IN THE EYE OF THE OBSERVER

WESTERN BALTIC COD UNDER A TRANSDISCIPLINARY FOCUS

HEIKE SCHWERMER

“Transdisciplinarity is about the recognition that ways of knowing are plural and that, to address human problems, it is necessary to engage in ongoing efforts to create and sustain bridges between different perspectives on the world.”

(Johnson et al. 2016)

In the eye of the observer.

Western Baltic cod under a transdisciplinary focus

DISSERTATION

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The unsustainable exploitation of fish stocks is one of the greatest anthropogenic impacts on oceans and coastal waters worldwide with consequences for the health of marine ecosystems, but also for the livelihoods of fishers and local fishing communities. One of the many reasons for unsustainable use of marine resources is a non-transparent and top-down fisheries management.

To address the deficiencies in achieving sustainable fisheries, the European Union increasingly adopts a holistic approach to the management of living marine resources through its Common Fisheries Policy (CFP), meaning ecosystem-based management that considers knowledge and social interactions among resource users and interest groups in decision-making processes. Nevertheless, differences in knowledge, but also values, norms and interaction with the system are a reason for different understanding regarding the functioning of a social-ecological system (SES) to which individuals and groups belong and can be a reason for profound conflicts. A very striking example in European fisheries is the management of Western Baltic (WB) cod (*Gadus morhua*), characterized by several management measures, including total allowable catch and marine protected area designation that met with varying levels of acceptance among the stakeholders involved.

This thesis focuses on the WB cod fisheries in general and more explicitly on the resource users and interest groups involved in or affected by its management. Multiple methods were used to uncover the stakeholder network of WB cod fisheries, and to investigate the perceptions of different stakeholders on the system, as well as to explore the diverse knowledges about the system and to formulate ideas for a ‘alternative’ management.

We first conducted a literature review with the objective of understanding the term ‘stakeholder’ and ‘participation’ in the context of coastal and marine fisheries (**Study I**). We found a strong increase in the number of projects in which ‘stakeholder participation’ was addressed. However, the results show that often only the term ‘stakeholder’ and ‘participation’ is used. Who exactly is defined as a stakeholder or what exactly is understood by participation in this context is often not or only very vaguely described.

To explore the WB cod fisheries, which has been chosen as a case study for this thesis, in more detail, we conducted an online questionnaire at the beginning aiming for the identification of relevant stakeholders involved in the further studies (**Study II, III, IV**).

We first investigted the perceptions of various stakeholders on the WB cod fisheries system using a participatory modeling approach (**Study II**). Furthermore, we found that not only the number of components per model differed strongly in some cases (simple vs. complex system understanding), but also the comparison of the number of relevant ecological and social

components showed significant differences. In addition, the results indicate that especially the social system components show a high variability in terms of their definitions and measures, which has been used to map the dynamic structure of the system. Expert interviews with representatives from commercial fisheries, angling, nature conservation, industry, tourism, science and administration, further served to describe and analyze WB cod and its underlying fisheries management (**Study III**). We were able to show a great diversity of knowledge types that form the basis for the description of WB cod, but also the evaluation and criticism of EU fisheries management. Lastly, we conducted a study involving mental models (collected in **Study II**) and a network analysis approach, based on the assumption that there is a relationship between identity diversity, meaning the range of social characteristics, and variations in the way people perceive and solve problems (**Study IV**). Our results empirically show that groups with higher identity diversity also exhibit greater cognitive diversity.

The Western Baltic cod fishery and its surrounding SES is diverse, partly complex and subject to different perceptions held by user and interest groups. Furthermore, the system is described by a high diversity of knowledge types, which among other things form the basis for describing the system and criticizing the EU fisheries management. Disclosure and recognition of these different system components, their interactions and dynamics, and thus the multiple knowledge types, could enhance transparency and trust among groups involved or affected by management and thus foster the success of different management measures. Therefore, the involvement of user and interest groups is fundamental to support the sustainable use of fish stocks such as the Western Baltic cod. Also, the stronger involvement of different stakeholders and the adoption of a transdisciplinary approach could contribute to safeguarding the fisheries sector, which is rich in culture and tradition.

Die nicht-nachhaltige Nutzung von Fischbeständen zählt weltweit zu einen der größten anthropogenen Einflüsse auf die Ozeane und Küstenmeere mit Folgen für die Gesundheit mariner Ökosysteme, aber auch für die Sicherung des Lebensunterhaltes von Fischern und lokalen Fischergemeinden. Einer der vielfältigen Gründe ist ein intransparentes sowie top-down gesteuertes Fischereimanagement.

Um die Defizite bei der Erreichung einer nachhaltigen Fischerei zu beheben, verfolgt die Europäische Union mit ihrer Gemeinsamen Fischereipolitik (GFP) einen ganzheitlichen Ansatz zur Bewirtschaftung der lebenden Meeresressourcen. Gemeint ist ein ökosystembasiertes Management unter Berücksichtigung von Wissen und sozialen Interaktionen zwischen Nutzer- und Interessengruppen in Entscheidungsprozessen. Dennoch, Unterschiede in Wissen, aber auch Werte, Normen und Interaktion mit dem System schaffen ein unterschiedliches Verständnis hinsichtlich der Funktionsweise eines sozial-ökologischen Systems, dem Individuen und Gruppen angehören und kann ein Grund für tiefgreifende Konflikte sein. Ein sehr markantes Beispiel in der europäischen Fischerei ist die Bewirtschaftung des Dorsches in der westlichen Ostsee (*Gadus morhua*), gekennzeichnet durch mehrere Managementmaßnahmen (u.a., zulässige Gesamtfangmenge, Ausweisung von Meeresschutzgebieten), die bei beteiligten Stakeholdern auf unterschiedliche Akzeptanz stießen.

Die vorliegende Doktorarbeit beschäftigt sich mit dem Fischereimanagement des Dorsches der westlichen Ostsee im Allgemeinen und explizit mit den Nutzer- und Interessengruppen, die am Management dieser Art beteiligt oder durch dieses beeinflusst sind. Vielfältige Methoden wurden verwendet nicht nur um das Stakeholdernetzwerk der westlichen Dorschfischerei aufzudecken, sondern vielmehr um die Wahrnehmungen unterschiedlichster Stakeholder auf das System zu untersuchen, Wissen über das System offen zu legen und Ideen für ein „alternatives“ Management zu formulieren.

Zunächst führten wir eine Literaturrecherche mit dem Ziel durch, die Begriffe ‚Stakeholder’ und ‚Partizipation’ im Kontext von Fallbeispielen in der Küsten- und Meeresfischerei zu verstehen (**Studie I**). Wir stellten fest, dass die Anzahl der Projekte in denen ‚Stakeholder Partizipation’ thematisiert wurde, stark gestiegen ist. Jedoch zeigen die Ergebnisse auch, dass es häufig nur zur Verwendung des Begriffes ‚Stakeholder Partizipation’ kommt. Wer genau als ‚Stakeholder’ definiert wird, oder was genau unter ‚Partizipation’ in diesem Zusammenhang verstanden wird, ist häufig nicht oder nur sehr vage beschrieben.

Um die Dorschfischerei der westlichen Ostsee, die als Fallstudie für diese Arbeit gewählt wurde, näher zu untersuchen, haben wir zunächst eine Onlinebefragung durchgeführt, mit dem Ziel relevante Stakeholder für die weiteren Studien (**Studie II, III, IV**) zu identifizieren.

Zunächst untersuchten wir mit Hilfe eines partizipativen Modellierungsansatzes die Wahrnehmungen verschiedener Stakeholder auf das sozial-ökologische System der Dorschfischerei der westlichen Ostsee (**Studie II**). Dabei konnten wir feststellen, dass sich diese Wahrnehmungen nicht nur zwischen den Stakeholdergruppen wie kommerzielle Fischerei, Natur- und Umweltschutz oder Tourismus unterscheiden, sondern auch innerhalb dieser Gruppen. Ferner demonstrierten wir, dass sich nicht nur die Anzahl der Komponenten je Modell teilweise stark unterschieden (einfach vs. komplexes Systemverständnis), auch der Vergleich der Anzahl relevanter ökologischer und soziale Komponenten wies signifikante Unterschiede auf. Zudem zeigen die Ergebnisse, dass gerade die sozialen Systemkomponenten eine hohe Variabilität hinsichtlich ihrer Definitionen und Messgröße (d.h., Abbildung der dynamischen Struktur des Systems) aufweisen. Experteninterviews mit Vertretern u.a. aus der Fischerei, der Angelfischerei und dem Naturschutz dienten der weiteren Beschreibung und Analyse des Systems westlicher Ostseedorsch und des ihm zugrundeliegenden Fischereimanagements (**Studie III**). Wir konnten darlegen, dass eine große Vielfalt verschiedener Wissenstypen existiert, die die Grundlage für die Beschreibung des westlichen Ostseedorsches, aber auch für die Bewertung und Kritik des EU-Fischereimanagements bildet. Schließlich haben wir eine weitere Untersuchung der mentalen Modelle (erhoben in **Studie II**) und eine Netzwerkanalyse durchgeführt. Diese beruht auf der Annahme, dass es einen Zusammenhang zwischen der Identitätsvielfalt (Bandbreite an sozialen Merkmalen) und der unterschiedlichen Art und Weise, wie Menschen Probleme wahrnehmen und lösen, gibt (**Studie IV**). Unsere Ergebnisse zeigen empirisch, dass Gruppen mit höherer Identitätsdiversität auch eine größere kognitive Vielfalt aufweisen.

Die Dorschfischerei der westlichen Ostsee und das ihn umgebende sozial-ökologische System ist vielfältig, in Teilen komplex und unterliegt verschiedenen Wahrnehmungen durch Nutzer- und Interessengruppen. Ferner wird das System durch eine hohe Vielfalt an Wissenstypen beschrieben, die unter anderem die Grundlage für die Beschreibung des Systems und die Kritik an dem EU-Fischereimanagement bilden. Durch die Offenlegung und Anerkennung dieser verschiedenen Systemkomponenten, ihren Interaktionen und Dynamiken und somit der vielfältigen Wissenstypen könnte das Vertrauen zwischen den am Management beteiligten oder betroffenen Gruppen gestärkt und damit der Erfolg verschiedener Managementmaßnahmen begünstigt werden. Die Einbeziehung von Nutzer- und Interessengruppen ist somit elementar um die nachhaltige Nutzung von Fischbeständen wie dem westlichen Ostseedorsch zu fördern. Auch könnte die stärkere Einbindung verschiedener Stakeholder und somit die Verfolgung eines transdisziplinären Ansatzes einen Beitrag zur Sicherung des kultur- und traditionsreichen Fischereisektors leisten.

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Fisheries management in the European Union

Fish and fisheries in the European Union (EU) are managed under the *Common Fisheries Policy* (CFP, EC 2013), with regions divided into different management areas. Western Baltic Sea (WBS), for example, is subdivided into 3 regions: The Belt Sea (SD22), the Sound (SD23), and the Arkona Sea (SD24) (Figure 1, Funk et al. 2021). The WBS borders the countries Denmark, Sweden and Germany, the latter forming the case study of the present work.

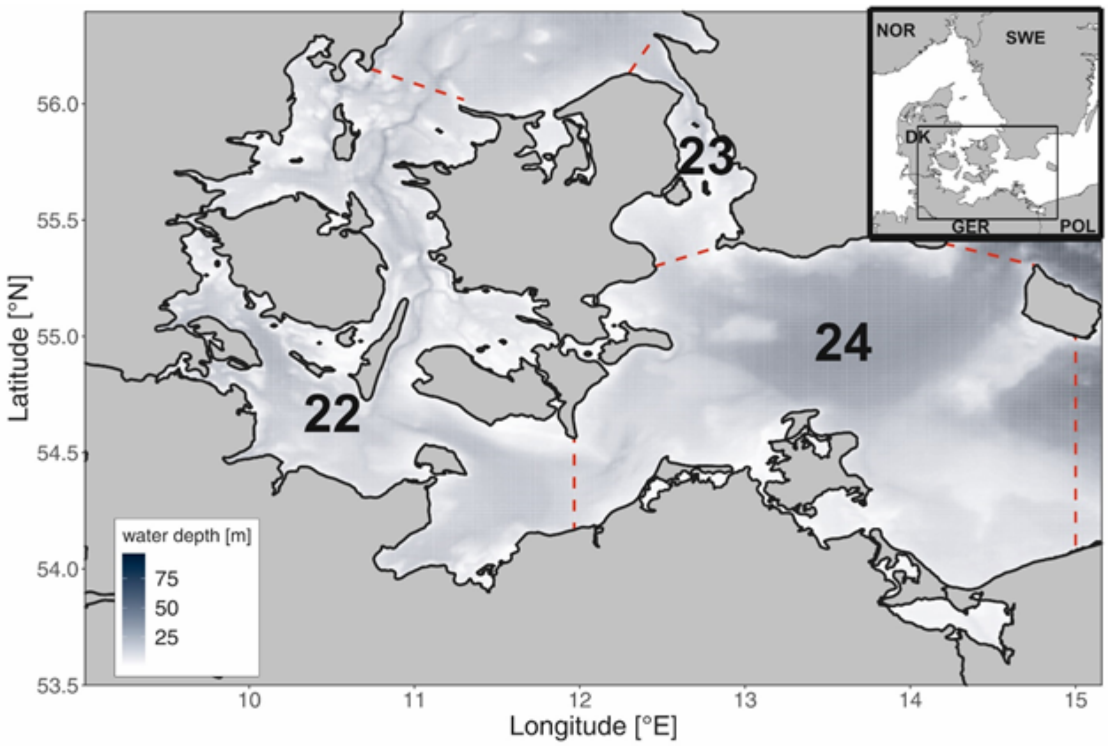

Figure 1. Map of the Western Baltic Sea region. This map shows the different subdivisions (SD) set by the FAO. The Western Baltic Sea and thus the distribution area of Western Baltic cod is represented by SD22-24, i.e. the Belt Sea (SD22), the Sound (SD23), and the Arkona Sea (SD24). Here, the region of interest is the German coast within SD22-24. (*Funk 2020*)

The fish community in the WBS is dominated by cod (*Gadus morhua*), herring (*Clupea harengus*), sprat (*Sprattus sprattus*), but also plaice (*Pleuronectes platessa*) and flounder (*Platichthys flesus*), to name a few (Voss et al. 2017). However, species diversity is very low compared to the North Sea, partly due to the brackish nature of the Baltic Sea, which is determined, among other things, by a limited influx of saltwater via the Kattegat and Skagerrak (MacKenzie et al. 2007).

As such, the Western Baltic (WB) cod represents one of the most important fish species for the commercial fisheries (Delaney 2007, Funk et al. 2020, Döring et al. 2020). Various measures (e.g., implemented in the multiannual plan, EC 2016) regulate the concerned commercial fisheries and define, for example, how much fish can be caught (e.g., catch quota), where (e.g., protected areas) and at what times (e.g., closed season in February to April) with the aim of achieving a sustainable management for this species (EC 2013, EC 2016, EC 2020). A yearly catch quota, known as the *total allowable catch* (TAC), is fixed for the commercial fisheries, based on the ecological conditions of WB cod as well as the economic and social circumstances of the fisheries itself. The TAC is negotiated and set at the supranational level (EU level) and further divided into national quotas based on a historically key known as the relative stability (Figure 2) (Baudron et al. 2020, Morin 2020, Döring et al. 2020). This allocation key dates back to the 1980s and determines which countries are allowed to fish a defined or certain share of a given quoted species (Baudron et al. 2020, Morin 2020). The share of the total quota for WB cod for the German Baltic fisheries is 21.3% (EC 2020).

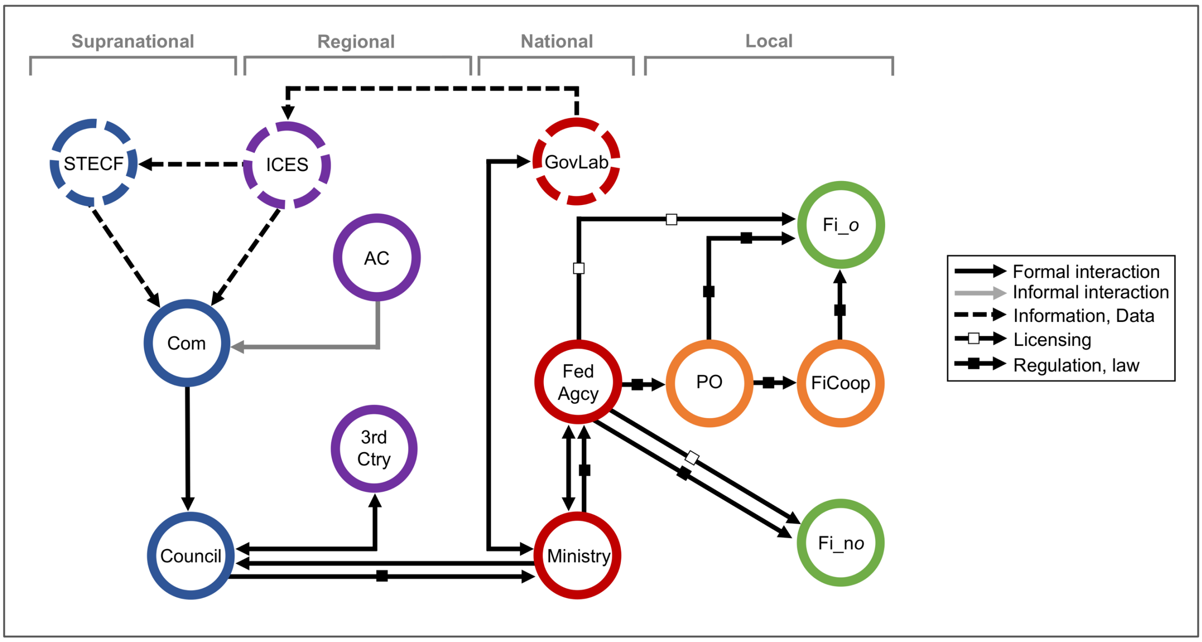

Figure 2. Quota allocation for fisheries at various governance levels. Simplified representation of different functions in terms of *advice* (Scientific, Technical and Economic Committee for Fisheries - STECF, International Council for the Exploration of the Sea - ICES, federal research institutes - GovLab, European Commission - Com), *quota negotiation* (Council, third countries - 3rdCtry, Ministry), and *quota distribution* at national and local levels (Ministry, federal agency - FedAgcy, producer organization - PO, fisheries cooperatives - FiCoop). Different colors represent the various governance levels (supranational (blue), regional (violet), national (red) and local (orange, green (only fisheries – Fi_o – fishers organized, Fi_no – fishers not organized)).

The *Council of Ministers of the European Union* (i.e. Council) negotiates and sets the TACs for the WB cod, based on several prior advisory processes, such as the *International Council for the Exploration of the Sea* (ICES), which publishes an annual TAC recommendation based on the ecological status of WB cod (Figure 2). The most recent ICES advice indicates that the *spawning-stock biomass* (SSB, total weight of all sexually mature fish in a stock) has fluctuated around the limit reference point ($B_{lim,}$ limit reference point for SSB) since 2009, but has increased in the last two years and is currently above B_{lim} and close to *MSY* $B_{trigger}$ (biomass reference point according to maximum sustainable yield approach) (ICES 2012, ICES 2020). This is similar for *fishing mortality* (F, proportion of total mortality caused by fisheries), which is currently above F_{MSY} (ICES 2020). But the *recruitment* (R, individuals added to the exploited component of a stock each year due to growth and/or migration into the fishing area (ICES 2012)) has been low since 1999, except for 2017, when the strong 2016-year class resulted in R being estimated to be above average (ICES 2020). In contrast, R in 2018 and 2019 (age 1) were the lowest in the time series (ICES 2020). For this reason, the 2016-year class has a special ecological as well as economic role, i.e. it contributed the most to the catches of commercial fisheries (ICES 2019, ICES 2020, Möllmann et al. 2021). In addition, since 2017, the relatively high recreational fisheries catches have been included in the WB cod stock assessment (Strehlow et al. 2010, Eero et al. 2014). To compensate for these removals and to contribute to further conservation of the stock, a so-called bag limit was introduced, which regulates angler removals through a fixed daily catch limit of five specimens or - during the eight-week closed season between February and April - two specimens (EC 2020).

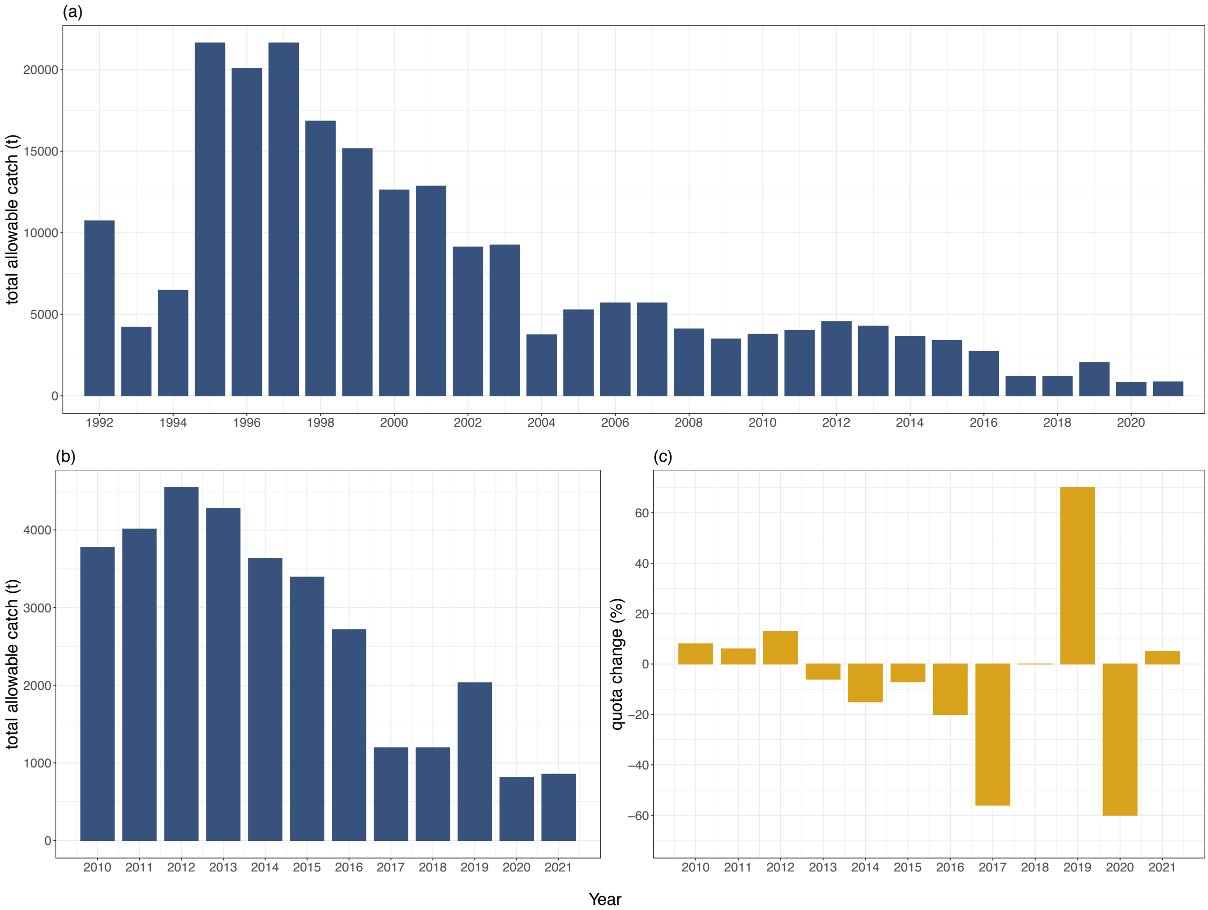

Figure 3. Development of Western Baltic cod quota. Each year in October, the *Total Allowable Catch quota* (TAC) for the Baltic Sea are negotiated and set by the *Council of Ministers of the European Union*. (a) shows the TAC development from 1992 - 2021. The highest quotas were set in 1995 (21638 t) and 1997 (21638 t). (b) + (c) highlight the TAC development of the past 11 year and (c) shows the percentage changes of each year compared to the previous. (*data from ICES 2020*)

WB cod development is reflected in the TACs, which have been subject to very strong fluctuations over the last 5 years (Figure 3 a-c), characterized by a strong reduction in 2017 (-56%) and 2020 (-60%) and a strong increase in 2019 (+70%) (Figure 3 a-c) (ICES 2020). Since 1995, the trend of TACs for WB cod has generally indicated a constant decline (1995, 1997: 21638t), with the lowest quota of 3806 t for 2020 (Figure 3 a). Since 2008, the quota has leveled off just below the 5000 t, with a constant reduction since 2012 except for 2019.

Institutional structure of fisheries management in Germany

Fisheries management legislation is negotiated and decided at the EU level, as described above, but its implementation is carried out at the national level. For this purpose, it is necessary to briefly outline the structure and responsibilities of the various institutions relevant to the German fisheries governance and management.

The greatest political competence in terms of managing commercial fisheries at the German level lies with the *Federal Ministry of Food and Agriculture*, which is involved in the annual negotiation of catch quotas, in measures of controlling illegal fishing and in the re-orientation of the CFP at the EU level (see Figure 2) (Bundesministerium für Ernährung und Landwirtschaft 2020a). In addition, the ministry is responsible for negotiating political issues on commercial fisheries at supranational level (EU) and for their implementation at national level (Bundesministerium für Ernährung und Landwirtschaft 2020a). The *Federal Agency for Agriculture and Food* holds the leading role as a central implementing authority within the area of responsibility of the ministry, and is active in the following areas: i) fisheries management (e.g., administration of national fishing quotas and fishing effort), ii) fisheries economics (e.g., implementation of the Common Fish Market Regulation) and in iii) fisheries monitoring (e.g., monitoring and enforcement of the community and German fisheries law) (Figure 2) (Bundesanstalt für Landwirtschaft und Ernährung 2021). Here, the agency is responsible for the Exclusive Economic Zone (EEZ) which extends 12-200 nautical miles from the coast into the sea.

At the state level, i.e. Schleswig-Holstein (SH) and Mecklenburg-Western Pomerania (MV) (area of responsibility: 0-12 nautical miles, coastal sea), further differentiation must be made between the state ministries (supreme fisheries authorities) and the state offices (upper fisheries authorities). Specifically, the state ministries are institutionally subordinate to the federal ministry and responsible for overarching tasks and matters of principle. The state offices are the technical authority in the area of competence of the state ministries and perform the following tasks: i) fisheries control on and in the waters of the states SH and MV, as well as control of specific marketing regulations of fisheries products according to EU and federal law, ii) investigations and procedures in case of violations of the law, iii) issuance of fishing permits (coastal waters) and fishing licenses to fishers, iv) registration of fishing businesses and fishing vessels in coastal fisheries, v) catch registration and maintenance of fisheries statistics, and vii) promotion of the coastal fisheries (LLUR 2015, LALLF 2021). In contrast to Schleswig-Holstein, for Mecklenburg-Western Pomerania, the *Federal Agency for Agriculture and Food* is already responsible for control at sea from 3 nautical miles upwards (Bundesministerium der Justiz und für Verbraucherschutz 1989).

Fisheries structure and development along the German Baltic coast

The German fisheries sector in the WBS can be described by vessel type (length), gear (e.g., trawl, gillnet), and the fisher's income type (full-time, part-time) (LLUR 2019, LALLF 2020). The annual fleet report, classifies vessel by length: i) <10 meters (m), ii) 10-12 m, iii) 12-18 m iv) 18-24 m and v) 24-40 m (Bundesministerium für Ernährung und Landwirtschaft 2020b). In comparison, Döring et al. (2020) only divide the WBS fleet between i) <8 m, ii) 8-12 m, and iii) >12 m, arguing that unlike other marine economies in Europe (e.g., in the North Sea), the fishery in the WBS is driven less by deep-sea trawlers and more by vessels smaller than 24m. This classification is particularly important at the administrative level, e.g. for permitted fishing areas, control and documentation of catches (e.g., EC 2009, Landesregierung Schleswig-Holstein 2018). For example, fishers with a vessel between 8 and 12 m in length use paper logbooks, whereas fishers with vessels >12m are required to keep digital documentation of their catches using electronic logbooks and install a vessel monitoring system (VMS) onboard of their vessel to track their fishing activities (EC 2009). Table 1 represents the amount of cod caught in the Western Baltic Sea by vessel size and gear in 2019.

Table 1. Overview of the amount of WB cod caught in 2019 by gear type and vessel size. Cod in the Western Baltic Sea were caught by both passive (PG=pelagic gillnet; PG VL0010, PG VL1012) and active gear (DTS=demersal trawls; DTS VL1012, DTS VL1218, DTS VL1824, DTS VL2440) (Bundesministerium für Landwirtschaft und Ernährung 2020b).

	PG VL0010	**PG VL1012**	**DTS VL1012**	**DTS VL1218**	**DTS VL1824**	**DTS VL2440**
Gear	Gillnet	Gillnet	Trawl	Trawl	Trawl	Trawl
Size	<10m	10-12 m	10 - 12 m	12 - 18 m	18 - 24 m	24 - 40 m
Tonnes	492	310	58 m	326	558	193

Both active and passive gears are used in the WBS for cod fisheries. Active gears including bottom trawls (Table 1, Figure 4a) and typical examples of passive gears are gillnets (Figure

4b), fyke nets, fishing rods or fish traps (Delaney 2007, Bundesministerium für Landwirtschaft und Ernährung 2020, Döring et al. 2020). The largest catches were in the segment of gillnet, <10m (492 t) and trawl, 18 - 24 m (558 t) (Bundesministerium für Landwirtschaft und Ernährung 2020). No trawl is used for boats smaller than 10 m, according to the size of the vessel and respective engine power.

In total, the German fisheries fleet consisted of 1308 vessels in 2019, with 1013 in small-scale coastal fisheries with a length of less than 12 m, most of which were active in the Baltic Sea with gillnets (Bundesministerium für Landwirtschaft und Ernährung 2020b).

a. 

b. 

Figure 4a, b. Fishing boats in the Baltic Sea. Both trawl (a. Port of Sassnitz in Mecklenburg-Western Pomerania) and gillnet (b. Port of Schönberg in Schleswig-Holstein) fisheries are practiced in the Western Baltic Sea.

In 2019, a total of 814 fishers were reported for the German Baltic Sea, of which 422 were registered as full-time fishers (SH=206, MV=216) (LLUR 2019, LALLF 2020). For Mecklenburg-Western Pomerania, a decrease of 14 fishers is published for 2020, with an increase of two part-time fishers indicated (no official data available for SH yet) (LALLF 2020). Although some former full-time fishers have transitioned to part-time fisheries, current trends are towards a further decline in the number of people employed in this fishery (LLUR 2019, LALLF 2020). This is particularly evident in the data from 2016: only 251 full-time fishers were registered in MV and 258 in SH, representing a decrease of 17% within the last four years (LLUR 2019, LALLF 2020).

Fishers can be classified into different types of income, and a further subdivision is possible according to the nature of their organization status. Here, a general distinction is made between organized and non-organized fishers, which is relevant in the context of TAC allocation and the possibility to apply for subsidies at EU level (Figure 2). Fish trade and sales are also largely managed by the fisheries cooperative or producer organization, while non-organized fishers mainly market the fish themselves directly to customers, hotels or restaurants. Fisheries cooperatives exist all along the Western Baltic coast, with four in Schleswig-Holstein (Heiligenhafen, Burgstaaken (Fehmarn), Kiel and Lübeck) and 10 in Mecklenburg-Western Pomerania (e.g., Wismar, Sassnitz (Rügen), Kröselin/Freest). Furthermore, there are five producer organizations for the WBS fisheries, which usually represent a union of several cooperatives, four of which are located in Mecklenburg-Western Pomerania (e.g., ZAG Rügenfang, Usedomfisch Freest) (EC 2005). Importantly, the fisheries cooperative in Heiligenhafen (SH) and in Wismar (MV) are equally listed as producer organizations; they therefore do not constitute a union of further cooperatives (EC 2005). In this context, the structural change is not only reflected in the decreasing number of fishers, but subsequently also in that of fisheries cooperatives. This is noticeable in the most recent development, namely that the fisheries cooperative Lauterbach (Rügen) had to cease business at the beginning of this year (Sommer 2021). The development is even more drastic with the dissolution of the *Landesfischereiverband Mecklenburg-Vorpommern e.V.*, which had to cease its activities due to constantly worsening conditions for the fisheries such as progressive quota reduction for the main fish species cod and herring, stricter requirements for nature, environmental and species protection and problems due to the loss of fishing areas. This resulted in a decline of its member numbers (Becker 2020, LVB MV 2021). As a response, a working group was established to further represent the interests of fishers in MV (LVB MV 2021).

Conflict over fish, fisher & conservation

The economic and also social-cultural importance of the WB cod, as well as its ecological function in the WBS ecosystem, makes this species of particular value to commercial fisheries, but also to recreational fisheries, nature conservation and tourism (Delaney 2007, Döring et al. 2020). However, the question of how to manage the stock and also the fisheries to a sustainable state is subject of an ongoing discourse that has gained considerable momentum, especially in recent years. Informal conversations, official events (e.g., Marine Environment Symposium, German Fisheries Day) but also social media (e.g., Facebook, Twitter) and newspapers serve as a source of information to get a brief insight into the overall conflict, and into the diverging perceptions of system components as well as their functioning (cause, effect) by different stakeholders.

In general, there is controversy among stakeholders about management measures taken (e.g., establishment of a closed season for cod), but also about their strength (e.g., duration of season) and effectiveness (WWF 2016, Veit 2016, WWF 2019). For example, the following statement by a representative of an eNGOs implies that the measures currently taken are not sufficient to manage the WB cod stock into a sustainable state.

"*Western Baltic cod is not receiving the protection it desperately needs to provide the majority of catches for the German Baltic Sea fishery beyond 2020.*" *(WWF 2019)*

Especially the strong fluctuations in catch quotas resulted in increasing conflicts between fishers and interest groups like eNGOs. In response to the first drastic TAC reduction in 2016, fishers spoke of a ban of their profession and that they "[...], are threatened with extinction!" (Burghardt 2016). For representatives from eNGOs on the other hand, the cuts do not go far enough, expressing concern about the complete collapse of the stock - "It is irresponsible to continue the overfishing!" (WWF 2016, Veit 2016). The interests are clearly reflected: while for fishers it is about economic (e.g., money) and social-cultural interest (e.g., preservation of fisheries sector and its tradition), for eNGO the stock and a sustainable management of it are paramount (ecological interest). These different interests and diverging perceptions of the problem led not only to increasing mistrust between the stakeholders, but also to mistrust in politics and science, resulting in unaccepted management decisions. This is once again clearly reflected in the following quote from a fisher:

"Our small fleet is no longer in the position to overfish anything. That's why this is an indictment of the entire EU fisheries policy. If sustainability means reducing all quotas until 0, then no one can understand that anymore." *(Backhaus 2019)*

The fisher expresses his dissatisfaction with management measures in general, but in particular with the lack of understanding of the political definition of sustainability.

Additional conflicts that gain traction in social media or newspapers arise from the designation of marine protected areas and the increasing populations of cormorants and seals (Hasselmann 2019, Sommer 2021). While their growing populations are considered a success of nature conservation on the one hand (Voss 2019), fishers on the other hand perceive an increasing threat to their profession (e.g., predation on their catch, gear damage) (Sander 2019, Hasselmann 2019).

Newspaper coverage of the conflict between cod, fisheries and nature conservation already demonstrates the explosive nature of this topic coupled with diverging perceptions of problems, causes and effects. In addition to the representation of these various bodies of knowledge by the many stakeholders involved, the prominent role of emotions in shaping the agenda of this environmental and economic conflict is also evident. These refers to emotions of *fear* (fear about the future of the fisheries and non-reversible structural changes, extinction of cod), *worries* (worries about the state of WB cod, its surrounding communities that make their living from fishing and lack of young fishers, great influence of fish industry), *anger* (anger at the policy that scientific recommendations are not followed, gear damage through seals), *disappointment* (disappointment with inadequate policy measures) and *frustration* (frustration about constant reductions in catch quotas) (Bughardt 2016, WWF 2016, Veith 2016, WWF 2019, Hasselmann 2019, Sander 2019, Sommer 2021).

However, newspaper and social media, among others, play an important role in representing different perceptions and knowledge, and especially in influencing ideas about the 'right' management measures to take (Quist & Rinne 2017). But to assist in resolving a conflict, for example, in many cases they are i) oversimplified and ii) often biased (e.g., unequal distribution of resources (money, time) across various stakeholder groups) (Hamborg et al. 2019). Enhanced participation of relevant resource users and interest groups may help stimulate mutual understanding of the system and its interactions (Gray et al. 2012), and thus assist in conflict resolution (Jentoft 2017, Stepanova 2019).

Stakeholder participation in its multifaceted aspects

Stakeholder involvement in fisheries management has become increasingly important, especially in recent decades (Kraan et al. 2014, Birnbaum 2015). This has brought a holistic understanding of the system into the spotlight, making stakeholder participation essential today (Mackinson et al. 2011, Linke et al. 2020). The beneficial role of involving stakeholders in natural resource management, and therefore recognizing their diverse 'knowledges' and perspectives, is evident, not least in the numerous published literature (Folke 2004, Reed 2008, Voinov et al. 2016, Steins et al. 2019). This shift towards a participatory governance approach seems fundamental to better understand natural resources in general, their distribution and reproductive behavior in particular (Funk et al. 2020), as well as to provide management with valuable information for sustainable natural resource management (Aanesen et al. 2014). This also includes a better understanding of the resource users (Barz et al. 2020), their values, cultural needs, perceptions of the system and its functioning of which they are a part (Gray et al. 2012, Sterling et al. 2017).

Stakeholder participation has become a fundamental part of fisheries legislation in many countries around the world, including the EU (EC 2013, Winter & Hutchings 2020). Through the application of an ecosystem-based management (EBM) and participatory approach, the EU with its CFP is increasingly aiming for a holistic approach to the management of living marine resources (EC 2013, Long et al. 2015, Linke & Jentoft 2016). In this context, since 2002 with the reformed CFP, *Advisory Councils* (ACs) have been established to promote the participation of various stakeholders in fisheries management at the regional scale (Long et al. 2015, Linke & Bruckmeier 2015). For example, ACs formulate proposals for the EU Commission that include compliance with socio-economic aspects of management such as the modification of the planned digital reporting of catches as part of the proposal for the new Control Regulation (Linke et al. 2011; Long 2009, Linke & Jentoft 2016). ACs are stakeholder-led organizations, divided into different European Seas, like the Baltic Advisory Council (i.e., 60% fishing industry, 40% other interest groups like NGOs) but also covering topics such as aquaculture (EC 2013, Linke & Jentoft 2016, EC 2021a). In Germany, a policy instrument comparable to the ACs is absent on national level. However, various forms of involvement exist, such as joint dialogues, such as the *cod round table* originally initiated by a political member of the EU Parliament.

The EU also initiated *Fisheries Local Action Groups* (FLAGs) but these focus on the development of fish communities at the local level and incorporate themes such as environment, culture or governance (EC 2021b). There are numerous FLAGs along the German Baltic coast, for example in Stein-Wendtorf, Eckernförde and Fehmarn in Schleswig-Holstein or in the regions of West-Mecklenburg and Rügen in Mecklenburg-Western Pomerania.

In the context of fisheries management, stakeholders' involvement in the EU takes place at different levels of governance. Furthermore, Köpsel et al. (2021) found that involving resource users and interest groups in scientific projects not only help make research more socially relevant and robust, but also makes it easier for a wide range of stakeholders to understand and accept. The importance of this topic is becoming increasingly significant when considering the growing number of projects focusing on stakeholder participation (Kraan et al. 2014, Köpsel et al. 2021). In this regard, stakeholder participation in scientific projects can be differentiated very general into informal (e.g., exchange of information via telephone or e-mail) or formal (e.g., direct involvement in a scientific project), but also according to the type and goal of participation. According to Stauffacher (2008), this can be classified as *very low* (e.g., general exchange of scientific results), *medium* (e.g., consultation by stakeholders for relevant model inputs), *high* (e.g., joint sampling of fisheries data) to *very high* (e.g., project management by stakeholders and scientists, see Living Lab approach) (Köpsel et al. 2021). There is further diverse literature addressing the typology of participation in general (*latter of participation*, Arnstein 1969) and specifically for environmental management (Reed 2008).

Cod plays a central role in the WBS ecosystem as top-predator in local food web dynamics, is of great economic importance for the fisheries along the coast in terms of jobs or tourist facilities like fish restaurants, and is framed by a deep culture and tradition. Reflecting on the status of cod, fisheries management in general, and quotas in particular, but also on the structure and development of the WB fisheries, this sector is clearly undergoing major changes (Döring et al. 2020, Möllmann et al. 2021). While it is becoming increasingly difficult to stay economically stable for small-scale fishers, the loss of this sector would lead to severe sociocultural disruption along the Baltic Sea coast (Bundesministerium für Ernährung und Landwirtschaft 2020b, Döring et al. 2020). Fishers and fisheries are currently facing a major transition, and the direction in which the system will evolve depends not only on the state of important commercial fish stocks like cod, but above all on effective measures that manage the stock into a sustainable state as well as to save the fisheries sector from extinction. Stakeholder involvement and participation in this process is one pillar to describe the problems and identify root causes, but even more important to find common solutions and increase their acceptance (Linke et al. 2020).

Motivation and outline of thesis

This thesis aims to improve the understanding of stakeholder participation using the example of cod in the Western Baltic Sea. We have investigated who is involved in or influenced by the respective fisheries management, how these resource users and inters groups perceive the system and what knowledge underlies it. The research results can contribute to a better understanding of the system in general and support conflict resolution and thus the sustainable management of this species.

