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Ever Changing Times: Sustainability Transformations of Galician Small-Scale Fisheries

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The Galician small-scale fisheries sector has been experiencing important changes. The presence of a wide range of ecological, economic, social and institutional drivers have forced the *statu quo* toward new transitions with the potential to generate desirable transformative changes. Sustainability transformations mean that changes fundamentally alter the entire system's ecological and/or social properties and functions. However, there is a limited understanding of how a transformative change may look in small-scale fisheries, when and by whom it can be triggered, supported, and implemented. To cover this research gap, the objectives of this paper are twofold: to document the current state of the art of Galician small-scale fisheries, and to evaluate the innovations and changes that occurred between 1990 and 2020, to explore whether such changes have scaled-up as seeds of desirable transformative changes and, if not, what obstacles and/or barriers have been identified in the scientific literature. We selected two cases, the Galician shellfisheries and the Marine Protected Area of Fishing Interest *Os Miñarzos*, to understand when and how profound changes in small-scale fisheries took place. We hypothesize that obstacles for building resilience to consolidate transformative changes once triggered are the still moderate effectiveness of the fisheries management systems, the low progress of incorporation of scientific and traditional knowledge into decision-making processes and policy arenas, the lack of studies about socio-economic contribution to coastal communities and commercialization models, and the presence of persistent ecological and economic drivers hindering desirable transformative changes.

Keywords: small-scale fisheries (SSF), transformative changes, Galicia (NW Spain), shellfisheries, marine protected area (MPA)

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INTRODUCTION

Hundreds of millions of people obtain key nutrients and livelihoods from small-scale fisheries (SSF), many of which are fully exploited or overexploited (Selig et al., 2017). Governments around the world have been carrying out huge institutional efforts during the last decades to develop fisheries regulations to avoid overexploitation, such as co-management systems (Gutiérrez et al., 2011; Macho et al., 2013), total allowable catches (TAC)

(Villasante and Sumaila, 2010), individual transferable quotas (Chu, 2009), vessel and gear restrictions (Selgrath et al., 2019), as well as *ad hoc* public institutions for enforcement and research (Gelcich et al., 2019). However, such efforts and regulations have not always been successful in achieving their objectives (Selig et al., 2017). Often, this is a consequence of addressing SSF from a resource management perspective and ignoring that SSF constitute complex social-ecological systems (SES) that impose key governance challenges (Berkes et al., 2001; Ostrom, 2009). Even SSF definition is contextual, relative and often elusive (Smith and Basurto, 2019; Symes, 2020). Yet, worldwide, SSF shares basic tenets including their embeddedness in coastal fishing communities, the multiplicity of targeted species and fishing gears, and a set of common problems and threats (Jentoft, 2020).

Galicia's SSF sector involves almost 10,043 fishers directly (including 3,724 mainly women working on intertidal shellfisheries) and more than 16,460 indirect employees, representing over 60% of the total population employed in the fisheries sector (Xunta de Galicia, 2019; IGE — Instituto Galego de Estatística, 2020). The SSF fleet operates from more than 80 towns and villages, where, according to the official census of the Galician fishing fleet updated in March 2021, there were over 3,827 small fishing vessels, who operate in coastal embayments and shallow oceanic waters (Xunta de Galicia, 2021). Many of the coastal towns and villages located along this extensive coastline in the NW of Spain are highly dependent on fishing and fishing-related activities (Freire and García-Allut, 2000). In Galicia there is a deep-rooted culture around the sea. The historical closeness between the Galician population and the coasts was able to promote, as already happened in other regions such as Bretagne or the Basque Country, a deep integration of the fisheries sector into the Galician social norms and traditions, including the configuration of the art, culture, gastronomy, and language (Villasante et al., 2005).

The fisheries sector is a major contributor to the regional gross domestic product (GDP) (IGE — Instituto Galego de Estatística, 2020; Pascual-Fernández et al., 2020). Galicia is also the main fishing region in Spain (Freire and García-Allut, 2000), and one of the most fishing dependent areas in the European Union (EU) (Villasante et al., 2016). Galicia accounts for around 40% of Spain's fleet, approximately 60% of total Spanish employment in fishery-related sectors and 50% of catches reported by Spanish fishing vessels in EU waters (STECF — Scientific, Technical and Economic Committee for Fisheries, 2020; Xunta de Galicia, 2021). However, in spite of the biological (Freire and García-Allut, 2000) and socio-economic (Varela-Lafuente et al., 2000) importance of the sector and the highest level of dependence on fishing activities in Europe (EC — European Commission, 2000), Galician SSF have received little attention from the scientific community (López-Veiga et al., 1993; Villasante et al., 2016).

In addition, the Galician SSF sector has been experiencing important changes due to the presence of a wide range of ecological, economic, social and institutional drivers, including overfishing (Freire and García-Allut, 2000), environmental changes of the Galician bays (Álvarez-Salgado et al., 2008), oil-spills (Loureiro et al., 2006) and other pollution events, increasing seafood demand (Villasante et al., 2021), development of new co-management systems (Macho et al., 2013), implementation of marine protected areas (MPAs), and conflicts with recreational fisheries (Pita et al., 2019), whose individual or combined effects are challenging the *statu quo* toward new transitions with the potential to generate desirable transformative changes.

In the last decade, there has been a growing interest in the study of transitions and transformations (Gunderson and Holling, 2002) of SES from undesirable development pathways toward more sustainable ones (Folke et al., 2010). In the scientific literature, transformation refers to a fundamental shift in human and environmental interactions and feedbacks (O'Brien, 2012; Olsson et al., 2014). Transformative changes convey something more substantial or radical than incremental change. While incremental changes may rely on current modes of thinking and governance structures to modify SES, radical change may require deep structural shifts that challenge our assumptions, practices, beliefs and values, along with government schemes and power relations (Villasante et al., 2017; Bennett et al., 2019).

References to transformative changes are found, for example, in the *The Intergovernmental Panel on Climate Change Special Report on Extreme Events*, which defines transformation as the altering of fundamental attributes of a system, including value systems, regulatory, legislative or bureaucratic regimes, financial institutions, and technological or biological systems (IPCC — Intergovernmental Panel on Climate Change, 2012). *The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* also calls for transformative changes to society, stating "*Goals for conserving and sustainably using nature and achieving sustainability* [. . .] *may only be achieved through transformative changes across economic, social, political and technological factors*" (IPBES — Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019). Transformations are also mentioned in the Sustainable Development Goals Preamble ("*transformative steps* [. . .] *to a sustainable and resilient path*") (UN — United Nations, 2015a) or in the Paris Agreement Article 7 ("*greater adaptation needs can involve greater adaptation costs*") (UN — United Nations, 2015b).

When used in the fisheries and marine SES literature, the concept of transformation entails profound changes in the structures, processes, rules and (social) norms that produce radical changes reconfigurations in social, political, economic, and/or ecological aspects of marine SES (Westley et al., 2011; O'Brien, 2012; Blythe et al., 2017; Villasante et al., 2017). This includes breaking the self-reinforcing interactions of a SES that produce undesired outcomes and let the system navigate new trajectories and feedbacks that can foster desirable directions (Olsson et al., 2017; Eriksson et al., 2021).

When faced with shocks, marine SES may deal with change through adaptation or transformation. A distinction is usually made between adaptation and transformation understood as different responses to uncertainty and change in SES (Folke et al., 2010). Incremental adaptation includes strategies to continue to provide benefits by accommodating changes, but without modifying the essential characteristics of the SES (Fedele et al., 2019). On the other hand, transformative changes mean that changes fundamentally alter the entire system's ecological and/or

social properties and functions. Deliberative transformations are those fundamental changes conducted by a group of people in a purposeful manner, sometimes in combination with the involvement of agencies (Chapin et al., 2010).

Given that transformative changes may require a long time period to see the benefits to manifest themselves, it may receive less social and political support because of the need for high human and financial investments (Adger et al., 2005). Frictions and contested reactions are often expected to be derived from the cognitive limits of failure perceived by actors to anticipate unexpected consequences of innovation (Westley et al., 2011). This is because transformative changes do not occur in a void, rather, they occur in complex, non-linear and dynamic social-ecological contexts and feedbacks between actors over space and time (Silver, 2014). The term transformative change has been analyzed to study community-based resource management (Blythe et al., 2017), just transformations (Bennett et al., 2019), transformation of ocean governance (Olsson et al., 2008; Gelcich et al., 2010; Brodie-Rudolph et al., 2020), and the social determinants to respond to climate change (Harper et al., 2018; Barnes et al., 2020), among others. Yet, we have a limited understanding of what a transformative change looks like in SSF, and when and by whom it can be triggered, supported, implemented and consolidated. The consolidation of sustainable trajectories is directly linked with efforts aimed at providing basic elements for resilience building such as (Biggs et al., 2012): addressing SSF as SES, maintaining diversity within SSF (e.g., stakeholders, fishing communities, institutions, targeted species, values), managing connectivity between stakeholders and within fishing communities, and promoting learning, participation and governance systems capable of effectively addressing local realities of fishing communities.

