing fleets (Leaute, 2008) in a general context of depletion of the fishery resource, symbolized in
140 particular by the first European Fleet Exit Plans, has left its mark on the communities of single-species oriented
141 fishers. If public authorities already have enacted regulations constraining fishing activities in the past, the issue of
142 bycatch is particularly controversial, and decision-makers are aiming to maintain the economic and social stability
143 in the ports and to sustain national production. It is worth highlighting that the fishing sector in France represents
144 only a small part of the economic activity of the country but it is an historical structuring activity of the French coastal
145 areas (Meunier, Daures and Girard, 2013). Moreover, there is a political trend to enhance sovereignty on food
146 production considering the increase in the trade balance deficit of fish and seafood products (FranceAgriMer, 2021).

147
148 Decision-makers are supporting the bloom of scientific projects to improve our understanding of bycatch, which is
149 still the source of scientific uncertainties regarding populations of small cetaceans and seabirds (abundance,
150 distribution) and incidental catches (rates, conditions) (Darrieu, 2018 ; Peltier et al., 2021). Research institutions
151 and scientists are progressively building knowledge, in partnership with fisher representative bodies, to evaluate
152 the circumstances, the magnitude and the impact of bycatch (target species, areas, periods), and to test escape
153 and repellent devices.

154
155 In this paper, we present a diagnosis of the interactions between fishers and scientists with regards to bycatch
156 mitigation projects in the Bay of Biscay. More specifically, we analyze the political and scientific approaches of
157 integrating fishers in knowledge production and in decision-making processes on bycatch reduction. How do
158 decision-makers, fishers and researchers interact to evaluate the options to reduce bycatch? How do they analyze
159 and compare the sets of policies, techno-economic and behavioral options to reduce bycatch? We also explore
160 the evolution of the cooperation dynamics between the different stakeholders, and the main sources of tension
161 arising from collaborating on bycatch mitigation projects.

162
163 We analyze the co-construction of knowledge on bycatch for both cetaceans and seabirds. If the impact of bycatch
164 on seabird populations receive less political and scientific attention in France, it is not less significant, with several
165 species vulnerable to bycatch, such as the balearic shearwater, being severely endangered (Genovart et al., 2016).
166 We do not mention projects to improve the selectivity of fisheries with regards to bycatch of fish species and

167 discards.

168

169 We argue that the process of co-creation of knowledge on bycatch through conflict and collaboration is key to
170 improve our understanding of the complex system dynamics at play, and to develop regulations adapted to local
171 specificities, towards an adaptive socio-ecosystem based management of the issue. Conflict analysis contributes
172 to highlighting the levers and blockages in the decision-making process regarding fishing policies and biodiversity
173 conservation regulations. We assess the potential of knowledge co-creation to improve fishers' ability to find
174 solutions to tackle the issue of bycatch. We conclude by presenting the lessons learned through conflicts between
175 fishers and researchers to inform bycatch mitigation policies.

176

177 **Method**

178

179 This article is the result of a research project which aims to analyze controversies on seabirds and cetaceans
180 bycatch in the Gulf of Biscay. The fieldwork combines several types of materials : archives, ethnographic interviews
181 with a diverse set of stakeholders, observations in professional gatherings, participation in scientific conferences,
182 and social science analyses (actor mapping, epistolary analysis, etc.).The interviews were conducted along the
183 french Atlantic coast to collect qualitative data, favoring face-to-face meetings, and following a flexible course of
184 discussion in order to adapt to the specificities of each actor. Data collection entailed the experiences of bycatch,
185 the interactions between actors within and without the stakeholder group, the roles in the decision making
186 processes, and the perception of the different measures for bycatch reduction. Participation in scientific
187 conferences and professional gatherings was used as an opportunity to collect additional feedback and to consider
188 the actors' discourses and strategies in debates on bycatch. Although the choice of actors intended to include a
189 diversity of expertises, the majority of fishers interviewed in this study are operating in small-scale fisheries. This
190 ethnographic approach aims at understanding complex maritime and coastal socio-ecosystems (Danto, Mazé &
191 Ragueneau, 2018), and exploring the relationships between knowledge and power (Mazé et al., 2017).

192

193 We acknowledge the limits associated with the categorization of stakeholders used for this publication, namely the
194 social groups designed as "fishers", "researchers", "government" and "NGOs". There is porosity between research
195 institutions and decision-making bodies for example. The AGLIA, a fishers' representative entity, has a hybrid
196 governance structure composed of both public actors and professionals from the fishing sector. Likewise, within
197 the same stakeholder group, important differences exist, such as between administrative bodies acting at the
198 national and at the regional scale. There are also differences between scientific institutions: the two main institutions
199 working on bycatch in the Bay, IFREMER and the Pelagis observatory, have different roles and are distinctively
200 perceived by the other stakeholders. Fishers also can not be considered to be a united social group. The profession
201 is heterogeneous, and there are power asymmetries between fishers. Different types of vessels, from France but
202 also from other countries such as Spain and Belgium, are operating in the Bay of Biscay, fishing specific species,
203 with various practices and interactions with marine biodiversity (Peltier et. al, 2021).

204

205

206 **Process of integrating fishers' contributions**

207

208 Tackling bycatch in the Bay of Biscay requires experimenting with technical solutions and regulating fishing
209 practices in a way that is adapted to the specificities of the socio-ecosystem. The co-design of research projects is
210 key to develop the knowledge necessary to implement efficient measures and to learn from experimentation at the
211 "boat scale". The notion of "co-design" is used here to refer to the co-creation of credible and legitimate ocean
212 knowledge solutions (IOC-UNESCO, 2021) to reduce bycatch. In theory, fishers' empirical knowledge can be
213 leveraged to inform Western science and policy making in order to create applicable mitigation measures which
214 would be adapted to local specificities. For example, fishers' Local Ecological Knowledge could be used to
215 determine which areas are to be managed, and when, to develop dynamic adaptive ecosystem management
216 (Mazé, 2020). We use the notion of Local Ecological Knowledge to refer to the set of knowledge derived from daily
217 interactions with the ecosystems, as opposed to Conventional Scientific Knowledge (Berkström et al., 2019), or
218 expert knowledge (Lascombes, 2001 ; Barthelemy, 2005), which is built from collecting data according to a
219 scientifically designed methodology, and theoretically interpreted.

220

221 The fishers are mostly mobilized to contribute to the scientific measures of the magnitude of bycatch and to the
222 test of technical devices. Yet, there are variations in the process of integrating their contributions and in the strategy
223 of each actor in the knowledge co-creation process.