By conducting a literature review, we aimed to gain an in-depth understanding regarding stakeholder participation in coastal and fisheries management in general (**Study I**). We investigated i) how the term stakeholder is described, ii) what variations exist for the term stakeholder, iii) how participation is defined and what variations exist in its application, and iv) what individual intentions are associated with the participation of resource users and interest groups.

In order to investigate the specific case of WB cod, I conducted an online stakeholder identification survey based on the previous results, including a sample of the institutions that either influence (e.g., management of this species) or are influenced (e.g., livelihood) by the management of WB cod (Appendix I). Relevant resource users and interest groups were identified and used for further research (**Studies II, III, and IV**).

Using participatory modeling, we conducted an analysis explicitly focusing on the perception of the WB cod fishery system across six stakeholder groups, such as, commercial fisheries, eNGO and tourism (**Study II**). We placed particular emphasis on i) how the cod fishery system in WBS is generally perceived and described, ii) which ecological and economic-social components are perceived as relevant, iii) how these components are interconnected (direction, weight), and iv) what differences can be identified between relevant stakeholder groups.

Furthermore, we performed a comprehensive analysis of complementary expert interviews to explore cod as an ecological system component, and in particular the management underlying this species (**Study III**). This study was designed to contribute to a better understanding of i) how cod as a fish species is perceived and described in the context of its fisheries management, ii) what knowledge types underlie this description, iii) what problems and improvements are formulated for fisheries management of WB cod, and iv) what the perceptions and criticisms of the science that informs the formulation of management measures are.

Considering that there is a link between identity diversity, i.e. the range of social characteristics, and the different ways people perceive and solve problems (e.g., interact with the system) sets the basis for the investigation in the last study of this thesis (**Study IV**). We used mental models and network analysis to examine the relationship between a stakeholders` identity characteristics and the way the system of WB cod fisheries is described, including interactions between system components. The analysis was guided by the following questions: i) what is the relationship between identity diversity and cognitive diversity among stakeholders affected and involved in the management of WB cod, ii) what are the cognitive distances within and between stakeholders of different social types, and iii) how can the outcomes effectively contribute to the resolution of conflicts related to natural resource management in general and WB cod in particular.

References

Aanesen, M., Armstrong, C. W., Bloomfield, H. J., & Röckmann, C. 2014. What does stakeholder involvement mean for fisheries management. Ecol. Soc., 19, 4, 35. doi:10.5751/ES-06947-190435

Arnstein, S.R. 1969. A ladder of citizen participation. J Am Plan Assoc 35, 4, 216-224

Backhaus, H. 2019. Neue Fangquoten: Ostseefischerei vor dem Aus? https://www.ndr.de/nachrichten/Neue-Fangquoten-Ostseefischerei-vor-dem-Aus,fangquoten146.html. [01.01.2020]

Barz, F., Eckhardt, J., Meyer, S., Kraak, S. B. M., & Strehlow, H. V. 2020. `Boats don't fish, people do′- how fishers′ agency can inform fisheries-management on bycatch mitigation of marine mammals and sea birds. Mar Policy, doi:10.1016/j.marpol.2020.104268

Baudron, A. R., Brunel, T., Blachet, M.-A., Hidalgo, M., Chust, G., Brown, E. J., ..., & Fernander, P. G. 2020. Changing fish distributions challenge the effective management of European fisheries. Ecography, 43, 494-505. doi: 10.1111/ecog.04864

Becker, A. 2020. Alarmierende Zahlen. Ostsee-Küstenfischer kurz vor dem Untergang. https://www.nordkurier.de/mecklenburg-vorpommern/ostsee-kuestenfischer-kurz-vor-dem-untergang-2640478808.html. [15.07.2021]

Birnbaum, S. 2015. Environmental Co-governance, Legitimacy, and the Quest for Compliance: When and Why Is Stakeholder Participation Desirable? J. Environ. Policy Plan. doi:10.1080/1523908X.2015.1077440

Bundesanstalt für Landwirtschaft und Ernährung. 2021. Unsere Themen. Fischerei. https://www.ble.de/DE/Themen/Fischerei/fischerei_node.html. [20.07.2021]

Bundesministerium der Justiz und für Verbraucherschutz. 1989. Seefischereiverordnung (SeefiV).https://www.gesetze-im-internet.de/seefiv/BJNR014850989.html. [15.07.2021]

Bundesministerium für Ernährung und Landwirtschaft. 2020a. Themen. Fischerei. Fischereipolitik.https://www.bmel.de/DE/themen/fischerei/fischereipolitik/fischereipolitik_node.html. [20.07.2021]

Bundesministerium für Ernährung und Landwirtschaft. 2020b. Bericht an die Europäische Kommission nach Artikel 22 der Verordnung (EU) Nr. 1380/2013 über das Gleichgewicht zwischen den Fangkapazitäten und den Fangmöglichkeiten der deutschen Fischereiflotte im Jahr 2019. https://www.portal-fischerei.de/fileadmin/SITE_MASTER/content/Dokumente/Bund/Flotte/Flottenbericht_2019.pdf. [15.07.2021]

Burghardt, P. 2016. Fangquoten. Im Trüben. https://www.sueddeutsche.de/politik/fangquoten-im-trueben-1.3204248. [15.07.2021]

Delaney, A. 2007. Profiling of Small-Scale Fishing Communities in the Baltic Sea: Study Requested by the European Commission. IFM-Innovative Fisheries Management

Döring, R., Berkenhagen, J., Hentsch., S, & Kraus, G. 2020. Small-Scale Fisheries in Germany: A Disappearing Profession?. In: Pascual-Fernández, J., Pita, C., & Bavinck, M. (ed). Small-Scale Fisheries in Europe: Status, Resilience and Governance. MARE Publication Series 23. doi:10.1007/978-3-030-37371-9_23

EC. 2005. C 293/15. List of the recognised producers` organisations in the fishery and aquaculture sector. 2005/C 293/07. Brussels, Belgium

EC. 2009. Regulation (EC) No 1224/2009 of the European Council of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy. Brussels, Belgium

EC. 2013. Regulation (EU) No 1380/2013 of the European Parliament and of the council of 11 December 2013 on the Common Fisheries Policy. Brussels, Belgium

EC. 2016. Regulation (EU) 2016/1139 of the European parliament and of the Council of 6 July 2016 on a multiannual plan for the stocks of cod, herring and sprat in the Baltic Sea and the fisheries exploiting those stocks. Brussels, Belgium

EC. 2020. Council Regulation (EU) 2019/1838 of 30 October 2019 fixing for 2020 the fishing opportunities for certain fish stocks and groups of fish stocks applicable in the Baltic Sea. Brussels, Belgium

EC. 2021a. Advisory Councils. https://ec.europa.eu/oceans-and-fisheries/fisheries/scientific-input/advisory-councils_de. [12.07.2021]

EC. 2021b. FARNET. Fisheries Areas Network. https://webgate.ec.europa.eu/fpfis/cms/farnet2/node_en. [12.07.2021]

Eero, M., Strehlow, H. V., Adams, C. M., & Vinther, M. 2014. Does recreational catch impact the TAC for commercial fisheries? ICES J. Mar. Sci., 72, 2, 450-457. doi:10.1093/icesjms/fsu121

Folke, C. 2004. Traditional knowledge in social–ecological systems. Ecol. Soc., 9, 7

Funk, S. 2020. Spatio-temporal distribution, food intake and growth of cod (Gadus morhua L.) in the Western Baltic Sea. (Doctoral thesis, University of Hamburg, Germany)

Funk, S., Krumme, U., Temming, A., & Möllmann, C. 2020. Gillnet fishers' knowledge reveals seasonality in depth and habitat use of cod (Gadus morhua) in the Western Baltic Sea. ICES J. Mar. Sci., 77, 5, 1816-1829, fsaa071. doi:10.1093/icesjms/fsaa071

Gray, S., Chan, A., Clark, D., & Jordan, R. C. 2012. Integrating stakeholder knowledge in social-ecological system decision-making: Benefits and limitations to knowledge diversity. Ecol Modell, 229, 88-96. doi:10.1016/j.ecolmodel.2011.09.011

Hamborg, F., Donnay, K., & Gipp, B. 2019. Automated identification of media bias in news articles: an interdisciplinary literature review. Int. J. Digit. Libr., 20, 391-415

Hasselmann, S. 2019. Streit an der Ostsee. Hungrige Robben verärgern Fischer. https://www.deutschlandfunkkultur.de/streit-an-der-ostsee-hungrige-robben-veraergern-fischer.1001.de.html?dram:article_id=451356. [15.07.2021]

ICES. 2012. Book 1. Introduction, Overviews and Special Requests. Copenhagen, Denmark. doi:10.17895/ices.pub.5467

ICES. 2019. ICES Advice on fishing opportunities, catch, and effort. Baltic Sea ecoregion. Cod (Gadus morhua) in subdivisions 22–24, western Baltic stock (western Baltic Sea). Copenhagen, Denmark. doi:10.17895/ices.advice.5587

ICES. 2020. ICES Advice on fishing opportunities, catch, and effort. Baltic Sea ecoregion. Cod (Gadus morhua) in subdivisions 22–24, western Baltic stock (western Baltic Sea). Copenhagen, Denmark. doi:10.17895/ices.advice.5942

Jentoft, S. 2017. Small-scale fisheries within maritime spatial planning: knowledge integration and power. J. Environ. Policy Plan. doi:10.1080/1523908X.2017.1304210

Köpsel, V., de Moura Kiipper, G., & Peck, M. 2021. Stakeholder engagement vs. social distancing—how does the Covid-19 pandemic affect participatory research in EU marine science projects?. Maritime Studies. doi:10.1007/s40152-021-00223-4

Kraan, M., Hendriksen, A., van Hoof, L., van Leeuwen, J., & Jouanneau, C. 2014. How to dance? The tango of stakeholder involvement in marine governance research. Mar Policy, 50, 347-352. doi:10.1016/j.marpol.2014.05.010

LALLF. 2020. Fischerei. Statistik. Fischer und Fahrzeuge. https://www.lallf.de/fischerei/statistik/fischer-und-fahrzeuge/. [15.07.2021]

LALLF. 2021. LALLF - Das Landesamt. Fischerei und Fischwirtschaft. https://www.lallf.de/ueber-uns/lallf-das-landesamt/fischerei-und-fischwirtschaft/. [15.07.2021]

Landesregierung Schleswig-Holstein. 2018. Landesverordnung über die Ausübung der Fischerei in den Küstengewässern (Küstenfischereiverordnung - KüFVO) Vom 3. Dezember 2018. https://www.gesetze-rechtsprechung.sh.juris.de/jportal/?quelle=jlink&query=KüFischV+SH+§+2&psml=bsshoprod.psml&max=true. [15.07.2021]

Linke, S., Dreyer, M., & Sellke, P. 2011. The Regional Advisory Councils. What is their potential to incorporate stakeholder knowledge into fisheries governance? AMBIO, 40, 133-143. doi:10.1007/s13280-010-0125-1

Linke, S., & Bruckmeier, K. 2015. Co-management in fisheries – Experiences and changing approaches in Europe. Ocean Coast Manag, 104, 170-181. doi:10.1016/j.ocecoaman.2014.11.017

Linke, S., & Jentoft, S. 2016. Ideals, realities and paradoxes of stakeholder participation in EU fisheries governance. Environ. Sociol., 2, 144-154. doi:1080/23251042.2016.1155792

Linke, S., Hadjimichael, M., Mackinson, S., & Holm, P. 2020. Knowledge for fisheries governance: participation, integration and institutional reform. In: Holm, P., Hadjimichael, M., Linke, S., & Mackinson, S. (ed). Collaborative Research in Fisheries. Co-creating Knowledge for Fisheries Governance in Europe. MARE Publication Series, 22, 7-26. Cham: Springer

Long, R. 2009. The Role of Regional Advisory Councils in the European Common Fisheries Policy: Legal Constraints and Future Options. Int. J. Mar. Coast. Law, 25, 289-346. doi:10.1163/157180810X516980

Long, R., Charles, A. T., & Stephenson, R. 2015. Key principles of marine ecosystem-based management. Mar Policy, 57, 53-60. doi:10.1016/j.marpol.2015.01.01

LLUR. 2015. Einblicke in die Arbeit des LLUR. Aufgaben – Menschen – Ergebnisse 2014 /15.http://www.umweltdaten.landsh.de/nuis/upool/gesamt/flyer/einblicke_llur.pdf. [15.07.2021]

LLUR. 2019. Die Fischerei und Fischereiverwaltung Schleswig-Holsteins im Jahr 2019 Jahresbericht des Landesamts für Landwirtschaft, Umwelt und ländliche Räume (LLUR) – Abteilung Fischerei. https://www.schleswig-holstein.de/DE/Landesregierung/LLUR/WirUeberUns/abteilungen/abteilung3.html. [15.07.2021]

LVB MV. 2021. Fischerei & Fischmarkt in Mecklenburg-Vorpommern. 01/2021 – 18.Jahrgang. https://www.lvbmv.de/download/zeitschrift/FF_1_2021.pdf. [19.07.2021]

MacKenzie, B. R., Gislason, H., Möllmann, C., & Köster, F. W. 2007. Impact of 21st century climate change on the Baltic Sea fish community and fisheries. Glob Chang Biol, 13, 1348-1367. doi:10.1111/j.1365-2486.2007.01369.x

Mackinson, S., Wilson, D.C., Galiay, P., & Deas, B. 2011. Engaging stakeholders in fisheries and marine research. Mar Policy, 35, 18-24

Möllmann, C., Cormon, X., Funk, F., Otto, S., Schmidt, J., Schwermer, H., …, & Quaas, M. 2021. Tipping point realized in cod fishery. Sci. Rep., 11, 14259. doi:10.1038/s41598-021-93843-z

Morin, M. 2020. The fisheries resources in the European Union. The distribution of TACs: principle of relative stability and quota-hopping. Mar Policy, 24, 265-273

Quist, L.-M., & Rinne, P. 2017. The Politics of Justification: Newspaper Representations of Environmental Conflict between Fishers and the Oil Industry in Mexico. Environ Values, 26, 4, 457-479. doi:10.3197/096327117x149769001373

Reed, M. S. 2008. Stakeholder participation for environmental management: A literature review. Biol. Conserv., 141, 2417-2431. doi:10.1016/j.biocon.2008.07.014

Sander, B. 2019. Wirtschaft vs. Tierschutz. Kegelrobben erobern die Ostsee zurück – zum Leidwesen der Fischer. https://www.svz.de/regionales/mecklenburg-vorpommern/Kegelrobben-erobern-die-Ostsee-zurueck-zum-Leidwesen-der-Fischer-id26827277.html. [15.07.2021]

Sommer, R. 2021. Insel Rügen. Lauterbacher Fischer geben auf. https://www.nordkurier.de/ruegen/lauterbacher-fischer-geben-auf-0 541953601.html. [15.07.2021]

Stauffacher, M., Flüeler, T., Krütli, P., & R.W. Scholz, R. W. 2008. Analytic and dynamic approach to collaboration: a transdisciplinary case study on sustainable landscape development in a Swiss Prealpine Region. Systemic Practice and Action Research 21, 6, 409-422. doi:10.1007/s11213-008-9107-7

Steins, N., Kraan, M. L., van der Reijden, K. J., Quirijns, F. J., van Broekhoven, W., & Poos, J. J. 2019. Integrating collaborative research in marine science: Recommendations from an evalua- tion of evolving science-industry partnerships in Dutch demersal fisheries. Fish Fish (Oxf), 21, 146-161. doi:10.1111/faf.12423

Stepanova, O. 2019. Power and knowledge use in coastal conflict resolution. In: Olsson, E. G. A., & Gooch, P. (ed). Natural resource conflicts and sustainable development. Routledge

Sterling, E., Filardi, C., Toomey, A., Sigouin, A., Betley E., Gazit, N., …, & Jupiter, S. 2017. Biocultural approaches to well-being and sustainability indicators across scales. Nat. Ecol. Evol., 1,12, 1798-1806. doi:10.1038/s41559-017-0349-6.hal-02107213

Strehlow, H. V., Schultz, N., Zimmermann, C., & Hammer, C. 2010. Cod catches taken by the German recreational fishery in the western Baltic Sea, 2005–2010: implications for stock assessment and management. ICES J. Mar. Sci., 69, 10, 1769-1780. doi:10.1093/icesjms/fss152

Veit, S.-M. 2016. Neue Fangquoten. Dorsch tot, Scholle satt. https://taz.de/Neue-Fangquoten/!5347153/. [15.07.2021]

Voinov, A., Kolagani, N., McCall, M. K., Glynn, P. D., Kragt, M. E., Ostermann, F. O., Pierce, S. A., & Ramu, P. 2016. Modelling with stakeholders—Next generation. Environ Model Softw, 77, 196-220. doi:10.1016/j.envsoft.2015.11.016

Voss, R., Quaas, M. F., Hoffmann, J., & Schmidt, J. O. 2017. Social–Ecological Trade-Offs in Baltic Sea Fisheries Management. Conservation for the Anthropocene Ocean, 359-377. doi:10.1016/b978-0-12-805375-1.00017-9

Voss, J. 2019. Tiere. Kegelrobben in der Ostsee: Deutschlands größtes Raubtier ist zurück. https://www.nationalgeographic.de/tiere/2019/08/kegelrobben-der-ostsee-deutschlands-groesstes-raubtier-ist-zurueck. [15.07.2021]

Winter, A.-M., & Hutchings, J. A. 2020. Impediments to fisheries recovery in Canada: Policy and institutional constraints on developing management practices compliant with the precautionary approach. Mar Policy. doi:10.1016/j.marpol.2020.104161

WWF. 2016. Dorsch am Scheideweg. https://www.wwf.de/2016/oktober/dorsch-am-scheideweg/. [15.07.2021]

WWF. 2019. Fischen Impossible. https://www.wwf.de/2019/oktober/fischen-impossible/. [01.01.2020]

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Kaminka. 2021. Postcard motif “Halt Dorsch”. https://www.etsy.com/de/shop/KaminkaShop. Greifswald, Germany. [commitment of the creator: 01.10.2021]


HALT
DORSCH!

STUDY I

Schwermer, H., Zablotski, Y., Barz, F. 2020. A Literature Review on Stakeholder Participation in Coastal and Marine fisheries. In: Jungblut, S., Liebich, V., & Bode-Dalby, M. (ed). YOUMARES 9 - The Oceans: Our Research, Our Future. *Springer*

STUDY II

Schwermer, H., Aminpour, P., Reza, C., Funk, S., Möllmann, C., & Gray, S. 2021. Modeling and understanding social-ecological knowledge diversity. *Conservation Science and Practice*. doi:10.1111/csp2.396

STUDY III

Schwermer, H., Blöckner, A., Möllmann, C., & Döring, M. 2021. The 'Cod-Multiple': Modes of Existence of Fish, Science and People. *Sustainability*. doi:10.3390/su132112229

STUDY IV

Aminpour, P., Schwermer, H., & Gray, S. 2021. Do social identity and cognitive diversity correlate in environmental stakeholders? A novel approach to measuring cognitive distance within and between groups. *Plos One*. doi: 10.1371/journal.pone.0244907

STUDY I

A Literature Review on Stakeholder Participation in Coastal and Marine fisheries

A Literature Review on Stakeholder Participation in Coastal and Marine Fisheries

2

Heike Schwermer, Fanny Barz, and Yury Zablotski

Abstract

Stakeholder participation is a fundamental component of many states' and local agencies' fisheries legislations worldwide. The European Common Fisheries Policy (CFP), as one example, increasingly adopted a holistic approach to managing marine living resources. An important component of such an ecosystem-based management approach is the consideration of knowledge, values, needs and social interactions of stakeholders in decision-making processes. However, despite that stakeholder participation is a widely used term, a great variety of definitions exist, which often cause misunderstanding. Stakeholder participation is often used as part of conducting research on stakeholders but not in the context of their participation in resource management. Here, we present the results of a comprehensive literature review on the topic *stakeholder participation* in coastal and marine fisheries. We identified 286 scientific publications in *Web of Science* of which 50 were relevant for our research questions. Publications were analysed regarding (i) definition of stakeholder participation, (ii) analysis of participating stakeholders, (iii) applied participatory methods and (iv) intention for participation. Stakeholder types addressed in the publications included, e.g. fishery (fishers and direct representatives, N = 48), politics (policymakers and managers, N = 31), science (N = 25) and environmental non-governmental organizations (eNGOs, N = 24). In total, 24 publications labelled their studies as stakeholder participation, while stakeholders were only used as a study object. We conclude that improving science and the practice of including stakeholders in the management of coastal and marine fisheries requires definitions of who is considered a stakeholder and the form of participation applied.

Keywords

Case survey method · Stakeholder types · Participatory methods · Multiple Correspondence Analysis

2.1 Introduction

Stakeholder participation is a fundamental component of many states´ and local agencies' fisheries legislations worldwide (NOAA 2015). As an example, the Common Fisheries Policy of the European Union increasingly adopted a holistic approach to managing marine living resources (Commission of the European Communities 2013). An important component of such an ecosystem-based management (EBM) approach is the consideration of knowledge, values, needs and social interactions of resource users and other interest groups in decision-making processes (Long et al. 2015). Aanesen et al. (2014) established that in the case of fisheries management, this implies having access to local ecological knowledge of fishers to complement scientific data which is often very limited. Furthermore, involving stakeholders is expected to increase the legitimacy of the management by creating understanding and support among the stakeholders for management measures such as new regulations (Aanesen et al. 2014). Moreover, stakeholders represent varying preferences about a resource and, therefore, ideally enable processes to reach sustainable management on different levels, such as ecological and social. But the terms 'stakeholder' and 'participation' have become 'buzz words' in environmental management (Voinov and Bousquet 2010). Deviating definitions and explanations of both terms occur, and it is often unclear what is actually meant by these concepts.

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We here reviewed worldwide case studies to investigate how stakeholder participation is applied in research projects concerning coastal and marine fisheries. The literature review creates an overview of current meanings and methods applied in this research field. The aim of our study is to highlight and to critically discuss the application of the term stakeholder participation and the significance of these findings for future research projects in general and particular in the field of coastal and marine fisheries. In our study, we developed and applied nine questions to review and analyse relevant publications. First, we investigated the publications regarding the use of the term *stakeholder*. Here, we focused on term definition, approach of analysing stakeholders as well as on the stakeholder types involved in the case study. Subsequently, we reviewed the publications in relation to the term *participation*, again first focusing on term definition, methods used related to the participation of stakeholders, description and intention for participation. Finally, we analysed all publications to evaluate whether the publications used participation as a tool for researching stakeholders (research tool) or for conducting true stakeholder participation (participation tool).

Our study revealed that only few publications in the research field of coastal and marine fisheries clearly defined the terms stakeholder and participation. Furthermore, the majority of publications labelled their studies as stakeholder participation, while stakeholders were only used as a study object. We conclude that improving the science and the practice of including stakeholders in the management of coastal and marine fisheries requires definitions of who is considered a stakeholder and the form of participation applied.

2.2 Material and Methods

We conducted a systematic literature review using the *case survey method* (Newig and Fritsch 2009), i.e. one article represented one analysis unit. Here, qualitative studies were transformed into semi-quantitative data, applying a coding scheme and expert judgements by multiple coders. The case survey method allowed us to synthesize case-based knowledge using at least two coders. We translated our research steps (RS) into a research protocol, adapted after Brandt et al. (2013), making RS repeatable and transparent. Our study included five working steps (WS): data gathering (WS 1), data screening (WS 2), data cleaning (WS 3), paper reviews (WS 4) and a statistical analysis of the collected data (WS 5) (Table 2.1).

In WS 1 we derived relevant publications from the *Web of Science* (WoS; www.isiknowledge.com), an extensive and multidisciplinary database covering a large number of scientific journals, books and proceedings in the field of natural science and technique, arts, humanities and social sciences (ETH Zürich 2018). We extracted articles published within the period from 2000 to 2018, considering the establishment of participation in (environmental) decision-making processes as a democratic right by the United Nations Economic Commission for Europe's 1998 Arhus Convention and an increased use (Reed 2008). To ensure an establishment in research publications, we started the review two years later. Publications were collected by using the basic search routine in the WoS (date of search: 16 May 2018) applying the following keyword strings: (i) stakeholder – participation – fishery, (ii) stakeholder – involvement – fishery and

Table 2.1 The five working steps (WS) of our literature review on stakeholder participation in the field of coastal and marine fisheries consisted of data gathering, data screening, data cleaning, paper review and statistical analysis. The review procedure and the results are presented for each WS

Working step (WS)	Review procedure	Result
1. Data gathering	Definition of Web of Science query (keywords: stakeholder, participation/engagement/involvement, fishery; 16 May 2018)	Bibliographical information of 286 potentially relevant publications
2. Data screening	Screening of publications guided by the question: Are all three keywords listed within the title, abstract or keywords of the publication?	A total of 81 publications were identified
3. Data cleaning	Cleaning of publications guided by the questions: i) Does the publication focus on coastal and marine fisheries? ii) Are the publications case studies?	A total of 50 relevant publications were identified
4. Paper review	Content analysis of relevant publications using a set of nine research questions concerning the term stakeholder participation	Different definitions and methods regarding the topic stakeholder participation in the field of coastal and marine fisheries were identified
5. Statistical analysis	Analysis of data using multiple correspondence analysis in R	Results are presented in this review publication

(iii) stakeholder – engagement – fishery. We additionally used the string 'fisheries' instead of 'fishery'.

In WS 2 we screened all publications derived in WS 1; we only further considered the publications that included all three keywords stakeholder, participation/involvement/engagement and fishery in (i) the title, (ii) the abstract or (iii) the keywords. We also included publications that either used the noun, the verb, i.e. to fish, to participate/involve/engage, or the adverb of the keyword, like 'fishing community'.

For the data cleaning (WS 3), we used an inductive approach to identify key issues of selected publications based on two characteristics:

1. Focus of the publication – fisheries, freshwater or estuarine ecosystems, recreational fisheries or marine protected areas; management (e.g. fishery, coastal management, EBM) or policy (e.g. Common Fisheries Policy (CFP), Marine Strategy Framework Directives (MSFD))
2. Study type of publication – a participation case study, a meta-analysis of participation studies or participation framework description

We here described policy as a set of rules or an established framework; management was defined by general environmental management approaches (e.g. ecosystem-based management (EBM), coastal management) or explicit management measures.

In WS 3 we excluded publications with focus on freshwater or estuarine ecosystems, recreational fisheries and marine protected areas. In addition, we discarded publications with focus on coastal management and EBM as well as publications looking at political frameworks (CFP, MSFD). All remaining publications focused on coastal and marine fisheries.

We further only analysed publications that presented a case study; in WS 3 we discarded studies that represented a meta-analysis or theoretical participation framework description. We here defined a case study as "[…], analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods. The case that is the subject of the inquiry will be an instance of a class of phenomena that provides an analytical frame — an object — within which the study is conducted and which the case illuminates and explicates" (Thomas 2011). For an evaluation of the regional distribution, we also extracted the continent where the case study has been conducted.

In WS 4 we analysed the content of the finally selected papers applying a mixed-method approach. We evaluated the publications based on 9s questions, investigating the terms *stakeholder* (questions 1–4) and *participation* (questions 5–8) first separately and subsequently in combination (question 9). The list of questions is shown in Table 2.2. We applied a quantitative approach to investigate naming and definition of both terms (questions 1–8, Table 2.2). Furthermore, we applied an inductive approach to generate categories for analysing derived data to elicit which type of stakeholders, participation tools and intention categories for participation were part of the research projects (questions 2, 6 and 8, Table 2.2) (Mayring 1988). Eight *stakeholder types* were distinguished in our analysis, i.e. science, politics, environmental non-governmental organizations (eNGOs), fisheries, fishery-related industry, recreational fisheries, public and others. Although we excluded publications that focus on recreational fisheries, this stakeholder type was part of the case studies focusing on coastal and marine fisheries and, therefore, was included as one stakeholder type within our analysis. The category 'others' included stakeholders that did not fit into any of the other categories but have been explicitly mentioned separately from them. We similarly analysed questions 6 and 8. Here, we distinguished between 11 *participatory methods*, i.e. workshop, interview, meeting, discussion, survey, questionnaire, modelling, coordination, mapping, presentation and conversation, and 10 *intention categories*, i.e. analysis, assessment, definition, description, development, establishment, evaluation, feedback, identification and improvement. Related to the description in the publications, we distinguished between active and passive participatory methods: active ones describing methods that directly involved stakeholders in decision-making processes; passive participatory methods had been described to support the participatory process but not to involve the stakeholders

Table 2.2 Nine questions used to review the identified case studies in coastal and marine fisheries management. The terms stakeholder (questions 1–4) and participation (questions 5–8) were investigated separately and in combination, i.e. stakeholder participation (question 9)

Term	Question
Stakeholder	1. How is the term stakeholder defined?
	2. Which types of stakeholder are part of the research project?
	3. Was a systematic approach used to analyse stakeholders?
	4. Which stakeholder analysis approach was used?
Participation	5. Was the term participation/engagement/involvement defined?
	6. Which participation/engagement/involvement methods were mentioned?
	7. How was the participation/engagement/involvement method described?
	8. What was the aim of using participation within this project?
Stakeholder participation	9. Is the described participation/engagement/involvement tool used for analysing stakeholders (research tool) or for involving stakeholders (participation tool)?

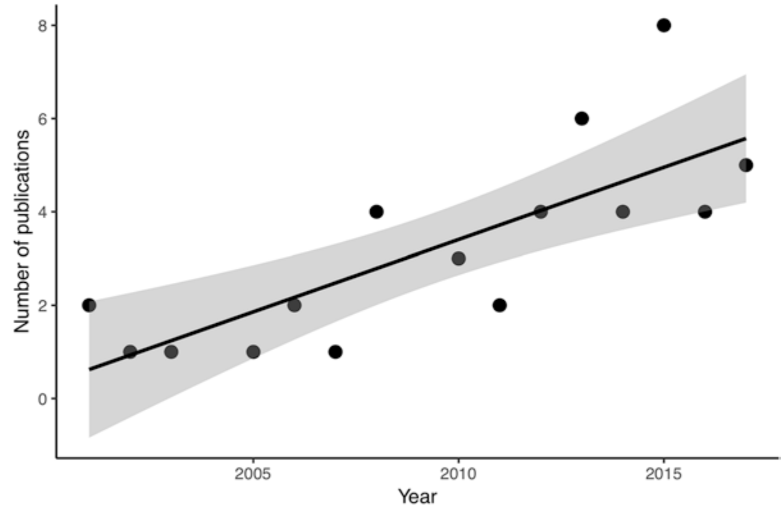

Fig. 2.1 Number of research publications published from 2000 to 2018 dealing with case studies in coastal and marine fisheries as found by Web of Science (keywords: stakeholder, participation/engagement/involvement, fishery) as of May 2018. Black line represents the linear regression with 95% confidence intervals; the grey area indicates the confidence band ($R^2 = 0.6045$, $p = 0.000645$)

in research or management (decision-making processes). Participatory methods and intention categories were extracted according to the mention in the publications. Related to the participatory methods, we also determined whether preparatory work was done using an inductive approach.

Eventually, we investigated whether (i) the case studies conducted participation to gather knowledge from stakeholders but without engaging these stakeholders in a decision-making process (*research tool*) or (ii) stakeholders had a direct influence on data interpretation and decision-making processes (*participation tool*).

In the final working step (WS 5 – statistical analysis), we used Multiple Correspondence Analysis (MCA) to explore the relationships between stakeholder types. MCA is able to uncover correlations (i.e. similarities, grouping) in otherwise inconvenient survey data (Higgs 1991) and was designed to apply on multiple binary (or nominal) variables (e.g. our categories stakeholder 'science': absent = 0, present = 1; stakeholder 'public': absent = 0, present = 1), all of which had the same status (Abdi and Valentin 2007). MCA explores the patterns in data by measuring the geometric proximity between stakeholder types (e.g. science and public) using weighted least squares (Abdi and Valentin 2007) and graphically represents the proximity of the categories on a simple plane, i.e. correspondence map. Thus, MCA allows finding similarities between categories based on the chi-square distance between them and using the percentage of the explained variance to the new (reduced) dimensions. More details related to the method of MCA can be found in the original work Greenacre (1984). We used MCA to answer the question: Which stakeholder types often appear together in the reviewed publications?

2.3 Results

We identified in total 286 scientific publications, which we further analysed according to our review protocol (see Sect. 2).

Of 286 publications, in total 81 contained all keywords of which 56 publications had their emphasis on coastal and marine fisheries. 50 publications out of 56 were categorized as case studies and were further analysed in our study (detailed description in Table 2.A1 of the Supplementary Material).

The number of publications that focused on stakeholder participation significantly increased within the last 18 years (Fig. 2.1). In 2015, a maximum value of eight was reached. The majority of the case studies was conducted in Europe (N = 18), North America (N = 11) and Australia (N = 9).

2.3.1 Paper Review: Stakeholders

2.3.1.1 Term Definition

We identified four publications defining the term stakeholder (Brzezinski et al. 2010; Haapasaari et al. 2013; Tiller et al. 2015; Kinds et al. 2016) (Fig. 2.2a). Even though they defined the term more indirectly and in general, Brzezinski et al. (2010) stated stakeholders as members of a particular group that hold a personal stake. They referred to Olson (1965) to suggest that the increase of the personal stake of these members will lead to an increase of their participation in regulatory processes. Haapasaari et al. (2013) described stakeholders as a group of people having a stake and contributing towards a knowledge base for fisheries management. On the other hand, Kinds et al. (2016) focused on stakeholders as all people and organizations (here producer organizations), which are actively involved in the fishing sector. Tiller

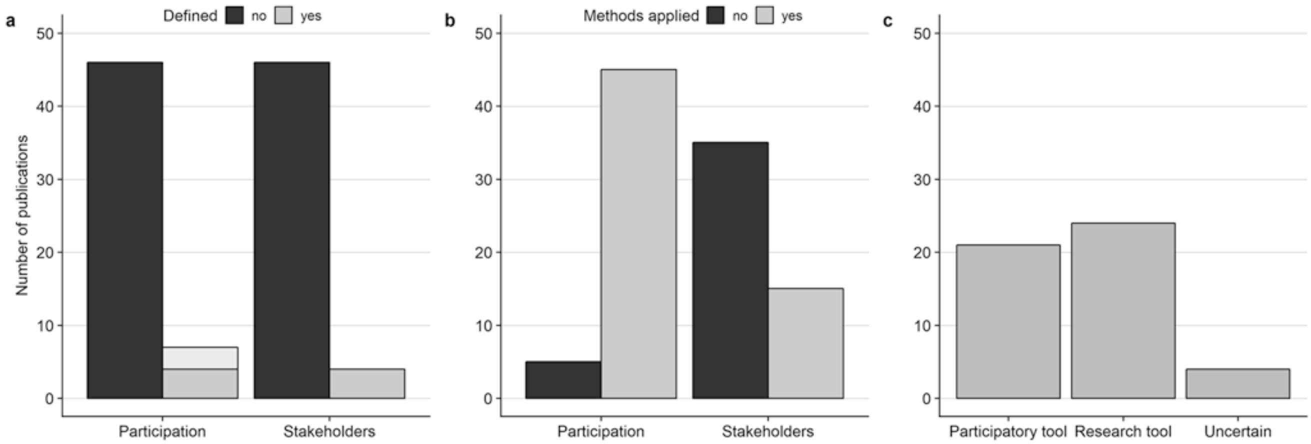

Fig. 2.2 Review of 50 research publications presenting case studies in coastal and marine fisheries (as of May 2018). (**a**) Term definition of participation and stakeholder; we distinguished between participation (grey) and participation-related terms (light grey), e.g. participatory management, participatory research and participatory action research; (**b**) method application for participation (e.g. interview, workshops and questionnaire) and stakeholders (e.g. snowball sampling); (**c**) the use of stakeholder participation, either as a participation or research tool

et al. (2015) took a deliberate look into the literature, referring to Freeman (2010). Freeman (2010) defined stakeholders as any group or individual who can affect, or is affected by, the achievement of the organization's objectives (Freeman 2010). Tiller et al. (2015) continued to criticize this definition as too broad; it allows the inclusion of nearly everyone as a stakeholder.

2.3.1.2 Stakeholder Analysis

Durham et al. (2014) stated that the selection of stakeholders strongly determines the outcome of the participation process. They, therefore, recommended to systematically select stakeholders based on the objective and impact of research. We, therefore, analysed the publications, looking for the description or reference of stakeholder analysis processes.

In our review corpus, 15 out of 50 publications applied methods to get an understanding of who their stakeholders are (Fig. 2.2b). We evaluated publications as using stakeholder analysis approaches if the case studies did not decide on stakeholder groups or stakeholder individuals (referring to Durham et al. 2014) but researched for them systematically. Three out of 15 publications defined stakeholder groups, three determined stakeholder groups as well as individual stakeholders and the remaining nine out of 15 case studies selected individual stakeholders out of a priori stakeholder groups.

Gray et al. (2012), Kinds et al. (2016), as well as Sampedro et al. (2017) evaluated stakeholder groups that were involved in past fisheries research and management; thereby, they have chosen the group of stakeholders they wanted to involve in their current research projects. Pristupa et al. (2016) applied three different approaches; on the one hand, they did not want to overlook a major stakeholder, and on the other hand, they aimed to identify the most knowledgeable individual within the appropriate stakeholder group: first they extracted information from reports and open-access information such as Marine Stewardship Council reports, interviews on specialized websites and scientific reports. Second, they identified stakeholders during a thematic conference, which was also used to establish contacts. Third, recommendations by fisheries experts were accumulated using the snowball approach (Pristupa et al. 2016). Different to the previous case studies, Miller et al. (2010) used two approaches to select relevant stakeholders. First, stakeholders were selected due to history, perspectives and relationships among those with a stake in a specific fishery (Miller et al. 2010). Second, relevant stakeholders should be knowledgeable and influential in their community as well as open minded for different views (Miller et al. 2010). Further, Mahon et al. (2003) analysed stakeholders based on public records before organizing discussion meetings where individual stakeholders were singled out.

Additionally, nine publications described methods that were applied to identify individual stakeholders, either within presumed stakeholder groups or randomly. Butler et al. (2015), Bitunjac et al. (2016) and Stratoudakis et al. (2015) based their choice of individual stakeholders on their long-time experience and their knowledge of the topic studied. Bitunjac et al. (2016) selected stakeholders of which the authors assumed to have a leading influence within their group and were, therefore, seen as representatives of their stakeholder group. Catedrilla et al. (2012), Kerr et al. (2006) and Murphy et al. (2015) had chosen fishers as individual stakeholders by sampling them from a registration list in their field of interest. Lorance et al. (2011) and Thiault et al. (2017) selected the stakeholders at random. Lorance et al. (2011) advertised workshops widely and, therefore, could not directly influence attendance; Thiault et al. (2017) did sampling among all households in their area of interest without focusing on a specific stakeholder group. Kittinger (2013) first conducted a snowball sampling followed by a 'purposive sampling approach' – a deliberately selective approach choosing knowledgeable individuals.

2.3.1.3 Stakeholder Types

Overall the stakeholder type 'fishery' had the highest frequency of appearance within all publications, followed by 'politics', 'science' and 'eNGO' (Table 2.3). In five publications, 'fishery' was considered as the only stakeholder (Clarke et al. 2002; Catedrilla et al. 2012; Eveson et al. 2015; Tiller et al. 2015; Thiault et al. 2017). Except for Catedrilla et al. (2012), these publications aimed at getting information about the spatial distribution of fishing grounds. Two case studies (Fletcher 2005; Dowling et al. 2008) did not name 'fishery' as a stakeholder but noted that fishers were involved in the conducted case study.

'Politics', 'science' and 'eNGO' were targeted in about half of the studies. Nonetheless, 12 case studies did not consider any of these three stakeholders at all (e.g. Mitchell and Baba 2006; Appledorn et al. 2008; Cox and Kronlund 2008). The stakeholder type 'others' mostly represented a business or the like (e.g. Carr and Heyman 2012; Butler et al. 2015). 'Public' stakeholders were mainly seen as community members (Kittinger 2013; Eriksson et al. 2016) or consumers (Mahon et al. 2003), who, therefore, did not have a primary economic or political interest in fisheries.

'Related industry' was described as processing and selling industry that was directly associated with fisheries and so depended on this stakeholder type (e.g. Cox and Kronlund 2008). 'Related industry' was considered 16 times in the reviewed case studies and differed widely in their topics in which context these stakeholder groups emerged, e.g. bycatch (Bojorquez-Tapia et al. 2016), stock assessment (Smith et al. 2001) or compliance (Garza-Gil et al. 2015). 'Recreational fishery' was represented in five publications, two in Australia (Fletcher 2005, Mitchell and Baba 2006) and three in North America (e.g. Miller et al. 2010; Gray et al. 2012; Murphy et al. 2015), all of them focused on management processes.

Table 2.3 Identified stakeholder types presented by case studies in coastal and marine fisheries (as of May 2018) and ranked by the frequency of their appearance (N). Description of stakeholder types corresponds to the one mentioned in the publication under review

Stakeholder type	Description of stakeholders	N
Fishery	Fishers and their direct representatives	48
Politics	Government officials, local and village officers	31
Science	Academic scientists	25
eNGO	Environmental non-governmental organizations	24
Others	E.g. local businesses, leaders of the tourism sector, leaders of other community-based associations	17
Related industry	Processing and selling businesses	16
Public	Community members, representatives from public organizations, consumers	7
Recreational fishery	Representatives of recreational fishery	5

2.3.1.4 Relationships Between Stakeholder Types

We applied a multiple correspondence analysis to evaluate the occurrence of certain stakeholder clusters. 48 publications included 'fishery' as a stakeholder, but this stakeholder type did not group with other stakeholders and, therefore, lessened the meaningfulness of other stakeholders. For this reason, we decided to exclude 'fishery' from the MCA, which resulted in a higher percentage of the variance explained by the dimensions. As a result, very similar variable clusters of categories appeared and were, therefore, easier to interpret. 'Others' were also excluded from the MCA; by definition this stakeholder type showed a great variety, and, therefore, interpretation of the data would be difficult.