The specific aims of the paper are twofold: (1) to know the current state of the art of Galician SSF, mainly from an economic and fleet-based perspective, and (2) to assess the innovations that have been developed around SSF between 1990 and 2020 in order to explore whether such changes have been ultimately generated desirable transformative changes and, if not, what obstacles and/or barriers have been identified in the scientific literature. This research helps to contribute to the growing number of studies that provide knowledge of the multiple factors that enable or hinder sustainability transformations of SSF.

To that end, the remainder of the article is structured as follows. Section "Materials and Methods" describes the methodology used to describe the current knowledge for Galician SSF as well as those initiatives which were able to generate new transitions and/or transformative changes toward sustainable fisheries. Sections "Results" and "Discussion" present and discuss results respectively, with special focus on potential ecological and economic implications for SSF development.

MATERIALS AND METHODS

Study Area

The Galician coast extends for approximately 1,295 km and has a highly varied morphology, with rías and inlets, cliff areas with beaches or marshes, and areas exposed to storms with shaded areas (Penas, 1986). The continental Galician shelf, defined as the coastal zone to 200 m deep, is relatively narrow; its width varies between 20 and 35 km and its total surface area, from Ribadeo (in the extreme north) to the estuary of the Miño river (in the extreme south), is approximately 10,000 km^2 (**Figure 1**).

The coasts of Galicia are seasonally influenced by wind-driven upwelling pulses that contribute to a high local primary production. From a biological point of view, the Galician rías are ecosystems with high primary production. The richness of Galician rías, which consist of old tectonic valleys occupied by the sea as a result of the high sea level during the last glaciations, is due to upwelling phenomena (Fraga and Margalef, 1979). This upwelling process fertilizes the coastal and shelf areas with deep-water nutrients in discrete events that can occur between March and October (Bode and Varela, 1998). Primary production can reach 250 gC/m^2/year in the Ría de Arousa (Varela et al., 1984), which is far higher than the average primary production observed in the Atlantic Ocean (100 g C/m^2/year) and is close to the estimated average for land ecosystems (Fraga and Margalef, 1979). This high productivity supports diverse and productive SSF around Galician coasts.

Galician SSF are typically multispecies and multigear (**Figure 2**). The SSF fleet is composed of vessels under 12 m that use fishing gears known as *artes menores* (including, traps, lines, small purse seines, and gill nets, while trawl nets are not included) and fishing trips last less than 24 h (**Figure 2A**). SSF activities traditionally involve family members and includes 1–2 fishers on board through different fleet segments. The main commercial species harvested by the Galician SSF fleet are common octopus (*Octopus vulgaris*, **Figure 2G**), velvet crab (*Necora puber*) and common prawn (*Palaemon serratus*) by using traps (*nasas*, **Figure 2F**), European sole (*Solea solea*), European seabass (*Dicentrarchus labrax*) and spider crab (*Maja brachydactyla*, **Figure 2B**) with trammel nets (*miños*), European hake (*Merluccius merluccius*), horse mackerel (*Trachurus trachurus*), pouting (*Trisopterus luscus*), and surmullet (*Mullus surmuletus*, **Figure 2C**) with gillnets (*betas*) (Villasante et al., 2016). Shellfishing activities mainly comprise the harvesting of clams (e.g., *Ruditapes phlippinarum*, *R. decussatus,* and *Venerupis corrugata*) and cockles (*Cerastoderma edule*) (**Figures 2D,E**).

Systematic Literature Review on Small-Scale Fisheries

To date there has been no systematic review of Galician SSF and their evolution over time from the environmental, social and economic disciplines. Such a review serves as a decision-making framework for determining which critical factors may have greater success in dealing with the implementation of management actions toward sustainable transformations of SSF.

We searched scientific papers, Ph.D. thesis, books, book chapters, and oral presentations presented at congresses proceedings published in English, Spanish, and Galician between 1990 and 2020 period in Scopus, Web of Science and Google Scholar by searching titles, abstracts and keywords using the following search string: "small-scale fisher*" OR "artisanal fisher*" OR "shellfisher*" AND "Galicia."

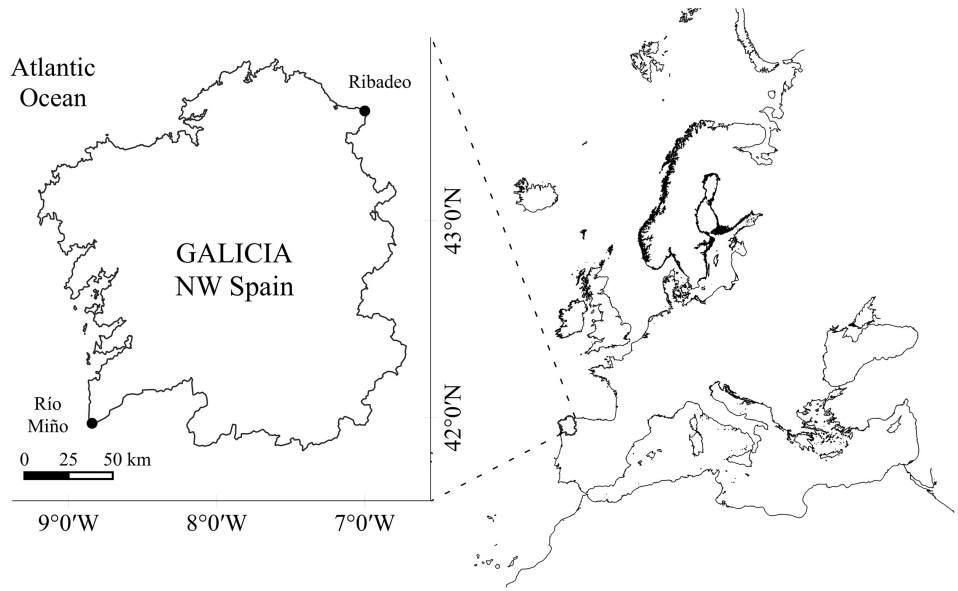


FIGURE 1 | Map of the study area (Galicia, NW Spain).

Data Collection

Once we compiled the relevant literature to be included in the review (**Supplementary Table 1**), we extracted 22 variables and their corresponding response categories (**Table 1**). These variables were recorded in pre-defined categories for comparability purposes. Data variables included, among others, SSF type assessed; location, scale, dimension and type of analysis; fishery management system; type of data used; key actors in the case study; drivers affecting SSF; innovations developed toward transformative changes; actors who promoted them; obstacles for SSF sustainability.

To document transitions and desirable transformative changes of Galician SSF, we also included variables already used in the scientific literature regarding transformative changes (Gelcich et al., 2019; IPBES — Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019). However, we also attempted to capture the key role of a given type of actor who promoted new transitions or transformational changes which are usually lacking in the scientific literature. This element should be considered essential for policy makers, given that developing programs or allocating public funds to stimulate transformative changes require knowing which actors would be in the position to lead that role. We also included obstacles for SSF sustainability and their link with the main knowledge gaps in analyzing transformative changes of Galician SSF.

We selected two specific case studies to better understand which actors are advocating for transformational change of Galician SSF, for what purposes, and to what expected outcomes, but also to understand where profound changes in the structures, processes, rules, and norms of ocean governance are currently underway. We purposefully selected these case studies because they illustrate transformations toward different governance approaches (rights-based and conservation-based) as well as because they are also dealing with different challenges of transformational phases (e.g., preparing, navigating and building resilience) (Olsson et al., 2004; Chapin et al., 2010; Moore et al., 2014; Herrfahrdt-Pähle et al., 2020).

Phases for Transformative Changes

Sustainability transformations are usually conceptualized as typically occurring in three phases: the preparation phase, the navigation phase and the stabilization or institutionalization phase, serving to build resilience of the new state or regime (Olsson et al., 2004; Moore et al., 2014).