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225 Evolution of cooperation dynamics

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Figure 2 : Sociogram of the actors' system involved in bycatch mitigation in the Bay of Biscay

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Platform for discussion

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Deliberative processes for remediation have also been implemented, such as the Interministerial national working group on incidental catches of small cetaceans in the Atlantic, created in 2017. This working group, led by the State Secretary for Sea (through the General Directorate of Maritime Affairs, Fisheries and Aquaculture) and the Ministry of Ecological Transition (through the Ecology and Biodiversity Directorate), is composed of a diverse set of stakeholders (administrations, scientists, NGOs, fishing professionals). The group meets regularly to discuss the latest results of the research projects on the interactions between fishing activities and small cetaceans, and the measures to limit bycatch in a sustainable manner. The initiative is nationally held, but it also aims to serve as a platform to organize collaboration with foreign counterparts operating in the Bay of Biscay, with the frequent participation of actors from border countries such as Spain and with the participation of the European Commission as an observer. The national group started with a limited number of members who previously collaborated in bycatch mitigation projects. The members interviewed mentioned that, as the number of people around the table increased, the dialogue dynamics progressively shifted to a sequence of presentations with limited opportunities

282 for discussions. The degradation of the dialogue dynamics was taken into account by the organizing institutions,
283 who decided to structure the national group into subgroups discussing specific dimensions of bycatch.

284

285 **Data collection with and without the fishers**

286

287 The current data collection on bycatch in France entails the estimation of bycatch rate (with observers deployed on
288 vessels, number of strandings recorded, fishers reporting), bycatch risk assessment (population distribution, areas
289 of mortality, fishing effort, interactions with fishing gear), estimation of the impact of bycatch (threshold, abundance,
290 cascade effects), and the measurement of the effectiveness of technical devices, such as pingers. Many scientific
291 studies are mobilizing observers to collect data. In that case, fishers' participation is limited to accepting, or not,
292 the observer on board. For example, the sea observation program Obsmer, led by the General Directorate of
293 Maritime Affairs, Fisheries and Aquaculture, and co-funded by the European Union, collects data on the vessels,
294 the catches, and the tidal environment from annual sampling realized with on-board observation since 2009, in
295 partnership with Ifremer and fishers' representatives (Ifremer, 2022). Fishers' knowledge has also been integrated
296 through surveys and voluntary statements in order to create a diagnosis of the fleets and to characterize the
297 interactions on pilot sites (Pelagis observatory, 2022). Some research projects, such as the program Obsenpeche,
298 are studying participatory science tools, with the aim to deploy a network of "sentinel fishers", using an application
299 to report knowledge on bycatch, and to initiate a reflection on the evolution of fishing strategies. Other data
300 collection methods bypass the fishers' and observers' onboard perspective regarding the interaction with cetaceans
301 and seabirds, and the biases associated with it. The Pelagis Observatory organizes aerial observation campaigns
302 of marine megafauna under the SAMM (Aerial Monitoring of the Marine Megafauna) program. This program is
303 intended to produce an inventory of the spatial distribution of certain species in metropolitan waters, to estimate
304 their abundance and to identify the preferential habitats of cetaceans and seabirds according to the seasons. The
305 two SAMM campaigns in 2011 and 2012 allowed the observation of nearly 3,000 marine mammals and 35,000
306 seabirds (Laran et al., 2017). Another program aiming to estimate the rate of bycatch is using electronic observation
307 devices to better understand the interactions between dolphins and gillnetters. The test of onboard cameras on
308 vessels and the development of an automated algorithm for image processing by artificial intelligence to consider
309 the extension of the system to 400 gillnetters was launched at the request of the ministry, in partnership with a
310 diverse set of stakeholders (Ascobans, 2021).

311

312 **Control over knowledge co-production**

313

314 The control over the process of knowledge co-production is held by research institutions, but also by fishers'
315 representative bodies. On one hand, scientists have the social capital and the legitimacy to have control over the
316 methodology adopted (Bourdieu, 1976). On the other hand, fishers' representatives (national, regional and
317 departmental committees, and fisher organizations, also called *Organisations de Producteurs*, OP) are almost
318 systematically involved as partners. Communicating and collaborating with fishers on the numerous projects
319 require logistics, hence the professional representative bodies (the regional and departmental committees and the
320 OP, depending on the area) manage the different requests, distributing the corresponding surveys and requests
321 among fishers. They play a decisive role, organizing data collection with the fishers, hence the research projects
322 depend on their approval.

323

324 **Incentives for knowledge co-creation**

325

326 Researchers and fishers are drawn into knowledge co-production by different incentives. Careful analysis of
327 incentives is crucial since the interactions of the stakeholders are unlikely to be socially or politically neutral
328 (Armitage et al., 2007). For scientists, the approval of fishers to participate is decisive, as they need a representative
329 sample to be able to draw conclusions. The significant statistical sample has been set by the European Commission
330 at a minimum of 5% of the fishing effort for cetaceans (Peltier et al., 2016), and 10 to 20% for the bycatch of
331 seabirds, since the bycatch of birds are rare events but when they occur, they can impact a significant number of
332 individuals (Babcock et al., 2003). Engaging in knowledge co-production is also the opportunity to have more
333 acceptable and objective results of the research projects, when the scientific experts finalize their diagnosis.

334

335 Fishers are contributing to scientific studies with the aim for transparency, and to contribute to rapidly finding
336 technical solutions to reduce bycatch. Yet, the participation in research projects is not a core aspect of their work,
337 and it is perceived as an additional constraint on their activities. Sometimes, a relationship of trust is already
338 established if the fisher and the researcher have already interacted at other occasions. If this is not the case, for a
339 research project to be accepted among the fishing communities, scientists need to highlight fishers' interests to

340 participate. They are promoting the integration of fishers' feedback, of their expertise and knowledge of the marine
341 ecosystems, in order to create more specific regulations, rather than applying regulations to all gears and fishing
342 practices. Participating in a research project on bycatch would give them the opportunity to refute the data with
343 which they do not relate.

344 Cooperation with researchers is not always voluntary, especially since the 2019 regulation requiring ship captains
345 to report any occurrence of cetacean bycatch. The Ministry of Ecological Transition and Solidarity, with the help of
346 researchers from the Pelagis observatory, have provided fishers with a guide on the declaration procedure (the
347 species concerned, the steps to report the occurrence of bycatch in the fishing paper's sheets and in electronic
348 fishing logbook) (Tachoures et al., 2018). However, the obligation of bycatch reporting is partially deficient, and the
349 data collected are not very usable, as they suffer from numerous biases.