Ideally, dimensions should be used to interpret the data whose eigenvalues exceed the mean of all eigenvalues (0.17). For this reason, we included three dimensions into our analysis, which together accounted for over 70% of the variance. Here, it is important that the dimensions obtained are hierarchical. Dimension 1 formed the strongest dimension (Dim1, Fig. 2.3, Table 2.A2 of the Supplementary Material), i.e. singled out 'science', 'eNGO' and 'politics', and explained 31.6% of the variance. Further, these three stakeholder types had the highest number of mentions after 'fishery'. Dimension 2 (Dim 2, Fig. 2.A2a of the Supplementary Material) focused on 'recreational fishery' and 'related industry', accounting for 21.8% of the variance. Although 'recreational fishery' was only considered in five case studies, this stakeholder type showed a strong contribution towards dimension 2. Also, explanatory power was increased by sharing contribution with 'related industry'. Less variance (17.7%) was explained by dimension 3, which was dominated by 'public' (Dim 3, Fig. 2.A2b, Table 2.A1 of the Supplementary Material).

Subsequently, MCA was applied separately to case studies from North America (N = 10) and Europe (N = 18) (Fig. 2.A3a-c of the Supplementary Material). The results of the MCA that was performed on North America case studies showed a similar picture as in Fig. 2.3, although these case studies did not dominate the review corpus. Even though 'science', 'eNGO' and 'politics' showed a strong contribution in different dimensions, these stakeholder types could

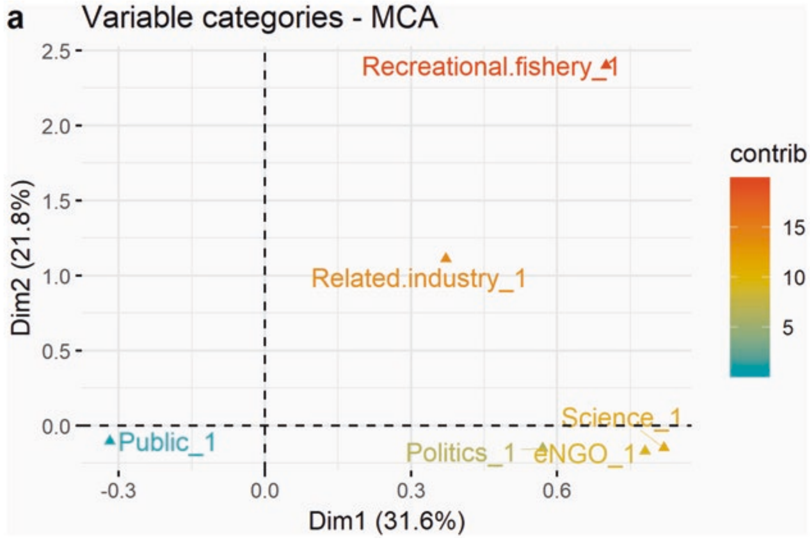

Fig. 2.3 Panel **a** of the visualization of correlation between dimension 1 (Dim1) and dimension 2 (Dim2), showing the variance of stakeholder types in 50 research publications of case studies in coastal and marine fisheries (as of May 2018) using multiple correspondence analysis (MCA). Figure shows which types of stakeholders are mostly correlated, i.e. regarding stakeholder participation in coastal and marine fisheries, 'eNGO', 'politics' and 'science' are often addressed together. Panels b and c of the MCA results for correlation of dimension 2 (Dim2) and 3 (Dim3) as well as dimension 1 (Dim1) and 3 (Dim3) are presented in Fig. A2 of the Supplementary Material

still be found as a group. In dimension 2 'related industry' and 'recreational fishery' were displayed in the negative area; the other stakeholder types moved from the negative area of dimension 2 into the positive area. 'Related industry' and 'recreational fishery' were also grouped together with a high contribution as seen in Fig. 2.A3a (Supplementary Material); 'public' was found apart.

We showed clearly that in European case studies, 'related industry' and 'public' as well as 'science' and 'eNGO' grouped together. 'Politics' was rather set apart and did not contribute much to dimension 1. 'Politics' solely dominated dimension 3; 'recreational fishery' did not appear in the case studies conducted in Europe.

2.3.2 Paper Review: Participation

2.3.2.1 Term Definition

In total, four publications defined the term participation (Brzezinski et al. 2010; Tiller et al. 2015; Pristupa et al. 2016; Sampedro et al. 2017); three publications described participation-related terms (Kittinger 2013; Hara et al. 2014; Trimble and Lazaro 2014) (Fig. 2.2a). After Sampedro et al. (2017), participation could take many different forms, e.g. from planning (Neis et al. 1999; Johannes and Neis 2007; Johnson and van Densen 2007) to co-management experiences (Berkes 2003; Wilson et al. 2003). Participation was described as a role that benefits the participating stakeholders (Brzezinski et al. 2010) and a strategy of involving the stakeholders in decision-making processes (Tiller et al. 2015). Further, dependent on the strategy of involvement, stakeholders could get further responsibilities in the results of the conducted participatory process (Tiller et al. 2015). Moreover, participation referred to the type and level of stakeholder or beneficiary involvement (Hickey and Kothari 2009; Pristupa et al. 2016). Pristupa et al. (2016) explained that countries had developed a whole range of formal mechanisms stipulating citizens and stakeholder participation, e.g. consultations, referendums and elections; the participation of the private sector was still challenging.

Within three case-study publications, participatory-related terms had been described, e.g. participatory management (PM, Hara et al. 2014), participatory research (Trimble and Lazaro 2014) and participatory action research (PAR, Kittinger 2013). PM or co-management was defined as an institutional and organizational arrangement for effective management between government and user groups (Hara et al. 2014). The function of PM was described as the sharing of power and the responsibility for the management decision-making, the encouragement of partnerships and provision of user incentives for sustainable use of resources (Wilson et al. 2003; Hara et al. 2014). Participatory research was defined as one way to create power sharing between researchers and communities for, e.g. developing resource management strategies (Arnold and Fernandez-Gimenez 2007; Trimble and Lazaro 2014). Related to the degree of participation or the relationships between researchers and the community, different modes of participatory research occurred (Trimble

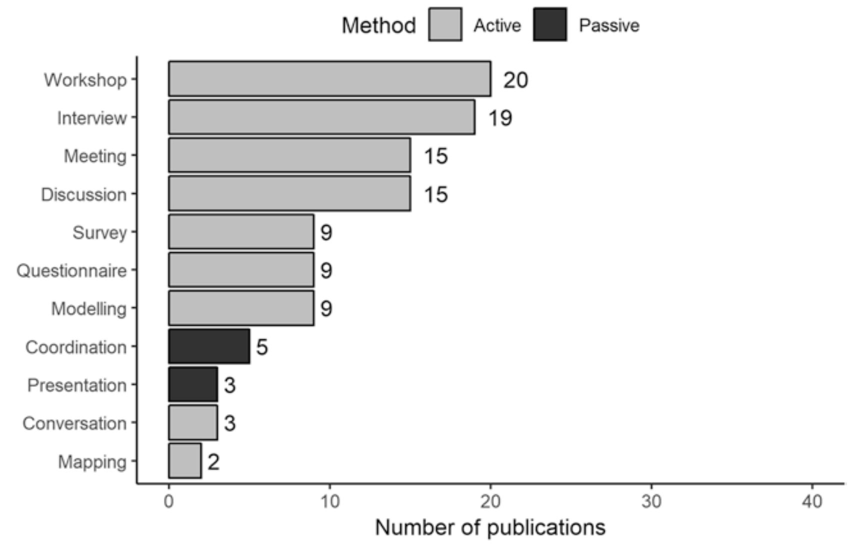

Fig. 2.4 Frequency of the appearance of active (workshop, interview, meeting, discussion, questionnaire, survey, modelling, conversation, mapping) and passive participation tools (coordination, presentation), related to stakeholder participation described in coastal and marine fisheries research publications (as of May 2018)

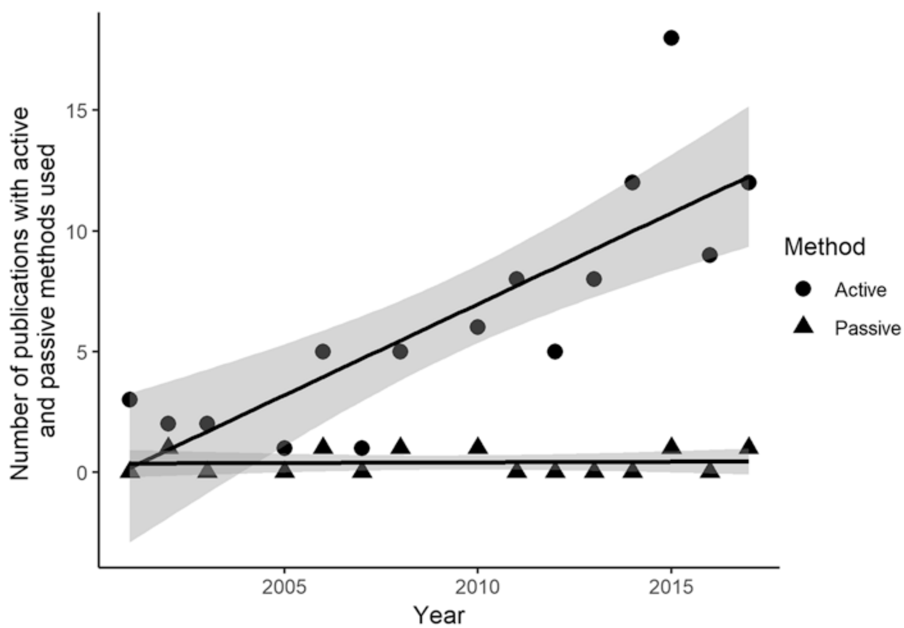

Fig. 2.5 Number of research publications with participation methods that occurred in coastal and marine fisheries research publications between 2000 and 2018; black lines represent the linear regression with 95% confidence intervals; grey area indicates the confidence band (Active: $R^2 = 0.670$, $p = 0.0001895$; passive: $R^2 = 0.00291$, $p = 0.8485$)

and Lazaro 2014), e.g. contractual, consultative, collaborative and collegiate (Biggs 1989), co-option, compliance, consultation, cooperation and co-learning (Kindon 2008). Kittinger (2013) used the term PAR, which is defined as a set of approaches related to the involvement of researchers and community members working collaboratively in the visioning, goal-getting, data gathering as well as assessment phases of research (Whyte et al. 1989; Kittinger 2013).

2.3.2.2 Participatory Tools

In contrast to the definition of participation, 45 publications focused on the description of participatory tools (Fig. 2.2b). We identified 11 participatory tools, which were divided into nine active and two passive participatory tools (Fig. 2.4). Active participation tools included workshops (N = 20), interviews (N = 19), meetings (N = 15), discussions (N = 15), questionnaires (N = 9), surveys (N = 9), modelling (N = 19), conversation (N = 3) and mapping (N = 2). Coordination (N = 5) and presentations (N = 3) represented passive participation tools (Fig. 2.4).

We detected no changes in the number of publications over time using passive methods. In contrast, we found a significant increase in the number of case studies applying active methods with a peak in 2015 (N = 19) (Fig. 2.5).

Table 2.4 presents utilized tools and related sub-tools. Here, the highest number of sub-tools was presented by interviews, including sub-tools (N = 14), e.g. semi-structured interview (e.g. Carr and Heyman 2012; Stöhr et al. 2014; Yates and Schoeman 2015; Rivera et al. 2017), unstructured interview (Hara et al. 2014) and key informant interview

Table 2.4 List of active as well as passive participation tools and including sub-tools, described within 50 research publications presenting case studies in coastal and marine fisheries (as of May 2018) between 2000 and 2018

	Participation tool	Participation sub-tool
Active	**Workshop**	Stakeholder workshop, 1-day workshop, 2-day workshop, participatory workshop, structured stakeholder workshop, value workshop, gaming workshop
	Meeting	Roundtable meeting, joint planning meeting, information meeting, face-to-face meetings, working group meeting, plenary meeting, group meeting, sub-group meeting, stakeholder group meeting, management group meeting
	Interview	Structured interview, semi-structured interview, unstructured interview, personal interview, key informant interview, in-depth interview, one-on-one interview, face-to-face interview, structured face-to-face interview, face-to-face semi-structured interview, open-end face-to-face interview, formal interview, informal interview, qualitative interview
	Conversation	Dialogue, informal conversation, focused conversation
	Discussion	Group discussion, focus group, forum discussion, open discussion, stakeholder advisory panel
	Questionnaire	Structured interview questionnaire, e-mail-based questionnaire, follow-up questionnaire
	Survey	Large-scale interview survey, face-to-face interview survey, online survey, in situ survey, attitudinal survey
	Modelling	Tool, participatory modelling, Bayesian belief network
	Mapping	Cognitive mapping, fuzzy cognitive mapping
Passive	**Coordination**	Voting, rating, evaluation
	Presentation	Video, poster, exhibition, tableaux

(Eriksson et al. 2016). Meetings and workshops showed the second and third highest number of sub-tools. Here, meetings were presented, with sub-tools (N = 10), e.g. roundtable meeting (Kerr et al. 2006), joint planning meeting (Kittinger 2013) and face-to-face meeting (Miller et al. 2010). However, workshops were shown, including sub-tools (N = 7), e.g. stakeholder workshop (Eriksson et al. 2016; Burdon et al. 2018) and participatory workshop (Bojorquez-Tapia et al. 2016). Passive participation methods included coordination, with sub-tools (N = 3), e.g. voting (Miller et al. 2010; Thiault et al. 2017; Zengin et al. 2018), rating (Goetz et al. 2015), evaluation (Cox and Kronlund 2008) and presentation, including sub-tools (N = 4), e.g. video (Clarke et al. 2002), poster (Kerr et al. 2006), exhibition (Kerr et al. 2006) and tableaux (Kerr et al. 2006). We also determined whether preparatory work was performed and described within the case studies under review. Among others, observations (Delaney et al. 2007; Granados-Dieseldorf et al. 2013; Trimble and Berkes 2013; Stöhr et al. 2014; Trimble and Lazaro 2014; Mabon and Kawabe 2015), fieldwork (Mabon and Kawabe 2015; Sampedro et al. 2017) and visits (Kerr et al. 2006) were carried out. Furthermore, newsletters (Kerr et al. 2006) and e-mails (Lorance et al. 2011) were sent out to call for participation within different stakeholder types. Moreover, telephone calls (Kerr et al. 2006) were made, and consultations took place, e.g. consultation with stakeholders (Cox and Kronlund 2008; Mapstone et al. 2008; Williams et al. 2011).

2.3.2.3 Intention for Participation

Within this review, we looked at the diversity of the intention for participation; we classified these intentions as types and sub-types (Table 2.5).

The intention types identification (N = 20), with sub-types, e.g. target species (Fletcher 2005), ways of communication (Zengin et al. 2018), stakeholder characteristics (Bojorquez-Tapia et al. 2016; Kinds et al. 2016; Burdon et al. 2018) and assessment (N = 12), with sub-types, e.g. management system (Lorance et al. 2011), knowledge (Carr and Heyman 2012) and data (Catedrilla et al. 2012) occurred most often (Fig. 2.6). Establishment (N = 5), development (N = 7), evaluation (N = 7) and improvement (N = 7) occurred moderately often (Fig. 2.6). Less widely used were analysis (N = 3), definition (N = 2), description (N = 2) and feedback (N = 2) (Fig. 2.6).

Establishment (N = 10), assessment (N = 7) and identification (N = 7) had the most sub-types within the case studies under review. Improvement (N = 5), development (N = 4) and evaluation (N = 4) showed a moderate diversity of sub-types, whereas feedback (N = 2), e.g. feedback from stakeholders on the meeting (Dowling et al. 2008), as well as description (N = 2), e.g. knowledge about socio-ecological systems (Gray et al. 2012) and management implications (Smith et al. 2001) presented the lowest diversity of sub-types.

2.3.3 Reflection on the Joint Term Stakeholder and Participation

In the final evaluation, we analysed the application of stakeholder participation as one term. We first evaluated whether

Table 2.5 Types and associated sub-types of intentions for participation determined within 50 research publications focusing on stakeholder participation in coastal and marine fisheries from 2000 to 2018

Type	Sub-type
Analysis	Stakeholders' perception
	Mental models
	Management system
Assessment	Management system (e.g. adaptive co-management, history of management implementation)
	Ideas of alternative livelihood
	Knowledge (e.g. fishers ecological knowledge), perception and attitude of stakeholders
	Method success
	Data (e.g. interviews, socioeconomic characteristics)
	Solution on regional level
	Effectiveness of collaboration between stakeholders
Definition	Criteria for evaluation
	Objectives
	Management implications
Description	Knowledge of socio-ecological system (SES)
	Management implications
Development	Consensus-building
	Comprehensive map
	Stakeholder-driven scenarios
	Criteria for participatory research
Establishment	Co-management mechanism
	Collective research agenda
	Vision for future fisheries management
	Comprehensive map of predicting fishing effort
	Guidance for scientists
	Scientific advice
	Theory of causal mechanisms
	Platform for information and decision-making
	Stakeholder-driven scenarios
	Clear and open views
Evaluation	Mental models
	Harvest policies
	Results from interview (cross-checking)
	Fishery and management system
Feedback	Forecast content
	Meeting
Identification	Stakeholders' characteristics (e.g. attitude, perception, wishes, concerns, knowledge (local ecological knowledge, fishers ecological knowledge)
	Information (e.g. socio-ecological)
	Target species
	Objectives (e.g. criteria, uncertainties, drivers, consequences, human dimensions, population needs, reference points)
	Weakness of fishery system
	Range of quantifiable objectives and strategies
	Ways of communication

(continued)

Table 2.5 (continued)

Type	Sub-type
Improvement	Stakeholder participation, relationships and requirements
	Management
	Socio-economic drivers
	Data
	Website

stakeholder participation was used for doing research on stakeholders or if the case studies were conducted with the participation of stakeholders. Overall, 24 publications utilized the term stakeholder participation for the research on stakeholders (research tool); 21 publications used stakeholder participation in their conducted case study (participation tool). Within five case studies, it was uncertain whether stakeholder participation was used or not (Fig. 2.2c).

In the case study conducted by Kinds et al. (2016), the term stakeholder participation was used to describe the development of a sustainability tool with the direct input from users, i.e. fishers. Here, the wishes and preferences of stakeholders were recognized and implemented to improve the output of the utilized tool but not to influence decision-making processes (*research tool*). Rivera et al. (2017) carried out semi-structured interviews to assess stakeholders' perceptions to identify management, biology and socioeconomic drivers related to the gooseneck barnacle fishery in Spain. This case study used the term stakeholder participation, but no influence on the management by stakeholders was mentioned (*research tool*). Tiller et al. (2015) applied an integrated approach of two methods, Systems Thinking and Bayesian Belief Networks, to elicit stakeholders' opinions through participatory engagement. Both methods were used to investigate, e.g. how stakeholders perceive the ecological system in the Trondheimsfjord, but with no further impact on decision-making processes (*research tool*). Through the method of Systems Thinking, shared mental models of the ecological system in the Trondheimsfjord were developed. Bayesian Belief Networks were further used for exploration of the priority issues as well as to represent causal relationships between defined variables. In contrast, Trimble and Berkes (2013) presented the concept of participatory research, i.e. involving fishers and policymakers as well as managers among other stakeholders in the case of a sea lion population and a fishery in Uruguay. Within this case study, stakeholders, e.g. fishers had an impact on decision-making processes related to the management of the sea lion population (*participation tool*). Williams et al. (2011) conducted a case study based on the participation of commercial fishers, defining various alternative management strategies related to the Torres Strait Finfish Fishery (TSFF) in Australia, i.e. sea-

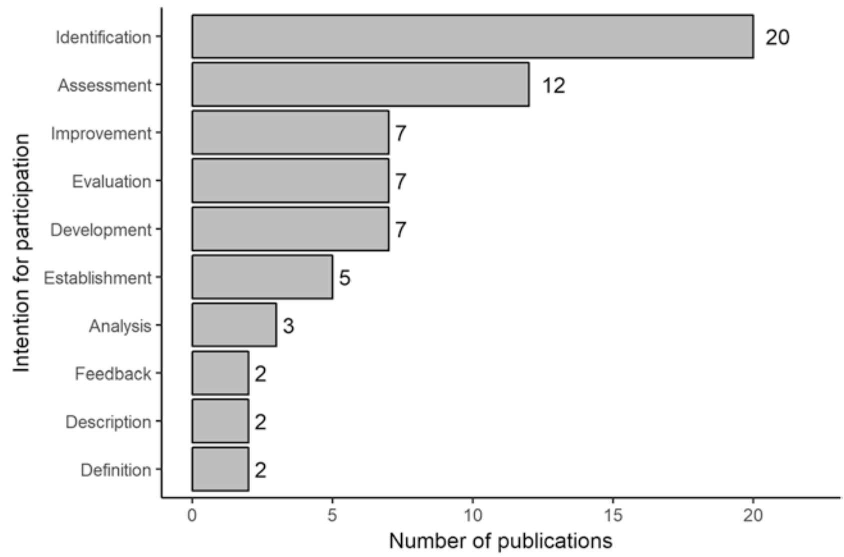

Fig. 2.6 Frequency at which types of intention for participation occurred in 50 research publication looking at coastal and marine fisheries (as of May 2018)

sonal closure, large minimum capture size, to provide a framework for impartial evaluation of management strategy performance (*participation tool*). In addition, Stöhr et al. (2014) described the concept of stakeholder participation by evaluating two case studies; only the Polish case had a coastal and marine focus. Within this case study, roundtables were applied to create a multi-stakeholder platform with the objective of informing and influencing decision-making processes (*participation tool*).

2.4 Discussion

In total, 50 case studies focusing on stakeholder participation in coastal and marine fisheries were identified and reviewed. Most of the publications did not define the term stakeholder or participation or described a systematical approach of selecting stakeholders. Moreover, stakeholder participation was mentioned in all 50 publications, but only half of the case studies involved stakeholders in the process of participation.

It should be noted that we could only show what has been described in the publications under review; here, we did not present a comprehensive overview of all relevant stakeholder types that would be possible in the respective contexts.

2.4.1 Stakeholder

2.4.1.1 Term Definition and Stakeholder Analysis

Four case studies defined the term stakeholder and, thus, showed a scientific examination of potentially concerned stakeholder types; 15 publications used a systematic description of how stakeholders were identified. The other publications used intuitive decisions to identify relevant stakeholders in their case study. This led to the fact that, related to our research focus on coastal and marine fisheries, the stakeholder type ‘fishery’ was mostly involved; ‘public’ stakeholders were only rarely involved.

All case studies included ‘fishery’ as a stakeholder type. Therefore, we proposed that ‘fishery’ is seen as the main stakeholder type in coastal and marine fisheries research. Mahon et al. (2003) supported this thesis literally by writing that within the conducted case study, the primary stakeholders are the fishers. In some publications, ‘fishery’ was even the only stakeholder type considered. Although at first sight this realization might seem logical, it can be discussed; fisheries are harvesting a common resource and, therefore, do not necessarily contribute towards the sustainable exploitation of coastal and marine fisheries resources, as most case studies consider stakeholder participation as a way of implementing more sustainable fisheries management (e.g. Wilson et al. 2003; Thiault et al. 2017). Although not all forms of fisheries were considered unsustainable, artisanal fisheries, for example, were often associated with having a small impact on fish stocks (Carvalho et al. 2011) but have been proven to cause impact beyond sustainable levels (Pomeroy

2012); they also deal with other sustainability issues such as bycatch of birds (Almeida et al. 2017).

Within our review, we used the category 'others' to classify stakeholders that did not fit into any other category. This fact shows very clearly that, on the one hand, there is great diversity of stakeholder types within the field of coastal and marine fisheries research; on the other hand, it describes existing discrepancies in the understanding of the term definition and the classification of corresponding stakeholders. We, therefore, suggest to clearly define the term stakeholder as well as to discuss their role in the specific context of the conducted case study. Although Tiller et al. (2015) criticized the stakeholder definition by Freeman (2010) as too broad, they did not give a clear term definition either in their own case study. We assume that there is a high risk of excluding relevant stakeholder types, when not applying a term definition for stakeholder as well as not using a stakeholder analysis tool to ensure that relevant stakeholders are approached. This could lead to the fact that, for example, no local ecological knowledge or fisheries ecological knowledge would be recorded for the corresponding case study, which is important inter alia for better understanding the marine ecology and making results more convincing for resource users (Davis et al. 2004) and, therefore, increase the legitimacy of resource management (Aanesen et al. 2014). It is not important to include all stakeholders available but to choose them carefully according to the objectives of the case study, which means applying a stakeholder analysis approach (Durham et al. 2014).

2.4.1.2 Stakeholder Clusters

We showed, with using MCA, that 'eNGO', 'politics' and 'science' are often addressed together within the strongest dimension. Therefore, we could conclude that these stakeholder types were considered important within many conducted case studies. This dimension described stakeholders that deal with a rather theoretical side in the field of fishery, i.e. in the form of regulations, research or campaigns. It can be argued that these stakeholders contributed towards research and management as well as towards different forms of sustainability; therefore, 'eNGO', 'politics' and 'science' have a more sustainability-oriented attitude. This finding is strongly supported by Aanesen et al. (2014); they concluded that, under the European Common Fisheries Policy, authorities, scientists and NGOs have a similar perspective on fisheries management. This is rather obvious for 'eNGO', as they are seen as representing the ecological sustainability. By contrast, 'politics' could be interpreted as representing the population, i.e. this stakeholder group acts in the interest of the sustainability of food, but is also driven by the economic sustainability. 'Science' could be seen as the representative and provider of research. We suggest that these stakeholder groups have a general interest in sustainable management and are not directly or financially dependent on the resource fish. Of course, it can be argued that certain jobs of eNGOs, scientists or politicians depend on the debate as well as on the public interest in fish and fishery. But this argument is to be classified as marginal in this context. One reason is that fish is one of the main protein sources for humans; even if the resource fish would shrink, it will always be of interest for certain stakeholder types.

In our sample of publications, 'politics', 'eNGO' and 'science' were mentioned most frequently after 'fishery'. For that reason, we can assume that these three stakeholder groups are deemed the second most important stakeholder groups. It can be discussed that 'politics', 'eNGO' and 'science' should have at least an equally strong stake in fisheries research compared to 'fishery'.

Another group displayed by MCA is formed by 'related industry' and 'recreational fishery'. Both stakeholder groups mostly occurred in the second strongest dimension, which can be interpreted as stakeholders who are handling the resource fish and, therefore, dealing with it in a practical way. Although they also have an interest in sustainable management, they, unlike 'science', 'politics' and 'eNGO', depend financially (especially 'fishery') or mentally (e.g. 'fishery' and 'recreational fishery') on the resource fish. Therefore, profit or benefit orientation can be seen as another factor describing dimension 2. This is supported by the fact that the two groups (dimension 1: sustainability vs. dimension 2: dependence) discussed are placed far away from each other in the MCA. Both stakeholder groups cannot be seen as independent from each other as their decisions are influencing each other's actions, e.g. if political regulations or campaigns led by 'eNGOs' resulted in decreasing harvest rates of fish, commercial and recreational fishers are negatively affected. We take a critical look at these stakeholder groups, as they are presented apart from each other in the conducted MCA and, therefore, are not engaged equally in the reviewed case studies. We recommend to engage these stakeholder types more equally. The cooperation between fishery-related stakeholders and scientists could lead to more informed stakeholders on both sides; therefore, a greater mutual understanding, trust as well as likelihood of long-lasting partnerships could be achieved (Hartley and Robertson 2006).

We showed that 'public' participation is relatively low in the field of coastal and marine fisheries research. This fact is reflected among other things in the low numbers of mention within the case studies. Here, 'public' as one stakeholder group contributed the least to the two strongest dimensions.

On the one hand, the low involvement could be interpreted as a lack of interest. On the other hand, we argue that public stakeholders were not directly addressed within the publications. In relation to the definition we used to classify 'public', it can be critically discussed that 'eNGOs' could also be seen as representatives of the civil society (e.g. Pristupa et al. 2016) and community leaders could include voted politicians (Rivera et al. 2017). But we decided to stick to the stakeholders as they were mentioned in the publications. The results showed that 'public' stakeholders are not part of any group; nevertheless, they dominated the weakest dimension and explained the high percentage of its variance.

Data from North American and European case studies resulted in different MCAs. This can be seen for example with 'recreational fishery'. Although this stakeholder type is part of the European Common Fisheries Policy, they are not considered as stakeholders in any of the case studies conducted in Europe. This is different for North American case studies; here 'recreational fishery' was seen as a stakeholder type. Even if this analysis gave only a small insight into the topic, regional differences related to stakeholder types could already be made clear here. These differences cannot be explained by different management systems, because both in Europe and in North America recreational fisheries are included in their regulations; the results further need to be investigated. Furthermore, we assumed different emphases of stakeholder types; therefore, when applying MCA to different regions, different interpretations of the dimensions have to be made. However, the small sample size for regional MCAs could reduce the significance of such interpretations.

Based on the application and analysis of the term stakeholder, we conclude that there were only a few case studies that critically assessed the concept of stakeholders. Nevertheless, our results provide an insight into how stakeholders were seen in the field of coastal and marine fisheries research, i.e. who is considered as important and which stakeholders are often consulted together.

2.4.2 Participation

2.4.2.1 Term Definition and Typologies

Out of 50 case studies focusing on the topic stakeholder participation in coastal and marine fisheries, only seven case studies defined the term participation or a participation-related term. However, there is a wide variety of definitions and typologies of stakeholder participation in the literature.

Green and Hunton-Clarke (2003) represented different typologies of participation regarding environmental decision-making. Five concepts of participation were listed and defined to increase the level of involvement. On the one hand, Arnstein's (1969) concept of stakeholder participation was described; this concept is based on eight levels: nonparticipation (manipulation and therapy), tokenism (informing, consultation and placation) and citizen power (partnership, delegated power and citizen control) (Luyet et al. 2012). On the other hand, the participation concept by Pretty and Shah (1994) was presented. Here, participation is classified by using six steps: passive participation, participation by information giving, participation by consultation, functional participation, interactive participation and self-mobilization. In Pristupa et al. (2016), participation was also described by the level of stakeholder involvement, but with regard to the concept of Arnstein (1969) and Pretty and Shah (1994), no further explanation was given of the different levels of participation in this case study.

In addition to Green and Hunton-Clarke (2003), Reed (2008) reviewed different typologies on stakeholder participation for environmental management. In this literature review, he defined the following typologies on which participation is based: (i) degrees of participation (e.g. Arnstein 1969), (ii) nature of participation (Rowe and Frewer 2000), (iii) theoretical basis (e.g. Thomas 1993) and (iv) participation based on objectives for which participation is used (e.g. Okali et al. 1994) (Reed 2008). The fourth typology was used in the case studies by Sampedro et al. (2017) and Tiller et al. (2015). Here, participation was described as the use for planning or co-management experiences (Sampedro et al. 2017) and as the strategy for involving stakeholders in decision-making processes (Tiller et al. 2015). Related to the case studies under review, we would add a fifth typology of participation, i.e. participation based on the opportunity to participate in relation to resources. Brzezinski et al. (2010) described and defined participation as a role benefiting participating stakeholders based on money and geographical proximity. The case study showed the connection between geographical closeness and the level of attendance, i.e. the closer stakeholders were to meetings, the higher was their level to attend at those meetings (Brzezinski et al. 2010).

As NOAA (2015) generalized, there is no 'one-size-fits-all' approach or definition of participation; the implementation and the process of participation is dependent on several aspects, e.g. issue at hand, stakeholders, geography, schedules, as well as on time frames. Furthermore, Green and Hunton-Clarke (2003) recommended selecting the type of participation suitable for the situation or the problem that needs to be solved. We argue, to create a successful resource management and increase the acceptance of management measures by resource users, a well thought out participation approach is essential with regard to the sustainable use of coastal and marine resources.

2.5 Conclusion

Stakeholder participation is and will continue to be of central importance when it comes to the management of ecosystems and its resources. Although our findings showed clear tendencies in stakeholder participation, they also opened several other questions.

The grouping of 'science', 'eNGO' and 'politics' was discussed critically, especially 'public', 'recreational fishery' and 'related industry' were presented far away in the MCA. We suggest that these groups should not be seen as opposed to each other but be included in a more integrated way in participatory research projects. Low involvement of 'public' stakeholders and their contribution towards decisions should be further discussed, because wild fish is widely seen and communicated as a common pool resource. As a consequence, 'public' stakeholders, i.e. representatives of the common, should also have a stake in the management of the resource also since ecosystem changes will affect all citizens.

We advise to include different stakeholder types and take advantages of their different experiences, although we recognize that pragmatic and methodological reasons such as the willingness to participate can constrain these efforts. While our analysis has not been profoundly focused on regional differences, it should be noted that there are regional differences between the relationships between and the contributions of stakeholders. Even though only done marginally in our analysis, dividing the data into different regions showed that relationships and contributions varied between stakeholder types. For further research, we advise to set a regional focus on stakeholder participation and discuss it under the light of different management regulations.

Although we presented stakeholder types carefully deducted from the texts, the perception of these types is always at risk to change throughout a paper review process. Soma and Vatn (2014), e.g. separated the role of stakeholders and citizens in participatory processes, not discussing citizens as stakeholders but also plead for the involvement of citizens in natural resource management; therefore, we categorized these stakeholders in the same manner.

Research projects and stakeholder participation processes apart from research projects are mostly restricted by resources, e.g. time, money (Angelstam et al. 2013), capacity (Mackinson et al. 2011), expertise, i.e. expertise of social researchers and the availability of researchers as well as of stakeholders in general. These limitations can be a reason for not including a systematic discussion of the term stakeholder or a scientific stakeholder analysis. Because only a few of the reviewed publications described a definition or an approach of analysing stakeholders, we conclude that there were also limitations of integration, i.e. the involvement of social scientists in the process of stakeholder participation. In addition, it is of great advantage to know which typology and degree of participation have been used and benefit from experienced advantages as well as disadvantages of applied methods (Luyet et al. 2012). This way, conflicts can be avoided and stakeholder participation can be implemented in a better way.

In times of interdisciplinary (Repko et al. 2011) as well as transdisciplinary research (Häberli et al. 2001), and the intention of further improving science in general, we call for an increasing involvement of social scientists regarding the processes of stakeholder participation in coastal and marine fisheries research; more funding opportunities are needed to support this kind of integrated research field.

Our review clearly showed that many different definitions of stakeholder participation exist, and so researchers need to be careful when they examine which one is applicable towards their research goal. Related to this great diversity of stakeholder participation definitions, we will not present *the* definition. Nevertheless, we advise to conduct a critical analysis of stakeholder types as well as on participation tools at the beginning of a new research project with the aim of involving stakeholders related to decision-making processes. Durham et al. (2014) and NOAA (2015) offer well-applicable and explained stakeholder participation guides, which can be applied at the process start of the project. A systematic and comprehensible consultation of the methods presented in these guides can lead to an improved transparency of the results and decreases the potential of overlooking stakeholder groups or participatory tools that fit the research goal.

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Appendix

This article is related to the YOUMARES 9 conference session no. 2: 'Towards a sustainable management of marine resources: integrating social and natural sciences.' The original Call for Abstracts and the abstracts of the presentations within this session can be found in the Appendix 'Conference Sessions and Abstracts', Chapter '2 Towards a sustainable management of marine resources: integrating social and natural sciences', of this book.