In the *preparation* phase, the SES is often triggered by a perturbation or crisis, and alternative governance systems, developed in the preparation phase, can be transferred into the *navigation* phase and start to become institutionalized. This phase may ultimately lead to the institutionalization of a sustainability transformation (Moore et al., 2014; Herrfahrdt-Pähle et al., 2020). Nevertheless, prevailing risks transferred from the previous regime influence the disruptive potential of the alternative pathways with the possibility that new ideas are actively contested, or even coopted by the *statu quo* system due to, namely, the socio-cultural features of the system (Westley et al., 2011; Moore et al., 2014; Brodie-Rudolph et al., 2020; Herrfahrdt-Pähle et al., 2020). This is because sustainability transformations are also political and context dependent, dealing with asymmetric social power relationships, tensions and conflicts. Therefore, they represent a space for potential conflicts and a source of social struggle (Avelino et al., 2017). The *stabilization* phase is usually characterized by the alternative modes which are now institutionalized in the governance system and embedded in the seascape level (Olsson et al., 2004, 2006; Moore et al., 2014). This dynamic process includes the consolidation of new values, implementing and

FIGURE 2 | Small-scale fishing in Galicia: **(A)** trammel nets (*miños*) fishing, **(B,C)** trammel nets (*miños*) catches (crustaceans and fish), **(D)** shellfishing on foot, **(E)** shellfishing catches (bivalves), **(F)** traps (*nasas*) fishing, **(G)** traps (*nasas*) catches (common octopus).

enforcing new rules and regulations, and internalization of new fishing practices (e.g., shifting toward desirable fishing gears which produce less damage to marine ecosystems).

RESULTS

Research on Small-Scale Fisheries

Publications on SSF in Galicia have been scarce until the 21st century (**Figure 3**). However, during the last two decades of this century, an average of 31 ± 4.2 (S.D.) publications per decade have been published in relation to this topic. In 2020, a maximum of 6 scientific articles were published.

A total of 72 publications were analyzed from 1990 to 2020 in relation to SSF in Galicia according to the type of publication (conceptual, empirical, and/or review), type of data used (interviews, models, official data, and/or other), type of analysis (quantitative and/or qualitative), scale (local, regional, national, or global), species studied (several species or a single species) and dimension (economic, environmental, governmental, and/or social) (**Figure 4**). Reviews (43.1%) were the most common type of publication, followed by empirical (37.5%) publications. Official data (48.6%) and interviews (18.1%) were the most common types of data used in the publications analyzed. The approaches used for analyzing these data were qualitative (48.6%), quantitative (20.8%) or both (30.6%). In general terms, the environmental (63.9%) and economic (51.4%) dimensions were predominant, and to a lesser extent the social (43.1%) and governance (37.5%) dimensions.

The regional scale (70.8%) prevailed in the publications analyzed (national and global: 2.8% each). At the local scale (23.6%), A Coruña (58.8%) and Pontevedra (41.2%) were the most studied provinces, highlighting locations such as Lira, in the province of A Coruña, or Ría de Arousa, in the province of Pontevedra. Other locations such as Ría de Cedeira, Ría de A Coruña (A Coruña), and Ría de Vigo (Pontevedra), also stand out (**Figure 5**).

A total of 29.2% of the recorded publications analyzed several species (n = 21), while 22.2% studied a single species (n = 16). Nevertheless, a large proportion of the publications analyzed (n = 35) do not specify targeted species. We recorded a total of 96 studied species, mainly bony fishes (34 spp.) and bivalves

TABLE 1 | Data variables and corresponding categories used to collect data in the systematic literature review.

Data variables	Description
Keywords	Keywords of the scientific contribution
Language	English | Spanish | Galician
Type of the paper	Conceptual | Empirical | Review
Dimension	Environmental | Economic | Social | Governance
Type of analysis	Quantitative | Qualitative | Mapping | Other
Scale	Local | Regional | National | Global
Location	Indicate the name of the place where the study is conducted
Province	Province of the study
Multispecies SSF	1 if the study is multispecies | 0 if only one species
Commercial species	Indicate the name of the species (or group of species, e.g., cephalopods)
Type of data used	Official data | Interviews | Models | Other
Temporal data	Indicate year or time series used
Source of data used	Indicate the name of the source with link if possible
Fishery management system	TAC | Co-management | TURF | MPA | Other
Key actors involved the case study	Women | Small-scale fishers | Shellfishers on foot | Shellfishers on boat | Other
Drivers affecting SSF	Climate change | Overexploitation | Other
Obstacles to SSF sustainability	Range of constraints and challenges that arise within and between political, legal, technological, physical (e.g., infrastructure), economic/financial and other social systems and the functioning of SSF
Innovations towards transformative changes?	Yes | No
Who promoted the change?	Fishers | Administration | Scientists | NGOs | Other
Specify innovations	Certification | MPA | Other
Values of inclusiveness, justice and equity are considered?	Yes | No
What are the most important knowledge gaps for achieving the transformative changes?	Provide a brief explanation of knowledge gaps

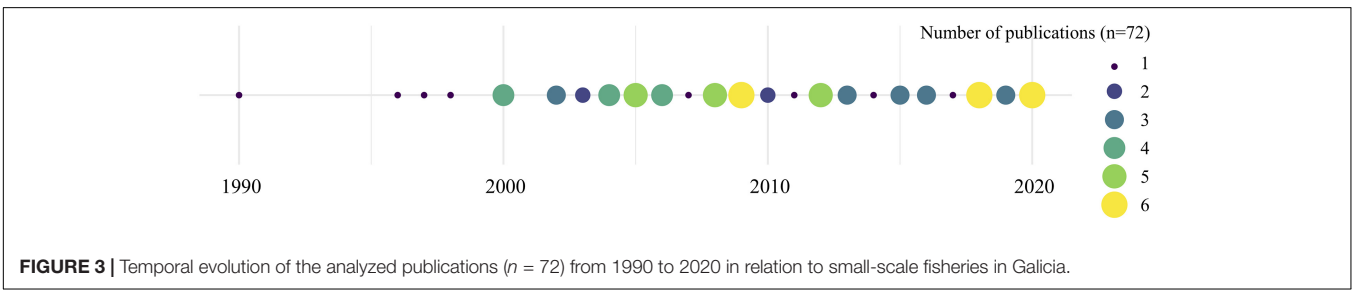


FIGURE 3 | Temporal evolution of the analyzed publications (n = 72) from 1990 to 2020 in relation to small-scale fisheries in Galicia.

(30 spp.). Other groups were also present such as algae (10 spp.), crustaceans (8 spp.), polychaetes (4 spp.), cephalopods (4 spp.), elasmobranchs (3 spp.), as well as an echinoderm, a gastropod and an anthozoan (**Figure 6A**). Cephalopods (n = 21), crustaceans (n = 16), and fish (n = 15) were the most represented taxa in the analyzed publications (**Figure 6B**).

The importance of cephalopods and crustaceans is particularly remarkable. In the case of cephalopods, three species were studied in 21 publications, being the common octopus of utmost relevance (19 publications). In the case of crustaceans, eight species have been studied in 16 different publications, the spider crab being the best represented crustacean species (10 publications). In addition to the common octopus (26.4% of publications) and the spider crab (13.9%), the importance of other species is remarkable; for example, bony fishes such as European hake (12.5%), ballan wrasse (*Labrus bergylta*, 6.9%), European seabass (6.9%), and pouting (6.9%); crustaceans such as the velvet crab (12.5%) and the common prawn (8.3%); cephalopods such as the cuttlefish (*Sepia officinalis*, 8.3%); echinoderms such as the purple sea urchin (*Paracentrotus lividus*, 8.3%); and bivalves such as the sword razor clam (*Ensis arcuatus*, 8.3%) (**Table 2** and **Figure 7**).