350 Regulations are adding legitimacy to scientists' approach. The regulatory framework in place becomes an argument
351 for scientists to incentivize fishers to collaborate. Even if the rules put in place are not always legally binding, they
352 can serve as an argument for scientists to convince fishers to take part in the projects. Researchers interviewed
353 have given the example of Biodiversity Law of 2016 (JORF, 2016), stating that risk assessment must be realized
354 in fisheries, or soft laws such as the National Action Plan 2021-2025 for the Balearic Shearwater.

355 **Conflicts hindering co-creation**

356
357 The knowledge co-creation process for bycatch reduction in the Bay of Biscay is hindered by several, interrelated
358 factors of tension constraining collective learning and limiting the capacity of actors to come up with shared
359 solutions.
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361 **Different interests and narratives for the sustainability of the fishing sector**

362 Fishers and researchers collaborate with the common objective to improve knowledge on the species vulnerable
363 to bycatch and to implement effective solutions to limit the occurrence of accidental captures. Indeed, for fishers,
364 cetaceans and seabirds arouse respect and consideration, and bycatch induces significant costs related to the
365 degradation of fishing gears. Pursuing this common objective, numerous disagreements arise from the interactions
366 between the different actors involved in bycatch mitigation projects.

367 The definition of the problem and the set of solutions perceived as acceptable vary not only according to the state
368 of the resource but also according to the interest perceived by the actors (Lapijover, 2018). Indeed, the actors
369 involved in the process have different perspectives regarding the impact of bycatch on marine biodiversity
370 depending on their interests. The research projects have not yet established a commonly agreed upon knowledge
371 basis, resulting in divergence regarding the perceived importance of the issue. For fishers, cetaceans and seabirds
372 are the signal for the presence of fish, but they are also competitors. The fishers are perceiving that the
373 phenomenon of depredation is increasing, and depredation, especially when using gears such as straight nets to
374 fish red mullet, is considered to have a significant negative effect on fishers' catch. The conflicting perceptions of
375 the impact of fishing on cetacean and seabird populations create friction in the process of co-creation. Fishers tend
376 to consider their individual experiences on a single vessel rather than the impact of the fishing sector as a whole,
377 thus if they perceive that their activity does not have a significant impact on cetaceans and seabirds, they tend to
378 disagree with the use of the notion of emergency with regards to bycatch in the Bay of Biscay, and with the hierarchy
379 of concerns for fisheries management resulting from it.

380 The stakeholders also disagree on the solutions envisioned by fisheries scientists and managers to reduce bycatch,
381 such as time/area closure, change of vessel, and economic compensation. Fishers have economic incentives to
382 invest in acoustic repellents, but they perceive limited interests in interrupting fishing in specific areas. Different
383 data are mobilized by each actor in order to defend their respective vision regarding policy priorities. Most
384 professional actors consider that since there were 467,673 common dolphins counted in the European waters of
385 the Atlantic in 2016 (Hammond et al., 2017), the population is not in danger of extinction in the short-term, thus
386 implementing measures such as time-area closures now would be a political demonstration of excessive
387 environmentalism. On the other hand, some researchers consider that waiting until a species is declared
388 endangered to implement conservation measures significantly reduces the probabilities of successfully preserving
389 this species, and thus they highlight the need to adopt a long-term vision in today's policies. Each actor refers to a
390 specific part of the knowledge on bycatch, according to which he develops an interpretation of the sector's history,
391 a vision for its evolution, and a strategy to defend this vision (Catanzano & Rey, 1997).

392 Actors' views and values are polarized resulting in different narratives for the sustainability of the fishing industry.
393 Take the example of beached dolphin bodies, which become a symbol of the impact of fishing on marine
394 ecosystems, and call into question the interrelationships between humans and nature, and more specifically the
395 industrial exploitation of the ocean (Clouette, 2022). Faced with this question, fishers argue that, in order to satisfy
396 the current national demand for seafood, the corresponding fishing techniques must be maintained, giving the
397 example of fish sole and scampi that can not be caught with fishing traps. The actors have different perceptions of
398 the socio-ecosystem, and of the behaviors of actors perceived as at risk (Lapjover, 2018). The knowledge
399 exchange deteriorates, as the actors are entrenched in their position regarding the transformations necessary to
400 reach sustainability, resulting in path-dependency. This notion originated in the discipline of economics in the 1980s
401 through the work of two of its main proponents, Paul David and Brian Arthur (Goldstein et al., 2023). The initial
402 observation is that, "even if a more efficient solution is known than the solution currently chosen by a firm (in terms
403 of technology, new product or rent, for example), this solution is not necessarily adopted (Palier, 2014). In this
404 sense, Paul David then demonstrates that "technological lock-ins" impede changes to more efficient practices
405 (Goldstein et al., 2023). If this notion of path dependence comes from economics, it is then taken up in other
406 disciplines, such as sociology or political science and even in political ecology more recently (Idem). Steins, Mattens
407 and Kraan observe that the uptake of more selective gears in the Netherlands, even if the innovation is fisher-led,
408 depends on a complex interplay of social, policy and science-related factors, among which the fishers' intrinsic
409 motivation and beliefs about sustainable fishing, and perceptions about the motivations and behaviors of other
410 fishers (Seins, Mattens and Kraan, 2022).

411

412 **Dichotomy between two worlds**

413 The disagreements are reinforced by the perceived dichotomy between the worlds of academia and fisheries, as
414 the measures envisioned do not always meet the reality faced by fishers (Suuronen, 2022). For the fisher, the
415 environmental manager, the decision maker and the natural scientist belong to the sphere of technocratic power
416 (Barthelemy, 2005), which is considered too far removed from the realities on the sea. The fishers are pointing to
417 a lack of knowledge of the field, and of their working conditions, and often invite decision-makers, scientists and
418 journalists to get on board to see for themselves. Indeed, fishers are generally aware of the basic requirements for
419 the sustainability of fishing, but due to the harsh circumstances of their work, it is challenging for them to undertake
420 these transformations (Suuronen, 2022). Fishers and their representatives highlight a gap between what is required
421 from them, and the core mission of their profession. This feeling of distance between bureaucratic professions and
422 sea labor can lead to doubt about the relevance of the different scientific approaches, and to the rejection of the
423 entire knowledge co-creation process.

424

425 **Climate of mistrust**

426

427 If co-creation of knowledge requires building trust between the different parties (Hakkarainen et al. 2021), trust can
428 be eroded very quickly, as a result of the failure to meet a commitment or because of an unexpected regulation for
429 example (Armitage et al., 2007). Although the researchers and fishers' representatives are realizing an important
430 work of communication to improve the collaboration dynamics, researchers and fishers are in a defensive position,
431 sharing doubts about each other's intentions.