Supplementary Material

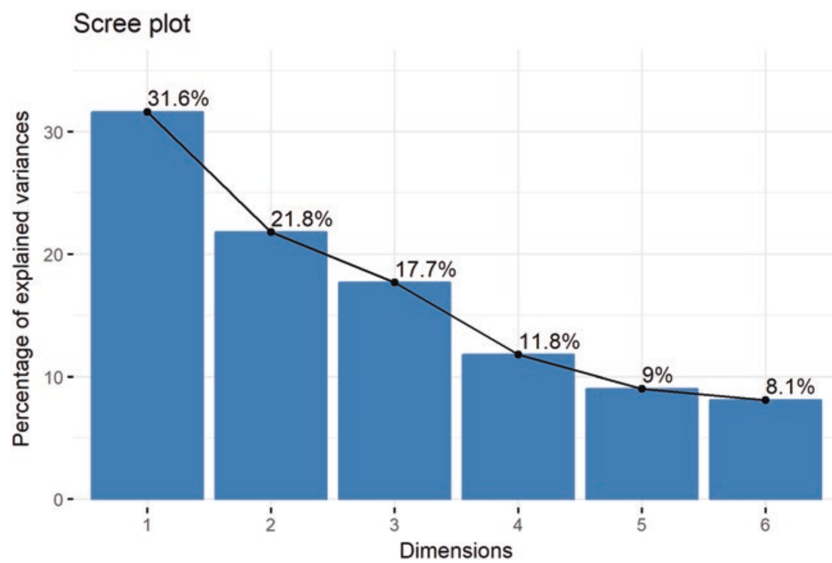

Figure 2.A1 Percentage of explained variance calculated by multiple correspondence analysis (MCA) showing the variance of stakeholder types within 50 research publications presenting 50 research publications of case studies in coastal and marine fisheries (as of May 2018)

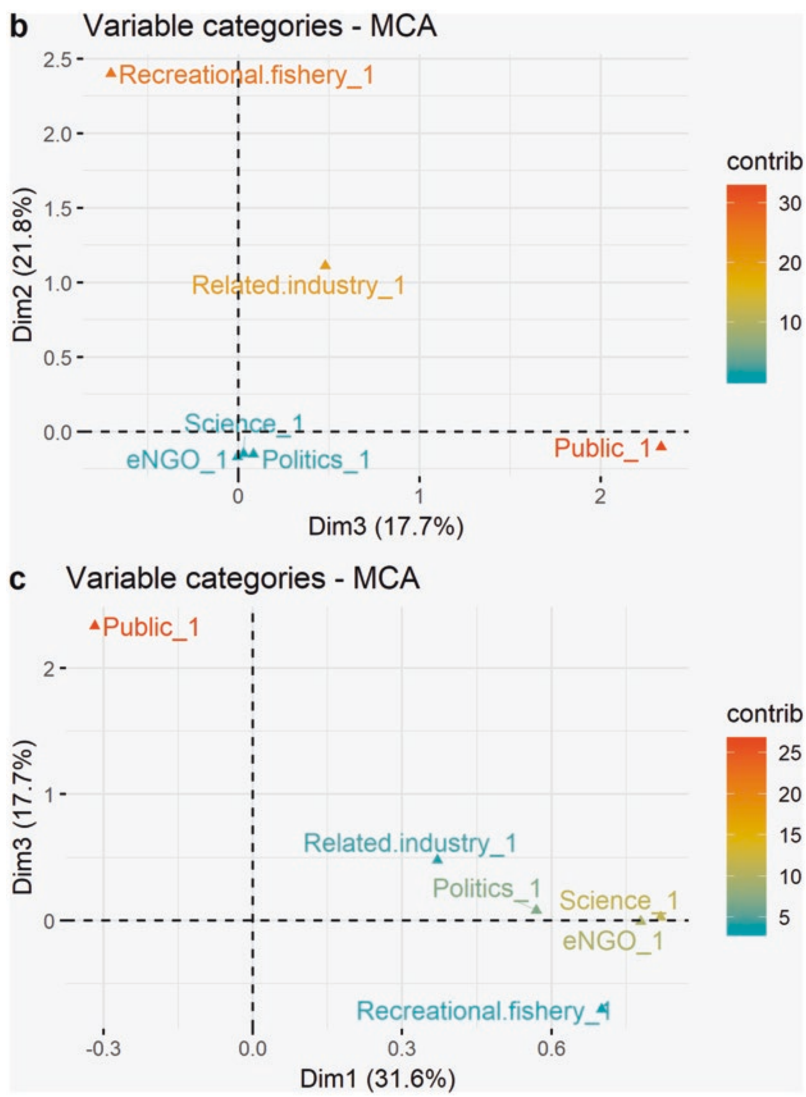

Fig. 2.A2 Panels **b** and **c** of the visualization of the correlation between dimension 2 (Dim2) and dimension 3 (Dim3) (**b**) as well as dimension 1 (Dim1) and dimension 3 (Dim3) (**c**) towards the variance of stakeholder types within in 50 research publications of case studies in coastal and marine fisheries (as of May 2018) using multiple correspondence analysis (MCA); (**b**) 21.8% of variance were explained; here 'recreational fishery' and 'related industry' were focused. (**c**) Less variance (17.7%) was explained; 'public' was the dominant stakeholder type

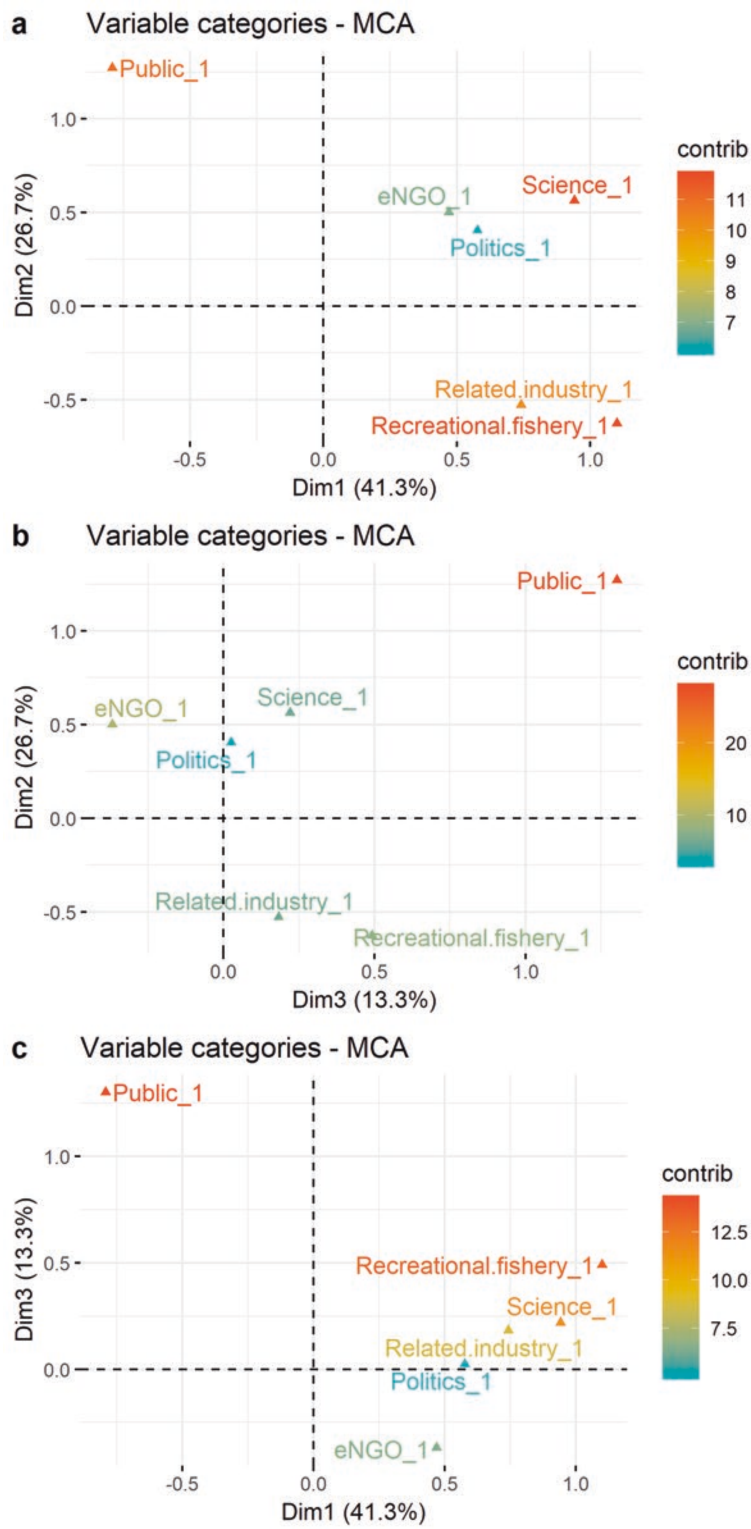

Figure 2.A3 Visualization of multiple correspondence analysis (MCA) results for case studies conducted in North America; here correlation between dimension 1 (Dim1), dimension 2 (Dim2) and dimension 3 (Dim3) is presented. (**a**) strong contribution was shown by 'science', 'eNGO' and 'politics'; 'related industry' and 'recreational fishery' were displayed in the negative area; (**b**) strong contribution was presented by 'science', 'eNGO' and 'politics'. (**c**) 'Public' was the dominant stakeholder type

Figure 2.A4 Visualization of multiple correspondence analysis (MCA) results for research publications of European case studies in coastal and marine fisheries (as of May 2018); here correlation between dimension 1 (Dim1), dimension 2 (Dim2) and dimension 3 (Dim3) is presented. (**a**), (**b**) 'Related industry', 'public', 'science' and 'eNGO' were grouped together; 'politics' was rather set apart. (**c**) 'Politics' was the dominant stakeholder type

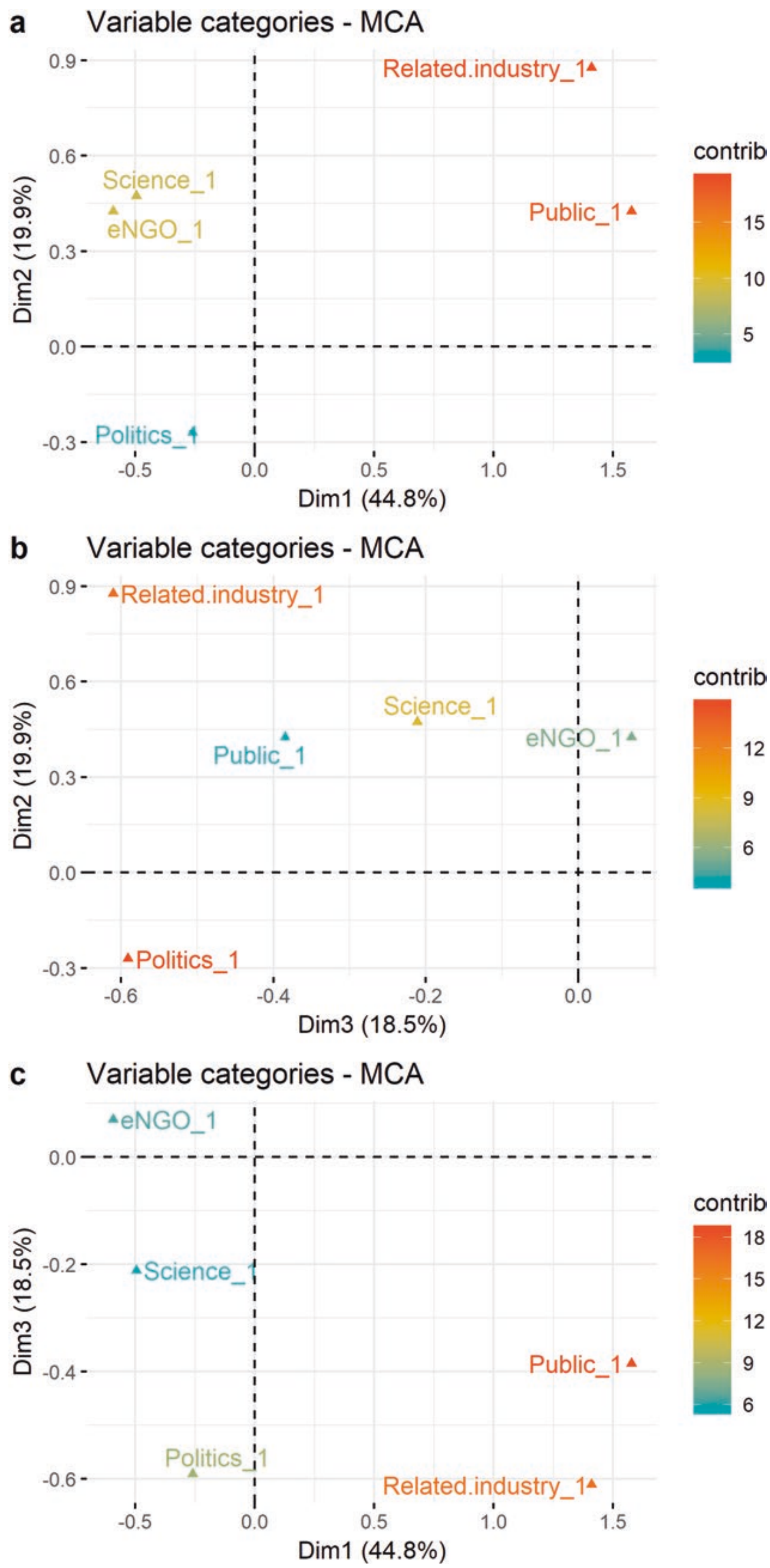

Table 2.A1 Contribution of variables, i.e. stakeholder types (measured in %) towards five dimensions using multiple correspondence analysis (MCA); stakeholder types, i.e. science, politics, eNGO, recreational fisheries, related industry and public occurred within 50 research publications presenting case studies in coastal and marine fisheries (as of May 2018)

	Dim 1	Dim 2	Dim 3	Dim 4	Dim 5
Science	35.37	1.69	0.07	0.38	0.28
Politics	27.89	2.88	1.02	36.32	19.43
eNGO	29.59	2.06	0.01	33.62	9.77
Recreational fishery	2.87	48.90	5.20	10.58	32.44
Related industry	3.41	44.34	10.16	11.79	30.04
Public	0.87	0.13	83.54	7.31	8.04

Table 2.A2 List of results related to the literature review focusing the topic stakeholder participation in the field of coastal and marine fisheries (type of stakeholder: S = science, PO = politics, E = eNGO, F = fisheries, RF = recreational fisheries, RI = related industry, PU = public, O = others; participatory method: MET = meeting, WOR = workshop, DIS = discussion, INT = interview, QUE = questionnaire, SUR = survey, CON = conversation, MOD = modelling, MAP = mapping, PRE = presentation, COO = coordination)

Author	Continent	Country	Definition of stakeholder?	Type of stakeholder	Stakeholder analysis approach?	Definition of participation?	Description of participatory method?	Which methods has been used?
Appeldoorn (2008)	North America	USA		F, O				
Bitunjac et al. (2016)	Europe	Adria		S, PO, E, F	x		x	DIS
Bojorquez-Tapia et al. (2017)	North America	Mexico		S, PO, E, F, RI			x	WOR, MOD
Brzezinski et al. (2010)	North America	USA	x	E, F		x		
Burdon et al. (2018)	Europe	Denmark, Germany		E, F, O			x	WOR, DIS, INT
Butler et al. (2015)	Europe	Scotland		PO, F, O	x		x	INT
Carr and Heyman (2012)	North America	USA		PO, E, F, O			x	INT, QUE
Catedrilla et al. (2012)	Asia	Philippines		F	x		x	DIS, INT
Clarke et al. (2002)	Asia	China, Hong Kong		F			x	MET, DIS, PRE
Cleland (2017)	Asia	Philippines		PO, E, F, RI			x	WOR
Coelho Dias da Silva et al. (2010)	South America	Brazil		F, O			x	MET, DIS
Cox and Kronlund (2008)	North America	Canada		F, RI			x	COO
Delaney et al. (2007)	Europe	NA		S, PO, E, F			x	INT
Dowling et al. (2008)	Australia	Australia		S, PO, O			x	MET, DIS
Eriksson et al. (2016)	Asia / Africa	Indonesia, Philippines, Solomon Islands, Tanzania		S, PO, E, F, PU, O			x	WOR, DIS, INT, SUR
Eveson et al. (2015)	Australia	Australia		F			x	DIS, SUR
Field et al. (2013)	Africa	South Africa		S, PO, E, F, O				

(continued)

Table 2.A2 (continued)

Author	Continent	Country	Definition of stakeholder?	Type of stakeholder	Stakeholder analysis approach?	Definition of participation?	Description of participatory method?	Which methods has been used?
Fletcher (2005)	Australia	Australia		S, PO, E, RF, RI, O			x	WOR
Garza-Gil et al. (2015)	Europe	Spain		S, PO, F, RI			x	QUE, SUR
Goetz et al. (2015)	Europe	Spain, Portugal		S, F, O			x	WOR, QUE, SUR, COO
Granados-Dieseldorf et al. (2013)	America	Belize		PO, F, O				
Gray et al. (2012)	North America	USA		S, PO, E, F, RF, RI, O	x		x	MAP
Haapasaari et al. (2013)	Europe	Central Baltic	x	S, PO, E, F			x	MOD
Hara et al. (2014)	Africa	South Africa		F, RI		x	x	MET, WOR, INT
Kaiser and Forsberg (2001)	Europe	Norway		F, RI, PU, O			x	WOR
Kerr et al. (2006)	Europe	Scotland, UK		S, PO, E, F, O			x	MET, INT, QUE, PRE
Kinds et al. (2016)	Europe	Belgium	x	PO, E, F	x		x	DIS, INT, MOD
Kittinger (2013)	North America	USA		S, E, F, PU	x	x	x	MET, INT
Lorance et al. (2011)	Europe	-		S, PO, E, F			x	WOR, DIS, INT, QUE, MAP
Mabon and Kawabe (2015)	Asia	Japan		S, PO, F, RI			x	MET, DIS, INT
Mahon et al. (2003)	North America	Barbados		PO, F, PU	x		x	WOR, CON
Mapstone et al. (2008)	Australia	Australia		PO, E, F, RI			x	MET, WOR, MOD
Miller et al. (2010)	North America	USA		S, PO, E, F, RF, RI	x		x	MET, WOR, DIS, MOD, COO
Mitchell and Baba (2006)	Australia	Australia		F, RF			x	QUE, SUR
Murphy et al. (2015)	North America	USA		F, RF, RI	x		x	SUR
Pristupa et al. (2016)	Europe	Russia		S, PO, F, RI, PU	x	x	x	INT
Punt et al. (2012)	Australia	Australia		S, PO, F, RI				

(continued)

Table 2.A2 (continued)

Author	Continent	Country	Definition of stakeholder?	Type of stakeholder	Stakeholder analysis approach?	Definition of participation?	Description of participatory method?	Which methods has been used?
Rivera et al. (2017)	Europe	Spain		PO, F, PU			x	DIS, INT, QUE
Sampedro et al. (2017)	Europe	Spain, Portugal		S, E, F, O	x	x	x	MET, WOR, INT, SUR, MOD
Smith et al. (2001)	Australia	Australia		S, PO, E, F, RI			x	MET, WOR
Stöhr et al. (2014)	Europe	Sweden, Poland		S, PO, E, F			x	MET, INT
Stratoudakis et al. (2015)	Europe	Portugal		S, PO, F, O	x		x	MET, WOR
Thiault et al. (2017)	Asia	French Polynesia		F	x		x	SUR
Tiller et al. (2015)	Europe	Norway	x	F		x	x	WOR, INT, QUE, MOD
Trimble and Berkes (2013)	South America	Uruguay		S, PO, E, F	x		x	MET, WOR, CON, INT
Trimble and Lazaro (2014)	South America	Uruguay		S, PO, E, F	x	x	x	MET, WOR, CON, INT, QUE
Watters et al. (2013)	NA	Scotia Sea, Drake Passage		F, O			x	MOD
Williams et al. (2011)	Australia	Australia		PO, F			x	WOR, DIS, MOD
Yáñez et al. (2014)	South America	Chile		S, PO, F			x	WOR, SUR
Zengin et al. (2018)	Europe	Riparian Countries		PO, F, RI, PU			x	DIS, PRE, COO

References

Aanesen M, Armstrong CW, Bloomfield HJ et al (2014) What does stakeholder involvement mean for fisheries management. Ecol Soc 19(4):35

Abdi H, Valentin D (2007) Multiple correspondence analysis. In: Salkind NJ (ed) Encyclopedia of measurement and statistics. Sage, Thousand Oaks

Almeida A, Ameryk A, Campos B et al (2017) Study on Mitigation Measures to Minimise Seabird Bycatch in Gillnet fisheries. European Commission. available at: https://publications.europa.eu/en/publication-detail/-/publication/f426200b-1138-11e8-9253-01aa75ed71a1/language-en

Angelstam P, Andersson K, Annerstedt M et al (2013) Solving problems in social-ecological systems: definition, practice and barriers of transdisciplinary research. Ambio 42(2):254–265. https://doi.org/10.1007/s13280-012-0372-4

Appeldoorn RS (2008) Transforming reef fisheries management: application of an ecosystem-based approach in the USA Caribbean. Environ Conserv 35(3):232–241

Arnold JS, Fernandez-Gimenez M (2007) Building social capital through participatory research: an analysis of collaboration on Tohono O'odham tribal rangelands in Arizona. Soc Nat Resour 20:481–495

Arnstein SR (1969) A ladder of citizen participation. J Am Plan Assoc 35(4):216–224

Berkes F (2003) Alternatives to conventional management: lessons from small-scale fisheries. Environments 31:5–19

Biggs S (1989) Resource-poor farmer participation in research: a synthesis of experiences from nine national agricultural research systems. OFCOR Comparative Study Paper 3, International Service for National Agricultural Research, The Hague

Bitunjac I, Jajac N, Katavic I (2016) Decision support to sustainable management of bottom trawl fleet. Sustainability 8:204

Bojorquez-Tapia LA, Pedroza D, Ponce-Diaz G et al (2016) A continual engagement framework to tackle wicked problems: curtailing loggerhead sea turtle fishing bycatch in Gulf of Ulloa, Mexico. Sustain Sci 12:535–548

Brandt P, Ernst A, Gralla F et al (2013) A review of transdisciplinary research in sustainability science. Ecol Econ 92:1–15

Brzezinski DT, Wilson J, Chen Y (2010) Voluntary participation in regional fisheries management council meetings. Ecol Soc 15(3):2

Burdon D, Boyes SJ, Elliott M et al (2018) Integrating natural and social sciences to manage sustainably vectors of change in the marine environment: Dogger Bank transnational case study. Estuar Coast Shelf Sci 201:234–247

Butler JRA, Young JC, McMyn IAG et al (2015) Evaluating adaptive co-management as conservation conflict resolution: learning from seals and salmon. J Environ Manag 160:212–225

Carr LM, Heyman WD (2012) "It's about seeing what's actually out there": quantifying fishers' ecological knowledge and biases in a small-scale commercial fishery as a path toward co-management. Ocean Coast Manage 69:118–132

Carvalho N, Edwards-Jones G, Isidro E (2011) Defining scale in fisheries: small versus large-scale fishing operations in the Azores. Fish Res 109:360–369

Catedrilla LC, Espectato LN, Serofia GD et al (2012) Fisheries law enforcement and compliance in District 1, Iloilo Province, Philippines. Ocean Coast Manage 60:31–37

Clarke S, Leung Wai-yin A, Mak YM et al (2002) Consultation with local fishers on the Hong Kong artificial reefs initiative. ICES J Mar Sci 59:171–177

Cleland D (2017) A playful shift: Field-based experimental games offer insight into capacity reduction in small-scale fisheries. Ocean Coast Manage 144:129–137

Coelho Dias da Silva AC, Comin de Castilhos J, Pinheiro dos Santos EA et al (2010) Efforts to reduce sea turtle bycatch in the shrimp fishery in Northeastern Brazil through a co-management process. Ocean Coast Manage 53(9):570–576

Commission of the European Communities (EC) (2013) Regulation (EU) No 1380/2013 of the European Parliament and of the Council. Brussels

Cox SP, Kronlund AR (2008) Practical stakeholder-driven harvest policies for groundfish fisheries in British Columbia, Canada. Fish Res 94:224–237

Davis A, Hanson JM, Watts H, MacPherson H (2004) Local ecological knowledge and marine fisheries research. The case of white hake (*Urophycis tenuis*) predation on juvenile American lobster (*Homarus americanus*). Can J Fish Aquat Sci 61(7):1191–1201

Delaney AE, McLay HA, van Densen WLT (2007) Influences of discourse on decision-making in EU fisheries management: the case of North Sea cod (*Gadus morhua*). ICES J Mar Sci 64:804–810

Dowling NA, Smith DC, Knuckey I et al (2008) Developing harvest strategies for low-value and data-poor fisheries: case studies from three Australian fisheries. Fish Res 94(3):380–390

Durham E, Baker H, Smith M et al (2014) The BiodivERsA stakeholder engagement handbook. BiodivERsA, Paris

Eriksson H, Adhuric DS, Adriantod L et al (2016) An ecosystem approach to small-scale fisheries through participatory diagnosis in four tropical countries. Global Environ Chang 36:56–66

Eveson JP, Hobday JA, Hartog JR et al (2015) Seasonal forecasting of tuna habitat in the Great Australian Bight. Fish Res 170:39–49

Field JG, Attwood CG, Jarre A et al (2013) Cooperation between scientists, NGOs and industry in support of sustainable fisheries: the South African hake *Merluccius* spp. trawl fishery experience. J Fish Biol 83:1019–1034

Fletcher W (2005) The application of qualitative risk assessment methodology to prioritize issues for fisheries management. ICES J Mar Sci 62:1576–1587

Freeman RE (2010) Strategic management: a stakeholder approach. Cambridge University Press, New York

Garza-Gil MD, Amigo-Dobano L, Surís-Regueiro JC et al (2015) Perceptions on incentives for compliance with regulation. The case of Spanish fishermen in the Atlantic. Fish Res 170:30–38

Goetz S, Read FL, Ferreira M et al (2015) Cetacean occurrence, habitat preferences and potential for cetacean–fishery interactions in Iberian Atlantic waters: results from cooperative research involving local stakeholders. Aquat Conserv Mar Freshw Ecosyst 25:138–154

Granados-Dieseldorff P, Heyman WD, Azuetad J (2013) History and co-management of the artisanal mutton snapper (*Lutjanus analis*) spawning aggregation fishery at Gladden Spit, Belize, 1950–2011. Fish Res 147:213–221

Gray S, Chan A, Clark D et al (2012) Modeling the integration of stakeholder knowledge in social-ecological decision-making: benefits and limitations to knowledge diversity. Ecol Model 229:88–96

Green AO, Hunton-Clarke L (2003) A typology of stakeholder participation for company environmental decision-making. Bus Strateg Environ 12:292–299

Greenacre MJ (1984) Theory and applications of correspondence analysis. Academic Press, London

Haapasaari P, Mäntyniemi S, Kuikka S (2013) Involving stakeholders in building integrated fisheries models using Bayesian methods. Environ Manag 51(6):1247–1261

Häberli R, Bill A, Grossenbacher-Mansuy W et al (2001) Synthesis. In: Thompson Klein J, Grossenbacher-Mansuy W, Häberli R et al (eds) Transdisciplinarity: joint problem solving among science, technology, and society. An effective way for managing complexity. Birkhäuser, Basel, pp 6–22

Hara MM, Rogerson J, de Goede J et al (2014) Fragmented participation in management of the fishery for small pelagic fish in South Africa – inclusion of small-rights holders is a complex matter. African J Mar Sci 36(2):185–196

Hartley T, Robertson R (2006) Stakeholder engagement, cooperative fisheries research, and democratic science: the case of the Northeast Consortium. Hum Ecol Rev 13:161–171

Hickey S, Kothari U (2009) Participation. International Encyclopedia of Human Geography, pp. 82–89

Higgs NT (1991) Practical and innovative uses of correspondence analysis. Statistician 40:183–194

Johannes RE, Neis B (2007) The value of anecdote. In: Haggan N, Neis B, Baird IG (eds) Fishers knowledge in fisheries science and management, Coastal Management Sourcebooks, 4. UNESCO, Paris, pp 41–58

Johnson TR, van Densen WLT (2007) Benefits and organization of cooperative research for fisheries management. ICES J Mar Sci 64:834–840

Kaiser M, Forsberg EM (2001) Assessing fisheries – using an ethical matrix in a participatory process. J Agric Environ Ethics 14:191–200

Kerr S, Johnson K, Side J et al (2006) Resolving conflicts in selecting a programme of fisheries science investigation. Fish Res 79:313–324

Kindon S (2008) Participatory action research. In: Hay I (ed) Qualitative research methods in human geography. Oxford University Press, Melbourne, pp 207–220

Kinds A, Sys K, Schotte L et al (2016) VALDUVIS: an innovative approach to assess the sustainability of fishing activities. Fish Res 182:158–171
Kittinger JN (2013) Participatory fishing community assessments to support coral reef fisheries co-management. Pacific Sci 67(3):1–43
Long RD, Charles A, Stephenson RL (2015) Key principles of marine ecosystem-based management. Mar Policy 57:53–60
Lorance P, Agnarsson S, Damalas D et al (2011) Using qualitative and quantitative stakeholder knowledge: examples from European deep-water fisheries. ICES J Mar Sci 68(8):1815–1824
Luyet V, Schlaepfer R, Parlange MB et al (2012) A framework to implement Stakeholder participation in environmental projects. J Environ Manag 111:213–219
Mabon L, Kawabe M (2015) Fisheries in Iwaki after the Fukushima Dai'ichi nuclear accident: lessons for coastal management under conditions of high uncertainty? Coast Manage 43(5):498–518
Mackinson S, Wilson DC, Galiay P et al (2011) Engaging stakeholders in fisheries and marine research. Mar Policy 35(1):18–24
Mahon R, Almerigi S, McConney P et al (2003) Participatory methodology used for sea urchin co-management in Barbados. Ocean Coast Manage 46:1–25
Mapstone BD, Little LR, Punt AE et al (2008) Management strategy evaluation for line fishing in the Great Barrier Reef: balancing conservation and multi-sector fishery objectives. Fish Res 94:315–329
Mayring P (1988) Die qualitative Wende. Arbeiten zur qualitativen Forschung. Augsburger Berichte zur Entwicklungspsychologie und Pädagogischen Psychologie, vol 32
Miller TJ, Blair JA, Ihde TF et al (2010) FishSmart: an innovative role for science in stakeholder-centered approaches to fisheries management. Fisheries 35(9):424–433
Mitchell R, Baba O (2006) Multi-sector resource allocation and integrated management of abalone stocks in Western Australia: review and discussion of management strategies. Fish Sci 72:278–288
Murphy RD, Scyphers SB, Grabowski JH (2015) Assessing fishers' support of striped bass management strategies. PLoS One 10:e0136412
Neis B, Schneider DC, Felt L et al (1999) Fisheries assessment: what can be learned from interviewing resource users. Can J Fish Aquat Sci 56:1949–1963
Newig J, Fritsch O (2009) The case survey method and applications in political Science: Paper Presented at the APSA 2009 Meeting, 3–6 September 2009, Toronto
NOAA (2015) Introduction to stakeholder participation. Office for coastal management. Available at: https://coast.noaa.gov/data/digitalcoast/pdf/stakeholder-participation.pdf. Accessed 18 July 2018
Okali C, Sumberg J, Farrington J (1994) Farmer participatory research. Intermediate Technology Publications, London
Olson M (1965) The logic of collective action. Harvard University Press, Cambridge
Pomeroy RS (2012) Managing overcapacity in small-scale fisheries in Southeast Asia. Mar Policy 36:520–527
Pretty J, Shah P (1994) Soil and water conservation in the twentieth century: a history of coercion and control. University of Reading Rural History Centre, 1
Pristupa AO, Lamers M, Amelung B (2016) Private informational governance in post-soviet waters: implications of the marine stewardship council certification in the Russian Barents Sea region. Fish Res 182:128–135
Punt AE, McGarvey R, Linnane A et al (2012) Evaluating empirical decision rules for southern rock lobster fisheries: a South Australian example. Fish Res 115–116:60–71
Reed MS (2008) Stakeholder participation for environmental management: a literature review. Biol Conserv 141:2417–2431
Repko AF, Newell WH, Szostak R (2011) Case studies in interdisciplinary research. Sage, Thousand Oaks
Rivera A, Gelcich S, García-Flórez L et al (2017) Trends, drivers, and lessons from a long-term data series of the Asturian (northern Spain) gooseneck barnacle territorial use rights system. Bull Mar Sci 93(1):35–51
Rowe G, Frewer L (2000) Public participation methods: a framework for evaluation in science. Sci Technol Hum Values 25:3–29
Sampedro P, Prellezo R, Garcia D et al (2017) To shape or to be shaped: engaging stakeholders in fishery management advice. ICES J Mar Sci 74(2):487–498
Smith DC, Smith ADM, Punt AE (2001) Approach and process for stock assessment in the South East fishery, Australia: a perspective. Mar Freshw Res 52:671–681
Soma K, Vatn A (2014) Representing the common goods – stakeholders vs. citizens. Land Use Policy 41:325–333
Stöhr C, Lundholm C, Crona B et al (2014) Stakeholder participation and sustainable fisheries: an integrative framework for assessing adaptive comanagement processes. Ecol Soc 19:14
Stratoudakis Y, Azevedo M, Farias I et al (2015) Benchmarking for data-limited fishery systems to support collaborative focus on solutions. Fish Res 171:122–129
Thiault L, Collin A, Chlous F et al (2017) Combining participatory and socioeconomic approaches to map fishing effort in small-scale fisheries. PLoS One 12(5):1–18
Thomas J (1993) Public involvement and governmental effectiveness: a decision-making model for public managers. Adm Soc 24:444–469
Thomas G (2011) A typology for the case study in social science following a review of definition, discourse, and structure. Qual Inq 17(6):511–521. https://doi.org/10.1177/1077800411409884
Tiller RG, Mork J, Liu Y et al (2015) To adapt or not adapt: assessing the adaptive capacity of artisanal fishers in the Trondheimsfjord (Norway) to jellyfish (*Periphylla periphylla*) bloom and purse seiners. Mar Coast Fish 7:260–273
Trimble M, Berkes F (2013) Participatory research towards co-management: lessons from artisanal fisheries in coastal Uruguay. J Environ Manag 128:768–778
Trimble M, Lazaro M (2014) Evaluation criteria for participatory research: insights from coastal Uruguay. Environ Manag 54:122–137
Voinov A, Bousquet F (2010) Modelling with stakeholders. Environ Model Softw 25:1268–1281
Watters GM, Hill SL, Hinke JT et al (2013) Decision-making for ecosystem-based management: evaluating options for a krill fishery with an ecosystem dynamics model. Ecol Appl 23(4):710–725
Whyte WF, Greenwood DJ, Lazes P (1989) Participatory action research: through practice to science in social research. Am Behav Sci 32:513–551
Williams AJ, Little LR, Begg GA (2011) Balancing indigenous and non-indigenous commercial objectives in a coral reef finfish fishery. ICES J Mar Sci 68(5):834–847
Wilson DG, Nielsen JR, Degnbol P (2003) The fisheries co-management experience: accomplishments, challenges and prospects. Kluwer Academic, Dordrecht

Yáñez E, Silva C, Barbieri MA et al (2014) Socio-ecological analysis of the artisanal fishing system on Easter Island. Lat Am J of Aquat Res 42(4):803–813

Yates KL, Schoeman DS (2015) Incorporating the spatial access priorities of fishers into strategic conservation planning and marine protected area design: reducing cost and increasing transparency. ICES J Mar Sci 72(2):587–594

Zengin M, Mihneva V, Duzgunes E (2018) Analysing the need of communication to improve Black Sea fisheries management policies in the Riparian Countries. Turk J Fish Aquat Sci 18:199–209

ETH Zürich (2018) Web of science core collection. Available at: www.library.ethz.ch/Ressourcen/Datenbanken/Web-of-Science-Core-Collection. Accessed 25 July 2018

STUDY II

Modeling and understanding social-ecological knowledge diversity

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LETTERS AND COMMENTS

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Modeling and understanding social–ecological knowledge diversity

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Abstract

The concept of social–ecological knowledge diversity (SEKD) provides a novel way of examining coupled human–environment interactions—it acknowledges differences in knowledge, values, and beliefs of stakeholder groups within social–ecological systems (SES). Thus, understanding and measuring SEKD is an essential component of sustainable management with implications for conflict resolution, collective action and policymaking. However, methods to efficiently define and model knowledge diversity are still underdeveloped. Using a semiquantitative cognitive mapping approach, we collected and analyzed stakeholder-specific knowledge and perceptions of the Western Baltic cod fishery to model SEKD. Results demonstrate substantial variation in perceptions across different individuals and social groups. SEKD was evident in (a) distinctive meanings attached to social factors relative to ecological factors, (b) causal relationships underlying the understanding of SES dynamics, and (c) social impacts of ecological changes on ecosystems (and vice versa). By identifying and representing knowledge-specific disparities in SES frameworks, our model explicitly improves the understanding of human–environment interactions with implications that could help reduce conflicts and legitimize management plans.

KEYWORDS

Baltic Sea, cod, fuzzy cognitive mapping, knowledge diversity, mental models, natural resource management, scenario analysis, social–ecological system, stakeholder engagement

1 | INTRODUCTION

Understanding the different ways in which human communities interact with ecosystems, and how these interactions influence unique perceptual and behavioral feedbacks between social and ecological systems (SES) provides a means to better manage natural resource systems used by multiple groups of stakeholders (Binder, Hinkel, Bots, & Pahl-Wostl, 2013; Sterling et al., 2017). We refer to this as social–ecological knowledge diversity (SEKD). Human communities construct their specific shared knowledge systems, as well as beliefs and values about the environment which surrounds them, depending on how they interact with these environments. Such shared knowledge systems, beliefs, and values influence how specific social groups perceive and react to real or anticipated changes. These can be either environmental impacts of social changes or the societal (or cultural-specific) impacts of environmental changes. Furthermore, these shared knowledge systems are thought to be reflected in peoples' mental models of SES, providing insight into how perceptions and behavior are shaped by their interaction with natural and social habitats (Aminpour et al., 2020; Oishi & Graham, 2010). To understand and model SEKD, however, we first need to consider various ways in which different communities interact with nature and how their distributed knowledge defines the social space of which they are a part.

Understanding SEKD across individuals and groups can provide insights into why collective action toward sustainability goals may fail. This is because the perceptions of and cultural values attached to the structure and function of a SES differ across various stakeholder groups (Adams, Brockington, Dyson, & Vira, 2003; Linke & Jentoft, 2016; Manfredo et al., 2017). Further, such differences may lead to conflicts, by creating mistrust that may result in unaccepted management decisions and potentially limiting the implementation of sustainability policies (Adams et al., 2003; Biggs et al., 2011; Burns & Stöhr, 2011; EC, 2013; King, Cavender-Bares, Balvanera, Mwampamba, & Polasky, 2015; Naranjo-Madrigal & van Putten, 2018). These conflicts can be attributed to the different ways stakeholders perceive the structure and function of natural resource systems, which in turn influences the perception of how and to what extent resource systems respond to management measures (Game et al., 2016; Gray, Chan, Clark, & Jordan, 2012).

At the same time, sustainable management of marine resources benefits from the participation of a multitude of stakeholders, and by extension the diversity of knowledge from resource users, environmental organizations, managers, and scientists (Folke, 2004; Reed, 2008; Steins et al., 2019; Voinov et al., 2016). In natural resource management, synthesizing different knowledge types distributed across diverse stakeholders may increase the potential for innovative ideas to emerge, and collectively provide insight into how these complex systems are structured (Folke, 2004; Gray et al., 2020; Steins et al., 2019; Stephenson et al., 2016). This is now considered an essential practice in the management of transboundary resources like marine fisheries (Berkes, Colding, & Folke, 2000; Folke, 2004).

The European Union, for example, established so-called Advisory Councils (ACs) aiming to increase the participation of different groups in fisheries management at regional level. ACs were an attempt to better resolve existing conflicts by maintaining dialogue and cooperation, increasing legitimacy and acceptance of management decisions, and creating social capital in the development and implementation of fisheries policies (Linke, Dreyer, & Sellke, 2011; Long, 2009, 2015; Linke & Jentoft, 2016). However, the incorporation of diverse knowledge systems did not dissipate persistent conflict (Burns & Stöhr, 2011; Long, 2017; Linke & Jentoft, 2016). A very relevant example in European fisheries management is the Western Baltic cod (*Gadus morhua*), characterized by several management measures met with different levels of public acceptance. These include highly fluctuating catch quotas, a daily catch limit for anglers, and increased designation of marine protected areas. In these cases, if knowledge diversity and stakeholder participation are seen as essential to understanding and managing marine fisheries, why does conflict persist? Further, how can we (a) increase our understanding of the disparate social–cultural spaces different stakeholders belong to, and (b) better determine where there is agreement and disagreement in how fishery SESs are structured and function?

Many researchers have looked to mental models to understand the relationship between anticipated social–ecological changes and differences in knowledge and perception (Biggs et al., 2011; Gray et al., 2012; Halbrendt et al., 2014; Jones, Ross, Lynam, Perez, & Leitch, 2011; Stier et al., 2017). Mental models are cognitive representations and interpretations of the external world, that is, an internal model of how the world works (Biggs et al., 2011; Jones et al., 2011). However, the analytical use of mental models to operationalize SEKD is somewhat limited, due to the (a) predominantly qualitative nature of mental model representations (Jones et al., 2011), (b) lack of standardized methods for comparing mental models within and across individuals or groups (Gray et al., 2012), and (c) challenge of eliciting knowledge about resource systems across a broad spectrum of stakeholders. Any attempt to compare mental models, however, is not generalizable to settings outside the SES context for which the mental models were collected. This is due to the highly dynamic and complex nature of these models, as well as their dependence on survey context. Nevertheless, their results remain relevant for other SES contexts and resource management situations.

To overcome these limitations, we applied a semi-quantitative fuzzy cognitive mapping (FCM) approach (Kosko, 1986) to understand and measure SEKD based on mental model variations. FCMs are characterized as external representations of internal mental models, which are graphical representations of peoples' knowledge and values (Gray et al., 2012; Gray, Hilsberg, McFall, & Arlinghaus, 2015; Halbrendt et al., 2014). They are used to represent peoples' system-level understanding by modeling perceived components, causal relationships, and the degree of positive or negative influence between components, which has implications for understanding system's dynamics (Gray et al., 2012). FCMs can visualize a person's mental model using a mathematical graph of nodes and connections that represents the individual knowledge and understanding of causal associations between qualitative components. For building an FCM, the person needs to identify important elements to describe a problem, a phenomenon or a system:

1. Components: Also known as "concepts" or "factors" that represent important variables participants use to describe a system, for example, ecological component—cod, phytoplankton; social components—trawl fisheries, tourism. Components must be variables that can increase or decrease in quality or quantity, and are anecdotally defined and labeled based on participants' understanding.
2. Causal relationships: Positive or negative connections between components that explain how they influence each other. Participants might draw an arrow (i.e., directed link) from one component to the other with a (+/−) sign assigned to it. These are also known as "edges" in a graph.
3. Strength of causal relationships: Degree of positive or negative influence between components. Participants can numerically/qualitatively determine the strength of causal relationships (e.g., the numeric edge weights between the nodes or qualitative Likert scales to specify the magnitude of relationships ranging from very weak to very strong). Based on fuzzy sets theory (Kim & Lee, 1998), these quantitative or qualitative weightings (i.e., strength) can be mapped into a normalized numeric scale between 0 and 1. The weighted, directed graphs resulting from FCM approach can be analyzed using artificial neural network analysis, which can computationally simulate the dynamic of the system they represent (see Supporting information).

These FCMs can therefore be compared across individuals and groups in terms of (a) qualitative and contextual understanding stakeholders attach to system components (i.e., how stakeholders qualitatively define and measure components); and (b) structural characteristics of the network of causal connections (how stakeholders perceive causal relationships that link their individually defined components), and (c) system dynamics (how these networks of causal relationships predict systems response to artificial changes and stimulate stakeholder perception of system behavior).

Here, we focused on stakeholder groups in Germany who are affected or involved in the fisheries management of Western Baltic cod, which we associated with different social groups grounded on their varying interactions with the same ecosystem. Based on a systematic literature review, we identified six stakeholder groups: commercial fisheries, recreational fisheries, tourism, nongovernmental organizations (NGOs), management, and science. Representatives of these stakeholder groups interact differently with cod fisheries at local, regional, national, and international levels, and thus strongly represent SKED in the present case study.

We found that the specific qualitative meanings stakeholders attach to social components, as opposed to ecological components, varied greatly across groups. Additionally, while stakeholders demonstrated higher degrees of shared understanding in their perceptions of causal relationships between ecological components (i.e., ecological-ecological relationships), these perceptions varied more considerably across groups regarding social–ecological and social–social causal relationships, respectively.

2 | METHODS

2.1 | Data collection

2.1.1 | Five-step process for capturing stakeholders' mental models

Six relevant stakeholder types were identified in a stakeholder analysis: representatives of commercial fisheries (ComFish comprising 21.2% of the sample), recreational fisheries (RecFish = 12.1%), tourism (12.1%), NGOs (18.2%), managers (18.2%), and scientists (18.2%). We selected study participants ($N = 33$) by performing purposeful sampling strategies using two key criteria: stakeholders needed to (a) be associated with a German institution by either their job or honorary position, and (b) have been involved in the Western Baltic cod fishery for more than 5 years (description of interviewed stakeholders in Supporting Information, Table S1). The first criterion is based on the intention of a national survey, whereas the second one was chosen as a reference point to ensure that the interviewees have established themselves in their position (job, volunteer) and are familiar with the subject of cod fishery in the Western Baltic Sea. Both criteria led to the exclusion of some actors, including stakeholders from the fishing industry or people who have only recently started working on this topic, for example, trainees.

We elicited stakeholders' mental models using a five-step process (Figure S1, Table S1). First, participants were given a handout to prepare for the interview 1 week in advance (Step 1). To avoid misunderstanding, again the handout was explained in detail before stakeholders' mental models were created (Step 2). These steps were followed by an identification of the system components and their causal relationships by the participants (Step 3), from which they then drew a concept map representing their mental model following routine FCM data collection practices with open-ended concepts (Step 4; Gray, Zanre, & Gray, 2014). These maps were digitized after the interview and sent back to the interviewees for validation (Step 5).

2.2 | Data analysis

2.2.1 | Qualitative analysis of system components

While the vast majority of FCM studies are mainly based on the analysis of the structure and dynamics of mental models, we chose to qualitatively analyze how stakeholders describe, define, and measure components included in their map. Specifically, while defining causal relationships that linked their individual components, stakeholders were asked to attach meaning to them by continuously using one unit of measure and one definition. In order to carry out a qualitative analysis of the component definitions, we first identified categories that allowed us to classify each definition: (a) a component is explicitly defined the same way it is labeled or by using a synonym, (b) a component is defined by identifying examples (e.g., *jellyfish* = species like fire jellyfish and ear jellyfish), (c) a component is defined using a general description (e.g., *consumer* = person, who eats fish), (d) a component is described by a short explanation of its task or role in the system (e.g., *fishery* = sector that deals with the capture and marketing of fish), and (e) a component is defined by a description of its impact on the whole system or system components (e.g., *porpoise* = predator on cod).

To analyze the variations in the qualitative semantics of system components represented in the cognitive maps, we used the overall ratio of how many unique measures or definitions were used by stakeholders (u) to how often that component was mentioned in total (m).

$$R = \frac{du}{dm}$$

Slope values (R) closer to one exemplify higher disagreement in how stakeholders define or measure a component. Note that this measure of disagreement illustrates the overall slope of variation among all individuals, and thus it does not necessarily show variation between stakeholder groups. Rather, it provides useful information about how the entire sample, on average, attaches diverging meanings to components.