New Trajectories Toward Transformative Changes of Small-Scale Fisheries

Based on the systematic literature review conducted in this research, our results showed that the main fisheries management systems studied in Galician SSF during the last three decades are -in this order of importance- co-management systems (including Territorial Users' Rights, TURFs) (Freire and García-Allut, 2000; Freire, 2004; Fernández-Boán et al., 2013; Casal et al., 2020; Garza-Gil et al., 2020), TACs for those species under the Common Fisheries Policy of the European Union, inputs-effort-outputs for the coastal fleet (Villasante, 2009), the development of a new Marine Reserve of Fishing

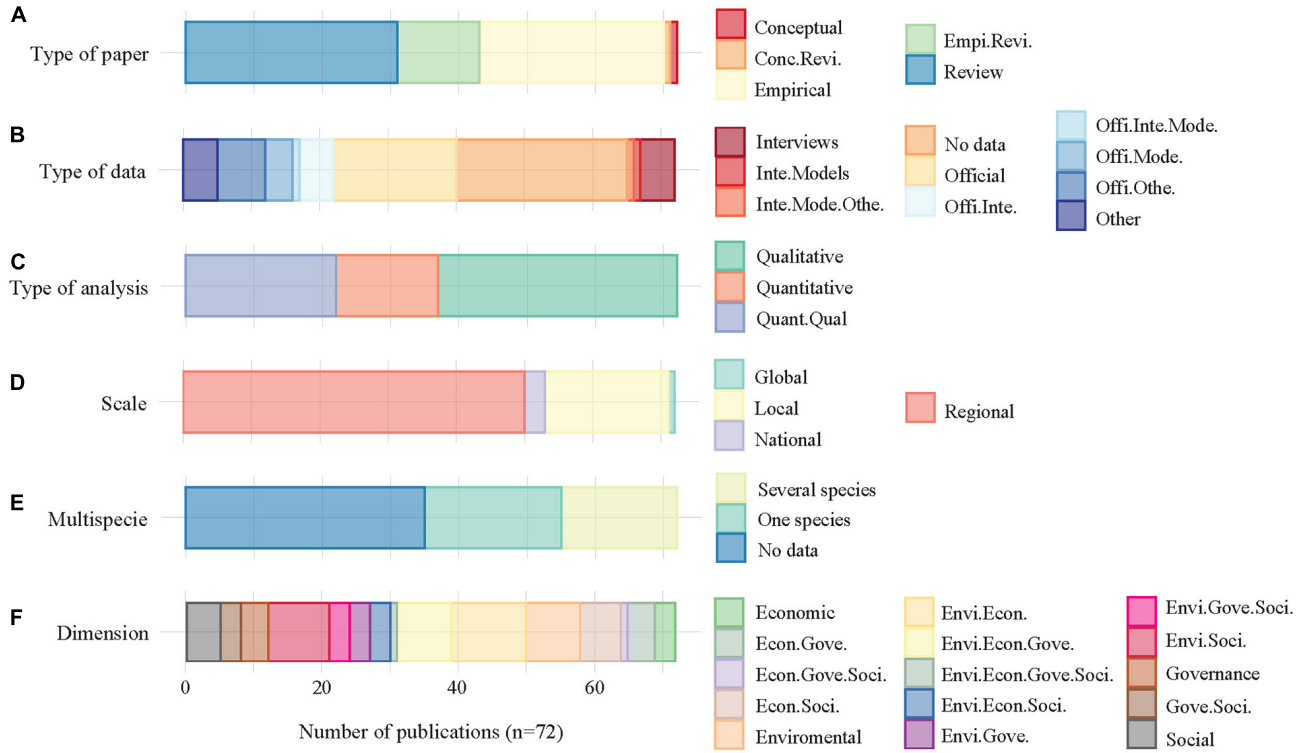


FIGURE 4 | Publications (*n* = 72) analyzed from 1990 to 2020 in relation to small-scale fisheries in Galicia, according to the type of publication **(A)**, type of data used **(B)**, type of analysis **(C)**, scale **(D)**, species studied **(E)**, and dimension **(F)**.

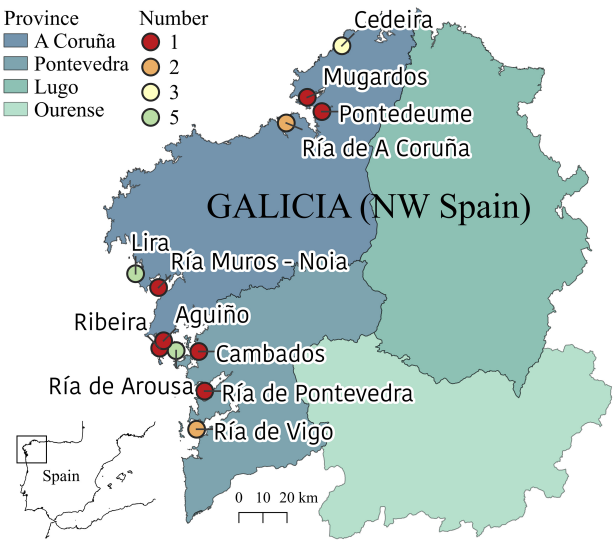


FIGURE 5 | Local scale study sites (*n* = 17) in Galicia by province (A Coruña and Pontevedra) and number of publications analyzed (1–5).

Interest (Fernández-Márquez, 2015; Tubío, 2015; Fernández-Vidal, 2017), and using private and/or public exploitation concessions to develop shellfishing activities for sedentary species in intertidal and subtidal waters (Macho et al., 2013; Pascual-Fernández et al., 2020).

In Galician SSF we found that a wide range of actors have been involved in the development of SSF, namely -in this order- ship-owners, skippers, fishers, women working on shellfisheries and other roles related to the fishing sector (Otero et al., 2005; Pita et al., 2018), the regional administration, with particular emphasis of the role of technical assistants, managers, and other staff from the Xunta de Galicia (Macho et al., 2013), and local institutions such as fishing guilds or *cofradías* (Pascual-Fernández et al., 2020; **Table 3**).

Regarding the analysis of key drivers affecting the sustainability of Galician SSF, our results indicated that overexploitation of commercial species has been the most predominant factor documented over time (Freire and García-Allut, 2000; Freire, 2004; Villasante, 2009; Fernández-Vidal, 2017; Pita et al., 2018; Garza-Gil et al., 2020). About 40% of the publications here analyzed point to overexploitation as the main factor affecting Galician SSF. Only recently scholars have analyzed the impacts of climate change on SSF as a notable driver currently threatening the capacity of SSF to provide food, jobs and revenues to coastal communities (Ruiz-Díaz et al., 2020). Other key drivers documented in the scientific literature are the problem of unreported catches (Simon et al., 1996; Otero, 2006; Villasante et al., 2015), the loss of fishers' traditional knowledge (Freire and García-Allut, 2000), the lack of trust between fishers and scientists (Freire, 2004), the role of commercialization in

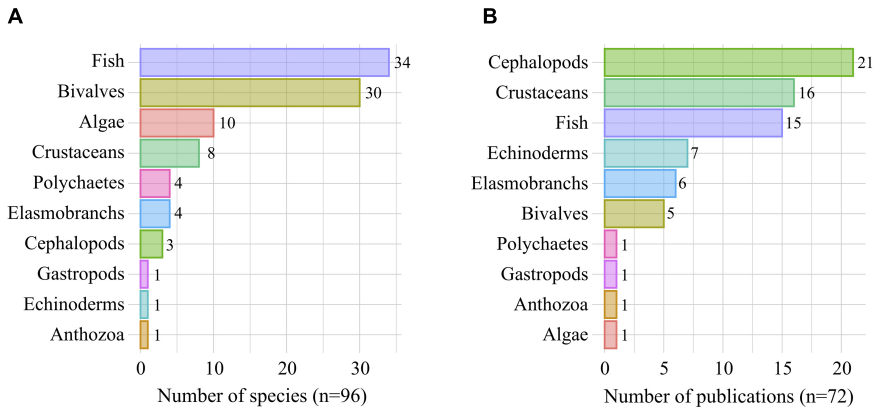


FIGURE 6 | Species **(A)** and publications **(B)** (in number) by taxonomic groups.

TABLE 2 | Species studied (**A:** several species and **B:** one species) in the analyzed publications. Subindexes: [1]Cephalopod, [2]Crustacean, [3]Fish, [4]Echinoderm, [5]Bivalve, and [6]Elasmobranch.