432

433 The change in scope of the responsible vessels altered the relationship of trust between fishers and researchers:
434 the finding that pelagic trawls were not the only vessels responsible for cetacean bycatch induced suspicion from
435 scientists regarding the willingness of fishers to collaborate.

436

437 Researchers' doubts regarding fishers' motivations are also based on the significant difference between the
438 number of accidental catches declared by fishers and the number of strandings recorded on the Atlantic coast.
439 Indeed, qualitative surveys in the human and social sciences reveal, within small fishing communities, a tendency
440 (unquantifiable for the moment), to under-report, for fear of administrative reprisals, of NGOs, or even of neo-rural
441 and neo-coastal inhabitants. As soon as the fishers do not comply with the regulation to disclose bycatch, they are
442 associated with "reluctant" partners whose refusal to report is a convincing sign of its unwillingness to collaborate.
443 Researchers assume that the fisheries feel threatened by the possibility that research projects contribute to the
444 development of new regulations and do not disclose all the information that they hold. The question of data reliability
445 becomes more acute as restrictions on fishing effort are tightened and, consequently, tensions between fishers
446 and scientists increase (Deldreve, 2010).

447

448 The fishers' defensive position is due to the assumption that sharing data could lead to more regulations. While the
449 fishing profession is traditionally associated with freedom, the inflation of rules and requirements are perceived by
450 some fishers as an infringement of freedom. The fishers interviewed also mentioned their apprehension of the
451 socio-economic impact of regulations such as the reduction of sole quotas in the Bay of Biscay, sole being one of
452 the main targets of the gillnetters. Hence the fishers are facing a conflict of interest, acknowledging the value of
453 their integration in bycatch mitigation projects, but having limited incentives to share catch information, fearing that
454 their participation may play against them (Calderwood et al., 2021). The research on change management models
455 for fisheries has highlighted the impact of intrinsic motivation factors concerns on the resistance to change fishing
456 practices, the most impactful factors being the concerns that change will be costly and painful, perceived lack of
457 incentives to offset any catch loss, perceived loss of cover over the fishing operations and uncertainty about the
458 future, including how fishers may be affected by change.

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Controversies around the conventional scientific approach to data production and interpretation

462 If the limits of integrating fishers' knowledge considering the existing conflict of interest are highlighted by scientific
463 institutions, conventional scientific knowledge production is also at the heart of controversies, for being accused of
464 normativity with political ends. The role of researchers in the development of bycatch mitigation policies is
465 generating debate over the acceptable level of normativity in sciences. Indeed, scientific experts who contribute to
466 the establishment of norms take ethical and political positions (Roy, 2001), which have direct implications for the
467 cooperative relationships between fishers and researchers (Deldreve, 2010). Scientific objectivity is questioned in
468 the discourses of the fishers: on the one hand, Ifremer researchers are accused by small-scale sustainable fisheries
469 of being too dependent on the fishing industry. On the other hand, the Pelagis observatory is considered by other
470 professional actors to have an ecological bias. The rationality so specifically attributed to natural, "hard" sciences
471 (Naim-Gesbert, 1999 ; Darrieu, 2018) is questioned, since the professional actors perceive that scientists are
472 tailoring their methodologies to the results they are aiming to get, pointing at a lack of coherence in the scientific
473 approach.

474 Moreover, fishers and their representative bodies report the lack of tangible results from their involvement in the
475 research projects on bycatch, except for the test of technological devices. Fishers perceive that their contributions
476 did not translate into the identification of concrete solutions: the outcomes of the research projects were for the
477 most part scientific publications, and the possibility to apply time-area closures is still considered an option.

478
479 Finally, there are important research gaps regarding fishers' Local Ecological Knowledge (LEK), and few projects
480 explicitly mention the intent to pair LEK with Conventional Scientific Knowledge. Fishers are generally rather
481 considered by researchers as "cooperating users" (Barthelemy, 2005), representing a potential source of scientific
482 data useful for bycatch management, although scientific projects sometimes organize discussions such as
483 seminars of cross sensibilization in order to integrate fishers' feedback and expectations on scientific studies. It is
484 assumed that fishers hold knowledge regarding the techniques which are the least and the most likely to cause
485 bycatch. Yet academic methodologies tend to disregard fishers as holders of empirical knowledge. Since the main
486 opportunity to share their experience is through participating in researchers' data collection, their refusal to
487 cooperate as participants to conventional scientific methods also leads to their non-participation as holders of this
488 empirical knowledge.

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Persistent uncertainties

492
493 There are persistent uncertainties regarding the occurrence of bycatch which wears out the motivation of the
494 different actors to engage in knowledge co-creation. The cause of the sharp increase in cetacean strandings is yet
495 to be scientifically explained. A possible explanation would be a change in distribution of the population relative to
496 the fishing grounds where fisheries posing the greatest risk of bycatch operate (Peltier et al., 2021), since the
497 results of several observation campaigns suggest that the abundance of the common dolphins population has
498 recently increased in the Bay of Biscay (Van Canneyt et al., 2020). However, the abundance estimates have a high
499 margin of uncertainty which makes statistical detection of change (Murphy et al., 2019) and estimation of long-term
500 trends challenging (Lapijover, 2018). The ICES raised that for any particular member state, it is nearly impossible
501 to establish whether the observed trend in local abundance of common dolphins represents a real change in
502 abundance or a shift in distribution (ICES, 2019). Likewise, little is known yet about the rate of occurrence and the
503 types of practices and the vessels responsible for cetacean and seabird bycatch in the Bay of Biscay.

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Uncertainties can also be found in what the scientists know. Biases have been identified in observer programs, such as “the deployment effect”, stemming from the lack of a sampling strategy, as the presence of observers depends on the willingness of the skippers; and “the observer effect”, i.e., the change in fishing practices when an observer is present (Amandè et al., 2012; Benoît and Allard, 2009; Faunce and Barbeaux, 2011; Murphy et al., 2019; Peltier, 2020). Moreover, the models to estimate bycatch from stranding data and from observer programs provide “ranges” with a large amplitude. For example, the work by the ICES Working Group on Bycatch (WGBYC), which collates and assesses information on bycatch monitoring and assessment for protected species, estimated in 2016 from observer programs the bycatch of common dolphins to be between 1,607 and 4,355 in ICES zone VIII, and between 1,400 and 4,800 from stranding data along the French Atlantic coastline (ICES, 2018).

There are different ideological positions regarding the process of data interpretation with regards to scientific uncertainties to conclude on the best measures for bycatch reduction. At the level of the strategic actor, uncertainty is a fundamental resource for negotiation between different interests (Lapjover, 2018). Some stakeholders argue that there are still too many uncertainties about the magnitude of the problem, and thus about the urgency of the situation, to apply constraining regulations on fishing activities, while others argue that the data available is sufficient to justify these measures. The negotiation process is well illustrated by the debates around space-time closures, and the use of a threshold to determine when and where the closures should take place.