2.3 | Analyzing the network structure of causal relationships

Individual mental models were aggregated mathematically to create a model representing the collective perception of each stakeholder group (Gray et al., 2012). Aggregation took place once all individual models were transformed into adjacency matrices (Özesmi & Özesmi, 2004). We combined individual mental models by stakeholder types to form stakeholder-specific group models using the arithmetic mean of their adjacency matrices (see for more detail Gray et al., 2012; Aminpour et al., 2020). To measure agreement/disagreement of causal relationships (i.e., network structure of links among components) across stakeholder-specific group models, we first identified components that were mentioned by the majority of the six stakeholder groups (i.e., at least half of the groups have the component in their collective mental models). We then compared the set of causal connections (i.e., edges) between these components across different stakeholder groups to examine how similar/different these causal relationships were between stakeholder groups. We quantified the degree of structural similarities (agreement) by measuring Jaccard similarity coefficient (JSC) between any pairs of stakeholder groups (Tantardini, Leva, Tajoli, & Piccardi, 2019). JSC is a measure of similarity for the two sets of data (here, the sets of causal relationships between components), with a range from 0 to 1, where higher values represent more similar sets. Given two graphs $G_1(V_1, E_1)$ and $G_2(V_2, E_2)$, JSC is defined as:

$$\mathrm{JSC}(G_1, G_2) = \frac{E_1 \cap E_2}{E_1 \cup E_2}$$

where V_1 and V_2 being the set of nodes, and E_1 and E_2 being the set of edges in the graphs (i.e., FCMs) that link those nodes. We measured pairwise JSC between all stakeholder groups for sets of causal connections (edges) that link two ecological components (eco), two social components (soc), or one ecological and one social components (soc–eco).

2.4 | Analysis of system dynamics

Stakeholder-specific FCMs can also be analyzed dynamically using certain artificial neural network analysis called autoassociative neural networks (Kramer, 1992; Özesmi & Özesmi, 2004). Here, we used FCM computational analysis to demonstrate how stakeholders predict the changes in the state of the system's components, given an artificial (hypothetical) change in one or combination of components. This is referred to as scenario analysis (Özesmi & Özesmi, 2004). A hypothetical increase (or decrease) in the value of a component (also known as component activation) can impact all other components that are causally dependent on it, and leads to a cascade of subsequent changes to other system components. This iterative propagation of the initial change continues until the system converges into a new, so-called "system state" (Özesmi & Özesmi, 2004). By comparing the system states (i.e., the activation of components) before and after running a scenario, FCM can be used to implement "what if" scenario analysis, and therefore represent the perceived dynamic behavior of the system (in this case, western Baltic cod fisheries) (see Supporting Information for mathematical representations).

We computationally manipulated aggregated models of six stakeholder groups to compare how social–ecological dynamics were perceived differently across groups (Supporting Information, Figures S3–S8). To measure the agreement/disagreement of network dynamics across multiple stakeholder groups regarding the dynamic functionality of the models, we ran two scenarios: (a) decreasing *cod*, which simulates an ecological shock, and (b) increasing *cod quota* simulating a social intervention. Selected scenarios were based on the components which, as described by stakeholders, will undergo the greatest change in the next 5 years. We quantified the agreement between stakeholder groups by measuring the percentage of matched patterns across groups regarding the changes in system components' values as a result of running a scenario. This included 10 social and ecological components that were mostly impacted by simulated changes in *cod* and *cod quota* (using 10 most strongly impacted components ensured that we included all of those components that changed considerably, that is changing more than 50%).

3 | RESULTS

3.1 | Qualitative perception and understanding of system components

The qualitative analysis of components' *measures* and *definitions* showed that stakeholders mainly attached the same meaning to ecological components, but there was much wider variation in the meanings attached to social ones. This greater variation (i.e., slope) in qualitative meanings attached to social components compared to ecological components is illustrated in Figure 1a,b, where the red line in (b) has a greater slope than the blue line in (a). In addition, while 96% of measures for ecological components demonstrated full-agreement (i.e., 0% variation in qualitative meanings attached to them), only 47% of the measures for social components demonstrated full-agreement (Figure 1c). Only for one ecological components (i.e., *age structure of cod*) varying meanings regarding the component's measure were attached. However, this component was only mentioned within *NGOs*. At the same time, stakeholder-specific contextual attachment to social components showed much greater variations. For a total of 20 components, there was considerable variation in meanings attached to the component measure. Greatest SEKD was found for *nature conservation* (e.g., strength of emotional attachment to nature conservation; level of quality of nature conservation), which occurred both between and within groups.

Components' definitions were also subject to variation regarding the specific contextual attachments by stakeholders. In total, 42 social components showed diverging meanings attached to them by individuals across groups; for 17 out of these components the definitions varied 100% (e.g., assumed stock size, regulations, or technical development). However, again only one ecological component (i.e., *jellyfish*) showed 100% variation across groups in terms of component's definition (detailed documentation on these variations regarding components' measures and definitions in Supporting Information, Tables S3 and S4a,b).

3.2 | Quantitative understanding of system structure

In addition to the qualitative measures and the analysis of qualitative contact of social and ecological components, our results also indicated that multiple stakeholder groups perceived the structure of the causal relationships between system components differently. We found a greater agreement across groups (i.e., similarity) in the perceived structural patterns of the causal relationships linking ecological components, referring to as ecological–ecological relationships (eco–eco) (the average between-group JSC for eco–eco relationships is 0.22) (Figure 2). However, social–ecological (soc–eco) relationships showed comparatively less agreement across stakeholder groups (the average between-group JSC for soc–eco edges is 0.15) (Figure 2). More importantly, the causal connections that link only social components referred to as social–social relationships (soc–soc), demonstrated the lowest level of agreement (the average between groups

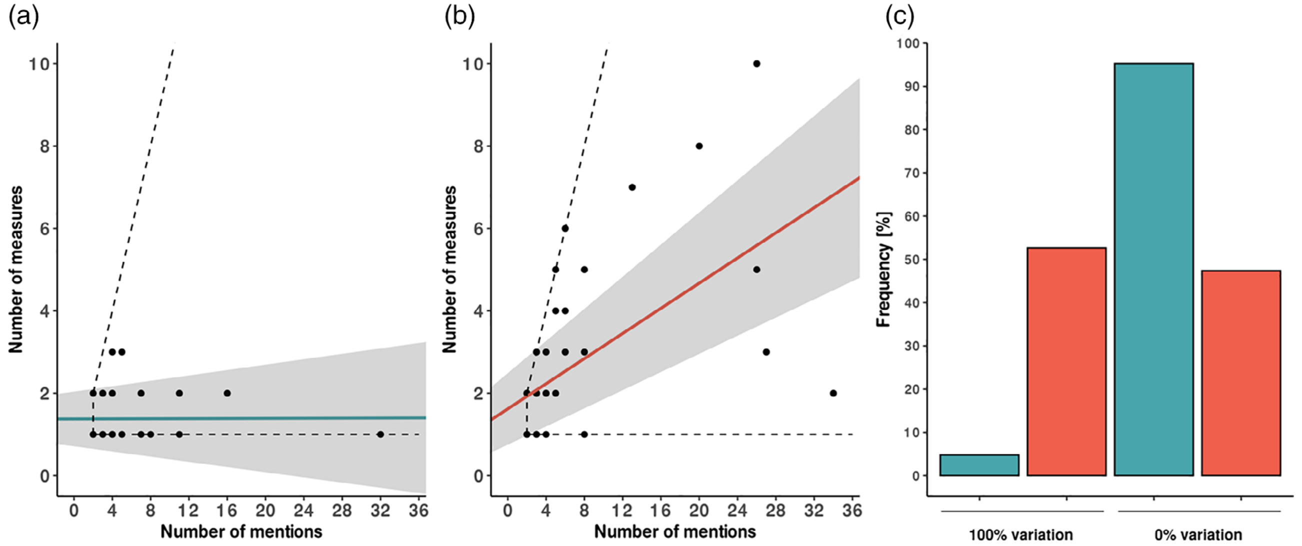

FIGURE 1 The variation of qualitative measures attached to ecological (a) and social (b) components. The greater variation in qualitative meanings attached to social components compared to ecological components is illustrated by the red line in (b) with greater slope than the blue line in (a) (95% confidence interval is represented by grey area). Dotted lines (a,b) delimit the area in which all the concepts, to which at least two different concept measures were attached, are placed. If a data point is at $x = 1$, stakeholders assigned only one unique measure to this component. (c) Distribution of ecological (blue) and social (red) components to which 100% same meaning as well as 100% different meaning were attached. Here, it is again evident that the understanding of the ecological system is more consistent due to the concept measures

JSC for soc–soc edges is 0.12). These results, together, indicate that the structure of the casual relationships for which a social component is involved may demonstrate higher variation across groups compared to the structure of causal relationships that link ecological factors, thereby more greatly representing SEKD.

3.3 | Quantitative understanding of system dynamics

Comparative analysis of how group FCMs simulated the system responses to scenario changes revealed that variations in the perception of system dynamics by stakeholders were more evident in social components than ecological ones (Figure 3, Table S5a,b). For both applied scenarios, there was little agreement on the dynamic changes of social components. In response to a decrease in *cod* (Scenario 1), managers perceived an increase in control, but a decrease in the number of anglers (recreational fisheries). On the contrary, commercial fishers predicted a decline in the income of fishery (side and main income). In addition, recreational fisheries and tourism identified a significant decline in recreational fisheries and related areas such as angling shops and angling tourism, while NGOs and scientists noted an increase in protected areas. However, all stakeholders across groups agreed on a decline in cod quota resulting from a decreasing cod biomass, but the strength of the influence varied (Figure 3, Table S5a,b).

On the contrary, when calculating the perceived changes in ecological components, we found greater agreement among components that were mostly impacted. As an example, a decrease in *cod* (Scenario 1) was seen, across all stakeholder groups, as a positive effect on prey abundance (e.g., *herring* and *sprat* populations). The increase in the *cod quota* (Scenario 2) reflected a similar outcome: a greater common understanding of changes in ecological components, but greater variations of perceived system dynamics in social components (Figure 3, Table S5a–c).

4 | DISCUSSION

Our study empirically demonstrates that the perception and understanding of the dynamics of the Western Baltic cod fishery SES varied across multiple stakeholder groups. Importantly, we provide evidence that while there is general agreement across groups about the structure and function of ecosystem dynamics, disagreement in their knowledge about SES can be largely explained by looking at how different social groups attach themselves to the natural environment. We drew on mental model theory and semiquantitative cognitive mapping techniques to measure these variations in social–ecological

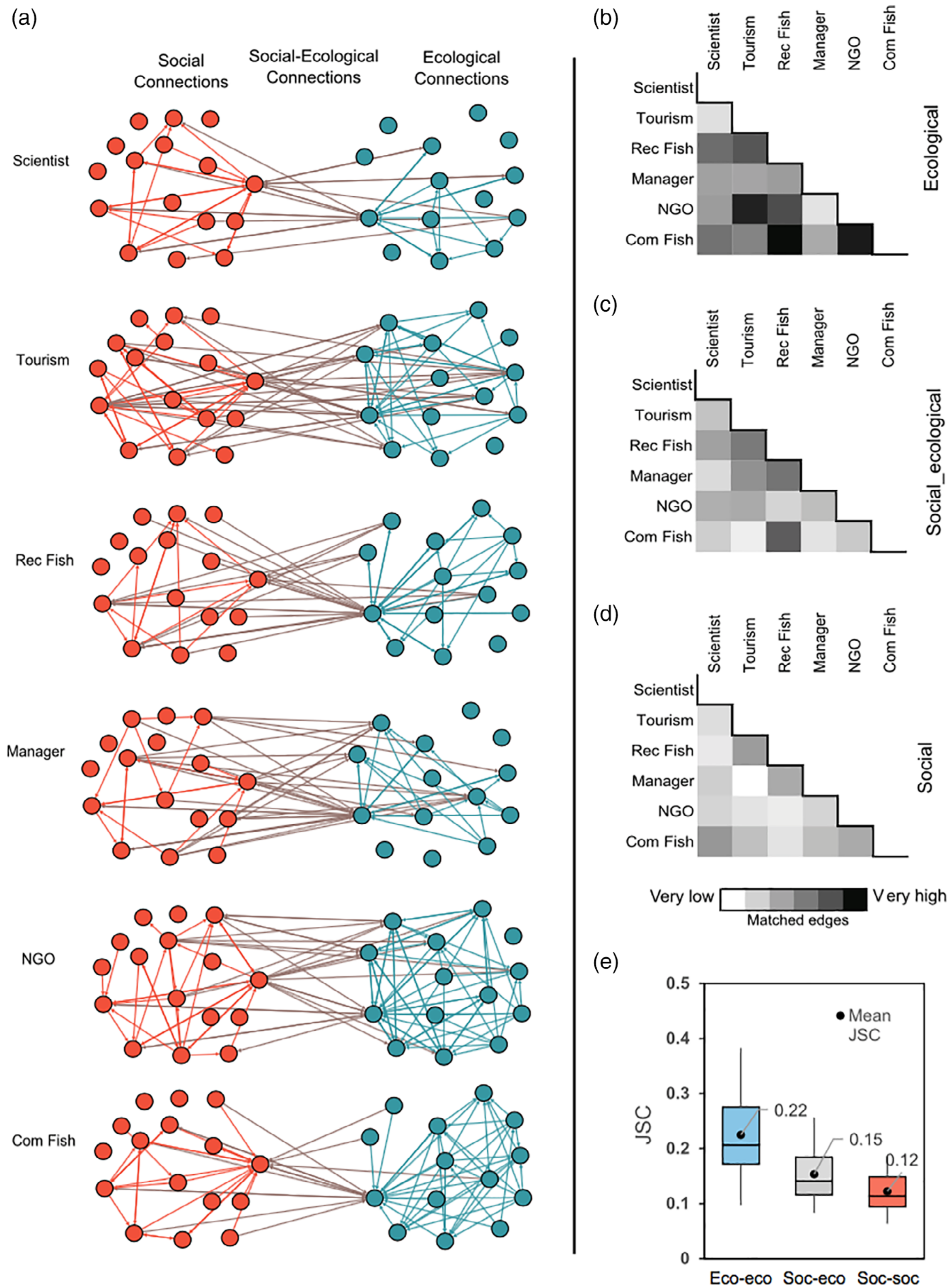

FIGURE 2 Agreement of the structure of the causal relationships between system components mentioned by the majority of groups (i.e., components that exist in the maps of more than half of all groups are visualized). The map of each group is shown in (a) by a directed graph, where nodes are classified by ecological (blue) and social (red) components, and edges illustrate the causal relationships between components. Between-groups pairwise agreement of ecological connections (b), social connections (c), and social–ecological connections (d). This agreement is measured by the Jaccard similarity coefficient (JSC) between the set edges in any pairs of groups. Box plots in (e) demonstrate the distribution of between-group pairwise JSC agreements for each class of connections, where the mean of JSC is highest for ecological connections (0.22) and is lowest for social connections (0.12)

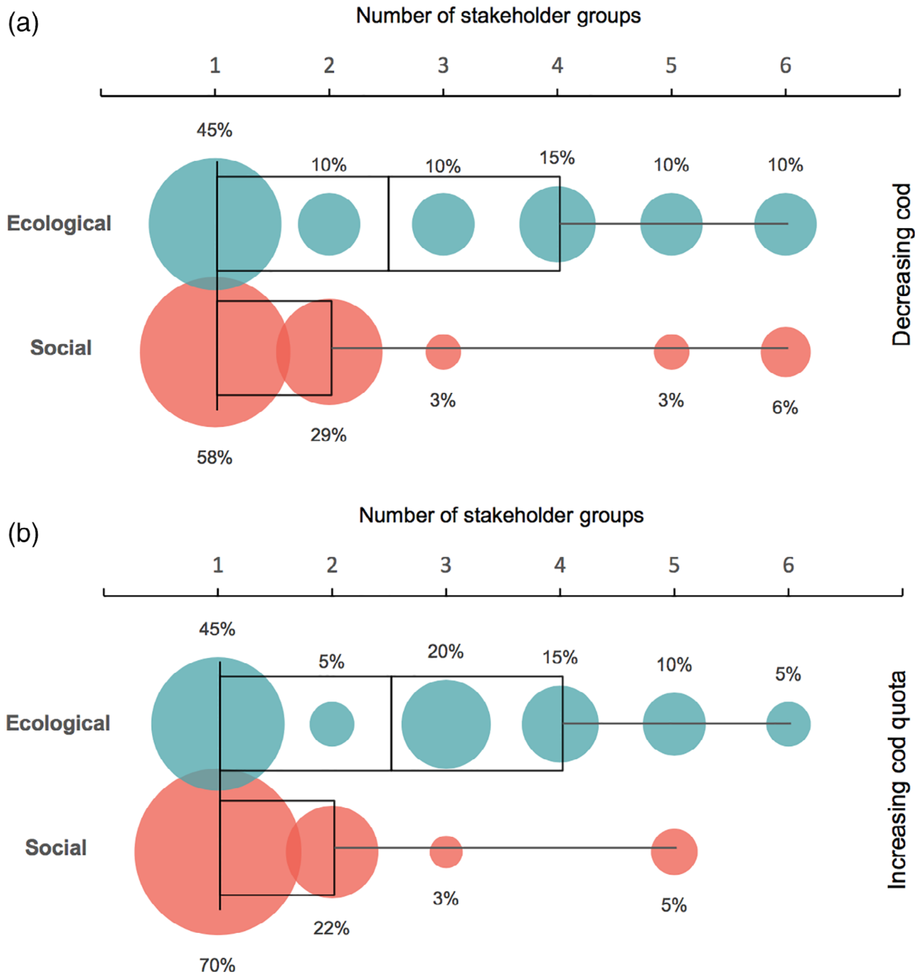

FIGURE 3 Agreement of dynamic changes across stakeholder groups as a result of (a) decreasing cod and (b) increasing cod quota. Bubbles' sizes show the percentage of mostly affected concepts; boxes represent the distribution of agreement. Ecological concepts that are mostly affected by decreasing cod and increasing cod quota are more aligned across stakeholder groups as illustrated by larger bubbles for higher degrees of agreement (degree of agreement is measured by the number of groups from 1 to 6 that agree). Detailed presentation of the concepts in each bubble is provided at Table S5c

knowledge. We considered disparities in qualitative meanings stakeholders attach to system components, the perception of causal relationships between them, as well as the functional implications of perceived SES changes by different social groups. These variations (here referred to as SEKD) were found to be more evident in social dimensions—while there was general agreement about ecological dimensions when considered in isolation.

Although many transboundary, large-scale fisheries management follow the ecosystem-based and participatory approaches to governance (Long, Charles, & Stephenson, 2017; Pitcher, Kalikoski, Short, Varkey, & Pramod, 2009), a state-of-the-art approach that allows for modeling the differences in system knowledge, values, beliefs, and perceptions across social groups is underdeveloped. Although there are many formal models showing how ecosystems function (Plagányi, 2007), for example, Ecopath (Watari et al., 2018) or Ecopath with Ecosim (Püts et al., 2020), a considerable gap remains in how social groups attach themselves to these dynamics. Collective understanding of ecosystem dynamics forms the basis for the establishment of reference points and is frequently used to determine sustainable catch quotas. However, the cultural and social impacts of structural changes in ecosystems and management frameworks are poorly understood. Our research finds that variation in social measurements and specific contextual attachments likely form the basis of disagreement, and could explain, at least partially, some of the multigroup conflict in natural resource management. Fisheries management routinely utilizes bio-econometric models to assess the economic impact of stress factors like tourism or fishing (Fulton, Smith, Smith, & van Putten, 2011) and evaluate different management strategies such as closed areas or quotas (integrated ecosystem assessment) (Levin, Fogarty, Murawski, & Fluharty, 2009). While they do integrate certain social components into policy assessment, most modeling techniques fail to address the many other human dimensions central to understanding the social impacts of management decisions (Hornborg et al., 2019). Incorporating the various objectives of stakeholders and diverging specific attachments they assign to system components might vastly increase both dialogue and conflict resolution when management decisions are being considered.

To strengthen the sustainable management of natural resources and to more fully understand fisheries as complex SES, we argue it is of utmost importance to involve a range of resource users and associated interest groups in the process. Of course, the individual case must be considered. Nevertheless, it is possible that the inclusion of people who, for example, have been involved in a fishery for only a short time, might have a different perspective on existing conflicts, and could potentially break up deadlocked problems by steering them in another direction. Future research could, therefore, incorporate these newer perspectives to explore how knowledge, values and beliefs may vary based on time spent in that specific fishery.

Without considering the broad spectrum of specific contextual attachments that stem from different stakeholder groups, variations in social–ecological knowledge are likely to undermine the practical implementation of management strategies and effective decision-making (Adams et al., 2003; King et al., 2015). By applying semi-quantitative cognitive mapping analysis, we are better able to model the variations reflected in stakeholders' perceptions of, knowledge about, and contextual attachments to system components, their causal relationships, and their dynamics. The novelty of our approach is particularly evident in the capture and representation of knowledge and perception divergences in a way that creates access for different stakeholders, with a particular emphasis in making this understandable for decision-makers. Although our study represents a single case study only, our approach demonstrates practical applicability to other research fields and to other geographical regions, worldwide. This enables others to analyze and understand resource conflicts of various kinds and validates the high adaptability of our novel approach to current issues in the field of nature conservation and natural resource use.

While a participatory approach is contemporarily routine to the management of large-scale fisheries (EC, 2013) and other transboundary SES like MPAs (Davies, Murchie, Kerr, & Lundquist, 2018), modeling the unique ways in which social groups attach meaning to SES components has yet to be incorporated into decision-making. Doing so could diminish conflicts, legitimize management plans, and ultimately lead to a better understanding of human–environment interactions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Heike Schwermer, **Payam Aminpour**, and **Steven Gray**: Conceptualization; **Heike Schwermer**, **Payam Aminpour**, and **Steven Gray**: Methodology. **Heike Schwermer**, **Payam Aminpour**, and **Steven Gray**: Formal analysis. **Heike Schwermer** and **Christian Möllmann**: Investigation. **Heike Schwermer**, **Payam Aminpour**, **Caitie Reza**, **Steven Gray**, and **Christian Möllmann**: Writing—original draft preparation. **Heike Schwermer**, **Payam Aminpour**, **Caitie Reza**, **Steffen Funk**, **Steven Gray**, and **Christian Möllmann**: Writing—review and editing. **Heike Schwermer**: Validation. **Heike Schwermer**, **Payam Aminpour**, and **Steffen Funk**: Visualization. **Heike Schwermer** and **Christian Möllmann**: Funding acquisition. All authors have read and agreed to the published version of the manuscript.

DATA AVAILABILITY STATEMENT

All necessary data supporting the findings of this study are available as Supporting Information. Data for obtaining the FCM of individuals are available and can be downloaded as Excel spreadsheets on https://osf.io/f45ux/.

ETHICS STATEMENT

All subjects gave their informed consent via email for inclusion before they participated in the study. The study was hence conducted in accordance with the Declaration of Helsinki.

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REFERENCES

Adams, W. M., Brockington, D., Dyson, J., & Vira, B. (2003). Managing the tragedies. Understanding conflicts over common pool resources. *Science*, *302*, 1915–1916. https://doi.org/10.1126/science.1087771

Aminpour, P., Gray, S. A., Jetter, A. J., Introne, J. E., Singer, A., & Arlinghaus, R. (2020). Wisdom of stakeholder crowds in complex social–ecological systems. *Nature Sustainability*, *3*, 191–199. https://doi.org/10.1038/s41893-019-0467-z

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, *10*, 1251–1262.

Biggs, D., Abel, N., Knight, A. T., Leitch, A., Langston, A., & Ban, N. C. (2011). The implementation crisis in conservation planning: Could "mental models" help? *Conservation Letters*, *4*, 169–183. https://doi.org/10.1111/j.1755-263X.2011.00170.x

Binder, C. R., Hinkel, J., Bots, P. W. G., & Pahl-Wostl, C. (2013). Comparison of frameworks for analyzing social-ecological systems. *Ecology and Society*, *18*, 4. https://doi.org/10.5751/ES-05551-180426

Burns, T. R., & Stöhr, C. (2011). Power, knowledge, and conflict in the shaping of commons governance. The case of EU Baltic fisheries. *International Journal of the Commons*, *5*(2), 233–258.

Davies, K., Murchie, A. A., Kerr, V., & Lundquist, C. (2018). The evolution of marine protected area planning in Aotearoa New Zealand: Reflections on participation and process. *Marine Policy*, *93*, 113–127. https://doi.org/10.1016/j.marpol.2018.03.025

EC. (2013). Regulation (EU) No 1380/2013 of the European Parliament and of the council of 11 December 2013 on the Common Fisheries Policy. Brussels

Folke, C. (2004). Traditional knowledge in social–ecological systems. *Ecology and Society*, *9*, 7.

Fulton, E. A., Smith, A. D. M., Smith, D. C., & van Putten, I. E. (2011). Human behaviour: The key source of uncertainty in fisheries management. *Fish and Fisheries*, *12*, 2–17. https://doi.org/10.1111/j.1467-2979.2010.00371.x

Game, E. T., Bremer, L. L., Calvache, A., Moreno, P. H., Vargas, A., Rivera, B., & Rodriguez, L. M. (2016). Fuzzy models to inform social and environmental indicator selection for conservation impact monitoring. *Conservation Letters*, *11*(1), 1–8. https://doi.org/10.1111/conl.12338

Gray, S., Chan, A., Clark, D., & Jordan, R. C. (2012). Integrating stakeholder knowledge in social-ecological system decision-making: Benefits and limitations to knowledge diversity. *Ecological Modeling*, *229*, 88–96. https://doi.org/10.1016/j.ecolmodel.2011.09.011

Gray, S., Hilsberg, J., McFall, A., & Arlinghaus, R. (2015). The structure and function of angler mental models about fish population ecology: The influence of specialization and target species. *Journal of Outdoor Recreation and Tourism*, *12*, 1–13. https://doi.org/10.1016/j.jort.2015.09.001

Gray, S., Aminpour, P., Reza, C., Scyphers, S, Grabowski, J, Murphy, Jr R., … & Instrone, J. (2020). Harnessing the collective intelligence of stakeholders for conservation. *Frontiers in Ecology and the Environment*, *18*(8), 465–472.

Gray, S. A., Zanre, E., & Gray, S. R. (2014). Fuzzy cognitive maps as representations of mental models and group beliefs. In E. I. Papageorgiou (Ed.), *Fuzzy cognitive maps for applied sciences and engineering. From fundamentals to extensions and learning algorithms* (pp. 29–48). Berlin, Heidelberg: Springer.

Halbrendt, J., Gray, S. A., Crow, S., Radovich, T., Kimura, A. H., & Tamang, B. B. (2014). Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture. *Global Environmental Change*, *28*, 50–62. https://doi.org/10.1016/j.gloenvcha.2014.05.001

Hornborg, S., van Putten, I., Novaglio, C., Fulton, E. A., Blanchard, J. L., Plagányi, É., … Sainsbury, K. (2019). Ecosystem-based fisheries management requires broader performance indicators for the human dimension. *Marine Policy*, *108*, 103639. https://doi.org/10.2016/j.marpol.2019.103639

Jones, N., Ross, H., Lynam, T., Perez, P., & Leitch, A. (2011). Mental models: An interdisciplinary synthesis of theory and methods. *Ecology and Society*, *16*(1), 46–46.

Kim, H. S., & Lee, K. C. (1998). Fuzzy implications of fuzzy cognitive map with emphasis on fuzzy causal relationship and fuzzy partially causal relationship. *Fuzzy Sets and Systems*, *97*(3), 303–313.

King, E., Cavender-Bares, J., Balvanera, P., Mwampamba, T. H., & Polasky, S. (2015). Trade-offs in ecosystem services and varying stakeholder preferences: Evaluating conflicts, obstacles, and opportunities. *Ecology and Society*, *20*, 3. https://doi.org/10.5751/ES-07822-200325

Kosko, B. (1986). Fuzzy cognitive maps. *International Journal of Man-Machine Studies*, *24*, 65–74.

Kramer, M. A. (1992). Auto associative neural networks. *Computers & Chemical Engineering*, *16*(4), 313–328.

Levin, P. S., Fogarty, M. J., Murawski, S. A., & Fluharty, D. (2009). Integrated ecosystem assessments: Developing the scientific basis for ecosystem-based management of the ocean. *PLoS Biology*, *7*(1), e1000014. https://doi.org/10.1371/journal.pbio.1000014

Linke, S., Dreyer, M., & Sellke, P. (2011). The regional advisory councils. What is their potential to incorporate stakeholder knowledge into fisheries governance? *AMBIO*, *40*, 133–143. https://doi.org/10.1007/s13280-010-0125-1

Linke, S., & Jentoft, S. (2016). Ideals, realities and paradoxes of stakeholder participation in EU fisheries governance. *Environmental Sociology*, *2*, 144–154. https://doi.org/10.1080/23251042.2016.1155792

Long, R. (2009). The role of regional advisory councils in the European common fisheries policy: Legal constraints and future options. *The International Journal of Marine and Coastal Law*, *25*, 289–346. https://doi.org/10.1163/157180810X516980

Long, R., Charles, A., & Stephenson, R. L. (2017). Key principles of ecosystem-based management: The fishermen's perspective. *Fish and Fisheries*, *18*, 244–253. https://doi.org/10.1111/faf.12175

Manfredo, M. J., Bruskotter, J. T., Teel, T. L., Fulton, D., Schwartz, S. H., Arlinghaus, R., … Sullivan, L. (2017). Why social values cannot be changed for the sake of conservation. *Conservation Biology*, *31*(4), 772–780. https://doi.org/10.1111/cobi.12855

Naranjo-Madrigal, H., & van Putten, I. (2018). The link between risk taking, fish catches, and social standing: Untangling a complex cultural landscape. *Marine Policy*, *100*, 173–182. https://doi.org/10.1016/j.marpol.2018.11.029

Oishi, S., & Graham, J. (2010). Social ecology: Lost and found in psychological science. *Perspectives on Psychological Science*, *5*(4), 356–377. https://doi.org/10.1177/1745691610374588

Özesmi, S. L., & Özesmi, U. (2004). Ecological models based on people's knowledge: A multi-step fuzzy logic cognitive modelling approach. *Ecological Modelling*, *176*, 43–64. https://doi.org/10.1016/j.ecolmodel.2003.10.027

Pitcher, T. J., Kalikoski, D., Short, K., Varkey, D., & Pramod, G. (2009). An evaluation of progress in implementing ecosystem-based management of fisheries in 33 countries. *Marine Policy*, *33*(2), 223–232. https://doi.org/10.1016/j.marpol.2008.06.002

Plagányi, E. E. (2007). Models for an ecosystem approach to fisheries. FAO Fisheries Technical Paper No. 477. Rome, FAO. 2007.108p.

Püts, M., Taylor, M. H., Núñez-Riboni, I., Steenbeck, J., Stäbler, M., … Kempf, A. (2020). Insights on integrating habitat preferences in process-oriented ecological models—A case study of the southern North Sea. *Ecological Modelling*, *431*, 109189. https://doi.org/10.1016/j.ecolmodel.2020.109189

Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, *141*, 2417–2431. https://doi.org/10.1016/j.biocon.2008.07.014

Steins, N., Kraan, M. L., van der Reijden, K. J., Quirijns, F. J., van Broekhoven, W., & Poos, J. J. (2019). Integrating collaborative research in marine science: Recommendations from an evaluation of evolving science-industry partnerships in Dutch demersal fisheries. *Fish and Fisheries*, *21*, 146–161. https://doi.org/10.1111/faf.12423

Stephenson, R. L., Paul, S., Pastoors, M. A., Kraan, M., Holm, P., Wiber, M., … Benson, A. (2016). Integrating fishers' knowledge research in science and management. *ICES Journal of Marine Science*, *73*, 1459–1465. https://doi.org/10.1093/icesjms/fsw025

Sterling, E., Filardi, C., Toomey, A., Sigouin, A., Betley, E., Gazit, N., … Jupiter, S. (2017). Biocultural approaches to well-being and sustainability indicators across scales. *Nature Ecology & Evolution*, *1*(12), 1798–1806. https://doi.org/10.1038/s41559-017-0349-6

Stier, A., Samhouri, J. F., Gray, S., Martone, R. G., Mach, M. E., Halpern, B. S., … Levin, P. S. (2017). Integrating expert perceptions into food web conservation and management. *Conservation Letters*, *0*(0), 1–10. https://doi.org/10.1111/conl.12245

Tantardini, M., Leva, F., Tajoli, L., & Piccardi, C. (2019). Comparing methods for comparing networks. *Scientific Reports*, *9*, 17557. https://doi.org/10.1038/s41598-019-53708-y

Voinov, A., Kolagani, N., McCall, M. K., Glynn, P. D., Kragt, M. E., Ostermann, F. O., … Ramu, P. (2016). Modelling with stakeholders—Next generation. *Environmental Modelling & Software*, *77*, 196–220. https://doi.org/10.1016/j.envsoft.2015.11.016

Watari, S., Murase, H., Yonezaki, S., Okazaki, M., Kiyofuji, H., … Kitakado, T. (2018). Ecosystem modeling in the western North Pacific using Ecopath, with a focus on small pelagic fishes. *Marine Ecology Progress Series*, *617–618*, 295–305. https://doi.org/10.3354/meps12508

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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Supporting methods

Mental Models Aggregation

Individual mental models represented as FCMs can be aggregated mathematically using matrix algebra operations on their adjacency matrices. These aggregated models can be used to represent the knowledge and perception of a group of participants and thus provide a tool for repressing a group's knowledge and collective perception (Gray et al., 2014). To combine mental models of a homogenous group with individuals from a specific stakeholder type, we used the arithmetic mean (i.e. simple average) of edge weights in all FCMs created by the group's individuals (see also Jetter & Kok, 2014 for more details):

$$A_{ij}^{FCM_g} = \frac{1}{N}\sum_{p=1}^{N} A_{ij}^{FCM_p} \quad (\boldsymbol{S1})$$

where A^{FCM_p} is the adjacency matrix of the FCM of participant p; N is the total number of participants in a group, and $A_{ij}^{FCM_p}$ is the element of this adjacency matrix with the value equals to the weight of the edge between node i and j. FCM_g represents the aggregated FCM of a group with the corresponding adjacency matrix A^{FCM_g}.

We used the above aggregation method to create stakeholder-specific models of different stakeholder groups (see Figures S3-S8).

FCM computation

FCM models are semi-quantitative simulation models (Voinov et al., 2018) that can be used to assess the perceived dynamic behavior of the system they represent (Stylios & Groumpos, 2004; Jetter & Sperry, 2013; Gray et al., 2014). Here, we used FCM computational analysis to demonstrate how stakeholders, based on their collective perceptions and knowledge, predicted the changes in the state of system's elements given an initial change in one or combination of concepts (i.e. scenario inputs) (here we changed *cod* and *cod quota*) (for details about scenario analysis see Giabbanelli et al., 2017). An increase (or a decrease) in a concept initiates a cascade of changes to other system concepts (typically normalized between 0 and 1), and this iterative propagation of the initial change evolves into a so-called new "system state" (Papageorgiou & Salmeron, 2014). By comparing the system states (i.e. the value of concepts) before and after initiation of a change, FCM can be used to implement "what if" scenario analysis, and therefore represent perceived dynamic behavior of the system (in this case, cod fisheries SES).

To run a scenario, the value of one or more concepts (i.e., scenario nodes) in a FCM was changed and forced to stay at either +1 (an increase) or -1 (a decrease). This initial change passes through the network of nodes and connections including feedback loops until the system reaches a new state. The consequent alterations in the state of other system concepts were calculated by subtracting their initial values from their values after the scenario was introduced and system evolved into a new state. The initial value of each concept, also known as steady state, is calculated using the following formula:

$$c_i^{(k+1)} = f\left(\sum_j c_j^{(k)}.A_{ji}\right) \quad (\boldsymbol{S3})$$

where $c_i^{(k+1)}$ is the value of concept C_i at iteration step k+1, $c_i^{(k)}$ is the value of concept C_i at iteration step k, $c_j^{(k)}$ is the value of concept C_j at iteration step k, and A_{ji} is the weight of the edge relationship between C_j and C_i. Function $f(x)$ is the "threshold function" that was used to squash the concept values at each step to a normalized interval between -1 and 1. In this study, we used a hyperbolic tangent function (for more details about hyperbolic tangent function see Harmati & Kóczy, 2019):

$$f(x) = \ Tanh\ (\lambda x) = \frac{e^{\lambda x} - e^{-\lambda x}}{e^{\lambda x} + \ e^{-\lambda x}} \quad (\boldsymbol{S4})$$

where λ is a real positive number (in our case $\lambda = 1$) which determines the steepness of the function f.

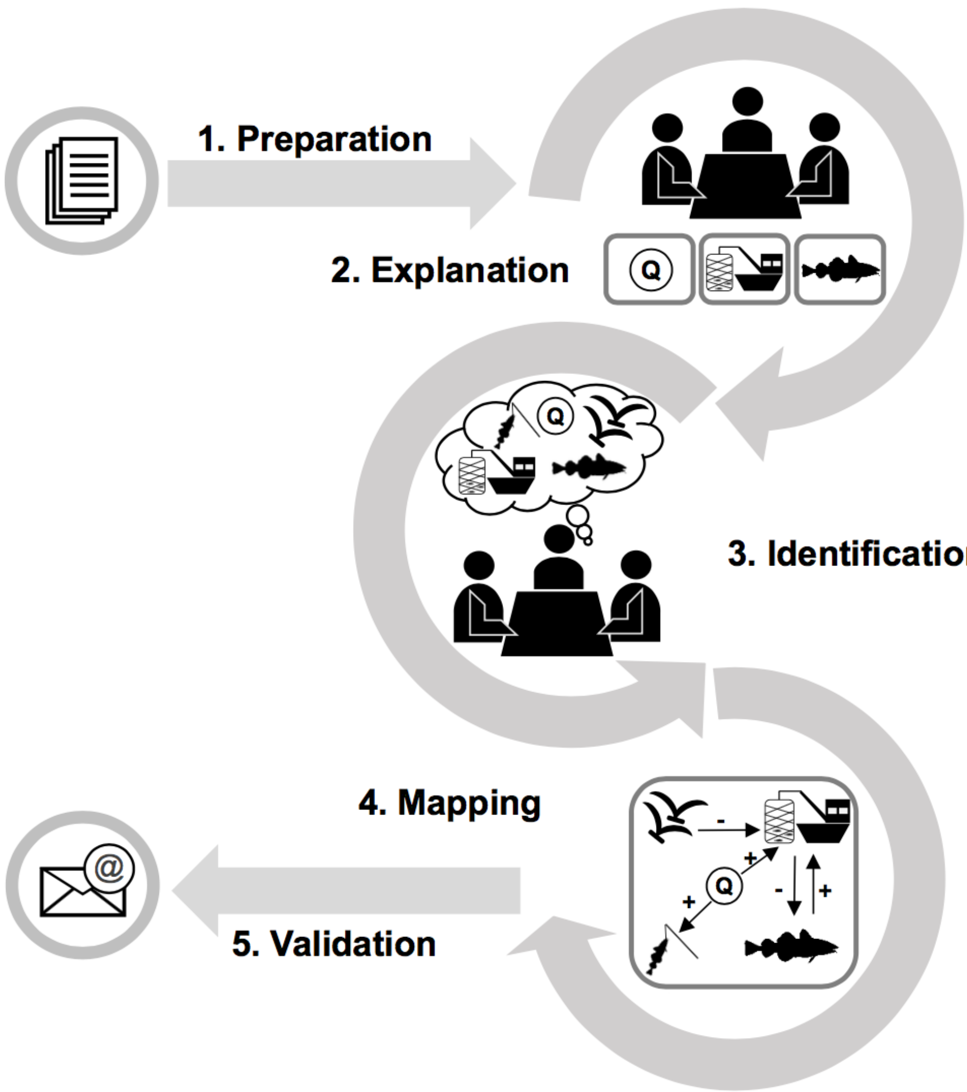
The value of each concept under a scenario was computed using the same formula (Eq. S3), but this time scenario nodes were forced to take fixed values (either +1 or -1). The scenario outcomes were then calculated as the differences between the values of the system's concepts when the system was self-administered and when it was forced by fixed manipulations in the state of scenario concepts (Gray et al., 2014; Papageorgiou & Salmeron, 2014). For each concept C_i the change in its value as a result of running a scenario is:

$$D_i^{sc} = c_i^{ss} - c_i^{sc} \quad (\boldsymbol{S5})$$

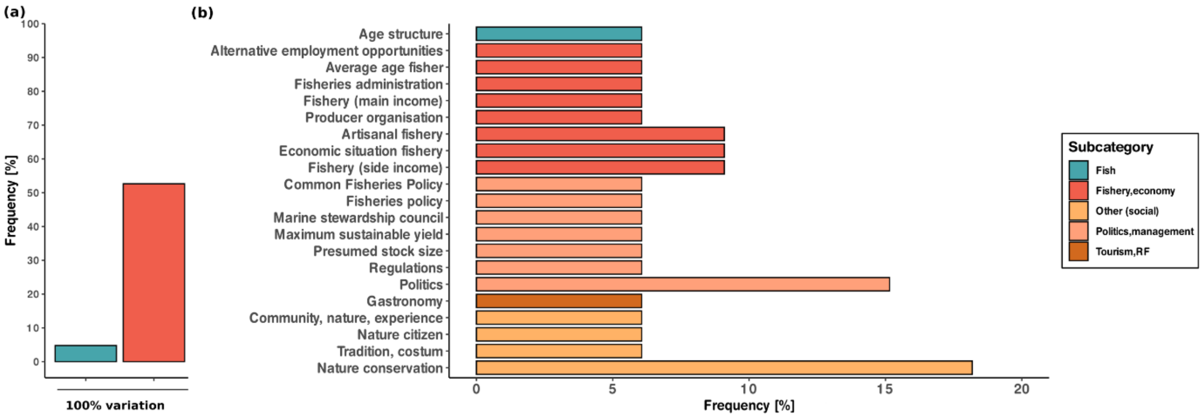
where D_i^{sc} is the change in the value of concept C_i, c_i^{ss} is the value of concept C_i in the steady state, and c_i^{sc} is the value of concept C_i after converging into a new state while scenario concepts are clamped on fixed values.