(A) Number of publications (*n* = 21) studying several species*			
Common octopus (*Octopus vulgaris*)[1]	12	Megrim (*Lepidorhombus* spp.)[3]	3
Velvet crab (*Necora puber*)[2]	9	Pollack (*Pollachius pollachius*)[3]	3
European hake (*Merluccius merluccius*)[3]	8	Red mullet (*Mullus surmuletus*)[3]	3
Spider crab (*Maja brachydactyla*)[2]	8	Purple sea urchin (*Paracentrotus lividus*)[4]	3
Common prawn (*Palaemon serratus*)[2]	6	Squids (*Loligo* spp.)[1]	3
Sword razor clam (*Ensis arcuatus*)[5]	6	Anglerfish (*Lophius piscatorius*)[3]	2
Common cuttlefish (*Sepia officinalis*)[1]	5	Atlantic horse mackerel (*Trachurus trachurus*)[3]	2
European seabass (*Dicentrarchus labrax*)[3]	5	Banned carpet shell (*Venerupis rhomboides*)[5]	2
Pouting (*Trisopterus luscus*)[3]	5	Barnacle (*Pollicipes pollicipes*)[2]	2
Rays (Rajidae)[6]	5	Black anglerfish (*Lophius budagessa*)[3]	2
Ballan wrasse (*Labrus bergylta*)[3]	4	Blue whiting (*Micromesistius poutassou*)[3]	2
Common cockle (*Cerastoderma edule*)[5]	4	Farmed turbot (*Scophthalmus maximus*)[3]	2
Queen scallop (*Aequipecten opercularis*)[5]	4	Grooved carpet shell (*Venerupis decussata*)[5]	2
Scallop (*Pecten maximus*)[5]	4	Japanese little neck (*Venerupis philippinarum*)[5]	2
Atlantic mackerel (*Scomber scombrus*)[3]	3	Norway lobster (*Nephrops norvegicus*)[2]	2
European conger (*Conger conger*)[3]	3	Pulled carpet shell (*Venerupis pullastra*)[5]	2
European flounder (*Platichthys flesus*)[3]	3	Wart venus shell (*Venus verrucosa*)[5]	2
European sole (*Solea solea*)[3]	3	Wedge clam (*Donax trunculus*)[5]	2
(B) Number of publications (*n* = 16) studying a single species			
Common octopus (*Octopus vulgaris*)[1]	7	Barnacle (*Pollicipes pollicipes*)[2]	1
Purple sea urchin (*Paracentrotus lividus*)[4]	3	European hake (*Merluccius merluccius*)[3]	1
Spider crab (*Maja brachydactyla*)[2]	2	Common cuttlefish (*Sepia officinalis*)[1]	1
Ballan wrasse (*Labrus bergylta*)[3]	1		

In the case of publications studying several species **(A), only the species recorded in more than one publication are shown (36 of 96 total species).*

providing attractive prices to secure fishing activities (García-Allut, 2006), or the still insufficient studies in SSF focusing on the socio-economic dimension (Outeiro et al., 2018).

Several factors have been studied when analyzing transformative changes of marine SES (Folke et al., 2010; Gelcich et al., 2010). However, which actors are promoting new transitions or transformative changes remain largely unknown in the literature. Here we provide, for the first time, insights of the documented transformative changes in Galician SSF, which indicate that scientists, small-scale fishers (including shellfishers) were, with the support of the regional government, the essential actors who triggered new changes for sustainable transitions. The role of consolidated research institutions and universities with the key role of the Technical Assistants, explain the capacity of Galician SSF to successfully navigate into new pathways. The main innovative actions promoted by scientists were the development of a new management policy based on the establishment of TURFs, the involvement of fishers in the

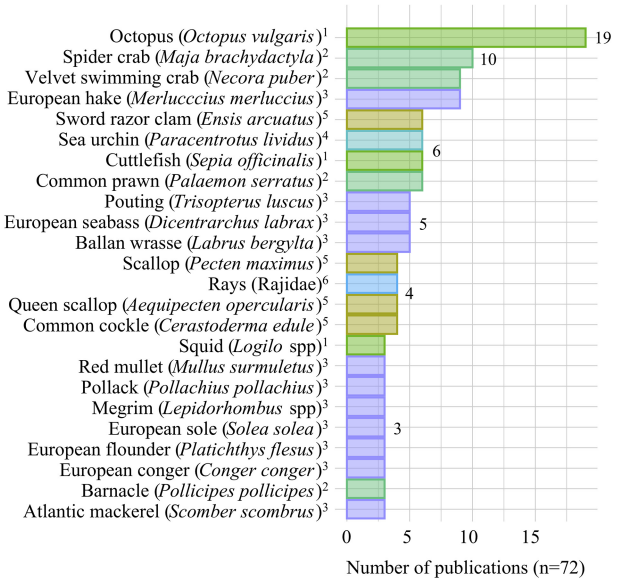


FIGURE 7 | Species studied in the analyzed publications. Subindexes (and colors according to **Figure 6**): [1]Cephalopod, [2]Crustacean, [3]Fish, [4]Echinoderm, [5]Bivalve, and [6]Elasmobranch. Only the species recorded in more than three publications are shown (24 of 96 total species).

assessment and management process, the creation of a novel figure for SSF management called Technical Assistants (Barefoot Fisheries Advisors) in shellfisheries management within the *cofradías* in 1993 (Macho et al., 2013), and the use of stock assessment models to assess coastal fisheries based on data obtained from fishers (Otero et al., 2005; Rocha et al., 2006; Guerra et al., 2008).

More recently, there were other institutional, social and marketing initiatives such as the development of tools to assess the socio-economic impacts of social-ecological crisis (Castro-Rial, 2016), the creation of MPAs, minimum sizes for managed of commercial species and the integrated spatial management systems as key regulation tools (Freire and García-Allut, 2000; Freire, 2004; Fernández-Boán et al., 2013; Tubío, 2015), the patrimonialization of knowledge held by artisanal fishers (García-Allut, 2003a), or the creation of business initiatives designed to improve the marketing of artisanal fishery products [e.g., *Lonxanet* (García-Allut, 2003b) or *PescadeRías, ¿de onde se non?*[1] created in 2008 as a certification to highlight the origin and identity of local Galician seafood products from SSF]. More recently, the University of Santiago de Compostela has also created the ecolabel *Pescaenverde*[2] to measure, based on life cycle approaches, the carbon footprint of seafood products landed in Galician auction markets (Vázquez-Rowe et al., 2016).

These initiatives have been highly positive to develop new sustainable trajectories, and they are currently in different phases of development and degree of success (García-Allut, 2003b; Macho et al., 2013; Vázquez-Rowe et al., 2016; Pita et al., 2018). However, in our review, we documented key issues that were not covered appropriately in the literature. These issues, with potential consequences for transformative change processes, include (1) the lack of fishers' participation in decision-making process (Coppel-Hidalgo, 2000), (2) the cultural tradition of cooperation between scientists and the fisheries sector (Freire and García-Allut, 2000), (3) the data and knowledge needed to improve traceability of harvested species (Otero et al., 2005; Villasante et al., 2015; Pita et al., 2018), (4) the limited integration of knowledge about species biology and ecosystem interactions in SSF management (García-Allut, 2003a), (5) the effects of local and global market dynamics (García-Allut, 2003b, 2006), and (6) the poor knowledge about the socio-economic contribution that SSF make to coastal communities (Freire, 2002; Villasante, 2009). Intriguingly, social vulnerability analysis based on the relationship between the social structures and dynamics of the family based small scale sector and fishing communities are lacking (Colburn et al., 2016).

As a result, only a few initiatives have been able to generate desirable transformative changes of Galician SSF. For this reason, in the following subsections we analyze two case studies under the lens of transformative changes framework (Moore et al., 2014): the Galician shellfishing on foot (*marisqueo a pie*) and the Marine Reserve for Fishing Interest *Os Miñarzos* (Lira).

Case Studies of Transformative Changes

Galician Shellfishing on Foot (*Marisqueo a Pie*)

Shellfish species can be harvested from vessels or through manual harvest during low tides. On-foot shellfishing (*marisqueo a pie*), an expression used to refer to shellfish gathering at accessible intertidal areas during low tides by using a variety of clam rakes and hoes (**Figure 2B**), is mostly carried out by women, while shellfishing from vessels is performed mostly by men in subtidal areas (Marugán-Pintos, 2004).

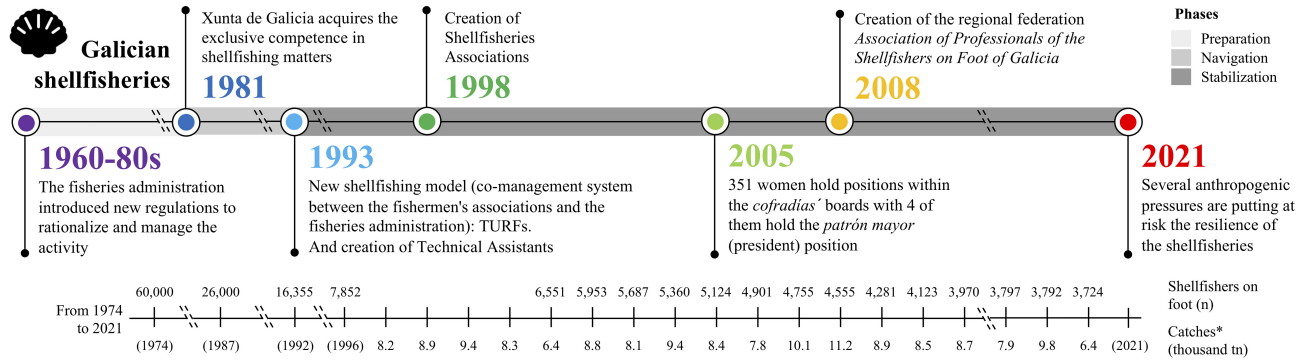
Under the *preparation* phase, Xunta de Galicia has managed coastal fishery activities for the last 50 years, while the Spanish Government manages fisheries in external waters, i.e., outside the imaginary lines connecting the main capes of the Galician shoreline (Pita et al., 2019). Shellfish gathering has historically been considered marginal, as a complementary way to increase household incomes and performed without real administrative control. It was characterized by technological backwardness compared to other related activities, reflected in an aging workforce, high feminization, scarce professional and technological training, lack of investment, all which resulted in poor marketing, poor internal cohesion of the sector, and overexploitation of most of shellfish species (Villasante et al., 2015). During the 1960s–1980s, coinciding with a general increase in the number of shellfishers, market demand, and economic value of shellfish species, the regional administration introduced step-by-step new regulations to rationalize and manage the activity (**Figure 8**). In 1963 an order established the obligatory nature of a shellfisher card, and the Law 59/1969 established the regulations for the concessions and authorizations of shellfishing areas (Frangoudes et al., 2008).