Media, science communication and activism

The media coverage of these strandings is significant and can be compared to that of news items. Marine mammals arouse emotions in the public, due to their cultural significance, being perceived as “iconic” animals (Lorimer 2007; Danto et al., 2020 ; Mathur 2021). The conflicts, the blood, the bodies of sea mammals are all visually powerful and tend to trigger public reactions (Geistdoerfer, 1984). The organizations dedicated to marine biodiversity conservation are leveraging these emotions through the media to raise awareness of civil society and to call the attention of the decision makers, in order to move the issue of bycatch further up in the political agenda. The choice of words such as “killing” or “slaughter” to describe fishers’ work plays on the emotional relationship with the marine mammal, stronger than the one shared with the fish or the seabird and is questioning the responsibility of the fishers (Clouette, 2022). The NGOs also use statistical surveys from research projects on bycatch in their communication, since data plays a key role in engaging an audience (Desrosières, 2014; Clouette, 2022).

Fisher representatives are pleading that the discourses of the NGOs in the media fail to present all the elements to grasp the complexity of the issue, and the uncertainties about the nature of the interaction. This tension is leading to numerous, sometimes violent altercations between some fishers and Sea Shepherd. This resentment was already present in 1994, when the media picked up on a conflict between French and Spanish fishers over the ban of driftnets, which they dubbed the “tuna war” (Lequesne, 2002). This new regulation was not well received among French fishers, who perceived that they were condemned “in the face of the fantastic media hype” (Antoine, 1995).

Both researchers and fishers perceive that collaboration dynamics are hindered by the media coverage and by the conflicts with the NGOs. Fisher representatives consider that researchers’ science communication strategy contributes to fuel the NGOs’ anti-fisheries discourse and to the oversimplification of the issue. Direct conflicts between fisher representatives and scientific institutions arose regarding the content of posts on social media for example, where representative bodies plead that the publications are not reflecting the work done and draw hasty conclusions on the stranding figures by failing to specify the context in which the data is elaborated and the attenuation factors to be taken into account when interpreting the numbers.

Discussion

Socio-ecological conflicts tend to be seen as negative phenomena to be avoided and “resolved” as quickly as possible by finding win-win solutions, through cooperation, negotiation and consensus seeking (Fisher and Ury 1981; Ury et al. 1988, Temper et al., 2018). In the case of bycatch mitigation, the conflicts hindering knowledge co-production have complex and profound roots, with important political, historical, social, environmental and cultural components. The conflicts highlight two key underlying identity issues: the establishment of the unquestionable legitimacy of scientific expertise and the image of fishing, either perceived as a diversified and legitimate activity or

561 as a destructive harvesting activity, and of fishers, either considered as responsible producers or as unconscious
562 predators (Deldre, 2010).

563
564 Temper et al. argue that conventional conflict resolution approaches have limited potential to successfully deal with
565 such socio-ecological frictions, and that they can lead environmental conflicts to become recurrent as they offer
566 little opportunities for developing robust democratic and sustainable agreements for the use and management of
567 the environment and territories (Temper et al., 2018). They suggest that conflicts are rooted in situations that are
568 perceived as unjust, and that, by expressing a questioning of the status quo, conflicts can have constructive
569 potential (Lederach 1995; Dukes 1996 ; Temper et al., 2018). Analyzing the points of friction related to bycatch
570 mitigation, and identifying power asymmetries and institutional failures, can help understanding the transformations
571 necessary to take into account the social and environmental issues in the decision-making process regarding the
572 management of a marine socio-ecosystem faced with anthropogenic pressures.

573
574 Actions taken to shift social–ecological systems through transformation towards more sustainable trajectories can
575 have negative social impacts and exclude people from decision-making processes (Bennett et al. 2019). Co-
576 creating knowledge with fishers requires understanding the governance structures for fishers, considering power
577 asymmetries in the governance and management of the ocean (Caze et al., 2022), and the economic domination
578 that some fishers undergo (Clouette, 2021). The literature on transformation research calls for a greater integration
579 of politics and power, by considering the decision-making process behind the measures leading to the
580 transformations of the system and of the practices, and by tracking winners and losers in the transformations, with
581 the aim for societal justice. For example, if the measures taken by the government are mobilizing economic
582 incentives, such as penalties or subsidies, the difference of impact on small-scale and industrial fisheries should
583 be considered. The impact on small-scale fisheries has already been used as an argument from fishers'
584 representatives to protest against a new regulation. In 2014, when the European Commission formulated a
585 proposal to ban all driftnets with the aim of reducing bycatch, among other objectives, considering the circumvention
586 of the regulation of 2002, fishers' representatives in France protested, arguing that the use of driftnets was used
587 by small-scale, sustainable fisheries. If the conflicts in co-designed bycatch mitigation projects reveal a perceived
588 injustice and gaps in the current governance system, can it also be a tool to start a process of transformation to
589 reach a more equitable and inclusive management process? Can knowledge co-creation be a way for fishers, as
590 agents of transformation, to improve their ability to find solutions to reduce bycatch and to adapt to future
591 regulations? In other words, beyond a greater understanding of the issue at hand, what is the political impact of
592 the knowledge co-creation process in this particular case?

593
594 In order to assess whether conflicts in co-designed bycatch mitigation projects in the Bay of Biscay can foster the
595 empowerment of fishers to tackle the issue of bycatch, it is necessary to understand the decision-making processes
596 and the science-policy interactions at play.

597
598 The decision-making process shaping the pathway of the fishing industry is cross-sectoral and multi-scalar, thus
599 the policies result from a process of mutual adjustment between different actors. The three distinctive entities
600 currently responsible for producing national policies on fishing are the Secretary of State for the Sea, the Ministry
601 of Agriculture and Food Sovereignty, and the Ministry of Ecological Transition and Territorial Cohesion. In the
602 French government, a Secretary of State has almost the same functions as a Ministry, with the exception that the
603 Secretary of State only attends the Council of Ministers when the agenda includes a question concerning their
604 ministerial department. The management of the resource was for a long time carried out by the Ministry of
605 Agriculture, and the management of fishers and vessels has long been disconnected from the management of
606 fishery resources and from biodiversity conservation. The inherent scientific work was partly carried out by a higher
607 education and research institution under the supervision of this same ministry, since fisheries constitutes in the
608 history and epistemology of French sciences a branch of agronomy. This distinction has led to difficulties in the
609 implementation of public policies that are not necessarily always coordinated on the field.