Supporting figures

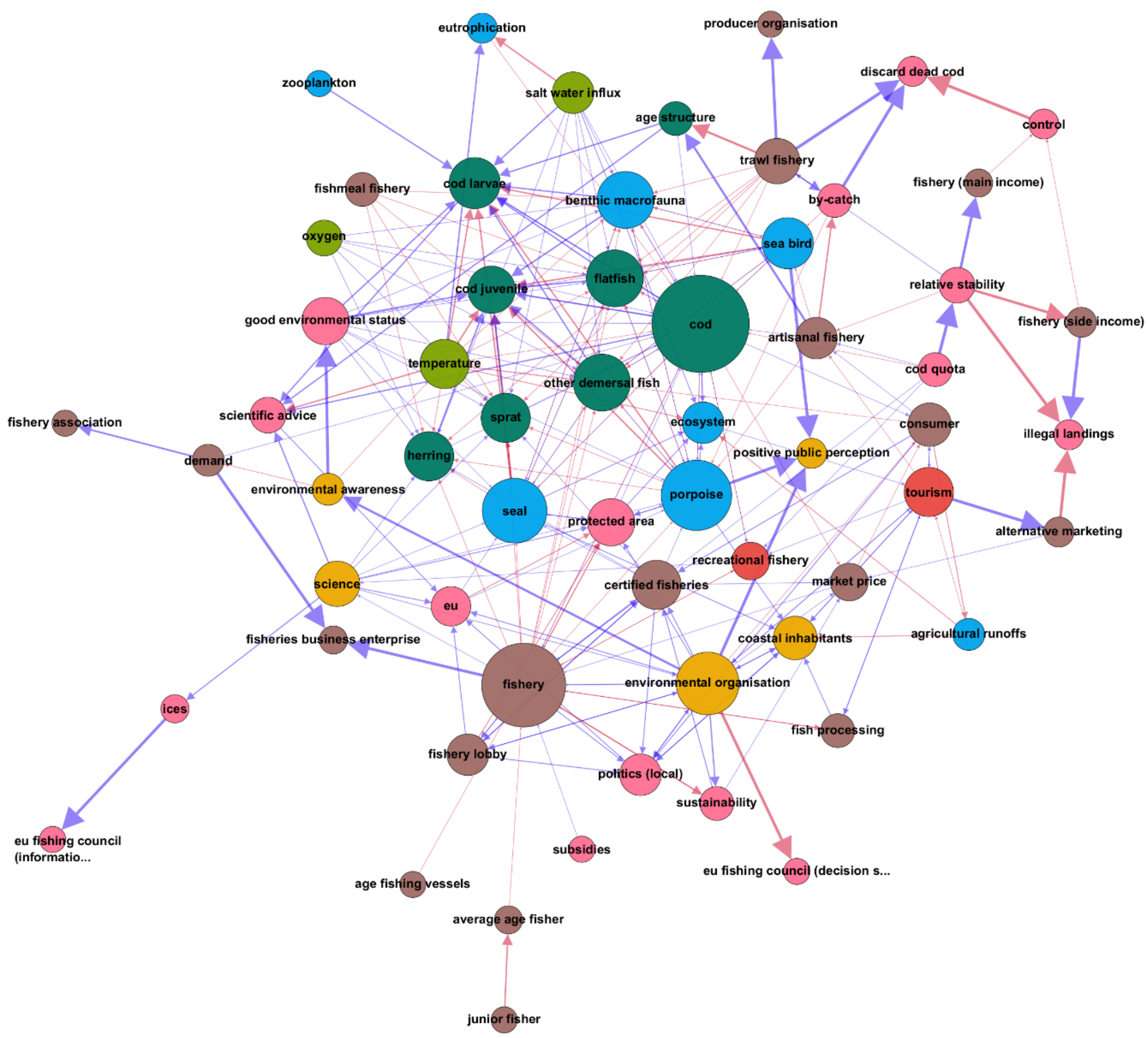
Supporting Figure S1. 5-step-process was being used to collect mental models of stakeholders` regarding their perception on the SES of Western Baltic cod fishery: **1.** Preparation (handout for interviewees to prepare for the interview), **2.** Explanation (description of all important information regarding the data collection), **3.** Identification ("activation" of interviewees' mental model), **4.** Mapping (representation of interviewees' mental model through components and links) and **5.** Validation (digitalized map was sent to interviewees to ask for changes or/and satisfaction).



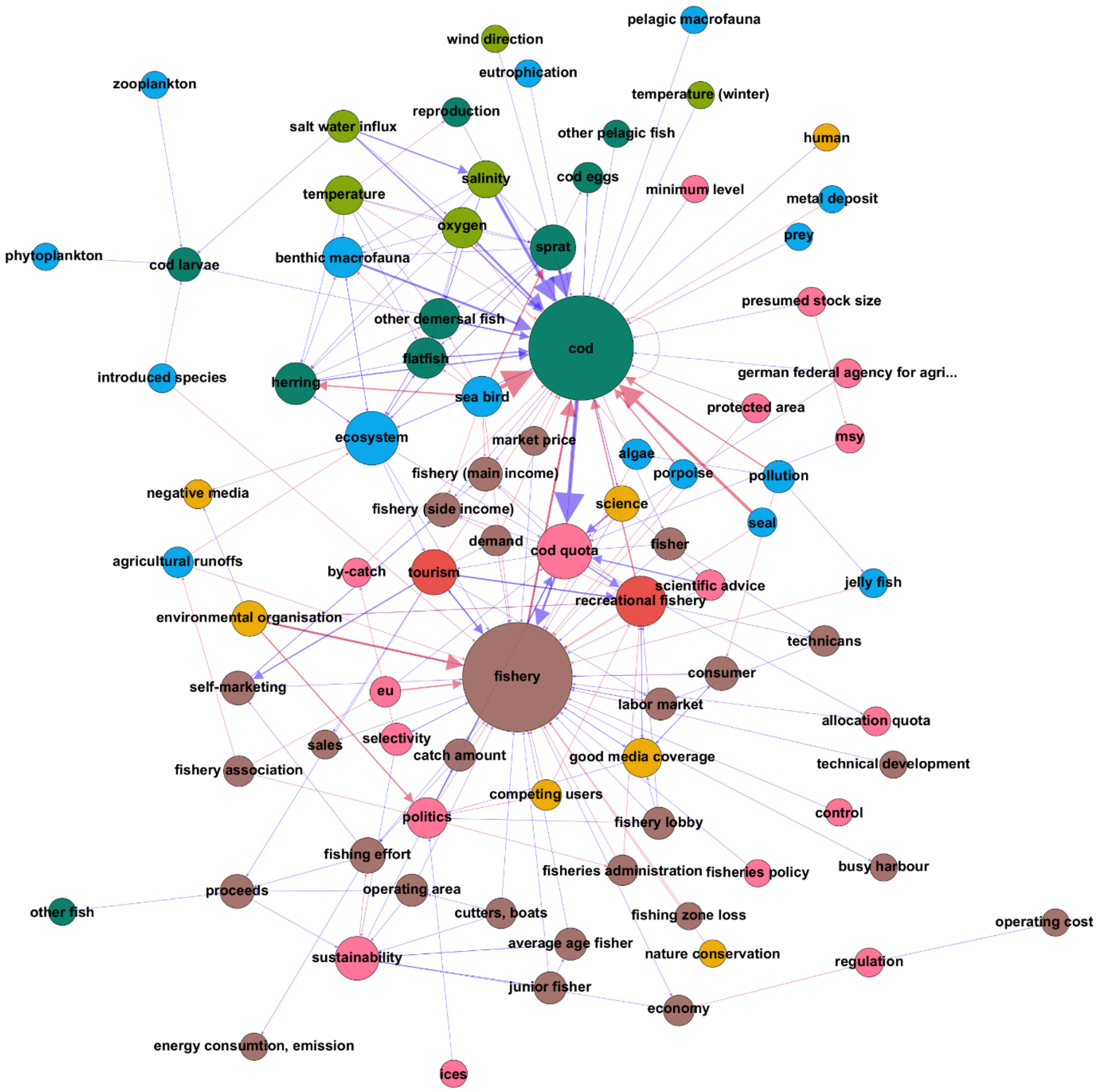
Supporting Figure S2. Frequency of ecological (4.76%) and social (52.63%) components for which no equivalent measure has been attached by stakeholders. All components have been assigned a corresponding subcategory; ecological components: fish, biotic, abiotic, ecological (other), and for social components: fisheries-economy, policy management, tourism recreational fisheries and other (social). Highest number of components with no cultural consensus is found for components of "Fisheries, economy" and "Politics, management" SC (e.g., *fishery (main income)*, *artisanal fishery* and *fishery (side income)*) and politics-management (N=7, e.g., *Common Fisheries Policy*), *regulations*, *maximum sustainable yield*)). Whereas the lowest number is found for components of “Tourism, RF” (*gastronomy*) and “Fish” SC (*age structure*). However, the highest frequency is shown for *nature conservation* (18.18%) and *politics* (15%) (See detailed description of each node in Table S3).



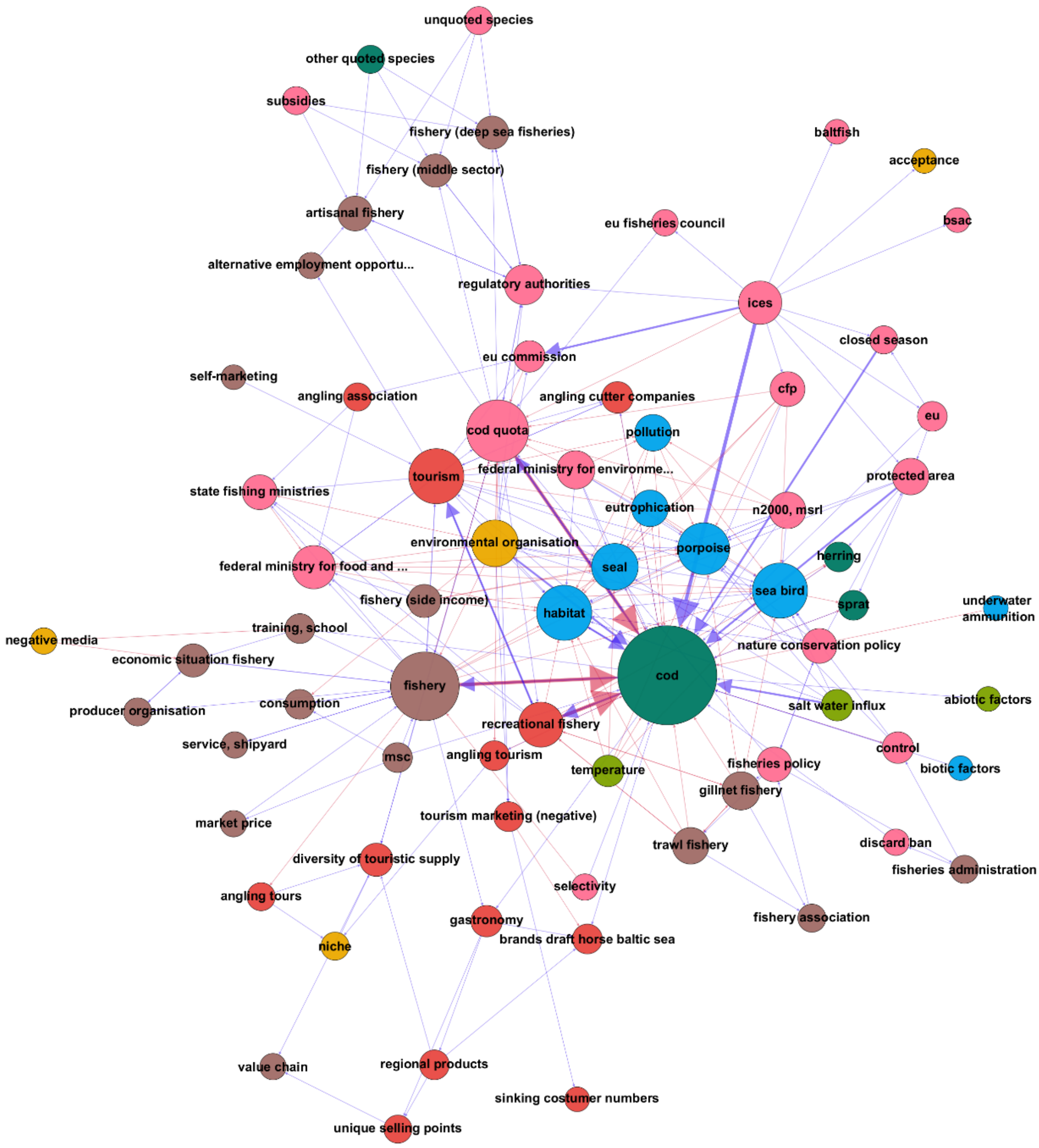
Supporting Figure S3. Core model of representatives from NGO (non-governmental organization, N= 18.2%). Nodes are displayed by its respective sub-category (ecological components: dark green= fish, light blue=biotic, green=abiotic, light brown=ecological-(other); social components: dark brown=fishery-economy, pink=politics-management, red=tourism-recreational fishery, yellow=other-(social). Node size is measured by using centrality measures *degree centrality*. Color of edges is presented by its decreasing (light pink) or increasing (violet) effect in the influencing component. *Cod* is the concept with the highest degree centrality, followed by *fishery*, *porpoise* and *environmental organization*.



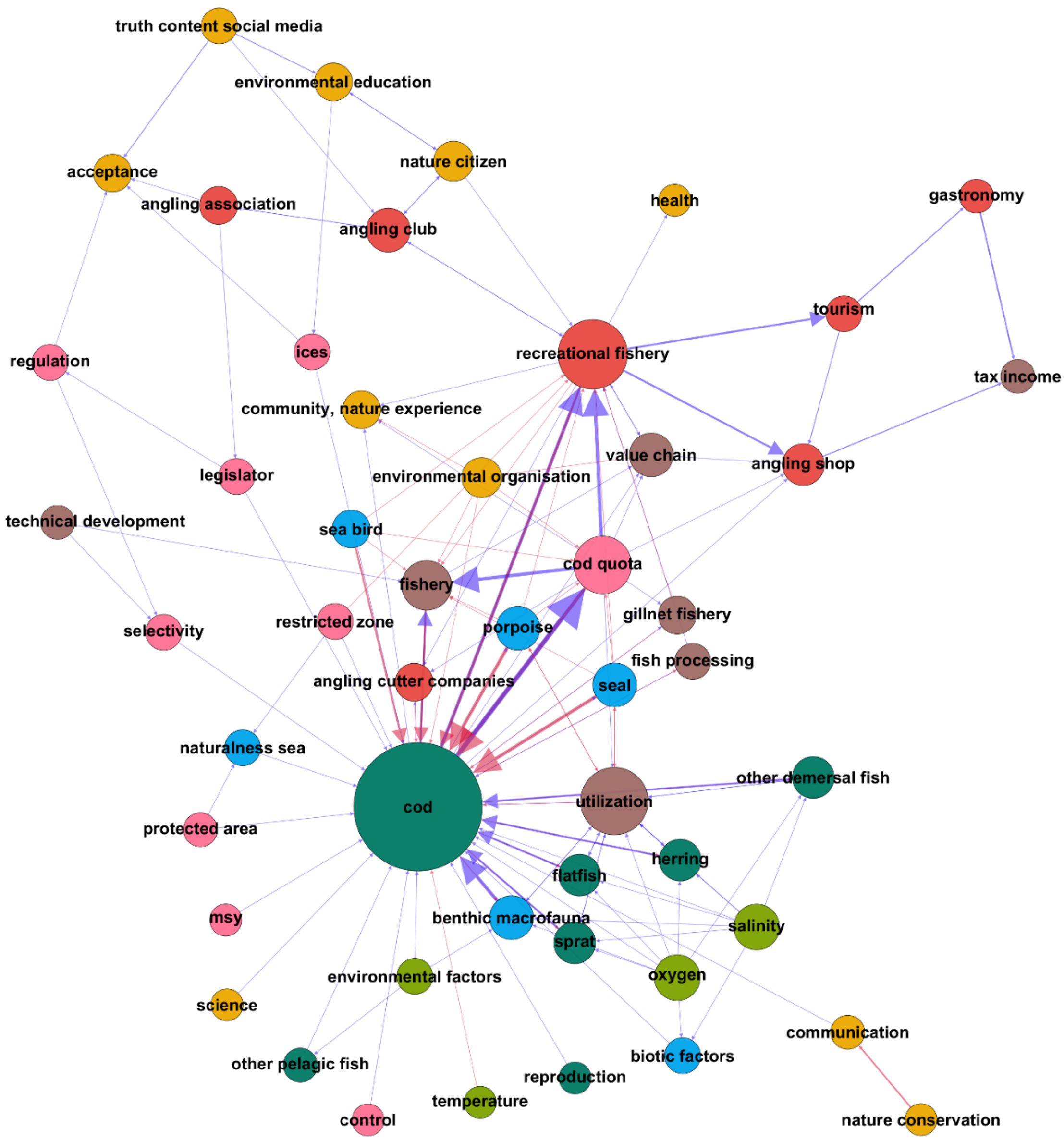
Supporting Figure S4. Core model of ComFish (commercial fishery, N=21.2 %). Nodes are displayed by their respective sub-category (ecological components: dark green= fish, light blue=biotic, green=abiotic, light brown=ecological-(other); social components: dark brown=fishery-economy, pink=politics-management, red=tourism-recreational fishery, yellow=other-(social). Node size is measured by using centrality measures *degree centrality*. Color of edges is presented by its decreasing (light pink) or increasing (violet) effect in the influencing component. The concepts with highest degree centrality are *cod* and *fishery*.



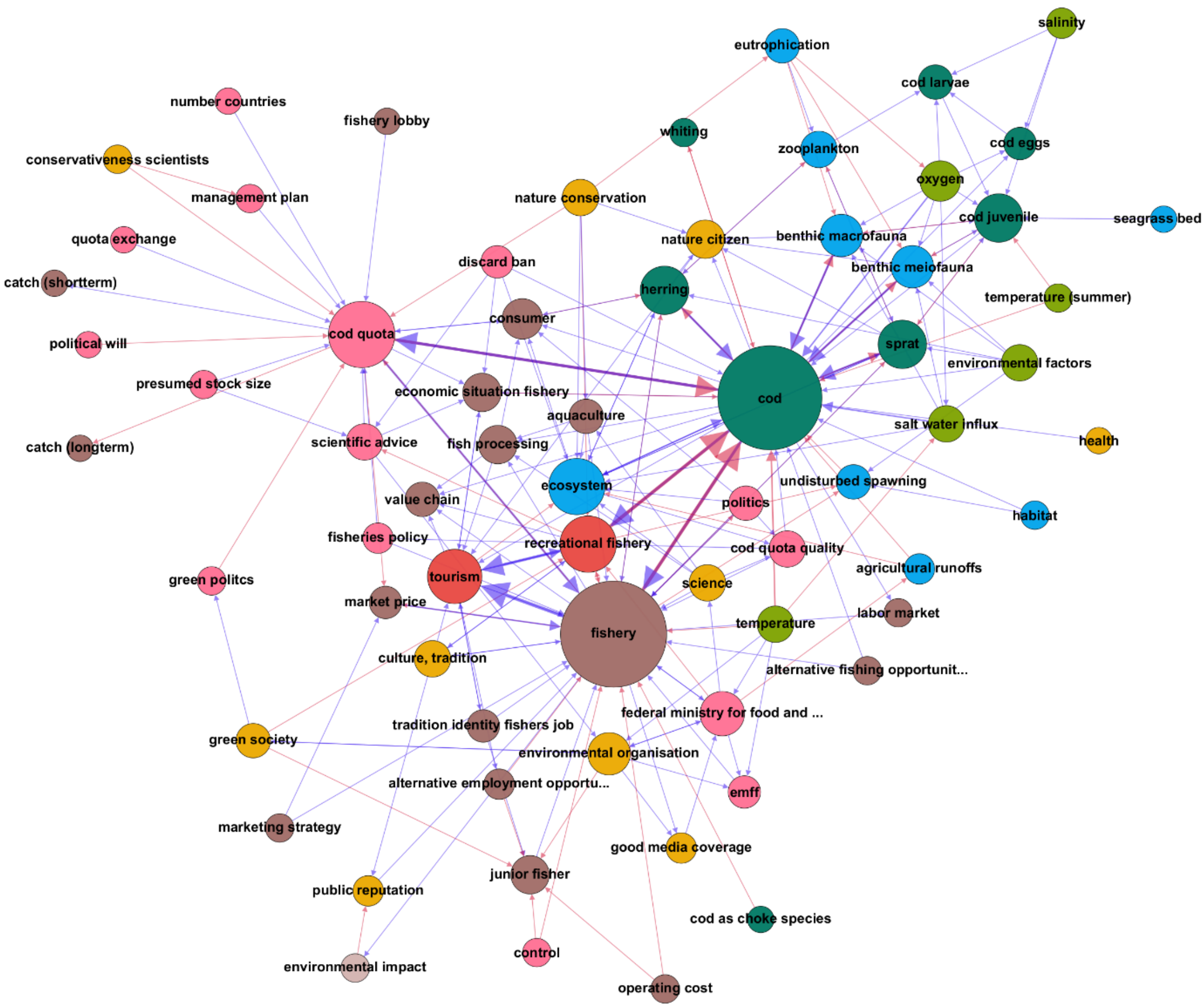
Supporting Figure S5. Core model of managers (N= 18.2 %). Nodes are displayed by its respective sub-category (ecological components: dark green= fish, light blue=biotic, green=abiotic, light brown=ecological-(other); social components: dark brown=fishery-economy, pink=politics-management, red=tourism-recreational fishery, yellow=other-(social). Node size is measured by using centrality measures *degree centrality*. Color of edges is presented by its decreasing (light pink) or increasing (violet) effect in the influencing component. *Cod* is the concept with the highest degree centrality, followed by *fishery* and *cod quota*. In comparison to the majority of the nodes, also *tourism*, *habitat*, *porpoise* and *seabird* are displayed by high centrality measures.



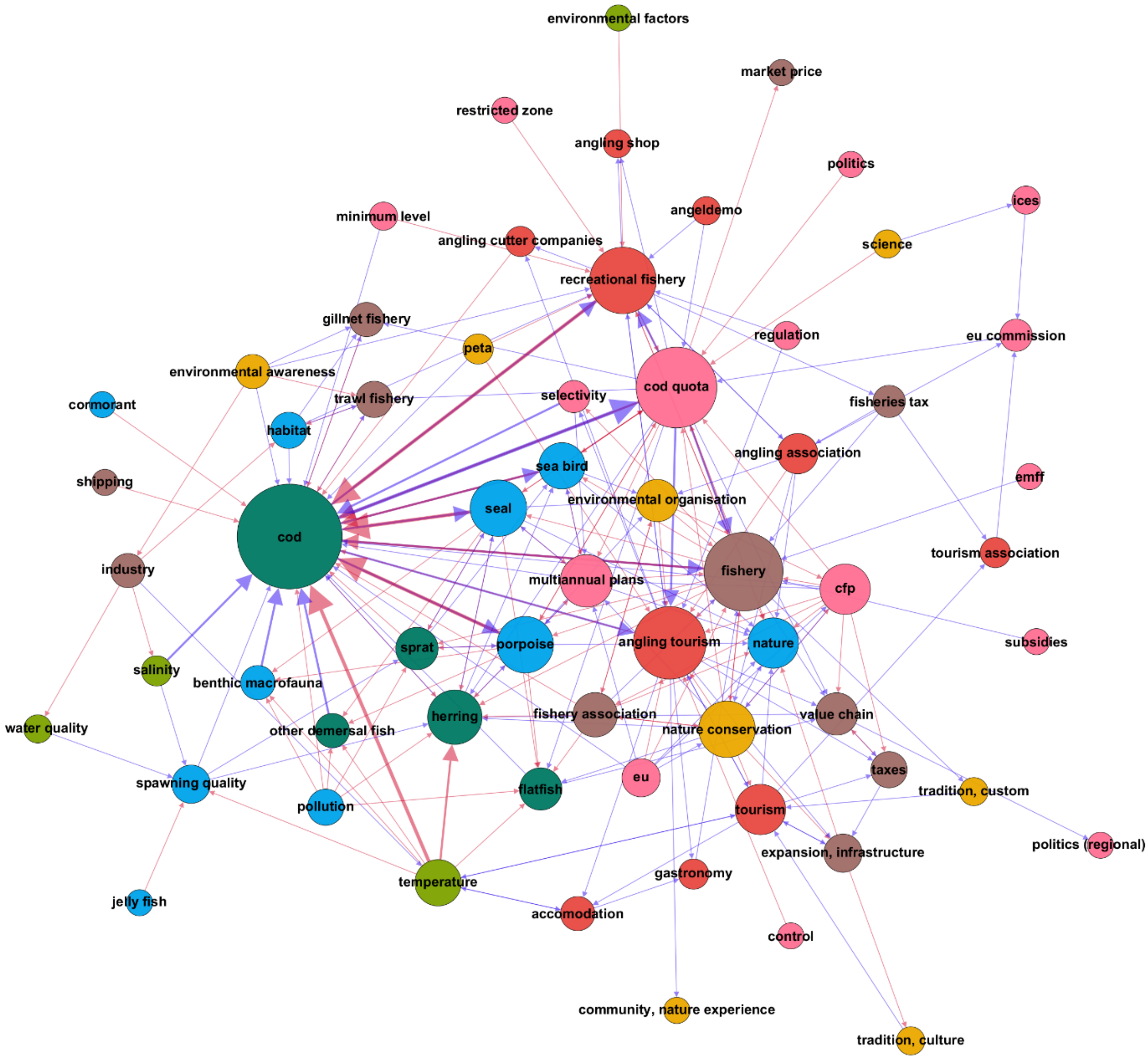
Supporting Figure S6. Core model RecFish (recreational fishery, N=12.1 %). Nodes are displayed by its respective sub-category (ecological components: dark green= fish, light blue=biotic, green=abiotic, light brown=ecological-(other); social components: dark brown=fishery-economy, pink=politics-management, red=tourism-recreational fishery, yellow=other-(social). Node size is measured by using centrality measures *degree centrality*. Edges color is presented by its decreasing (light pink) or increasing (violet) effect in the influencing component. *Cod* is the concepts with the highest degree centrality, followed by *recreational fishery* and *utilization*.



Supporting Figure S7. Core model of representatives from science (N= 18.2 %). Nodes are displayed by its respective sub-category (ecological components: dark green= fish, light blue=biotic, green=abiotic, light brown=ecological-(other); social components: dark brown=fishery-economy, pink=politics-management, red=tourism-recreational fishery, yellow=other-(social). Node size is measured by using centrality measures *degree centrality*. Color of edges is presented by its decreasing (light pink) or increasing (violet) effect in the influencing component. *Cod* and fishery are the concepts with the highest degree centrality, followed by *cod quota* as well as *ecosystem*, *tourism* and *recreational fishery*.



Supporting Figure S8. Core model of representatives from tourism (N= 12.1 %). Nodes are displayed by its respective sub-category (ecological components: dark green= fish, light blue=biotic, green=abiotic, light brown=ecological-(other); social components: dark brown=fishery-economy, pink=politics-management, red=tourism-recreational fishery, yellow=other-(social). Node size is measured by using centrality measures *degree centrality*. Color of edges is presented by its decreasing (light pink) or increasing (violet) effect in the influencing component. The highest degree centrality is displayed by *cod*. Also, *cod quota* as well as *recreational fishery*, *angling tourism* and *fishery* show high degree centrality in comparison to the majority of concepts.



Supporting tables

Supporting Table S1. Stakeholders from six different groups were interviewed on their perception of the social-ecological system (SES) of Western Baltic cod fishery (ComFish=commercial fishery representatives, NGO=environmental non-governmental organization, MV=Mecklenburg-Western Pomerania, RecFish=recreational fishery representatives, SH=Schleswig-Holstein).

Stakeholder group	Description	%
NGO	Representatives for regional and international marine conservation, local fisheries in SH and certification of marine resources, campaigner for fisheries and fisheries management	18.2
ComFish	Representatives of the German fisheries and fisheries in MV and SH, manager of fishing cooperative, fishers in MV and SH (main- and side-income fishery)	21.2
Managers	Officials with focus on catch quota, nature conservation, fisheries management, angling tourism	18.2
RecFish	Representative of recreational fisheries in Germany and in MV and SH, representative with focus on sea angling	12.1
Scientists	Academics with research focus on fish economics, fish ecology, artificial reef, alternative fishing gears	18.2
Tourism	Association members with focus on the promotion of regional fishing tourism, owner of fishing shop, project manager-activity in nature	12.1

Supporting Table S2. Detailed description of the 5-step-approach (1. Preparation, 2. Explanation, 3. Identification, 4. Mapping and 5. Stakeholder communication), which has been used to collect mental models of multiple stakeholders related to their perception of the SES Western Baltic cod fishery (eNGO=environmental non-governmental organization).

Step	Description
1. Preparation	One week in advance stakeholders were provided with a handout explaining the aim of the project, giving an explanation of social-ecological systems and mental models. Further, a detailed list of what the data collection should look like was described and a definition of the three starting components, cod, fishery and catch quota, was attached.
2. Explanation	At the beginning of each semi-structured face-to-face interview (Halbrendt et al., 2014; Vasslides & Jensen, 2016), we went over the handout and described in detail what the modelling exercise should look like; after the project description in the beginning, stakeholders were asked to introduce themselves and describe what working with cod in the Western Baltic Sea looked like in the past and how long this work has been done.
3. Identification	Stakeholders need to describe components and their relation to each other by answering the following two questions: 1. When you think of the Western Baltic cod, which components come into your mind? (Definition of components); 2. What is the relation between these components? (Description of links between components). Components could be either social, ecological or economic. A standard value of 20 components has been specified.
4. Mapping	It was up to the stakeholders how they proceed with the visualization of their mental model; they could first write down all components and afterwards link them, or combine question 1 and 2. To understand stakeholders` mental model in detail, it was important that a definition of the components as well as a description of the relationship was given. When finishing the mapping, stakeholders were presented a list of components (food for thought, i.e. predation, prey, environmental factors, other fish, recreational fishery, tourism and eNGO); the components were always suggested in the same order and could either be accepted or rejected. It should be noted that the components were only proposed if they were not already defined by the stakeholder, beforehand. The following materials were used to create the mental models: a) portable whiteboard, b) board markers, c) empty laminated component cards and laminated pre-defined component cards (starting components, i.e. cod, fishery, catch quota and components served as food for thought); pre-defined components are based on a pre-test with scientists. To describe the link between component A and B, an increase in the influencing component A must be assumed to describe the effect achieved by the influencing component B. The effect is based on the components measured and can lead either to an increase (+) or a decrease (-) in either.
5. Validation	Three days after the interview took place, a digitized version of the mental model was sent to the interviewee by email; for visualization, we used the software *MentalModeler* (www.mentalmodeler.com), a novel computer-based FCM tool. Interviewees were given the opportunity to make changes or additions to their mental model.

Supporting Table S3. Qualitative analysis was used to describe variation in concept measures; listed by sub-categories, table represents the concepts where not the same meaning of concept measures was attached by stakeholders (SC, i.e. fish, fishery-economy, politics-management (Pol, Man), tourism-recreational fishery (Tou, Rf) and other-(social)). Further, the individual measure description as well as the frequency of each stakeholder group is shown (Com Fish=commercial fishery, Rec Fish=recreational fishery, S=scientist, M=managers, NGO=non-governmental organization, T=tourism).

SC	Node	Measure	Com Fish	Rec Fish	S	M	NGO	T
Fish	Age structure	Number of large and old cod					1	
		Strength of mixing					1	
Fishery, economy	Alternative employment opportunities	Number of alternative employment opportunities			1			
		Amount of other income				1		
	Average age fisher	Strength of age distribution	1					
		Height of the average age					1	
	Fisheries administration	Amount of bureaucracy	1					
		Number of implemented measures				1		
	Fishery main income	Amount of sales	1					
		Number of people in main-income fishery					1	
	Producer organization	Number of stable economic relationships				1		
		Amount of sales					1	
	Artisanal fishery	Amount of sales					1	
		Degree of conservation				1		
		Amount of catch					1	
	Economic situation fishery	Amount of sales			1			
		Strength of lobbying					1	
		Level of conditions in fishery				1		
	Fishery (side income)	Level of fishing effort (fishing intensity)				1		
		Amount of sales	1					
		Number of people in side-income fishery					1	
Pol, Man	Common Fisheries Policy (CFP)	Number of implemented measures						1
		Strength of implemented measures				1		
	Fisheries policy	Quality of fisheries policy			1			
		Level of effectiveness of fisheries measures				1		
	Marine Stewardship Council	Number of certification					1	
		Number of certified fisheries				1		
	Maximum Sustainable Yield	Strength of compliance with this set target size		1				
		Height of value of F_{MSY}	1					

	Presumed stock size	Value of $B_{MSY\text{-}trigger}$	1					
		Amount of assumed stock size			1			
	Regulations	Number of regulations	1					
		Level of quality and applicability of the regulations		1				
	Politics	Strength of influence						1
		Quality of politics			1			
		Strength of political influence regarding fishery	1					
		Amount of bureaucracy	1					
		Strength of economic orientation	1					
Tou, Rf	Gastronomy	Number of gastronomies				1		
		Number of restaurant visits						1
Other (social)	Community, nature, experience	Level of good environmental status		1				
		Strength of nature experience, being outside, sense of community		1				
	Nature citizen	Level of satisfaction						1
		Amount of interest in nature-friendly life		1				
	Tradition, custom	Strength of existence of culture and tradition						1
		Number of fishing company						1
	Nature conservation	Strength of the emotional attachment to nature conservation		1				
		Level of quality of nature conservation			1			
		Strength of the requirement of nature protection	1					
		Number of measures						1
		Number of implemented measures			1			
		Strength of influence						1

Supporting Table S4 a. Qualitative analysis of social concepts which are described by at least 2 different definitions; variation is exemplified by showing two different definitions (Example 1, Example 2).

Node	Variation	Example 1	Example 2
Cod quota	5,88	Total allowable catches (=TACs) are fishing opportunities, expressed in tones or numbers; TACs are distributed as national quotas and for WB cod, set every year in October	Total allowable catches (=TACs) are fishing opportunities, expressed in tones or numbers; TACs are distributed as national quotas and for WB cod, set every year in October. The quality of the TACs are characterized due to scientific and ecological principles and therefor a meaningful set of the quota
Fishery	15,38	Sector that deals with the capture and the marketing of fish, i.a. different types of fishing gear are used (gillnet, trawl)	Economic sector characterized by all people engaged in the fishery, i.e. fishers, an individual with his own plans and wishes and no influence on the fishery lobby but rather the fishery
Recreational fishery	33,33	People who do angling, i.e. anglers, recreational fishery	Hobby, which is not commercial and where people use the angle
Market price	37,50	Price for cod on market	Is defined by how well cod can be sold on the market
Science	38,46	Data (e.g. collection of data) and models (e.g. determination of stock size)	Institution (=black box), which works according to certain rules
Control	40,00	Control the fishery (on land and sea)	Linked to the monitoring of management measures
ICES	42,86	Defined as the science, i.e. fish biologists and scientists, who give advice to sustainable use of cod due to MSY	Provide the scientific basis for the EU commission and therefore gives advice to the EU
Tourism	46,15	Including angling tourism, tourism agents, cutter tourism	Excluded from angling tourism
Nature conservation	50,00	Linked to regulations (e.g. for anglers) and measures, e.g. natura2000 areas	Group and its lobby, which stand for to the protection of the environment (in some case: want to have everything out), and do quota recommendation
EU	50,00	Politics on international (=EU) level, i.e. EU commission, council of ministers	Toothless tiger (linked to bureaucracy)
Environmental organization	50,00	Environmental protection associations/ nature conservation lobby who would plead for the lowest quota	Civil society interest group and part of the social contract, i.e. eNGOs fulfill this mission anchored in the social contract
Consumer	57,14	Person who eats fish	Person who eats fish due to quantity (price-orientated)

Angling cutter companies	66,67	Companies (cutters and guiding companies) offering fishing on boat and short	Differentiated from recreational fishery; they are the big losers in this round with no lobby
Demand	66,67	Demand for other fish	Demand for cod by consumers
EU Commission	66,67	EU institution who has an influence on the catch quota by formulating an advice for the tac	European commission, i.e. Directorate-General for Maritime Affairs and Fisheries (DG MARE)
Fishery lobby	66,67	Representation of the fishery, especially on EU level (catch quota) with an economic perspective, i.e. high quotas	Fishery itself as an interest group, i.e. local fishery associations (federal & state) and fishery cooperatives
Junior fisher	66,67	Young fisher in general	Young fisher whose father was already a fisher
Subsidies	66,67	Funding for fishery from politics, i.e. to set up the fishery differently	Given by federal or state politics to allow fishers to fish more than they could from EU
Sustainability	66,67	Social, economic and ecological sustainability	Linked to the factors used by the marine stewardship council (MSC), i.e. impact on species population and habitats
Scientific advice	66,67	Indirect influence on the politics, i.e. science gives advice to politics by measuring cod	Based on research results
Selectivity	66,67	Selective removal of fish	Linked especially to fishing gear, i.e. traps baskets, modified nets
Angling association	75,00	Federal and state level representation of the interests of anglers, e.g. individual clubs and its members	Are part of eNGO, but they are considered differentiated from them
Angling tourism	75,00	Branch of industry (=only tourists) within it is not allowed to sell fish	Economic sector in which recreational fishing is included (=tourism with anglers), i.e. all people who travel to a place to practice angling
Labor market	75,00	Jobs linked to cod fishery, i.e. fisher, restaurants, hotel	Jobs, trainees
Trawl fishery	75,00	Fishery using trawl net, i.a. bottom trawl	Fishery between artisanal fishery and industrial fishery
Politics	80,00	Make recommendation and influence the catch quota, but do not decide rationally	Heterogeneous group acting as legislative body
Protected area	80,00	Areas (e.g. FFH habitats) established by the EU, which are linked to restriction for anglers, e.g. time limit of angling, closed to angling	Linked to the protected good within a specific area with the goal of having a high number of possible species that are in good or favorable condition

Fishing effort	100,00	Opportunity to fish	Measure for the activity of fishing vessels in a given region, i.e. operating time and catching performance and the number of vessels with which this activity is carried out
Acceptance	100,00	Social acceptance, i.e. acceptance of advice and quota by society	Acceptance of research by fishers and recreational fishers
Discard ban	100,00	Ban on discarding fish	Management measure which should give the fishery incentives to use selective fishing gear in order to have a positive effect on cod
Environmental awareness	100,00	Awareness of consumer, which are linked to the shopping for food	Environmental education by non-governmental organizations
Fisheries policy	100,00	Approach of how to manage a fisheries community	Measures implemented in the Common Fisheries Policy and liked to nature conservation policy
Fishery association	100,00	Political representation of the fishery at regional and national level	Follow short economic interests, which is harmful for the fishery itself
Gastronomy	100,00	Restaurants as an important part of the vacation, i.e. good food	Restaurants, which offer drinks and food
Good media coverage	100,00	Good press release	Good press release, i.e. fishery friendly
Health	100,00	The condition of a person	The live setting of a person
MSC	100,00	Marine Stewardship Council	Social player which interacts strongly with fishery
Presumed stock size	100,00	Management measure to determine the catch quota	Description on how big the stock is
Producer organization	100,00	Cooperatives, which have a great responsibility in terms of fisheries economic stability	Cooperatives in general
Regulations	100,00	Regulation as restriction	Specific regulations are named like minimum size, catch areas and closed seasons
Technical development	100,00	Improvement and modification of the fishery due to technology	Development of fishing gear
Tradition custom	100,00	Tradition and culture in general	Fishery as a tradition, i.e. ships in the harbor and sale of fresh fish from the boat

Artisanal fishery	100,00	Local fishery under 12m using fish traps and gillnet (very rarely trawling), which do self-marketing and other financing	Fishery up to 10m and mostly passive
Economic situation fishery	100,00	Linked to the number of fishers and its representatives (lobby)	Linked to the situation of junior fishers, which is defined as a big problem in the Baltic fishery

Supporting Table S4 b. Qualitative analysis of ecological concepts which are described by at least 2 different definitions; variation is exemplified by showing two different definitions (Example 1, Example 2).