[1]https://deondesenon.xunta.gal

[2]https://www.usc.gal/pescaenverde/es/marca-pescaenverde

TABLE 3 | Summary of main drivers, actors, and obstacles for transformative changes of Galician small-scale fisheries.

Fishery management system (species)	Key actors involved in SSF	Drivers of change	Actor/s promoting changes	Innovations towards transformative change	Transformative changes	Current obstacles	References (examples)
Co-management systems - TURFs (e.g., clams and common cockle)	•Small-scale fishers •Shellfishers women •Regional administration •*Cofradías*	•Over- exploitation •Climate change	•Scientists •Shellfishers women •Regional administration	•New co-management system •Development of exploitation plans •Creation of technical assistants	Yes, under *stabilization* phase	•Extreme events •Poaching •Pollution •IUU activities •Lack of social and economic impacts in fisheries management •Lack of ecosystem approach	Freire and García-Allut, 2000; Freire, 2004; Fernández-Boán et al., 2013; Macho et al., 2013; Fernández-Gestido and Pastoriza, 2018; Casal et al., 2020; Ruiz-Díaz et al., 2020; Garza-Gil et al., 2020
Marine Protected Areas – MPAs (e.g., octopus, urchin, cockle, barnacle, and spider crab)	•Small-scale fishers •*Cofradías* •NGOs	•Oil spill •Over- exploitation	•Small-scale fishers •*Cofradías* •Scientists •NGOs	•New MPA •Management body of MPA	Yes, under *stabilization* phase	•Insufficient support from administrations •IUU activities •Lack of social and economic impacts in fisheries management •Lack of ecosystem approach	García-Allut and Seijo-Villamizar, 2010; García-Allut and Vázquez-Portela, 2012; Burgós and Fernández, 2014; Fernández-Márquez, 2015; Tubío, 2015; Fernández-Vidal, 2017
TAC / input-output measures (e.g., hake, horse mackerel, mackerel and octopus)	•Small-scale fishers •*Cofradías*	•Over- exploitation •Environmental changes •Lack of quotas	•Scientists •Small-scale fishers	•Experimental plans for key species (e.g., octopus) •Exchange of quotas •Ecolabeling and certification schemes •Horizontal integration with the canned industry (e.g., pelagics)	No, still under *preparation* or *navigating* phase	•Environmental changes •IUU activities •Increasing imports •Lower prices •Lack of social and economic impacts in fisheries management •Lack of ecosystem approach	Carballo-Penela et al., 2005; Villasante, 2009; Villasante et al., 2016; García-Lorenzo et al., 2019; Villasante et al., 2019



Source: own data, PescadeGalicia (https://www.pescadegalicia.gal), IGE (https://www.ige.eu) and Frangoudes et al. 2008. (*) Catch data include shellfishing from vessels.

FIGURE 8 | Main landmarks of shellfishing in Galicia from 1960 to 2021.

In the early 1980s, Spain initiated a process of decentralization entering into the *navigation* phase, and with this came the creation of distinct Autonomous Communities (Villasante et al., 2015). Prior to the decentralization process, fisheries regulations were vague or largely non-existent; in most cases, there was no control of compliance to the law. The transition from a traditional and non-formal activity to the development of a professional sector encountered several obstacles, e.g., a high level of poaching, social conflicts, women exclusion and political instability (Marugán-Pintos, 2004; Villasante et al., 2015). During this decade, the regional authorities introduced several regulations that refined the requirements for shellfishing, for example, a shellfisher training certificate was required (Decree 116/1987 regulating the requirements for shellfishers).

But it was not until 1993 when the Galician government, with fishing powers since 1981, introduced a fundamental transformative change entering into the *stabilization* phase: a new model for shellfishing, promoting a co-management system between *cofradías* and fisheries administration, advised by scientists, based on TURFs over a large area and its resources (**Figure 8**). In Galicia coexist three types of co-management systems with a different participation of fishers and scientists in the decision making process: (1) *TURFs,* for species that an exploitation plan is mandatory (i.e., Atlantic goose barnacle, razor clams, echinoderms, polychaetes, anemones and abalone), (2) *Top-down*, including species caught with traps from vessels (i.e., crabs and related species, and cephalopods), and Mediterranean mussel (*Mytilus galloprovincialis)* as a seed for mussel aquaculture, and (3) *Mollusks* species that can be included in exploitation plans (i.e., bivalves except razor clams and gastropods, e.g., limpets) and whose inclusion may even be mandatory in certain coastal areas. Otherwise, they are directly managed by the regional government (Xunta de Galicia) (Pita et al., 2019).

The new co-management -which included the previous three models- successfully allowed an increase in the volume of catches while, at the same time, women improved their income and social conditions due to the creation of Shellfisheries Associations, moving away from an uncontrolled and marginalized activity, to a professional shellfishing, one that now have to pay taxes to ensure the benefits of the social security system (Marugán-Pintos, 2004; Pita et al., 2019).

Although these changes have been institutionalized within the new governance regime, the shellfishing activity is currently under several anthropogenic and social pressures which are putting at risk the capacity to build resilience. The increasing market pressure due to the high national and international seafood demand is driving shellfishers to harvest Japanese carpet shell (*Ruditapes philippinarum*), an invasive species with better resistance to deal with environmental changes which has been introduced in the 1980s in Galician bays (Xunta de Galicia, 1987).

From an ecological perspective, the health of shellfishing grounds have been affected by a combined and cumulative impacts of overfishing (Freire and García-Allut, 2000; Pita et al., 2019), long-term degradation of key habitats, increasing poaching (Alló and Loureiro, 2017), IUU (Illegal, Unreported and Unregulated) fishing activities (Villasante et al., 2015), and growing exposure and sensitivity to extreme events (Ruiz-Díaz et al., 2020), leading to an increase of vulnerability to social-ecological crisis such as the COVID19 pandemic (Villasante et al., 2021).

From the socio-economic view, the shellfisheries sector has been substantially increasing the volume and value of the Japanese carpet shell, growing from 0.41 thousand tn and €3.7 million in 2001 to 3.3 thousand tn and €30.5 million in 2019 respectively (Xunta de Galicia, 2021). While increasing landings of the Japanese carpet shell have been positive for shellfishers to deal with the lower resistance of native clams as well as to ensure economic revenues over time, developing a strategy toward a monoculture production by concentrating most landings in a single species can be risky in a rapidly changing environment.

Social drivers such as the intergenerational gap between old shellfish women and the new shellfishers (which included men for the first time), the lack of interest of new generations to get involved in SSF, and current conflicts derived from new and less experienced shellfishers entering the fishery are currently affecting the co-management procedures. Galician shellfisheries are also facing indirect drivers such as loss of local population,

increasing tourism and gentrification, impacts of economic crisis, delocalization of companies, and lack of labor opportunities for young people. Under this new scenario, local shellfish producers need to compete in a highly competitive and uncertain global seafood market, facing a higher risk of financial bankruptcy over time (Pita et al., 2019).

The Marine Protected Area of Fishing Interest Os Miñarzos (Lira)

After the abrupt shock and the huge impacts of the Prestige oil spill in 2002 (Garza-Gil et al., 2006), artisanal fishers from Lira (north-central coast of Galicia) initiated a process or *preparation* phase to create a 'Marine Reserve of Fishing Interest' (hereinafter referred to as MPA to simplify) that concluded with its formalization in April 2007, with the name of 'Os Miñarzos' (**Figure 9**). Under the Fisheries Law of the Xunta de Galicia (Law 11/2008, December 3, of Galician Fishing), *marine reserves of fishing interest* are tools for the management of fishing resources and conservation of marine ecosystems (Fernández-Vidal, 2017). In the process of creating the MPA of *Os Miñarzos*, fishers have taken an active participation in the design and collectively defined the most suitable management plans for sustainable fishing within the reserve (Pascual-Fernández et al., 2020), which led to a greater acceptability and compliance of norms, entering into the *navigation* phase.