610
611 Various successive reforms, marked by the spirit of the New Public Management (Barone, Mayaux and Guerrin,
612 2018), led to the closure of a large number of administrative maritime services. The concept of New Public
613 Management emerged in the early 1980s in the United Kingdom and New Zealand, and then gradually spread to
614 many countries, including France. It is based on the main idea that the public sector, organized according to
615 bureaucratic structures and principles, is inefficient and that it would be desirable to draw inspiration from private
616 sector principles (Pollitt and Bouckaert, 2011). In the maritime administration, the services that originally constituted
617 the first territorial level of Maritime Affairs, called the "Syndic des gens de mer", which were considered as a
618 referent for fishers, were closed, as well as the Maritime Affairs Quarters, with the subsequent disappearance of

619 the Chief Administrator of the Quarter, the second point of contact with fishers for more political or serious matters
620 (Danto, 2021).The increasing centralization of institutional bodies could negatively impact the implementation of
621 the policies to mitigate bycatch, policies to which the fishers often do not lend any legitimacy. Moreover, fishers'
622 access to speech in the social and political system is variable, depending on their social position and of their
623 network, which accentuate the power asymmetries within the fishing communities in a context of administrative
624 centralization. The fishers' representative bodies play a crucial role to bridge the communication gap, connecting
625 fishers with policy-makers and researchers, yet little is known so far about their actual role in the decision-making
626 process, and fishers' positions with regards to this representation. Improving our knowledge of the "invisible"
627 professional fishers who are not members of OPs and refuse contacts with the Committees, as well as of the level
628 of satisfaction of fishers with regards to the representative democracy within the maritime political sphere, could
629 contribute to a better apprehension of fishers' reception with regards to new fishing policies and biodiversity
630 conservation regulations.

631
632 The balancing of ecological concerns within the social, economic, cultural and democratic spheres of the decision-
633 making process is shaped and constrained by different factors that can be distinguished in three categories: values,
634 rules and knowledge (Coloff et al., 2017). First, the choice of bycatch mitigation policies is impacted by the
635 preferences, and thus by the values of decision-makers: fear of social unrest in the Atlantic ports, incentives to
636 maintain the fishing industry, duty of protecting marine biodiversity... Then, the institutional context in which the
637 decision-makers operate determines the prescribed and proscribed actions and the associated bodies of laws and
638 social norms for how rules are applied (Coloff et al., 2018). In France, the European Union has an exclusive
639 competence over "the conservation of the biological resources of the sea within the framework of the Common
640 Fisheries Policy". This strategic competence gives the European institutions a central and widely discussed role
641 (Khalilian et al. 2010; Lapijover, 2018), and it is exercised by the use of different instruments, such as European
642 Directives. The Habitat Directive, the Birds Directive, and the Marine Strategy Framework Directive (MSFD) are all
643 impacting the science-policy approach to bycatch mitigation in the Bay of Biscay. The MSFD, for example, aims to
644 set a European strategy for the marine environment that intertwines acquisition of scientific data and
645 implementation of management measures, while taking into account the local specificities. The Directive
646 demonstrates the intertwining of scientific knowledge and decision-making processes, giving a central place to
647 scientists and decision-makers, but it does not mention the integration of other representations of the marine
648 environment (Lapijover, 2018). If the government is not complying with the European norms, the European
649 agencies can directly exercise pressure through an infringement procedure. The interactions between the different
650 scales of governance which shape the institutional context of bycatch mitigation policies are taking place in arenas
651 that are highly distant to fishers' reality. However, as it has often been the case with regards to French political
652 decisions, this mechanism does not prevent a State from following a strategy that is divergent from the European
653 norms.

654
655 Finally, decision-makers formulate policies according to their understanding of the world, which is defined by the
656 political use of scientific expertise, but also by their experiential knowledge and world views. Knowledge production
657 on bycatch emerges as a key step to the management of an issue that remains the subject of uncertainties, hence
658 participating in knowledge production through the academic system could theoretically be a lever for empowering
659 stakeholders to take an active role in shaping the policies for sustainability (Caze et al., 2022). Power is linked to
660 deliberation, learning (and who defines what type of learning), the choice of indicators for measuring outcomes,
661 and the sharing of risk (Armitage et al., 2007). However, in this situation, the scientific approach to integrate fishers'
662 knowledge is often limited to data production, and fishers' representatives are not systematically integrated at the
663 step of interpretation of the projects' results to inform policy making and develop bycatch mitigation tools such as
664 thresholds. In some cases, research projects are concluded by negotiation on measures to take based on the
665 project results, and fisher representatives are given the opportunity to be represented in the different operating
666 committees to discuss and express their disapproval. Consultation, as an operation to collect the opinions of the
667 actors concerned, does not lead to the sharing of decision-making power, nor does it guarantee that the opinions
668 expressed will be taken into account. The government, which is responsible for implementing the European
669 directives from which most of the research work stems, has the final word on the measures to be applied.

670
671 The empowerment of fishers to mitigate bycatch through the participation in research projects is also questionable
672 due to the controversies regarding the impact of science on decision-making. When scientists present their
673 assessments of the bycatch impact analysis with plausible ranges of values, recognizing the uncertainties in their
674 conclusions, policy makers must choose a single value, knowing that the subtleties of a variance or confidence
675 interval are generally beyond their grasp. Political arbitrage is not only determined by political will, since the
676 research projects did not result in the identification of a silver bullet solution for bycatch. Scientists argue that

677 uncertainty should not justify inaction, especially since for many of them the reality of the impact, in view of the
678 state of knowledge and data available, is largely underestimated (Deldreuve, 2010 ; Peltier, 2020). However, the
679 interpretation of scientific results by policy makers has most often led them to choose the least constraining option
680 for fishermen in the immediate term, even if this option has negative consequences in the medium and long term
681 (Deldreuve, 2010). Only a few binding regulations exist, such as the ban on driftnets. Moreover, researchers highlight
682 that the current governmental incentives to pursue research can be interpreted as a political strategy to postpone
683 political arbitrage. Indeed, research projects on bycatch are criticized for being instrumentalized in order to validate
684 either conservation or exploitation policies, depending on the research institutions and on the political directives.
685