Node	**Variation**	**Example 1**	**Example 2**
Prey	31,25	Supply of benthos, small pelagic fish (e.g. herring, sprat), crayfish	Prey for cod
Salinity	37,50	Environmental impact	Linked to salt water inflows by the North Sea and spring storms
Herring	40,00	Fish species	Prey for cod
Oxygen	40,00	Oxygen content in the water	Linked to salt water inflows by the North Sea and spring storms
Temperature	42,86	Climate component	Water temperature of the Baltic Sea
Predation	45,45	Prey on cod, i.e. reduction of cod population by the number of natural predators	Natural predators, i.e. marine mammals (e.g. porpoise, gray seal) and sea birds (e.g. cormorants)
Agricultural runoffs	50,00	Caused by agriculture with monoculture	Agriculture entries, e.g. nitrate or pollutants, occurring from the fertilization of farmland, which lead into algae blooms or eutrophication
Cormorant	50,00	Bird species	Predator in the system and on cod, e.g. cormorant
Ecosystem	50,00	Condition and health status of the Baltic Sea	Biotic and abiotic factors of the ecosystem, i.e. input of nutrients, oxygen content, environmental influences, salt water influx, salinity
Reproduction	50,00	Recruits	Production of offspring linked to ecological factors (e.g. temperature, salt water inflow, bacteria)
Sprat	50,00	Fish species	Prey for cod
Sprat, herring	50,00	Fish species	Prey for cod

Salt water influx	54,55	Biological component, i.e. inflow of salt- and oxygen-rich water from North Sea	Important for the ecosystem
Climate change	57,14	Change of climate over time	Change in temperature and oxygen, i.e. ocean acidification
Other fish	66,67	Baltic sea fish, which have an impact on the system of Western Baltic cod	Predator on cod; most of all sprat and herring on small cod
Porpoise	66,67	Predator on cod	Protected good and predator
Pollution	75,00	Pollutants through fertilization of farmland (e.g. nitrate, mercury) and therefore contamination with fish, i.e. negative effect on the fish liver	Poised fish due to pollutants which turns into health risk for consumers
Eutrophication	75,00	Linked to the influence by zooplankton on the system	Caused by inputs of nutrients
Habitat	75,00	A fixed area by humans	Habitat types, i.e. reefs, sandbanks, FFH habitats, rocky fields
Sea bird	75,00	Predator, i.e. gulls, herons, cormorants, fish eagles	Protected good and predator
Jelly fish	100,00	Species like fire jellyfish and ear jellyfish	Predator on cod eggs

Supporting Table S5 a. Predicted changes per stakeholder group in social and ecological components under the scenario 1 (decrease in cod biomass; NGO=non-governmental organization, ComFish=commercial fishery, RecFish=recreational fishery).

Cat	NGO	%	ComFish	%	Management	%	RecFish	%	Science	%	Tourism	%
Social	Market price	0,15	Consumer	0,01	Control	0,18	Fish processing	0,29	Market price	0,05	Multiannual plans	0,09
	Fish processing	0,02	Labor market	0,01	Angling tours	0,02			Scientific advice	0,03	Nature conservation	0,02
	Sustainability	0,02	Negative media	0,01	Trawl fishery	0,02			Catch (long-term)	0,03	Market price	0,02
	Protected area	0,01	Politics	0,00	Gillnet fishery	0,02			Politics	0,02	CFP	0,00
	By-catch	0,00	By-catch	0,00	Fishery association	0,00			Environmental organization	0,00	Fishery association	0,00
	Cod quota	-0,76	Cod quota	-0,74	Recreational fishery	-0,39	Cod quota	-1,00	Recreational fishery	-0,65	Recreational fishery	-0,44
	Fishery	-0,42	Fishery	-0,25	Fishery	-0,38	Recreational fishery	-0,98	Cod quota	-0,63	Fishery	-0,42
	Recreational fishery	-0,18	Fisher	-0,19	Cod quota	-0,34	Fishery	-0,66	Fishery	-0,50	Angling tourism	-0,40
	Consumer	-0,16	Fishery (side income)	-0,19	Tourism	-0,23	Angling shop	-0,47	Tourism	-0,26	Cod quota	-0,36
	Scientific advice	-0,16	Fishery (main income)	-0,19	Angling cutter companies	-0,21	Value chain	-0,45	Value chain	-0,22	Trawl fishery	-0,22
Ecological	Other demersal fish	0,18	Sprat	0,16	Herring	0,18	Other demersal fish	0,27	Herring	0,35	Herring	0,24
	Benthic macrofauna	0,18			Sprat	0,18	Flatfish	0,27	Sprat	0,34	Sprat	0,07
	Flatfish	0,18			Seabird	0,02	Herring	0,27	Benthic macrofauna	0,33	Other demersal fish	0,04
	Herring	0,02			Porpoise	0,01	Sprat	0,27	Benthic meiofauna	0,33	Benthic macrofauna	0,04

Sprat	0,02			Eutrophication	0,01	Benthic macrofauna	0,26	Whiting	0,16	Flatfish	0,02
Ecosystem	-0,17	Cod eggs	-0,17	Seal	-0,17	Seal	-0,28	Cod eggs	-0,16	Sea bird	-0,33
Seabird	-0,13	Cod larvae	-0,16	Habitat	-0,16	Porpoise	-0,28	Ecosystem	-0,12	Seal	-0,33
Cod juvenile	-0,12	Ecosystem	-0,15					Zooplankton	-0,03	Porpoise	-0,33
Porpoise	-0,11	Herring	-0,01					Environmental impact	-0,02	Nature	-0,01
Seal	-0,11							Cod larvae	-0,01	Temperature	0,00

Supporting Table S5 b. Perceived changes per stakeholder group in social and ecological components under the scenario 2 (increasing cod quota; NGO=non-governmental organization, ComFish=commercial fishery, RecFish=recreational fishery).

Cat	NGO	%	ComFish	%	Management	%	RecFish	%	Science	%	Tourism	%
Social	Fishery	0,93	Fishery	0,80	Regulatory authorities	0,49	Recreational fishery	0,95	Fishery	0,75	Angling tourism	0,82
	Recreational fishery	0,55	Recreational fishery	0,67	Artisanal fishery	0,44	Fishery	0,94	Catch (short-term)	0,41	Fishery	0,81
	Relative stability	0,41	Tourism	0,44	Fishery (middle sector)	0,44	Angling shop	0,71	Economic situation fishery	0,35	Recreational fishery	0,81
	Artisanal fishery	0,37	Catch amount	0,35	Fishery (deep sea fisheries)	0,44	Value chain	0,64	Consumer	0,33	Value chain	0,76
	Science	0,12	Allocation quota	0,35	Diversity of touristic supply	0,42	Utilization	0,60	Tourism	0,14	Angling shop	0,64
	Consumer	-0,10	Science	-0,39	Angling tourism	-0,47			Market price	-0,46	Market price	-0,57
	Protected area	-0,09	Consumer	-0,05	Brands draft horse Baltic sea	-0,11			Catch (long-term)	-0,41	Nature	-0,36

	Fish processing	-0,08	Human	-0,04	Training, school	-0,08			Recreational fishery	-0,35	Environmental organization	-0,26
	Scientific advice	-0,07	Scientific advice	-0,03	Gastronomy	-0,05			Health	-0,08	Nature conservation	-0,09
	Sustainability	-0,07	Labor market	-0,02	Niche	-0,04			Politics	-0,06	Tradition, culture	-0,02
Ecological	Other demersal fish	0,04	Sprat	0,04	Herring	0,08	Other demersal fish	0,20	Benthic macrofauna	0,16	Flatfish	0,67
	Benthic macrofauna	0,04			Sprat	0,08	Benthic macrofauna	0,20	Benthic meiofauna	0,16	Herring	0,67
	Flatfish	0,04					Flatfish	0,20	Sprat	0,09	Other demersal fish	0,18
	Age structure	0,03					Herring	0,20	Whiting	0,08	Benthic macrofauna	0,18
	Agricultural runoffs	0,01					Sprat	0,20	Herring	0,06	Sprat	0,08
	Cod	-0,99	Cod	-0,58	Cod	-0,90	Cod	-1,00	Cod	-0,97	Cod	-0,83
	Porpoise	-0,17	Cod eggs	-0,04	Habitat	-0,12	Seal	-0,20	Ecosystem	-0,08	Nature	-0,80
	Seal	-0,14	Cod larvae	-0,04	Seal	-0,10	Porpoise	-0,20	Cod eggs	-0,08	Seabird	-0,73
	Ecosystem	-0,12	Ecosystem	-0,04	Seabird	-0,05			Undisturbed spawning	-0,03	Seal	-0,73
	Seabird	-0,10	Herring	0,00	Porpoise	-0,02			Zooplankton	-0,01	Porpoise	-0,73

Supporting Table S5 c. Agreement of dynamic changes across stakeholder groups as a result of (a) Decreasing cod and (b) Increasing cod quota.

	Increasing cod quota		**Decreasing cod**	
#Groups	Social	Ecological	Social	Ecological
1	Regulatory authorities Fishery (middle sector) Fishery (deep sea fisheries) Diversity of touristic supply Utilization Catch amount Allocation quota Relative stability Catch (shortterm) Economic situation fishery Brands draft horse Baltic Sea Training, school Gastronomy Niche Human Labor market Protected area Fish processing Sustainability Catch (longterm) Health Politics Multiannual plans Environmental organisation Nature conservation Tradition, culture	Age structure Agricultural runoffs Benthic meiofauna Whiting Habitat Cod larvae Undisturbed spawning Zooplankton Nature	Control Angling tours Gillnet fishery Nature conservation Labor market Negative media Sustainability Protected area Catch (longterm) Environmental organisation Multiannual plans CFP Angling cutter companies Angling shop Fisher Fishery (side income) Fishery (main income) Angling tourism	Eutrophication Temperature Benthic meiofauna Whiting Habitat Cod juvenile Zooplankton Environmental impact Nature
2	Artisanal fishery Angling shop Value chain Tourism Science Angling tourism Scientific advice Market price	Cod eggs	Trawl fishery Fishery association Fish processing Consumer Politics By-catch Scientific advice Tourism Value chain	Cod eggs Cod larvae
3	Consumer	Other demersal fish Flatfish Sea bird Ecosystem	Market price	Flatfish Ecosystem
4		Benthic macrofauna Seal Porpoise		Porpoise Other demersal fish Benthic macrofauna
5	Recreational fishery Fishery	Herring Sprat	Recreational fishery	Sea bird Seal
6		Cod	Fishery Cod quota	Herring Sprat

Supporting references

Giabbanelli, P. J., Gray, S. A., & Aminpour, P. (2017). Combining fuzzy cognitive maps with agent-based modeling: Frameworks and pitfalls of a powerful hybrid modeling approach to understand human-environment interactions. *Environmental Modelling & Software*, 95, 320–325. doi:10.1016/j.envsoft.2017.06.040

Gray, S. A., Zanre, E., & Gray, S. R. J. (2014). Fuzzy cognitive maps as representations of mental models and group beliefs. In Fuzzy cognitive maps for applied sciences and engineering, 29–48. *Springer*

Halbrendt, J., Gray, S. A., Crow, S., Radovich, T., Kimura, A. H., & Tamang, B. B. (2014). Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture. *Global Environmental Change*, 28, 50-62. doi:10.1016/j.gloenvcha.2014.05.001

Harmati, I. Á., & Kóczy, L. T. (2019). Notes on the Dynamics of Hyperbolic Tangent Fuzzy Cognitive Maps. *2019 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE),* 1–6. doi:10.1109/FUZZ-IEEE.2019.8858950

Jetter, A. J., & Sperry, R. C. (2013). Fuzzy cognitive maps for product planning: using stakeholder knowledge to achieve corporate responsibility. *2013 46th Hawaii International Conference on System Sciences*, 925–934. doi:10.1109/HICSS.2013.238

Jetter, A. J., & Kok, K. (2014). Fuzzy Cognitive Maps for futures studies—A methodological assessment of concepts and methods. *Futures*, 61, 45–57. doi:10.1016/j.futures.2014.05.002

Papageorgiou, E. I., & Salmeron, J. L. (2014). Methods and algorithms for fuzzy cognitive map-based modeling. In Fuzzy cognitive maps for applied sciences and engineering, 1–28. *Springer.* doi:10.1007/978-3-642-39739-4_1

Stylios, C. D., & Groumpos, P. P. (2004). Modeling complex systems using fuzzy cognitive maps. *IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans*, 34(1), 155–162. doi:10.1109/TSMCA.2003.818878

Vasslides, J. M., & Jensen, O.P. (2016). Fuzzy cognitive mapping in support of integrated ecosystem assessments: Developing a shared conceptual model among stakeholders. *Journal of Environmental Management*, 166, 348-356. doi:10.1016/j.jenvman.2015.10.038

Voinov, A., Jenni, K., Gray, S., Kolagani, N., Glynn, P. D., Bommel, P., … Smajgl, A. (2018). Tools and methods in participatory modeling: Selecting the right tool for the job. *Environmental Modelling & Software*, 109, 232–255. doi: 10.1016/j.envsoft.2018.08.028

STUDY III
The 'Cod-Multiple': Modes of Existence of Fish, Science and People

sustainability

Article

The 'Cod-Multiple': Modes of Existence of Fish, Science and People

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Abstract: Fish represent a politically regulated, scientifically researched, industrially processed, commercially marketed and socially contested living marine resource. Related to this, the incorporation of resource users and stakeholders into fisheries management is particularly important. Such involvement has recently improved in terms of frequency, but institutional frameworks often result in a lack of recognition and integration of the diverse 'knowledges' of stakeholders involved. Against this background, we aim to uncover the potentials of additional knowledge types for management purposes, paving the way toward a more collaborative management. We first conducted qualitative expert interviews with different stakeholder groups (e.g., commercial fisheries, eNGO and administration) to map various 'knowledges' about cod (*Gadus morhua*), a major resource species in the Western Baltic Sea to reveal the various experiences and epistemologies revolving around it. The second analytical step consisted of examining how these 'knowledges' structure, inform and often enter into conflict with perspectives on and assessments of fisheries management. Potentials were identified regarding enhanced stakeholder engagement in management processes that provide food for thought to seek change in sustainable management of fish stocks in the future. Our study is a pointer to the need to transform fisheries management in a more social and participatory way. We argue that sustainable natural resource management cannot be designed solely by integrating more 'knowledges' (knowledge sharing) but requires the creation of social contexts and institutions with stakeholder empowerment at the local level (power sharing) to sustainably manage natural resources such as commercially importance fish stocks.

Keywords: Baltic Sea; fisheries management; cod; stakeholder participation; interviews; knowledge types; qualitative content analysis; co-management

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1. Introduction

Fish is a living marine resource that is politically regulated (management), scientifically researched (advice to inform management), industrially processed and commercially marketed (sales to restaurants, supermarkets and auctions) but also socially controversial (resource and spatial conflicts). The interaction of interest groups and resource users (referred to as stakeholders), their institutional rationales and the respective 'knowledges' (encompassing the multiplicity of various knowledge types) produced about and revolving a fish species have developed into existing management approaches and regimes. These, in turn, are constantly shaping and reshaping the relationship between fishing communities, fishing industry, scientists, institutional representatives, political stakeholders and regulating bodies. More importantly though, they are in many cases based on a normative and enacted understanding of what fish actually is. However, there is not only one but rather various framings of 'knowledges' and representations of fish, turning it into a messy multiplicity.

This messy multiplicity of the resource fish is in many cases reduced to the rationale of natural resource governance aiming at regulating human behavior [1]. Embodied in laws, assessments, interventions and prohibitions, the regulation of the removal of fish is based on the basic presupposition that human actions negatively affect nature [2]. There is, however, the epistemological problem that fish is not directly or fully graspable for humans. Turning it into a manageable and governable entity requires acts of classification as well as processes of justification. In most cases, these are relegated to science defining and legitimating all sorts of interventions and regulations [3]. For this to be performed, specific scientific techniques and procedures are used to assess, organize, translate and define what fish actually is [4]. Once measurements, quantifications and model runs have been gathered, the fish is re-assembled and reified as a somewhat homogeneous object [5]. Thereby, fish is reduced to a powerful scientific mode of existence that legitimates the creation of concrete management [3].

Such interventions are not uncontroversial, which has recently led to reshaping the research agenda in marine and fisheries management. Traditionally seen, people have been framed as the key drivers for negative impacts representing their activities as one of the most pressing challenges for the sea and its fish stocks [2]. This perspective underwent change partially due the increasing role of external environmental stressors on fish populations [6]. Examples include the expected implications of climate change, while the growing relevance of communities, interest groups and resource users in developing solutions has also continuously been acknowledged [6]. Hence, the concepts of environmental stewardship, citizenship [7,8] or marine citizenship [9] have been taken up. Here, emphasis has been placed on the relevance of non-scientific ocean knowledge in re-assessing scientific approaches while at the same time enlarging the scope of management interventions [10].

For society, communities [11] or social stakeholders to be conceived as an important part for developing marine management options, a relational approach has been considered to be of particular relevance. Simply put, such an approach investigates the various ways through which people and the sea relate to each other which is for example emphasized in the context of co-designing options for the exploitation of natural resources [12]. This understanding reveals and provides insight into the multiplicity of perspectives through which the various dimensions of the multifaceted 'relationality' between human beings and the sea could be studied. Consequently, methodological, theoretical and practical approaches have been explored. These, for example, focused the attention on (i) the social dimensions of management options [13–15], (ii) the perception of different stakeholder groups [16,17] and (iii) the framing of fishers with regard to management structures and measures bearing an impact on their everyday lives [18]. Moreover, the research on ocean literacy characterizes approaches in the area of local ocean knowledge disclosing the aspect that these dimensions could considerably contribute to ocean citizenship and stewardship, including other interest groups or resource users such as fishers [19].

Besides these more general aspects addressed, additional specific aspects such as varying epistemologies as a barrier for integrative research have only recently gathered attention [20]. The co-construction and implementation of differing 'knowledges' in the context of management have been defined as an important task [21], although approaches of this kind appear to be still at the beginning. Based on the insight, that various disciplines and social groups produce and hold differently structured 'knowledges' about fish and fisheries [22,23], relatively new research has focused on understanding what presuppositions underpin this knowledge, how this knowledge is produced and in what ways it is conceived to be applicable in the context of governance and management [20]. Discussions of robustness, adequacy and legitimacy accompany the discussion about non-scientific 'knowledges'. However, objective scientific knowledge also supposedly came under scrutiny [24]. This critical perspective on the epistemilogicization has fueled co-constructive management approaches [25], among which the co-development of qualitative models [26] or mental mapping procedures [17] represent more recent approaches.

The problem with co-management approaches including differing 'knowledges' and procedures lies in the fact that they were regarded as a panacea for solving problematic aspects of governance and sustainable management [27]. The acknowledgement and incorporation of local 'knowledges' is, however, still thwarted by the sometimes underlying rationale of evidence-based management approaches, the extension of scientific epistemologies and the maintenance of their implicit objectivist rationales (see for an early assessment [28]). A critical investigation of this dimension is still missing in many cases and touches upon the prevailing assumption that social life is determined by deep social structures which underlie and rationally regulate "[. . .] the seemingly chaotic world of [the] social [. . .]" ([29], p. 382). This understanding was challenged by approaches that frame the social as an assemblage or formation as based on social practice. These approaches reckon practices as processes that assemble or network—in our case—fish, fishers, the fishing industry, scientists, politicians, etc., together. Focusing on the social to provide better management options thus promotes an important shift from the why (deep cause) of social formations and framings to the how (surface processes). In brief, the focus of research is taken away from uncovering the deep and governing structures toward a more dynamic understanding in terms of social networks or assemblages. In doing so, it could pave the way toward a more inclusive and symmetric way of managing fish [30].

For this to be achieved, a critical inspection of the scientifically informed discourses revolving around fish is necessary. Such an investigation of the problem framing puts emphasis on the messiness [31] of fish discourses. This would mean that one has to reveal the many human practices and 'knowledges' that create and re-create fish [32]. These processes indicate how fish is framed by various stakeholders and how fish, humans and science are woven together in specific ways and contexts [33,34]. Such an understanding strongly contrasts with current approaches in which fish is framed in specific—mainly scientific—ways and becomes a governable and manageable object.

These procedures and ways of conceptualizing fish often obtain a truth-like social status which is questionable. There is no independent fish from the world 'out there', but only socially embedded theories and models constructed about it. Hence, fishers, scientists or politicians do not describe the world from a neutral point or perspective, they rather engage with it specifically and thereby shape it. Such a shift from decontextualized thinking (epistemology) to a situated engagement (ontology) and generation of knowledge represents a challenging step. This affects fishing practice and introduces new regimes of control. What becomes apparent is the fact that this construction of fish is stabilized and networked into a regime by "[. . .] tying fish with fishermen, echo integrators, log books, legislation, computers, bureaucracies, mathematical formulas, and surveillance procedures" ([35] p. 239). The same holds true for stock assessment models: "they move fish from the water [. . .] to the paper of reports and policy" ([36] p. 1017), framing them as swimming inventories of future biomass and economic value [37]. Clearly, decontextualized scientific or political abstractions of fish contrast contextualized human–fish relations [38]. The question consequently remains which knowledge type has to be considered as relevant and for what reason?

Western Baltic (WB) cod (*Gadus morhua*) is one of these fish (stocks) that is politically regulated, scientifically researched, commercially marketed and socially contested. Because of its depleted stock status, this fish stock is presently of special concern and debate among fishers, scientists, environmental conservationists and politicians [39]. WB cod is ecologically important as a top-predator in local food web dynamics [40] but is also an economic asset (e.g., for jobs or tourist facilities such as fish restaurants) for coastal areas in Germany [41]. Moreover, from a cultural point of view, cod has a special status at the WB coast because commercial fisheries here have a long tradition and culture that is anchored in and strongly attributed to cod (a description of stock assessment details can be found in Supplementary Material). The WB cod case is a typical example of a conflict over the state and the right management measures to recover a depleted fish stock while safeguarding the social system depending on it not only in the EU. At the same time, it becomes apparent that there is not one but different framings, 'knowledges' and representations for WB cod, making it a confusing diversity or, as we call it, a 'cod multiple' [12,31,42].

Deconstruction, the critical analysis of discourse in terms of knowledge orderings and the insight that humans are enmeshed [43] with the world, opened up a perspective in which the complexities of the social revolving around fish can come into view. Understanding fish, humans and science as entangled [44], we now take the turn to investigate the forms of 'knowledges' revolving around WB cod and its current management. 'Knowledges' here encompasses multiple forms of 'knowledges', which are informed by different rationales. Examples include evidence-based knowledge (e.g., collected by established surveys to determine the distribution of fish stocks) and tacit knowledge (knowledge generated through job-related interaction with the ecosystem, i.e., fishers' ecological knowledge). We here follow the diverse 'knowledges' held by various groups, meaning commercial fisheries, science or environmental non-governmental organizations (eNGOs) with the aim to reveal its complexities and multiplicities. Our analysis eventually aims to understand how ignoring specific knowledge types potentially causes conflicts in fisheries management. We propose how different 'knowledges' can be integrated to regain the trust of stakeholders in the decision-making process.

2. Materials and Methods

To empirically and qualitatively study the 'knowledges' revolving around the management of WB cod, we applied an interconnected sequence of methodological steps (Figure 1, consisting of data collection, coding and data analysis). At its core, this is based on conducting and analyzing expert interviews. With this approach, we were able to uncover the diverse 'knowledges' revolving around WB cod as well as its local, national and supranational background [45].

2.1. Data Collection

We initially conducted a systematic in-depth reading and content-oriented document analysis of a wide variety of written sources comprising the news coverage in German newspapers of the last 10 years, as well as recent political and governmental documents (e.g., Common Fisheries Policy) [46] (Figure 1A). In addition, we analyzed published opinions, reports or written statements of the various stakeholder groups regarding the issue of WB cod, its fisheries, and the problems surrounding it [47]. In addition, we studied project reports as well as scientific publications to gather various perspectives on the multiple issues associated with the cod resource [48–51]. This first step helped us to reconstruct and understand the developments, disputes and discourses pervading the so-called 'cod-controversy' persisting between different groups involved in the management.

Based on the media analysis (Figure 1A), which served as a thematic background analysis on cod fisheries in the Western Baltic Sea, an interview guide was developed and tested during two sample interviews [52] (Figure 1B). A previous scientific analysis of German newspaper articles on WBS fisheries revealed a high media presence (i.e., absolute frequency) of the topics ecology, management, economy and communication within the news coverage. These were selected as thematic building blocks of the interview guide (Table 1).

The interview guide included questions about the current condition of WB cod, elaborating on causes for this situation and discussing possible solutions in terms of various national and EU-wide management options (Table 1). Economic as well as social impacts regarding WB cod fisheries and its management were also addressed (Table 1). At the end of each interview, all interviewees were given the opportunity to reflect on the future development of WB cod within the coming years. Likewise, space was provided for further aspects not addressed in the interview (Table 1; all interview questions are listed in detail in the Supplementary Material Table S1).

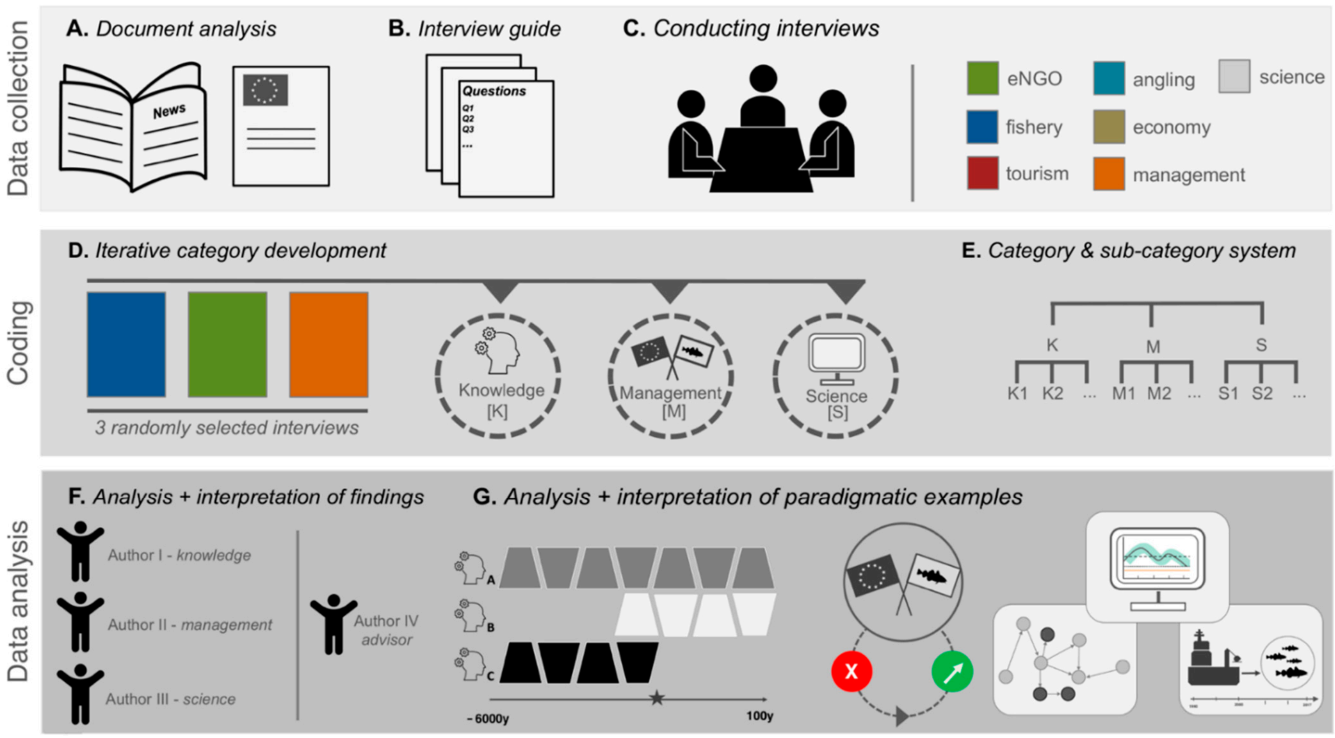

Figure 1. Illustration of the applied methodological procedure including data collection, coding and data analysis. (**A**) A systematic in-depth reading and content analysis of a variety of different written sources was conducted, including news coverage in newspaper databases as well as political and governmental documents. (**B**) An interview guide was developed including questions related to ecology, management and economy of WB cod and the communication between stakeholders. (**C**) Each interviewee was provided with the interview guide a week in advance and was walked through the guide at the beginning of the interview. All interviews were carried out by two to four interviewers and have been transcribed verbatim. (**D**) To start the analysis, three interviews of different stakeholder groups were separately read and discussed for general content, key issues and unexpected, emerged topics. Interview calibration confirmed a set of three main themes: 'knowledge' of WB cod, role of 'science' in the disputes, and perceptions and critiques of the EU fisheries management. (**E**) Categories were applied to all interviews resulting in a category and subcategory system. (**F**) After the completed interview coding, each of the three categories was assigned to one author conducting an in-depth analysis. (**G**) The data provide a deep insight into the diversity of knowledge types in time and structure, perceptions and descriptions of fisheries management, and scientific use of models and their underlying data collection form.

Table 1. Description of thematic blocks addressed during the interviews.

Thematic Block	Description
Ecology	Understanding and knowledge of the ecology of the Western Baltic Sea in general and of WB cod in particular; identification as well as description of abiotic and biotic factors influencing the system
Management	Understanding of European fisheries management and description of different measures; outlining the criticisms of fisheries management in general and description of the effectiveness as well as consequences of different measures
Economy	Description of economic links concerning the commercial fishery as well as economic effects of management measures on the regions of Schleswig-Holstein and Mecklenburg-Vorpommern
Communication	Perception of communication and description of the current involvement of different groups in fisheries management and ideas for improving the current situation

Using purpose sampling strategies, relevant stakeholders were selected on the basis of (i) the first authors knowledge, (ii) a desktop study of relevant institutions and (iii) the aforementioned analysis of German newspaper articles [53,54]. Interviewees were selected using two key criteria: stakeholders needed to (i) be associated with a German institution dealing with commercial fisheries by either their job or honorary position and to (ii) have been involved in the WB cod fisheries for more than 5 years. The latter criterion was chosen as a reference point to ensure that interviewees had established themselves in their professional position (job, volunteer) and are familiar with the subject of WB cod fisheries over a relevant period of time. All interviewees selected act as managers or working group leaders (of their associated institution), which guaranteed their content-related immersion into as well as their expertise about the topic of WB cod fisheries (Table 2). Furthermore, interviewees were chosen with regard to their role in the discourse revolving around WB cod, their political, administrative or professional function while they differed in terms of gender and educational level representing a great variety of stakeholders involved in the disputes.

Table 2. Stakeholders from seven different groups were interviewed on the topic of ecology, EU fisheries management and economy of Western Baltic cod fisheries (eNGO = environmental non-governmental organization).

Stakeholder Group	Description	%
Fisheries	Representatives of the German commercial fisheries and head of the fishery cooperative, i.e., political representation of the fisheries and communication of management measures to the fishers	2
Economy	Representatives of the German fishing industry with focus on consumer information	1
Administration	Officials focusing on catch quotas and fisheries management at federal and state level	2
eNGO	Representative working on marine conservation (with a focus, e.g., on catch quotas and environmental education) on international, national and regional level	3
Angling	Representative of the German recreational fisheries with, e.g., tasks of communication of political regulations as well as nature conservation projects	1
Scientists	Researchers with focus on fish stock assessment, Baltic cod ecology and recreational fisheries	3
Tourism	Association members with focus on the promotion of angling tourism at regional level	1

In total, we selected 13 stakeholders of seven different groups comprising commercial and recreational fisheries, eNGO, tourism, economy, administration and science (Table 2, Figure 1C). To allow for content-related preparation, the interview guide was provided to the interviewees one week in advance. Before each interview, information on the respective interviewee (institution, person) was gathered to gain background knowledge and to prepare interviewers. To maintain a good interview atmosphere, interviews were conducted at places chosen by the interviewees [55] and started by asking questions about the individual expertise of the interviewee. All interviews were carried out by a minimum of two, maximum of four interviewers (period: 2 November 2017–18 May 2018), lasted between 45 min and 2 h and were transcribed verbatim.

2.2. Data Analysis

To zoom in on the analysis, we chose a qualitative approach including a re-screening of relevant documents to begin with [56]. This perspective held the potential to disclose the somewhat unconscious patterns of interpretation and meanings permeating the varying perceptions and assessments of the cod problem at work in the disputes [57].

In a first analytical round, three interviews of different stakeholder groups were separately read and analyzed by three authors (HS, AMB, MD) of this paper. The selected interviews were discussed in terms of general content, key issues and unexpected topics that emerged during the provisional analysis (Figure 1D). The outcome led to the decision to analyze all interviews from a grounded point of view [58,59]. This approach offers the opportunity to inductively develop analytical categories and holds the potential to avoid as far as possible preconceptions or circular reasoning based as on unarticulated or unconscious presuppositions by the analyst. Hence, once central themes or topics emerged, segments of the interviews transcribed were individually grouped in preliminary analytical categories. These bottom-up categories were discussed in a step-by-step approach among three authors (HS, AMB and MD) to assess their general meaning, analytical plausibility and empirical relevance for the study. This procedure contributed to calibrating the coding of all interviews resulting in a corroborated set of three main topics of interest [60]: 'knowledges' about WB cod in terms of ecology and economy, the role of science in the disputes and the perception and criticism of respective management approaches (e.g., catch quotas) (Figure 1E). For further coding and categorization, simple tables were used in which text segments, their interpretation with a focus on the language used, the explanatory ascription to a category and the interview reference plus line numbers of the respective transcripts were entered. All categories were constantly discussed between the three authors to secure intercoder reliability.

Once the three endpoints, knowledge, science and management, were analytically established, each of these categories was assigned to one of the three authors performing an in-depth analysis of one of these overarching categories (Figure 1F). Respective subcategories were defined using an inductive approach which means that main categories were defined beforehand and corresponding subcategories were developed during subsequent analyses from the material [61]. Subcategories were developed step by step, i.e., general units were grouped during reading and, if possible, categorized in the process of re-reading the selected segments (see Supplementary Material Table S2a,b, S3 and S4). All developed subcategories provide a meaningful and empirically sound analysis of the three categories of knowledge, science and management. As a result, the analysis provided a fine-grained insight into the multifaceted and dynamic processes of social meaning making with regard to the structure of controversies revolving around the current fisheries management of WB cod.

3. Results

Overall, our comprehensive analysis of the interviews revealed a large number of different subcategories, which were assigned to the three main categories knowledge, science and management (see Supplementary Material Tables S2a,b, S3 and S4 for a detailed description of all subcategories). These represent to a large extent the complexity of the data gathered and give a deep insight into the meaning structure of the topic (Figure 2). Of particular importance is the description and analysis of the WB cod stock (further referred to as cod), the perception and attributed role of science, and the evaluation of current management measures, with specific attention to the prevailing problems and its potential for improvement (Figure 2). In the following section, selected interview excerpts are translated from German (interview language) into English.

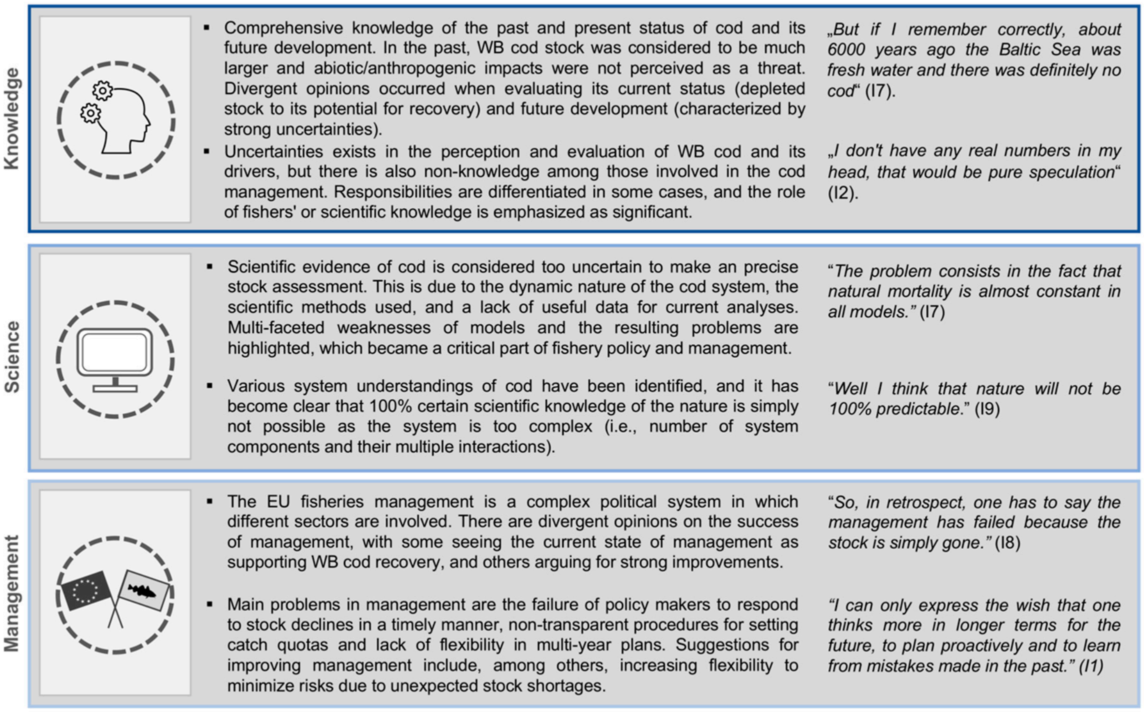

Figure 2. Overview of the results deriving from the comprehensive analysis. The three main categories of knowledge, science and management are expressed according to selected subcategories, focusing on the complexity of cod, its fisheries and management. Of particular relevance are the description cod in the past, present and future, the perception and attributed role of science, and the evaluation of current management measures, its problems and potential for improvement. The description of each category is complemented by meaningful quotes from the interviews conducted.

3.1. Knowledge

In general, the category knowledge includes all content that can be traced back to the knowledge of the interviewees and is not ostensibly related to the categories management or science. From the text, we have developed subcategories that either have a local reference (e.g., local knowledge) or focus on a temporal component (e.g., historical and future knowledge), and also represent situated knowledge of individual stakeholders in the system such as fishers or anglers (for a detailed description of assigned subcategories see Supplementary Material Table S2a,b). To gain a detailed insight into the subject of cod, we further focus explicitly on the stock in different time periods. Based on our interview analysis, it became apparent that the general assessment of the cod stock strongly relies on a threefold distinction made between historical and future knowledge and the description of its current state. The consideration of these three dimensions with their implicated temporal dimensions refers to the importance of a detailed presentation analyzing the various knowledge types separately and in a differentiated manner.

3.1.1. What We Know—The Past, Present and Future Cod Stock Status under Review

1. Historical knowledge

In both, their perception and description of the past state of the cod stock, interviewees not only refer to different time periods but also explicitly to stock characteristics such as biomass or recruitment (i.e., individuals added to the exploited component of a stock). In this regard, we detected a wide range of reference periods from only two years up to several thousand years in the past as well as different temporalities (e.g., biological, institutional temporality).

The greatest reference time of 6000 years was used to express that "the Baltic Sea was roughly fresh water and there was certainly no cod there" (I7). By using a biological temporality, the interviewee reflects an evolutionary change of the Baltic Sea ecosystem and expresses his knowledge regarding the cod's salinity preference. The interviewee is not concerned with describing the size of the stock or its individual characteristics such as recruitment, rather he wants to show that cod was not always present in this ecosystem due to its physiological characteristics. In addition, using a biological temporality, there is a description of the past size of cod during spawning, which "used to spawn at 70 cm, 70, 80 cm." (I10). Reference is made to the change in spawning size in general, as well as to the exact length during past spawning.

However, the interviewees do not only use the physiological characteristics of cod to describe its past condition. Rather, as the following example shows, they refer to its occurrence as a food source for the community, which is here placed in relation to its stock size.

> "People always like to talk about the breadwinning fish of the region. Well, there were times when you probably got a choking feeling when there was cod again, people would say, or children would say: Not cod again. And there was always cod, because it was there in masses." (I10)

The use of a social temporality very much reflects the interviewees' knowledge regarding past cod biomasses, which were so high that cod metaphorically tended to be equated with "a choking feeling" (I10).

However, if the past relates to a shorter reference period such as a few "decades" or even fewer years, interviewees primarily refer to an institutional temporality, meaning reference periods directly linked, in our case, to the fisheries management. When interviewees describe past cod stock conditions to a period such as "the last decades" (I10), this is performed by using the exact reference value at which time the stock had both high biomass values and "very high recruitment years" (I2). This institutional temporality is used by the interviewees to show a contrasting state of the cod stock, compared to the current one, from a management perspective. The same temporality applies when interviewees consider shorter time references such as "the last years" (I8) to make direct reference to recruitment in 2015 and 2016 in particular, or to define "recruitment has been poor [in general] the last few years" (I8). More specifically, the 2016 recruitment was an "exceptionally strong cohort" (I5) and a "reason for hope" (I11), while the "[20] 15 was even historically the worst ever" (I13). However, there are also "people who doubt that the [20] 15 really failed" (I7).

Both the ecological conditions (biological temporality) such as the state of the Baltic Sea and anthropogenic influences such as fishing pressure or nutrient inputs are used by the interviewees to express historical knowledge about cod. One interviewee even refers to "the highest cod stocks" (I9) at a time when phosphorus inputs into the Baltic Sea were among the highest. Interestingly, nutrient input is not described as a limiting factor for marine fish species. Rather, the increased high nutrient levels lead to increased fish biomasses.

2. Knowledge on present cod stock

However, in order to present a comprehensive understanding regarding the assessment of the cod stock, the perception and description of the current status are also key, here focusing on the biological and tacit knowledge only. Diverging opinions across interviewees are present, ranging on a continuum from "worried" (I12) to strong assumptions of a rapid recovery of the stock. In terms of very low stock level, the cod stock is described as currently "close to collapse" (I8), indicating very low recruitment as well as low biomass values. The latter is particularly evident in the curves after which the stock has "gone very, very much into the cellar" (I10). The following example also uses this metaphorical representation "in the cellar" to highlight the very poor stock conditions of cod.