More than 10 years after its full implementation, the transformative change that took place since the creation of the MPA not only had repercussions on fishing practices, but also on the beliefs and social values of the main fishers, scientists and representatives of the regional administration involved in the Management Body of the MPA. The latter provided the foundations for the stabilization phase (**Figure 9**). Trust and cooperation, essential elements to successfully govern common pool resources (Ostrom, 2009), have been improved since fishers provide data and participate in different monitoring programs. There has also been a notable reduction of conflicts and mistrust between the administration and the fisheries sector, favoring that most decisions concerning fishing activities within the MPA are taken by consensus (Pita et al., 2018). Another sign of progress was the collective behavior of local fishers working within the MPA who, after the decision of the regional administration to discontinue financially supporting the surveillance to the area in 2010, continued with the inertia of social norms to comply with the fisheries law, even 2 years after that decision.

Starting with a fragmented and divided fisheries sector, the main challenge was to construct a common vision of a sustainable future for the MPA and the economic development of the associated coastal communities. The MPA has inspired other neighboring communities to propose another MPA of fishing interest on the Northern coast of Galicia (Decree 28/2009, of January 29, creating the Marine Reserve of Fishing Interest *Ría de Cedeira*), while a procedure for the extension of the MPA of *Os Miñarzos* has also been initiated and it is currently in the final stage. The objective is to move from the current protected area of 2,074 to 50,000 ha (in coastal waters), where eight fishing communities and 750 small-scale fishing vessels will potentially benefit (Pita et al., 2018).

This process of collective construction has also been complex and not exempt from tensions and contested actions from some *cofradías* and fishers, since it is necessary to not only trust in the MPA but also to increase the fisheries sector commitment to sustainability targets. Indeed, currently there are obstacles putting at risk the consolidation of the *stabilization* phase, namely the reduction of the public budget to cover costs for surveillance allocated by the regional administration and the lack of support from some *cofradías* fishing in the MPA (Fernández-Vidal and Muiño, 2014). This is leading to an increase of poaching, IUU fishing activities inside and outside the MPA and a lower effectiveness of the MPA.

DISCUSSION

Small-scale fisheries and their associated coastal communities are facing a critical time around the world. The social-ecological drivers they are suffering from overfishing, climate change, pollution, urbanization, industrialization, and increasing demand of seafood are in many aspects unprecedented (Jouffray et al., 2020). However, the good news is that our coastal communities are progressively responding to the threats to their coastal commons (Armitage et al., 2017).

Our results show that Galician SSF are still understudied, and most research was focused on a few commercial species, while the study of the governance dimension as well as the relationship between the social structures and dynamics of the family based small scale sector and fishing communities should be strengthened in the short term (Colburn et al., 2016).

Our analysis of two specific transformative changes with different motivations (rights-based and conservation-based)

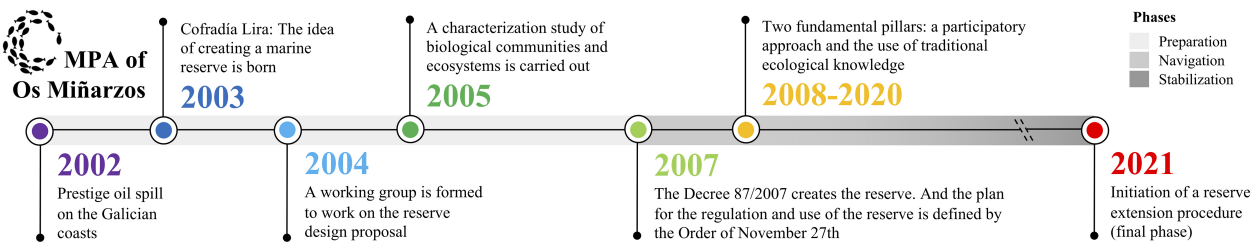


FIGURE 9 | Main landmarks of the Marine Reserve of Fishing Interest of *Os Miñarzos* (Lira, Galicia) from 2002 to 2021.

showed that Galician SSF is still struggling to consolidate the transformative changes that were navigated. Successful experiences should not be taken for granted as they are threatened by a combination of drivers, and to foster new transformative changes we should leverage on the key role that some actors had in promoting trust, cooperation and social innovation. Although we were able to document several incremental changes, knowing in detail the role of actors involved stimulating and/or triggering in SSF were elusive. We hypothesize that obstacles for building resilience to consolidate transformative changes once triggered are the still moderate effectiveness of the fisheries management systems, the low progress of incorporation of scientific and traditional knowledge into decision-making processes and policy arenas, the lack of studies about SSF socio-economic contribution to coastal communities (and vice versa) and commercialization models, and the presence of persistent ecological and economic drivers hindering desirable transformative changes.

Nevertheless, we acknowledge that the role of scientific initiatives, and hence scientists' role, in promoting transformative changes may be somewhat overestimated. As we are analyzing only scientific sources (i.e., scientific articles, thesis, proceedings), place-based or autonomous initiatives motivated by local actors could be to some extent under-represented in our review. Future research should focus on the collection, through participatory methods, of ongoing experiences of innovation and/or transformation that are not documented in scientific literature.

In this section we discuss the most plausible causes for the lack of further scientific studies and a still slow capacity of SSF for further consolidation of transformative changes. Based on the systematic literature review conducted in our study, we hypothesize that these causes are the still insufficient incorporation of the scientific and traditional knowledge into the decision-making policy, advances toward the socio-economic contribution to coastal communities, and the persistence of ecological and economic drivers hindering desirable transformative changes.

Scientific Knowledge

Overexploitation of fishery resources, in particular those unassessed fisheries, is usually considered the responsible factor for the poor performance of SSF (Costello et al., 2012). In spite of the biological and socio-economic importance of the Galician SSF sector (Freire and García-Allut, 2000; Varela-Lafuente et al., 2000), little attention has been devoted to it by the scientific community (López-Veiga et al., 1993; Freire and García-Allut, 2000; García-Allut, 2003b).

Our review of the research conducted on SSF in Galicia (72 publications in the last 30 years) confirms the still scarce biological, social, and economic knowledge about this sector. There is a basic knowledge of the biology and life history of some of the species of commercial interest, for example fishes such as ballan wrasse (Pita and Freire, 2011, 2017; Villegas-Ríos, 2013) or European pilchard (Villanueva-Rey et al., 2017); crustaceans such as spider crab (Corgos et al., 2011); cephalopods such as common octopus (Otero, 2006, Otero et al., 2007, 2008; Pita et al., 2021) or squid (García-Mayoral et al., 2020); echinoderms such as purple sea urchin (Fernández-Boán et al., 2012; Casal et al., 2020) or sea cucumber (Ballesteros et al., 2021); bivalves such as razor clams (Darriba et al., 2004; Hernández-Otero et al., 2014; **Figure 7**). These studies provide important basic biological information to adapt management measures based on size limits and/or sex (and other life history stages) restrictions (Freire and García-Allut, 2000). Only 13% of the publications analyzed in this study include biological aspects of the species studied. However, the processes that determine the population dynamics of these species (recruitment, spatial structure, density-dependent processes, and spatial variability of growth, reproduction, or mortality) are not well understood yet (Freire and García-Allut, 2000).

Recently, Alonso-Fernández et al. (2021) studied the temporal trends and main drivers of body size in the catch of a set of key commercial species (15 fishes, 3 cephalopods, and 2 crustaceans) exploited by the Galician SSF fleets, in order to assess the current performance of such species. Although their results showed relatively stable trends both inter-annual and seasonal (annual), the authors highlighted the need to align management measures with biological reference points to avoid long-term reductions in stock productivity. Therefore, it is a priority to know the biological aspects of the species of commercial interest in Galician SSF, since this lack of biological knowledge prevents the development of TAC/quota or effort regulations or closed area systems (Caddy, 1999; Freire and García-Allut, 2000).

Traditional Knowledge

The current poor knowledge of Galician SSF and shellfisheries is, most likely, a direct consequence of the fact that a systematic and integrated collection of biological and socio-economic data is still not fully developed, even for key commercial species.