686 The decision-makers' approach to learn from the conflicts could suggest that controversies and alternative
687 practices have had little impact on the genesis of knowledge and management methods. But it is difficult to evaluate
688 the influence of the different sources of knowledge in the negotiation process informing the political arbitrage, due
689 to the opacity of the process of construction of the political strategy. It is understood that scientific knowledge,
690 although indispensable, could not be sufficient in view of the uncertainties that weigh on the data, the variables to
691 be considered, and more broadly on the complex and uncertain realities of the marine and associated social
692 environments. Recognizing the limits of the scientific approach when managing situations of crisis and high
693 uncertainty is part of a more general reflection on the limits of representative, delegative democracy, where political
694 actions are produced by central authority bodies which define both the objectives and the means to achieve them
695 (Deldreuve, 2010). This raises an interesting question about the extent of power-sharing that is required to find
696 solutions for bycatch mitigation. The different manifestations of power in the conflicts, and the way power emerges
697 and evolves through control, resistance, and solidarity, influence collaboration and learning (Armitage et al., 2007).
698 The issue of the debates regarding whether the power gap is a factor blocking or facilitating transformation is critical
699 for determining what "knowledge co-production" means for the future of fisheries science in settings where research
700 is mobilized to foster innovation.
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702

703 **Recommendations**

704
705 There are contradictions in the needs of the actors involved in the process of knowledge co-creation that does not
706 lead to a holistic, silver bullet solution for bycatch. The complexities associated with the issue of bycatch requires
707 to reject ready-made solutions, and instead compose a "situated knowledge", emphasizing the local and contingent
708 connections. Collective commitment in bycatch mitigation projects, through conflict and collaboration, can be an
709 opportunity to engage in collective learning (Fabricius and Cundill, 2010) and to inform decision-making processes
710 to create inclusive and just biodiversity conservation policies.
711

712 The limits of the scientific approach highlighted by the conflicts with the fishers suggest that reform can not be
713 driven only by providing evidence that the current status quo has to change. Acknowledging the presence of
714 conflicts between the stakeholders, and understanding their roots and their impact on the co-design process can
715 allow the identification of factors of path-dependency hindering the adaptive capacity of institutions. Conflicts can
716 also prepare the system for change, and disagreements can become catalysts for social change and generate
717 positive friction, if the necessary negotiating processes are in place to allow discussion among different narratives
718 for the sustainability of the fishing sector.
719

720 The process of knowledge co-production on bycatch should be pursued, with the aim to foster a change in
721 perspective of the actors involved, and a greater understanding of the other, creating incentives to think beyond
722 dogmatic positions. Ensuring that the process will generate collective learning requires acknowledging the
723 perceived dichotomy between academia and the fishing activities and to continue the effort of acculturating
724 scientific and administrative structures to the working conditions of fishers. The collaboration between scientists
725 and fishers has a very strong vocation to convey concepts produced in science to societal actors, but it requires to
726 create the appropriate framework to be in capacity to share a common vocabulary (Cundill and Fabricius, 2014).
727 Social science scientists can play a key role when shaping such a framework (Geistdoerfer, 2007), as well as a
728 supranational organization dedicated to the issue, inspired by existing organizations, integrating the issue of
729 ecological knowledge in their management processes (Danto, 2022).
730

731 Transformation of the fishing sector can not be achieved without the fishers. As the research projects on bycatch
732 progressively improve our understanding of the human-species interactions, national policies should be designed
733 to empower fishers to foster the emergence of alternative practices through experimentation and through the
734 sharing of good practices.

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When negotiations fail to move further, and the actors are entrenched in their position, activating other levers in parallel of the political debate can help to recreate dialogue between the stakeholders. The current national strategies to reduce bycatch of small cetaceans and seabirds should be regularly updated with concrete actions to support the experimentation of alternative practices in order to rapidly find applicable solutions. For example, creating economic incentives for fishers to change practices.

The actors are placing a lot emphasis on the test of technological innovations to reduce bycatch. Market-based approaches or technological innovations are, in many instances, insufficient to produce sustainability transformations (Scoones, Leach, and Newell, 2015). Accelerating long-term structural transitions also requires to leverage change of the social groups' standards, by contesting dominant social and political structures, and to reconsider the macro-economic dynamics of food production, as well as the deep cultural patterns interrelated with these dynamics (Geels and Schot, 2007).

Improving the quantitative and qualitative data and the sharing of other forms of knowledge provided by the fishers requires creating incentives for the different fishers to further contribute to the research projects, but also overcoming the resistance to non-scientific knowledge sources. Continuing to assess the potential of an hybridization of knowledges, with scientists, naturalists, and fishing professionals experimenting practices to reduce bycatch, is key to eventually creating the foundations for an inclusive decision-making framework.

Knowledge co-creation is a lengthy process which presents the risk of slowing down the transformation of the fishing sector. Yet, enough time needs to be dedicated to consult all stakeholders when conceptualizing the project, as well as to present them the methods of data analysis, and to give feedback on how the consultation has been integrated, or not, in the project. Particular attention should be given to the process of data interpretation and to the composition of the committee responsible for concluding on the measures to be taken.

The conflicts on bycatch mitigation relate to questions of identity, tradition, modes of production and individual consumption, which are often barriers to set alternative governance systems to foster the transformation of human-nature interrelations. Lessons can be drawn from the conflicts on bycatch mitigation to experiment adaptive management and set up a polycentric governance system. Adopting a critical and reflexive approach in bycatch research can contribute to the identification of best practices with regards to the role of governance in conservation conflicts.

The lack of consideration of fishers' needs and voice can undermine support of constituents and produce opposition, potentially undermining the long-term success of sustainability initiatives. Restoring a climate of trust requires understanding the needs, concerns, and motivations of the groups of fishers (Calderwood, 2021). The conflicts analyzed in this paper emphasize the critical importance of fishers' motivation and readiness to adapt to bycatch reduction policies. Fishers' fears and doubts should be taken seriously, and the objectives and solutions must be meaningful to them (Ears and Pol, 2022 ; Suuronen, 2022).

There are still important knowledge gaps regarding how to evaluate the outcomes of co-design processes in a context of tension. Further research should be realized on methods to measure to what extent collective learning is generated and how it enhances the resilience of communities beyond the research projects. Further studies should also be realized on the interactions between fishers and scientists with regards to bycatch mitigation and on fishers' perception of their political representation.