In addition to the scientific, there are other forms of knowledge, which have demonstrated their effectiveness and ability to survive insofar as they have withstood the world of experience and have been able to make certain predictions or to make certain phenomena occur or prevent them from occurring (García-Allut, 2003a). Traditional ecological knowledge, and specifically, fisher's (including women) ecological knowledge, contains empirical and conceptual aspects, is cumulative generationally and is dynamic insofar as it responds to technological, ecological and socio-economic changes (Freire and García-Allut, 1999; García-Allut, 2003a; Pascual-Fernández et al., 2020).

Given that integrating knowledge systems (i.e., scientific and local/traditional) is challenging (Berkes et al., 2015), the traditional ecological knowledge of fishers can be used combined with scientific knowledge, and incorporated into concrete projects, fisheries management, MPA design and implementation, ecosystem assessments and the commercialization of SSF products. Accommodating traditional ecological knowledge of fishers can provide a more complete understanding than each knowledge system alone and can generate an open space to alternative epistemologies for navigating change (Gianelli et al., 2021). For example, Pita et al. (2020) who worked with data-poor recreational fisheries in Galicia, tested the use of traditional ecological knowledge of

fishers as an alternative to the absence of scientific information to support fisheries management.

In the case of the *Os Miñarzos* (Lira) MPA of Fishing Interest, fishers' ecological knowledge played a pivotal role in defining the location and size of the MPA, and the most suitable management model. This knowledge contributed to the design of an innovative management model for the MPA in which the representation of the fishing sector and the administration is balanced, even though consensus constitutes the criterion for deliberation of the Management Body. For the MPA extension proposal fishers' knowledge was critical to (1) identify species essential habitats, including those for spawning and recruiting; and (2) perceive resource scarcity and changes in abundance of commercial species. The MPA co-construction process helped to move away from a competitive mental model to a more cooperative one, in which disregarding the ecological knowledge of fishers is unlikely, if not impossible (Pita et al., 2019; Pascual-Fernández et al., 2020).

SSF and Fisheries Management Systems

Several studies have examined the factors that contribute to the successful implementation of management tools in SSF (Cinner et al., 2012; Selig et al., 2017). SSF in Galicia are almost entirely managed by the autonomous administration. Regulatory measures are aimed at species (e.g., minimum catch sizes, protection of ovigerous females, maximum catch limits), fishing gear (e.g., number of gears per vessel and fishers, maximum length, minimum mesh size), and spatial/temporal closures (specific zones and depths for specific gears and species) (Freire and García-Allut, 2000; Villasante et al., 2016; Pita et al., 2019). The historical lack of fishers' participation in decision-making has led to weak fisheries and shellfisheries management and it partially explains the poor results obtained so far in the conservation of marine resources (Garza-Gil et al., 2020). However, some important progress has been made in the SSF sector, particularly in shellfisheries (e.g., Macho et al., 2013; Fernández-Vidal et al., 2020; Garza-Gil et al., 2020). According to Garza-Gil et al. (2020), Galician small-scale fishers are in favor of moving toward co-management on issues such as participation in the establishment of regulatory mechanisms, control of compliance with fishing rules, and delimitation of areas for recreational fishing.

The participation of the fishing sector in the decision-making process will ensure that the measures adopted better reflect local circumstances. However, although in the last decade a few initiatives have attempted to promote collaboration in the design of new rights of use, these have not been effectively accomplished (Fernández-Vidal et al., 2020). Therefore, it is necessary to reopen the path of promoting cooperation and dialogue for discussion within the regional, national and European public agenda.

According to Frangoudes et al. (2008) and Villasante et al. (2016), two different points of view coexist for sustainable fisheries management in Galicia. The fishing sector prioritizes social and economic aspects, while scientists and the administration tend to focus more on fishing resource conservation (Frangoudes et al., 2008; Pascual-Fernández et al., 2020). However, effective resource conservation requires a balance between the "three pillars" (i.e., economic development, social development, and environmental protection) of sustainability in fisheries (Anderson et al., 2015; Asche et al., 2018). In this respect, stakeholders (fishers/shellfishers, scientists and managers) should share empirical and scientific knowledge about fishing/shellfish resources as a basis for agreement. As we have seen, an example of this balance is the MPA of *Os Miñarzos*, focused on the sustainability of fishing resources and artisanal fisheries, designed and to some extent controlled by fishers and shellfishers themselves.

Commercialization of Seafood

SSF communities employ millions of people at all levels, from catching, landing and processing to commercialization and services. The products of SSF usually have a higher unit value than products obtained from industrial fishing (Jacquet and Pauly, 2008), and they can provide added value to the market by indicating that they were caught with more selective and environmentally friendly gear (García-Allut, 2003a,b). In this sense, six fishers' guilds (including the *Cofradía de Lira*) in Galicia have taken the initiative to become direct distributors of their products. These initiatives provide social and economic benefits as shown in García-Allut (2003a,b). Indeed, the certification of these products increased their added value and generated greater consumer acceptance. In this regard, García-Allut (2006) and Amigo-Dobaño et al. (2008) suggest that the fishing sector should put more efforts into designing commercialization models that not only seek to optimize price but also combine profitability and commercial benefits with the sustainability of their fisheries.

Drivers of Change

Drivers of change usually undermine sustainability transformations of global fisheries (IPBES — Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019). Direct drivers such as climate change (Ruiz-Díaz et al., 2020), increasing pollution (Rodil et al., 2019), overexploitation of fishery resources (Ouréns et al., 2015), and indirect drivers such as a culture of tolerance to unsustainable practices and values are hindering the capacity of the Galician SSF sector to further consolidate stabilization phases of transformative changes.

Explicitly addressing these problems in an ecosystem-based management approach while countering with systemic ecological and socio-economic information at the same time would be extremely valuable for policymakers, scientists, and the SSF sector. This would help to build resilience and adaptive capacity to tackle social-ecological crises such as the current COVID-19 pandemic, which has been severely impacting Galician SSF and shellfisheries (Villasante et al., 2021). For example, one of the most important/valuable SSF in the EU, the Galician common octopus' fishery, was synergistically affected by changing environmental conditions, overfishing and the COVID-19 pandemic. This combination of press and pulse perturbations led to a reduction of 52% in landings (from 2.1 thousand tn 2019 to 1 thousand tn in 2020) and 51% in value (from 16.1 million euros to 7.8 million euros in the same period)

(Xunta de Galicia, 2021). These drastic changes of landings can lead to disruptions of local and international seafood dynamics and coastal communities that, combined with abrupt shocks such as the COVID-19, can seriously impact SSF viability because of the effects of a decrease in productivity on enterprises' revenues and the rapid growth in uncertainty.

CONCLUDING REMARKS: MOVING FORWARD

Our study provides evidence about the current state of the art of Galician SSF, which shows that scientific attention to this highly important socio-economic activity is still scarce. We also present a first step toward a better understanding of critical insights into processes of transformations. Essential elements of these transformations have been the capacity and ability of scientists, small-scale fishers and shellfishers who, with the support of the regional administration, were able to enhance dialogues and collaborative research to recognize that overexploitation of fishery resources needed sustainability transformations. Based on that shared recognition two main transformations took place, one based on fishing rights and the other one in the harmonization of conservation and fishery goals.

We also argue that these sustainability transformations cannot be considered a success yet as the still limited number of studies highlights the high level of uncertainty in relation to the social-ecological knowledge and status of Galician SSF. However, a higher number of scientific studies is not necessarily a reliable metric of success for sustainability transformations. Rather, they would help to provide more elements to evaluate the success of the studied sustainability transformations. Our study suggests that Galician SSF were able to maintain key basic elements for resilience building over space and time such as the maintenance of a high diversity of harvested species, an institutionalized connectivity between stakeholders and fishing communities, and the support of active participation through the decision making processes. Keeping these elements alive was not possible without profound changes in the social processes, rules and (social) norms of Galician SSF. We show that gaining a better understanding of when and by whom sustainability transformations can be intentionally triggered, supported and implemented, including visions of fishers' traditional knowledge, are essential to foster desirable changes. We also highlight the importance of avoiding the prescription of unique solutions to different social-ecological conditions of local settings.

A key question remains: are these transformations being rapid enough to deal with social-ecological drivers and crises? Although fine tuning is necessary to build resilience of these new regimes, these transformations have improved the sustainability of Galician SSF. Continued efforts are needed to further extend the focus on the inclusion of social justice at the core of transformations. Given the relevance of Galician SSF in the context of Europe and globally, our analysis of how these transformations unfolded provides insights into how the Galician SSF could be further developed and identifies generalized pathways for improved ocean stewardship of SSF.

AUTHOR CONTRIBUTIONS

SV conceived the theoretical idea and developed the methods. AT, IG, PP, and AG-A contributed equally to the writing of the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2021.712819/full#supplementary-material

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