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In review

Figure 1.JPEG

In review

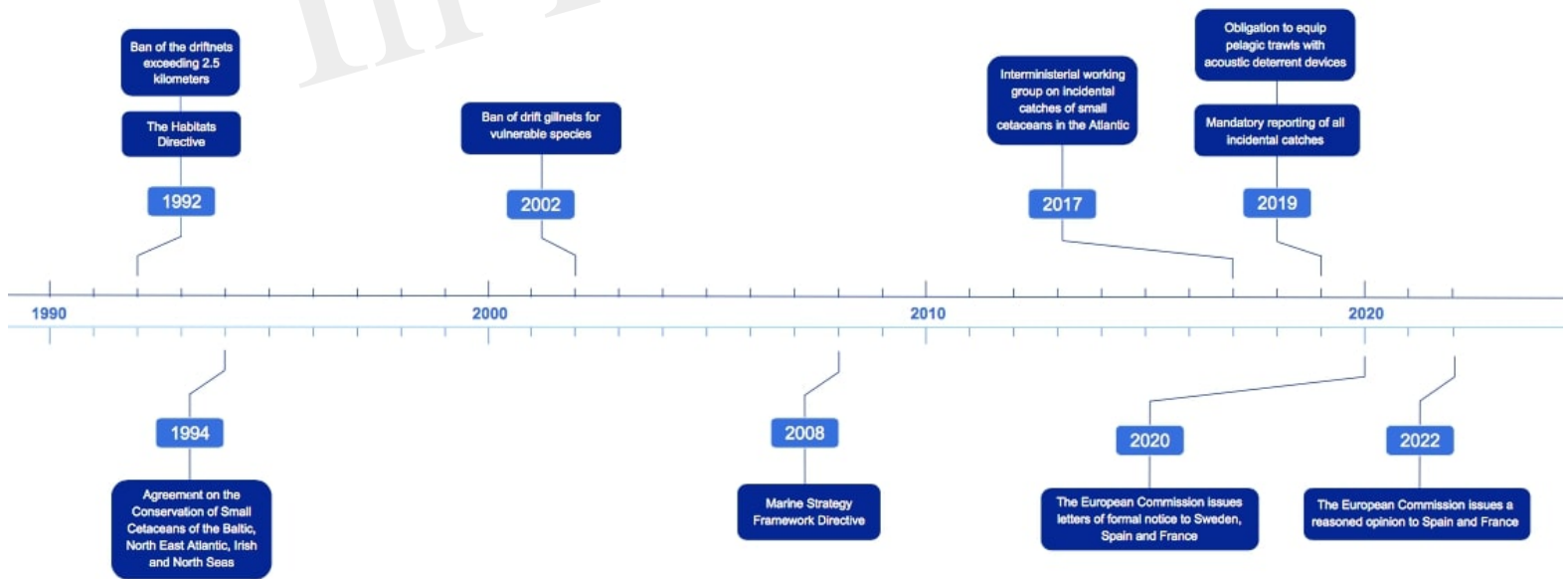
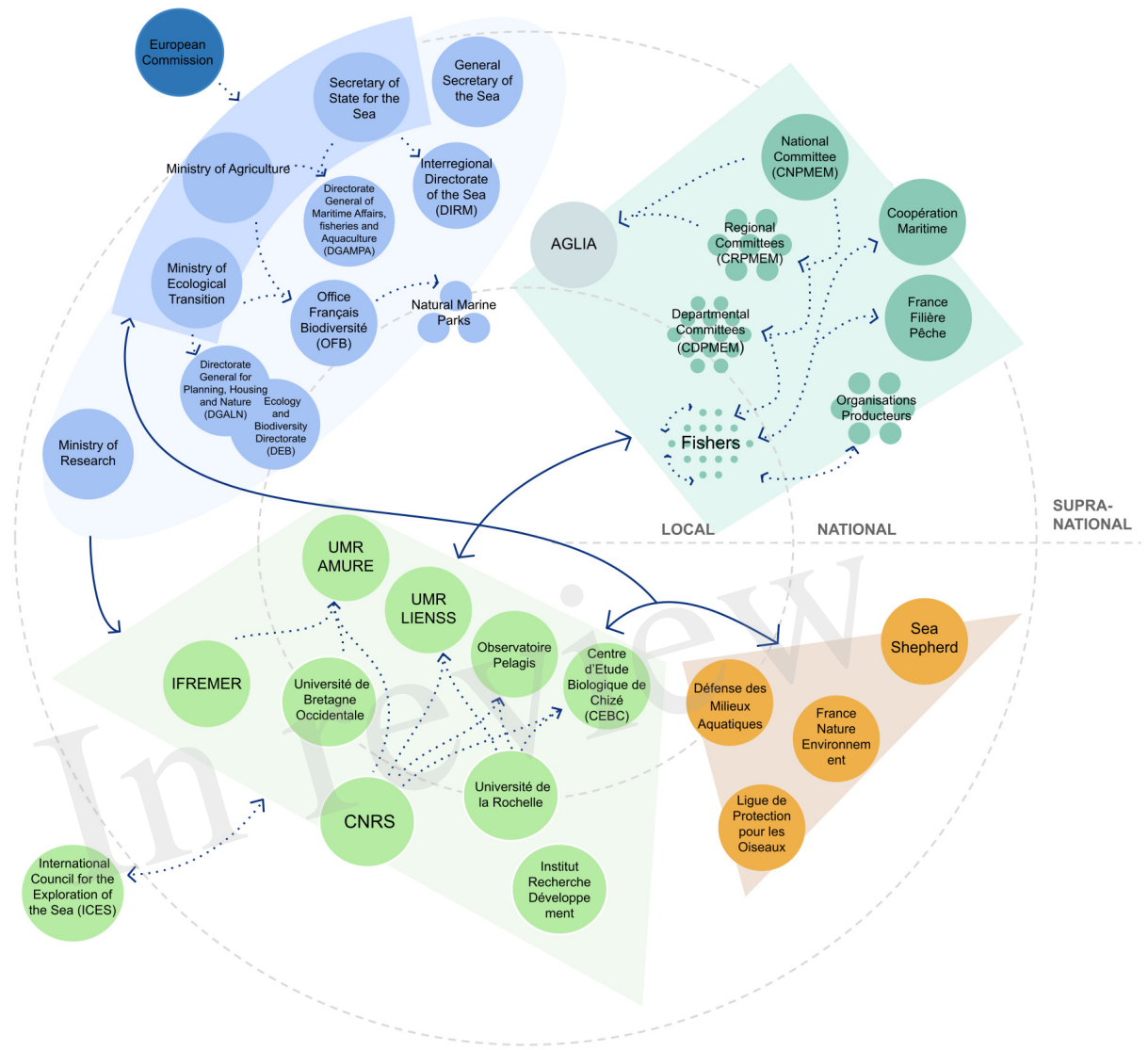


Figure 2.JPEG



- **Research organisations**
 - **Public institutions**
 - **Supranational institutions**
 - **Fishers and industry representatives**
 - **NGOs for the protection of marine biodiversity**
-
- ▬ **Main entities producing fishery policies**
 - ▬ **Governmental entities**
 - ▬ **Academia**
 - ▬ **Fishing sector**
 - ▬ **Fishers and industry representatives**
 - ▬ **NGOs for the protection of marine biodiversity**
-
- ⋯→ **Direct impact within stakeholder group**
 - **Direct impact between stakeholder groups**