> "Overall, this is a difficult water for marine species because of the low salt content, and in the case of cod it is impossible because the stock is simply in the cellar, and it always takes them two or three years, if a good recruitment is achieved, for them to grow in biomass." (I8)

Furthermore, stock condition is strongly distinguished from a former "golden age" (I13), which symbolically refers to past positive periods with higher biomasses and strong recruitment. The current situation is that the stock "is basically no longer economically exploitable. It has reached one of the lowest spawning biomasses we have ever had [and] [i]s deep in the red" (I4). Not only in this example is the color red used to symbolized the very poor condition of the stock. In addition, "[t]he size distribution tends towards smaller cod" (I13), which again indicates that the overall stock is currently not in a good state. Some interviewees go even further by saying that the "existence is definitely at risk" (I8), while framings on the present stock status vary. A contrasting positive assessment is generally linked to the 2016 recruitment leading to a predicted stock recovery.

> "So, we were very, very happy in spring when we got the first information about the evaluation from 2016, that this is going into the right direction." (I13)

Interviewees also describe the development toward the current state as "pure luck" (I4) and again refer to the uncertain predictability of the recruitment and the stock in general. However, cod is also characterized by its biological properties which allows assumptions to be made regarding its future development. This includes a description of as a migratory fish species meaning its non-stationary habit and ability to move over long distances, resulting in mixing with the eastern stock.

> "The cod is not necessarily stationary, it is also always looking for the same structures, which is why it is important to say that reefs, for example, need to be generally protected. But then the cod will migrate and at some point, it will be somewhere else, it can migrate for many kilometers." (I12)

The broad adaptability of the cod stock, as to different salinity levels, is seen by interviewees as an advantage with regard to future changes in abiotic factors, i.e., there is no "risk of losing this stock or the species" (I7).

A closer look at the past of WB cod described by the interviewees highlights that the stock has not only undergone an evolutionary change according to its size during spawning, but that in the past, the stock was so large that even the community experienced vomiting stimuli. In addition, special mentioning should be made of the cod's recruitment, which was one of the worst in the time series in 2015, while recruitment in 2016 was so strong that it had the "potential to at least extremely accelerate the stock build-up" (I11). A strongly divergent opinion emerged when looking at the current state of the cod. It is "pure luck" (I4) that there was such a strong new cohort, and the current development is rather a cause for concern and the stock "close of collapse" (I8). Furthermore, consideration of the current status already gives indications of its future development—for example, a development toward a smaller cod population is assumed (I13).

3. Future knowledge

Considering the future of WB cod, different time horizons were also used by interviewees compared to historical knowledge. It is important to note, however, that estimates are usually not made for exact years.

According to one interviewees and his/her use of a biological temporality, "[cod] will never die out" (I8), only if "no more salt water comes in at all and the Baltic Sea becomes a freshwater lake, then it will no longer be there" (I7). Here, again, reference is made to the state of the Baltic Sea ecosystem and a possible extinction of cod in view of its preference for saltwater. The following example also picks up on the biological endangerment of the stock but, compared to the other statements, gives a clear statement about the time reference:

> "And whether this will be the case again in 5 or 6000 years, who knows? But with the manageable horizon of 100 years, which we always roughly take, I don't really have the worry that the cod will become extinct biologically." (I7)

Furthermore, in an attempt to make a statement about a possible future development of the stock, explicit reference is made to the strong recruitment in 2016 (institutional temporality).

> "If it goes somewhere, it's more likely to go up, how much this step actually goes up now, through the 2016 cohort, you have to see. But it's not like they say it's

> rock bottom and we don't see any light at the end of the tunnel at all, but there are actually gateways that somehow seem to be opening up right now" (I5).

The images "light at the end of the tunnel" and "gateway" strongly imply a dynamic development in the context of stock condition. A clearly positive development of the stock is predicted but also an indefinite time reference, meaning that it is not foreseeable when the "tunnel" will be crossed. "But the perspective [regarding the spawning stock biomass] is at least good" (I4). This is contrasted with prognoses that do not assume that "this good recruitment will actually occur" (I8). It can thus be seen that the perception of this development diverges among interviewees, giving a clear indication of existing uncertainties of future stock conditions.

There is also considerable uncertainty about the factors affecting the cod stock such as temperature or North Sea inflow events (biological temporality) determining the perception of an uncertain stock development (institutional temporality).

> "And that is the great danger, so I see the greatest risks in these factors. They can go in all directions. It is possible that the stock recovers drastically and then there is too little food, which has an impact on other habitats. But it is also possible that it will collapse completely again. And we cannot foresee this." (I1)

The future perspective on stock conditions is characterized by uncertainties strongly reflected by the use of mostly no time indications. All interviewees assume that WB cod will "never die out" (I8), yet the perception of its future development is characterized by diverging opinions. While on the one hand "light [is seen] at the end of the tunnel" (I5), on the other hand, it is clear to the interviewees that there is no good recruitment in sight.

Stakeholders not only have a comprehensive knowledge of the cod's past and present condition but also an anticipation of its future. Historically, cod was conceived as much larger in terms of its biomass, and there was mostly a consensus on its good historical status among interviewees. Abiotic or anthropogenic impacts were not perceived as posing a threat to the state of the cod, and even from a social perspective, cod was highly abundant, as its status as a valuable food source was not comparable to today. Diverging opinions emerge when looking at the current stock status, ranging from a depleted stock to its potential for recovery. Above all, the evaluation of recruitment plays a significant role on all time levels. The 2016 cohort is under special scrutiny and determines the opinions of the interviewees not only about the present stock state but also about its future development. The latter is most strongly characterized by uncertainties and shows a high variability in the perception and assessment of the interviewees.

3.1.2. What We Do Not Know–Exploring the Diversity between Uncertainties and Non-Knowledge

The interviewees' knowledge is reflected in many different types, ranging from local and tacit knowledge to biological or economic knowledge. However, our comprehensive analysis of the interviews also shows that the perceptions and descriptions of cod and its surrounding factors are subject to uncertainties and even explicit non-knowledge (see Supplementary Material, Table S2a for a detailed description).

The following quote serves as a very appropriate introduction into the discourse of diversity between uncertainty and non-knowledge, clearly demonstrating the existence of knowledge constraints in the context of WB cod, including various impacts on the stock such as abiotic and biotic variables.

> "What we might have to say about this is that, of course-interestingly, cod that is economically so important, but actually we have the least information if we are honest." (I1)

The interviewee is aware of great economic importance of cod but also states that limited information is available about it in general. This "least information" suggests not only existing uncertainties but also non-knowledge regarding WB cod.

When it comes to assessing the cod stock, there are strong uncertainties or even non-knowledge associated with the 2015 recruitment. There is knowledge that "except that the 2015 cohort has failed for inexplicable reasons and the 2016 cohort is one of the strongest since records began for the Western stock" (I7). However, there is uncertainty about the reasons that explain this phenomenon, as well as a lack of knowledge about "what age group is there now and why are they small and is this still an older age group" (I1). Uncertainty in the assessment of stock size also arises in relation to the gadoid outburst and high nutrient inputs that occurred in this context (biological temporality). The question is not if/whether high cod biomasses occurred but rather "[. . .], if this has been discussed before [. . .], whether that was also nutrient driven" (I7).

However, it becomes apparent that uncertainties and non-knowledge are in many cases legitimized by the profession carried out by the interviewees. Interestingly, this legitimacy is derived exclusively at the level of stakeholders from fisheries and science. Interviewees describe themselves as "not doing any scientific work" (I3), not being "a biological expert on Baltic cod" (I7) or not being a "climate scientist" (I13). In other examples, interviewees explicitly point out that this is "a question that has to be answered by practitioners" (I2) or "[s]cience has described it" (I7). The last-mentioned example goes back to the description and evaluation of the 2015 cohort. The interviewee describes that "[a]ctually, there is nothing special going on, except that the 2015 cohort failed for some inexplicable reason and the 2016 cohort is one of the strongest since records began for the Western stock." (I7). Further, non-knowledge is pointed out by stating "Why this is so I don't know, but it is." This statement is ultimately legitimized by "[s]cience has described it." (I7).

The important role that fishers' knowledge plays in the context of legitimizing uncertainty or non-knowledge of other stakeholders is again brought strongly into perspective by the following, very illustrative example. While the interviewee does not want to comment on the cormorant's influence on the cod stock, he/she refers directly to "practitioners, [...], who are out there every day and say yes, I see the cormorants throwing themselves at our young cod and pulling them out of the water by the kilo, no, by the ton" (I2). The acknowledgment of fishers' knowledge, arising from the direct interaction of fishers with the ecosystem itself ("who are out there every day"), is once again highlighted here. This is further emphasized by the question of the cod's economic role in commercial fisheries. Another interviewee clearly points out that "[he/she is] not a professional fisher, it is difficult to judge" (I10).

In the following section, we would like to explicitly address the uncertainties and lack of knowledge about parameters affecting WB cod. Climate change is one example influencing stock dynamics, where its legitimacy varies from "I am a businessman and have little knowledge of climate issues" (I13) or "I am actually a normal citizen" to the indirect assignment of science as a source of knowledge meaning "I am not a climate researcher" (I13) and "I honestly do not know the models in detail" (I8). It should be emphasized that in the context of climate change, both the professional role of the interviewee but also the position as a citizen are used to derive uncertainties and non-knowledge. However, knowledge about the presence and impacts of climate change regarding cod exists across interviewees, because if "climate change affects us all, [...] it naturally also affects the marine environment" (I3), only "in which direction it is going" (I13) cannot be clarified. The latter explicitly alludes to the uncertainties that can be attributed to climate projections. However, the influence of climate change and the uncertainty that arises is often linked to the migration behavior of cod as a cold water-loving species: "we just don't know whether it might also offer an opportunity for other species" (I3) or "[. . .], another species might then gain disproportionately" (I13).

Besides the assigned role of fishers and scientific knowledge, in some examples, however, interviewees clearly state "I don't know." (I13), or "[. . .], that would be pure speculation" (I11) without giving any indication of possible sources of knowledge.

A detailed examination of the interviews content clearly shows that there is not only uncertainty in the perception and assessment of the stock and its drivers, but also non-knowledge among those involved in the cod-question. In some cases, responsibilities are differentiated and the role of fishers' knowledge ("A question that needs to be answered by practitioners." (I2)) or science ("This is what science has described." (I7)) as important is stressed.

3.2. Science and Western Baltic Cod

The scientific evidence about cod is framed by almost all interviewees as too insecure to provide a precise stock assessment bearing also an impact on the evaluation of management measures in general (for a detailed description of assigned subcategories, see Supplementary Material Table S3). This deficiency is basically attributed to the dynamic character of the system cod itself, the scientific methods applied and a gap in useful or applicable data to specify and make current analyses more precise. However, a somewhat general trust in science and its best intentions is expressed by many interviewees. This aspect can be seen in the following quote:

> "Yes, I trust the scientists, they do their science in all conscience and try to estimate stocks correctly. But the models obviously contain certain deficiencies if not faults which entail considerable consequences. And I think that it is the responsibility of politicians to reflect these deficiencies [. . .]." (I11)

To be emphasized, reference is made here to the so-called "model-question" showing the weaknesses of models and the problems resulting from them. The phrase "considerable consequences" highlights subsequent developments: it raises the issue of how these deficiencies become perpetuated in the realm of policy and become inbuilt and sometimes problematic ingredients in fishing policies and ensuing management measures. The general call to a responsible handling of uncertain model or scientific results becomes apparent here.

Besides such general aspects, the uncertainty of science also is divided into different dimensions and phenomena—natural mortality rates in the following example—which define certain areas in need of further research and a better scientific understanding. The image of "lies in the dark" in the following excerpt makes reference to a lack of visibility which in turn refers to light as clarity enabling vision and therefore knowledge:

> "I think, the whole issue of natural mortality still lies in the dark and requires scientific research. The problem consists in the fact that natural mortality is almost constant in all models. We are not happy with this procedure." (I7)

The strategy to concentrate on a specific knowledge gap becomes clear and is connected to the need for further scientific research. Hence, deficiencies or knowledge gaps in science are not taken as such but are immediately linked to the need for further research ("requires scientific research") bridging and taming this lack. This demand is yet contrasted in the quote with an outline of the problematic practice of setting the parameter of mortality on a constant level in the respective models. This reflection is accompanied by an emotional framing depicting a scientifically tenable compromise ("We are not happy with this procedure"). However, knowledge gaps are related here to the usual practice of scientific tinkering in terms of doing research while also expressing dissatisfaction with this situation. The only solution to fill this gap and to provide firmer knowledge for an improved management though remains in more research.

Another scale of science becomes apparent in the following quote, which refers to the impact of certain developments in the stock in general and to the lack of predictive knowledge in special. The scale alluded to is social ("the scientists") and geographical as implicitly expressed by the metaphor "on the doorstep" which generates an imaginative framework of proximity and direct effects. Additionally, the phrase "none of the scientists" identifies a social group and attributes responsibility for the lack of knowledge about the development of the stock to them:

> "How this bears and impacts the stock, meaning what is going on, I would say none of the scientists would have been able to predict this development. I think this is really appalling, I mean that there is so little research on a stock living right on the doorstep." (I1)

This situation of science becomes even more difficult with regard to other social groups that frame problems revolving around fishing in various ways. Fishers, for example, conceptualize the sea, the species living in it as well as their inherent dynamics differently than scientists. The following quote exhibits the opinion that the appearance of rising fish stocks cannot solely be explained with the help of science:

> "Well, that is a tricky and difficult topic for fishers, when you say, well guys, this is impossible . . . Because the basin, the maritime zone cannot be empty of fish. But if so from where does this proliferating stock come from?" (I2)

Such differences between scientific prediction and everyday experiences undermine scientific credibility. They point to diverse and sometimes contradicting forms of knowledge and evidences going beyond science itself. This is also mirrored in the spatial framing of the Baltic Sea as a "basin" which connotes water and implies most probably certain types of species living in it such as cod. This framing is complemented by the notion of "maritime zone" that renders the Baltic Sea a discrete spatial entity while also reference is made to the stocks that apparently proliferate in an unexpected way. These everyday experiences of harvesting fish from this supposedly empty basin contrast with scientific knowledge of a declining stock as informed by modeling. The reasons for this opposition lie between the life-world experience of social stakeholders such as fishers and the scientific epistemology of engaging with cod. The latter is now further analyzed with regard to its conceptual aspects and how these are assessed by those involved in or exposed to cod management.

3.2.1. Perspectives on 'Cod-Epistemologies': Systems, Methods and Data

Fisheries science is to a large extent based on a scientific rationale comprising measurements, field studies, statistical analyses and, in many cases, uses modelling to assess the development of fish stocks. This also applies to research on WB cod and represents a way of producing scientific knowledge for stock assessments and the development of management measures. We, however, take here another analytical route and provide an epistemological study of the research undertaken on cod in the Western Baltic Sea. Hence, the investigation addresses how the entity of cod is scientifically constructed, what analytical concepts and notions are applied to develop this construction and how this way of producing knowledge about cod is assessed by those involved in the cod question. For this to be achieved, we focus on three most salient and sometimes controversial aspects that emerged in the course of our interview analysis: (i) the system understanding of cod, (ii) the various methods used to explore the entity of cod and (iii) the closely connected aspect of data generation and availability.

To start with, various system understandings of cod exist. There are general statements, which suggest that a complete or 100% secure scientific knowledge about nature is simply not possible as the system is too complex to be studied and understood as a whole:

> "Well I think that nature will not be 100% predictable. And I am not sure whether it is worthwhile to strengthen scientific expertise in terms of personnel and money for getting 1% better results which really might improve management. I would doubt this fact." (I9)

The statement "nature will not be 100% predictable" clearly sets an epistemological and normative scientific limit with regard to prediction and contrasts this with an economic argument: the small benefit of improving the scientific system understanding for one percent does not equal the investment to be made "in terms of personnel and money". Moreover, this investment is not expected to improve management. All in all, it is scientifically and economically seen as a non-profitable endeavor.

The aspect of complexity with regard to the system cod and its relation to other subsystems within the overarching ecosystem such as seals also plays an important role. Consequently, the interaction among system components is often depicted, and the results of scientific research are highlighted while reference is, in many cases, also made to the remaining insecurity of this scientific knowledge. This uncertainty is based on the system's understanding in general or the conceptual framing of constitutive processes or elements within it. This can for example be the size of a population and the connected problem of measuring it:

> "Marine mammals, well, they definitely have an impact. We know from food-studies of grey seals that they can consume a considerable amount of cod. But the grey seal population in the Western Baltic is minuscule and its impact is consequently not measurable. Maybe, there are other effects." (I4)

Frequently, other aspects are mentioned causing developments in the system which are not understood. In many cases, solutions cannot be tackled or fully grasped because the amount or quality of data needed is too low or even non-existent. However, a cause–effect relationship is characteristic for such a system understanding requiring a certain degree of quantifiable data to scientifically explain and understand developments within the cod system.

Besides these aspects of measurability and the characteristics of a more or less scientific systems understanding, the results from this thinking and research are also assessed by interest groups or resource users who are not scientists. These qualified 'outsiders' are exposed to a systems thinking in the form of numbers of stocks or species that lead them to individually assess the current state of the cod stock:

> "If one trusts the numbers which have been published in the recent years by the Thünen-Institute [federal research institute], we then have to consider the fact that the stock has been brought to its knees, that there will be considerable deficits in terms of cod." (I10)

Bearing in mind that one cannot count the total amount of cod in the Western Baltic Sea, the quote clearly relates to expected trends as generated by scientific system thinking and, though probably, statistical calculation and modelling. The reference made to "numbers which have been published in recent years by the Thünen-Institute" suggests this aspect and emphasizes via the temporal allusion "recent years" to a certain scientific credibility and representativeness in terms of an aggregated time series. The status quo of the stock is, moreover, metaphorically portrayed negatively as being "brought to its knees".

Besides the various and sometimes obfuscating questions revolving around a system thinking, issues related to methods and data generation are raised by our interviewees. Systems are in many cases conceptually conceived as interwoven or networked entities. Hence, reference is made to the multifaceted connections in a system and the consequential causalities. This causes methodological problems in terms of what variables for a stock assessment should be taken into consideration and with what data. These aspects become apparent in the following quote:

> "It is all considerably interwoven, very complex. We start with a very small number of samples and then project what should be in the sea. We never have an overview over the total stock. We hence compartmentalize the stock, then we make a projection and then we gross up. There is a considerable uncertainty in this. But it is nevertheless sold as a safe result." (I2)

The quote clearly exhibits how scientific data are assembled, constructed and generated: a holistic systems understanding is outlined, evoking a system-image in which everything is connected to everything. Against this general background, a reductionist and deductive rational is promoted ("we start with a very small number of samples") in which a though small empirical basis is used for a grounded estimation. This methodological step is legitimated by the claim that one can never "have an overview over the total stock". Hereafter, the holistic vision and the reductionist necessities are assessed and used to legitimate the heuristic "compartmentalization of the stock" which forms the basis for the estimated development. This skillful and scientifically sound procedure is, moreover, characterized as "uncertain" and critically contrasted with the conceptual leap of taking it as the "real" state of cod-stocks out there in the sea. The final line in the quote metaphorically assesses the aspect of results becoming a tradable good in terms of "sold as a safe result" and criticizes this aspect. In sum, what we witness here is an insight into the methodological and epistemological ways of constructing scientific knowledge about cod.

Such scientific knowledge, including the generalization in terms of safe results, is often questioned among those involved in cod management. Population dynamics represent a difficult topic and require several methodological and epistemological steps about which various stakeholders have gathered some knowledge during the years of their involvement. Thus, scientific results are not taken for granted but are scrutinized on a theoretical, methodological and sometimes empirical level. One of the basic questions often revolves around the methodological aspect as to whether and how the stock and "its special biology could be exactly described":

> "Concerning the Western Baltic cod, I think that the question should be given back to the scientists and one should ask whether the population dynamics and the parameters for sustainable use of the stock with its special biology could be exactly described, meaning that everything is clear." (I7)

The need for clarity ("everything is clear") in terms of visibility is in this quote metaphorically depicted and used to conceptualize knowledge. This image is applied against the background of the methodological understanding of "population dynamics" together with the "parameters for sustainable use". Both phrases refer to a relatively detailed knowledge of the interviewee about the scientific approach and the conceptual complexities of cod. These are played out against the though tentative aspect of whether safe knowledge about the special biology of the cod stock is possible at all. Hence, prevailing conceptual issues of an exact systems understanding for an envisioned "sustainable use of the stock" are raised and relegated back to science.

Comparable aspects are also addressed in the next quote. Here, the methodological aspects in terms of taking samples are depicted and contrasted with an assessment of fishers to whom the approach appears to be wrong at worst or inconsistent at best:

> "We have here this one topic. Science leaves on the 5th of May. They exactly set sails on this very date and do their catch. And they wonder, oh dear, last year we fished more fish. This year nothing. Well, they need it for their statistical analysis, it has to be carried out that way. But no fisher understands this. He tells it the scientist every time. You should not fish here. There is no fish here in these and these weather conditions here. And the scientist says: No fisher, I have to do it due to reasons of statistical analysis." (I13)

What is shown here is a dispute about a different methodological approach to make stock size estimates mainly characterized by an interplay of different times, study locations and weather conditions, leading to different results. While the scientific approach is legitimated by an ongoing "statistical analysis", the way fishers gather their knowledge appears to be based on experiential knowledge gained over time. The incompatibility between these two approaches and their constituting parameters (different temporalities, dissimilar sites and, according to the fishers, weather conditions) lies at the heart of this mutual incomprehension and conceptual incompatibility. The results and the assessment of the stock understandably differ and socially materialize as disagreement.

A way to tame this methodological difference and pacify the ensuing incongruities consists in view of scientists in improving the data basis for producing scientific evidence. Data appear to be the most important entity or object which is expected to provide a remedy for disagreement. Various stakeholders, especially from scientific and governmental institutions, continuously refer to the need for more data: "For this, for all these things, [...] we need more, more data" (I4). These data are conceived to close gaps in scientific knowledge and offer a more precise evidence. However, such a framing does not address possible conceptual inconsistencies in the systems understanding of cod and the consecutive modelling of stocks. Such aspects are ironically depicted in the following quote by an 'outsider' to science:

> "So, you can think about it because yesterday mister [...] said it in a meeting what he wishes for in the future. He said three times in a row: data, data, data." (I2)

The phrase "data, data, data" on the one hand emphasizes the real need for data, while the ongoing repetition on the other hand adds a critical if not ironic undertone to this aspect. This matches one prevailing picture of fisheries science among some stakeholders: science is perceived as considerably funded that simply does not deliver. By contrast, it continuously asks for more funds and more data to produce, somewhere in the future, an evidence-base for better predictions and management decisions. However, this picture is contrasted with another, namely poor data bases:

> "That they do not ask the critical question, exactly mention the aspect, that the data basis is bad. I would have expected an outcry some years ago. [...] They should outline that all they have in terms of evidence generating mechanisms is a crystal ball. This means, we believe but we do not know. And I do not accuse them, that they cannot do science. But I would have expected that they say: 'It is about time, we have to do something now.' But such an activity is still lacking." (I1)

The necessity for articulating scientific needs is expressed and combined with a personal astonishment about the silence of science in view of the bad basis of data. This behavior results in believing instead of knowing, as expressed by the metaphor of the "crystal ball" that connotes fortune telling. Repercussions are scientific imprecision, knowledge gaps which in turn bear an impact on the scientific evidence used to make and legitimate management decisions.

3.2.2. Perspectives on Insecure Scientific Epistemologies

Scientific knowledge in fisheries science appears, as we have seen, to be a tricky entity, and the aspects raised here about its generation make things even more complex, complicated and confusing. The various system concepts depicted, the different methodological approaches outlined, as well as various assumptions made and the notion of data as a consolidating remedy unraveled in the analysis exhibited the multifaceted and sometimes inconsistent epistemologies at work in fisheries science as seen through the interviewee's eyes. These bear a direct impact on the knowledge fabricated for management. They result in inconsistencies and imprecisions as referred to by various stakeholders and scientists, and as expressed, for example, by fishers who hold a different knowledge about fish as based on their epistemologies. More data, as expressed by scientists and institutional representatives, do appear to be one but not the only solution for the problems encountered. This is because they do not close the qualitative gap between the need for conceptual improvements of systems thinking and methods, and the implicit rationale of 'more data' generate better knowledge for stock assessments. So far, the analysis of our interviewee's perceptions indicates that knowledge about cod is imprecise due to the complexity of the Western Baltic Sea ecosystem and its subsystem cod. This conceptual and methodological gap cannot be addressed solely by increasing the amount of data to be used for analysis. We would rather suggest here that science about cod in the Western Baltic Sea (and likely in many other fisheries management cases) requires social re-organization and at the same time an extension of scientific evidence.

3.3. Management

Our coding of the interview transcripts and the derived subcategories give us a deep insight into fisheries management at the different levels of action (EU, national and local levels) including a detailed description of various management measures as well as the participation of stakeholders within management. In addition, the state of the management, its problems and possible improvements are outlined below (see Supplementary Material Table S4 for a detailed description).

3.3.1. The Current State of the Baltic Sea Fisheries Management

Our detailed analysis revealed that the interviewees express various views on current fisheries management problems and possible improvements. Concerning current management procedures to quota distribution, the following quote is paradigmatic:

> "And one says, you still, you, the member state, still owe me something. Because I gave privileges to you back then, during the banana contingent and I now want to get a bigger share here. There is a mercatorial element included. Trade. Dithmarscher horse market, yes. (I2)"

The metaphor of the "horse market" refers to the bigger, money-valued trade between several market levels. Trade is not restricted to one sector such as fisheries, and decisions often interact with those in other sectors such as agriculture. Here, trade takes place continuously at all levels such as a "horse market" taking place frequently. The fisheries sector rather obtains small monetary shares with this market, hence the trade. As member states "owe" something to each other, it becomes clear that the catch quota distribution is often conditional on negotiations between the different sectors. This trade-off between the fisheries and other sectors is also raised by a further interviewee where the process is called "dealing" (I1) between fisheries ministers. This implies that the ministers exchange money economically in a large dimension—meaning catch quotas in fisheries management—between member states. These choices are made due to "actions causing the least resistance" (I2) between stakeholders involved. The representation of interests within the trade-off process, which "is not like in the past anymore" (I7), became less profitable for fishers. Given the diverse underlying trades between sectors and rather small shares for the fishery sector in fisheries management, interviewees express divers opinion on the manner of how well the WB cod stock is currently managed.

As some interviewees agree that cod stocks are currently well managed and that management is taking the right direction, other interviewees express diverse opinions. Positive opinions are articulated with statements such as the following:

> "Exactly. I guess, I won't implement more than what we have so far. I think we will reach our aim with the measures which are currently implemented in alignment with the fisheries policy." (I9)

Current management measures are conceived as sufficient to reach the goals set by the EU to promote the sustainable exploitation of WB cod. It is also mentioned that the current actions taken are the "exact ones needed to reach the aim as fast as possible" (I7). "Exact the ones" shows that from the broad range of possible measures the correct ones were chosen and that no further thinking about alternatives is required. Another interviewee supports the execution of current procedures with the fact that "it is decided now and needs to be implemented. Because deviating from this would make it worse" (I1). The fact of "making it worse" shows that the policy implemented is currently the best at hand, and no alternatives are available. It also refers to the fact that fish stocks are in a bad state and that improvement by management measures is needed.

Further interviewees add a time aspect to the positive connotation of the current measures: "in the short term, everything needed is done" (I4) or "much more cannot be done in the short term" (I6). The temporal aspect as expressed via "short term" determines the limits of successful implementation. The measures appear to be sufficient for now, but taking long-term aspects into account, they seem to be insufficient for a sustainable management of the cod stock in the Baltic. In brief, short-term measures are the fastest and easiest to implement, whereas now is the time to create long-term measures.

Opponents, in contrast, declare that "there is no sustainable management for 100 percent" (I13) and the fisheries management is "catastrophic" (I13) and has failed:

> "So, in retrospect, one has to say the management has failed because the stock is simply gone. That is the clear evidence." (I8)

"Simply gone" and "clear evidence" explicitly frame the negative situation of the cod stock. It appears that cod has disappeared under the supervision of the policy makers, who are now confronted with the fact that their management did not work. The "catastrophic" aspect shows the felt and urgent need for improvement and puts management as well as decision makers under immense pressure.

In the context of poor management, the time aspect is perceived as the duration of bad management as expressed in "and this has been managed badly for eight or nine years by politicians being aware of that" (I4) or "No, of course not. Otherwise he wouldn't have collapsed. He wasn't managed sustainably for 20 years. And this has led to the current precarious situation"(I4). "Managed badly" and "wasn't managed sustainably" depict the severe situation and how it has failed over multiple time periods. The phrase "precarious situation" clearly frames the current state of the management and puts it in the grim position of no prospect of success.

Interviewees also mentioned that the management did not reach the aims of a multi-annual measure implementation:

> "The stock will be managed, governed, and the common aim is to manage it at the MSY-level. We are not there yet." (I7)

"Not there yet" is a metaphor for a path, which is currently 'walked' to achieve a sustainable cod stock. The management is on the right track, but the aim has not been reached yet. Further support of the statement is given by one interviewee, who said "there would be the case where the cohort is managed in a good way and might increase in numbers, but this is nearly impossible until 2020" (I8). Moreover, "not there yet" emphasizes a chance to achieve a sustainable management of the stock, whereas "nearly impossible" rather pictures a strongly diminished chance.

As we have seen, the current way of fisheries management is framed differently between the interviewees. It lies within a complex policy system where different sectors are involved and so-called trade is taking place. The fisheries sector is forced constantly to consider other sectors' privileges, which makes implementing management measures on its own rather impossible. Whereas some interviewees agree that the current state of the management is sufficient to support the recovery of cod, others argue for improvements.

3.3.2. Problems

The analysis of the interviews, furthermore, highlights that concern exists regarding the current management of cod. As raised by one interviewee, the scientifically established maximum sustainable yield (MSY, a fishing reference level to sustain sustainable stock development) approach is not fully implemented by the policy makers: "As I said, I think it would have been good for all participants if one would have focused on the MSY goal 2020 on time." (I13)

The temporal aspect of "on time" underlines that policy makers failed to focus on fisheries goals and started their adjustments in terms of management too late. These adjustments have consequently to be carried out in a stricter and intensive way bearing bigger influences on the fisheries sector and the connected economy. This failure of management for several years is also going hand in hand with concrete scientific quota proposals:

> "Science recommends to reduce for further 20 percent, and they [policy makers] only reduce for 10 percent, and that is how the stock becomes steadily smaller and smaller. There is no way out of this spiral." (I4)

The policy makers kept the cod quota higher than the scientific advice for several years. The image of the "spiral" highlights the drastic situation and presumes, in this context, a way down, where there appears no chance for the stock to recover. The follow-up problem consists of the lack of transparency for the reason of higher cod quota: "It is fundamentally non-transparent why catch quotas are set above the scientific recommendations" (I11). This lack of transparency is an important issue concerning catch quota distribution, which appears to be a "not really transparent process" (I5). The underlying reasons explaining the catch quota distribution process are missing, which creates conflicts due to lack of knowledge and can cause distrust among stakeholders.

Further complications are mentioned in relation to multiannual plans. These plans imply the common fisheries policy (CFP) including the aim for fish stock being exploited at sustainable levels or the control and implementation of fishing effort restrictions over multiple years [62]:

> "Of course, something happened in the first year, which was not taken into account during the composition; the complete failure of the year 2015. The plan did not have enough flexibility for this unexpected situation. Simply interfere with the fisheries activities and take away 80 percent of the quota: that is not sustainable." (I7)

The aspect of lacking "flexibility" of the plans is a complicated issue. Yearly failures of recruitment can occur due to environmental changes, which makes it difficult to stick to commonly developed practice when these unexpected situations happen. "Flexibility" would broaden the capacity of adaption for the economy and fishers. Furthermore, "simply interfere" represents the diminished possibility for fishers to intervene in these severe situations, since management plan was set. They have to follow the policies and measures implemented with no space for negotiation or flexibility.

The main topics of current problems include the failure of policy makers to react on time to the stock decrease, the non-transparent processes of catch quota determination given scientific advice, as well as complications due to lacking flexibility in multi-annual plans. These problems lead to distrust of stakeholders in the management and have great implications for fishers, whose livelihoods largely depend on the catch quota and thus the amount of fish they are allowed to catch. Based on these issues, the interviewees propose suggestions for an improvement of management to enhance flexibility and risk minimization due to unexpected stock failures.

3.3.3. Improvements

Given the accounts about the current way of cod management and its problems, the interviewees proposed improvements with respect to flexibility, long-term planning and scientific advice:

> "And as the next step: that the policy can react fast to it. It is important to have a really good stock, so with the years you can say flexibly: okay, the anglers don't need the bag limit anymore and the fishers can go up a bit. And in the next year it can be decreased rapidly. So, it would be, I think, very important to include a certain flexibility." (I10)

In alignment with one of the problems, lack of flexibility, the interviewees raised the issue for improvement. It is noteworthy that the interviewee mentions the relevance for a "fast" reaction of policy makers and emphasizes the "flexibility" of providing quickly adjustable catch quotas to fishers. "Fast" refers to the fact that current reactions are perceived as rather slow, whereas "flexibility" in contrast demands rapid changes. Flexibility would provide decision makers with the chance to conduct short-term measures with rather smaller impacts on fishers and economy instead of implementing harsh regulations to react to a too severe situation. In alignment with the flexibility, interviewees suggest to implement a long-term management:

> "My immediate measure would be to directly start thinking about setting up a long-term management and to implement this for 100 percent, to create safe circumstances for all participants." (I13)

"[D]irectly" and "100 percent" illustrate the need for a change and safety in the management. The actions need to take place now to ensure "safety" for the participants, so that they can rely on agreed management measures in cases of unexpected situations. The statement is also supported by one interviewee who proposes to "integrate enough buffer, think a bit more in mid- and long-terms" (I6). The buffer would make it easier for decision makers to decide during unforeseen developments and provides security for the resource users. The long-term planning is also associated with a learning process from the past:

> "I can only express the wish that one thinks more in longer terms for the future, to plan proactively and to learn from mistakes made in the past." (I1)

It becomes clear from "proactively" that this aspect is not part of current management. "Mistakes" also include that responsibility lies solely on each stakeholder group, but the idea is to spread responsibility across the various groups (I1).

As the aspect of TAC settings is implemented on a yearly approach, it seems rather impossible to plan more years ahead. To ensure a better safety and probably also transparency within the process itself, the need for long-term management is stated quite often by the interviewees. Even though the multiannual plan for cod, herring and sprat in the Baltic Sea was adopted in 2016 under the new CFP [62], several interviewees still call for a long-term solution to be implemented for WB cod.

Another suggestion to improve the lack of safety in terms of economic projectability was mentioned concerning scientific advice:

> "The EU needs to be oriented towards and implement the scientific advice. Then, they don't have to live with the insecurity anymore and the stock could recover, and would have the room to vary, which would also minimize the risk." (I12)

The direction of the EU in this context does not consider the scientific basis that is needed to manage the stock in to a sustainable condition. The criticism about management giving higher catch quotas than scientific advice suggested is seen as a chance for improving the situation. The positive consequences of such an improvement mentioned are the stock recovery or the increasing security given a "risk" minimization. "[T]he risk" represents the great uncertainty for fishers due to strong reductions of catch quotas. The insecurity is also mentioned in the context of science, where it represents the uncertainty of catch quota ranges:

> "But in a system with this high variety like the Western Baltic Sea or the Baltic Sea in general, this will reoccur to us constantly. And what I always propose to politicians in this case is to not concentrate that much on what they can do with even more money, but they should accept the uncertainty which we specify. Make your management that robust that it is not built upon less than 10 percent uncertainty. I don't want to say mistake. Because these are not mistakes, but it is uncertainty." (I4)

What is depicted here are the ingredients and aspects of "robust" management. Robust management lies within "decision making under deep uncertainty" which entails complex systems that are difficult to estimate and where experts have diverse opinions on the system's functions and its relationships [63–65]. The models, capturing this deep uncertainty, analyze different possible choices against different compelling futures [66], from which robust management trade-offs are developed as tools for promising the management of socioecological systems [67]. For the cod management, this requires a lot of cautiousness from decision makers who have to deal with several aspects: environmental variability, insecurity of the fishers, the economy and the uncertainty provided by scientific advice. "Robust", however, means that management can withstand all uncertainties and still satisfies all stakeholders affected. The proposal for this tricky situation consists of the suggestion for managers to focus less on money-related issues but rather consult science to incorporate its advice into management.

From the detailed analysis of the interviews, we gained various perspectives and descriptions on the current management situation, its inherent problems and suggestions for improvements. The opinion on whether management is sufficient differs among interviewees, as well as their consecutive argumentation for or against certain measures. Nonetheless, fisheries management has not prevented the stock from reaching a depleted state and is not achieving a recovery of the stock. Problems raised by interviewees include management timing (i.e., implementation of measures seems to occur far too late), flexibility in catch quota allocation and management adjustments (i.e., ability to respond to unforeseen events such as stock failures). More flexibility in the catch quota allocation is primarily suggested to mitigate the impact on fishers and their livelihoods. However, interviewees did not describe what this flexibility might entail. In addition, they say that better implementation of scientific advice would improve the situation of the WB cod fisheries.

4. Discussion

The interviews we conducted reveal a broad spectrum of existing problems but also hold possible solutions to support a sustainable harvesting of fish stocks. Above all, they provide potential entry points to generally make the fisheries sector more stable and sustainable for the future. The interacting and mutually dependent issues of knowledge, science and management were conceived as relevant by our interviewees and provided a comprehensive insight into the manifold problems revolving around WB cod.

We have shown that there are various 'knowledges' in the consideration of cod as a species ranging from historical knowledge, biological knowledge and tacit knowledge to economic knowledge. Such diversity in the description of cod and its related ecological, economic and social dimensions reflects a multilayered picture among various stakeholders and demonstrates different lenses through which this species can be seen (Figure 3). Furthermore, we have shown how cod is conceptualized in different scientific ways, leading to a jumble of framings which lack the challenging task of an integrated understanding of the cod system itself (Figure 3). This not only leads to mistrust among various stakeholders but also to conflicts that arise from the methods used to collect data and the resulting conclusions drawn from them. Thus, there are not only gaps in scientific knowledge, which nestle in the limitations or diversity of methods and models, but there are various framings based on various ways of 'knowing' cod. These aspects become apparent in the framing of cod management where different perspectives were identified mirroring current problems on the local, national and EU level while also calling for improvements (Figure 3). The analysis revealed multiple points of criticism, e.g., that management lacks flexibility (i.e., rapid response to environmental, economic or social changes) or transparency in the allocation and distribution of fishing quotas. There are, moreover, calls to better implement a long-term management plan that would not only safeguard the stock but also fisheries. One way forward could be to use approaches in which 'knowledges', scientific evidence and management options can be negotiated in an open-ended and symmetrical way (Figure 3). This would generally mean to make the process a more social endeavor in which the ecological and the social hold equal places.

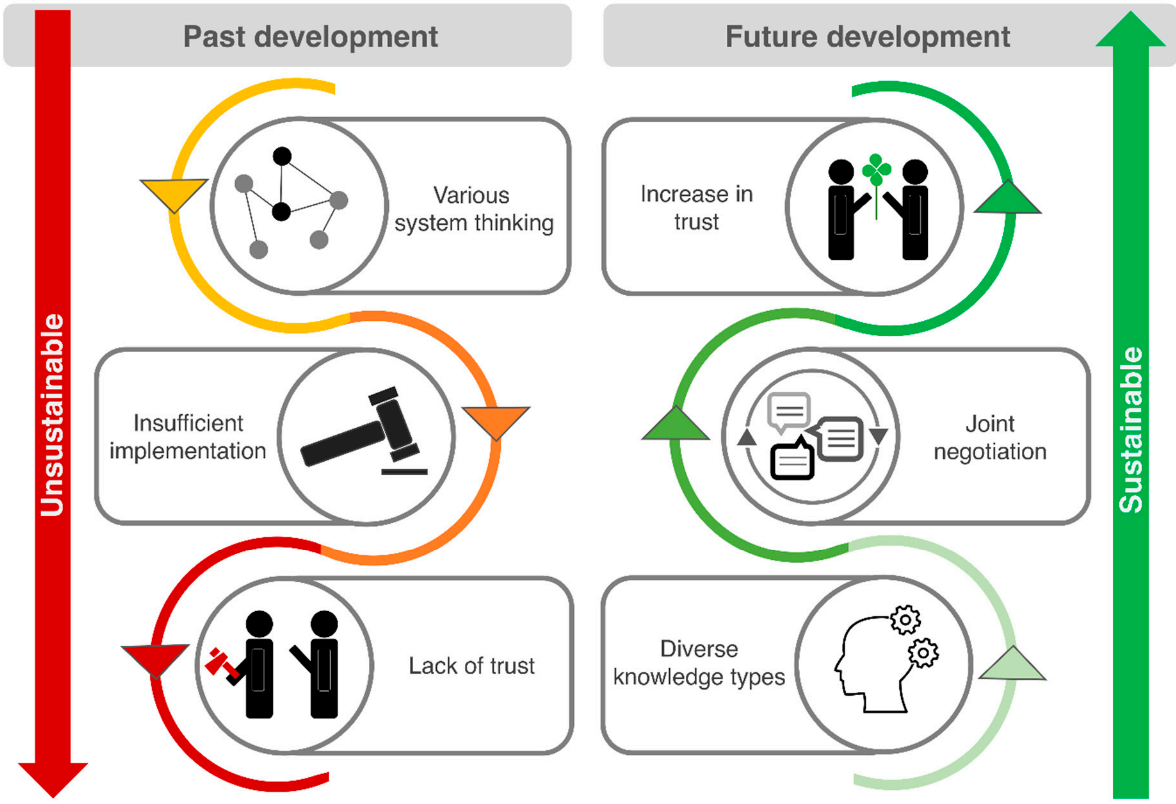

Figure 3. Circle of trust implying un- and sustainability. The analysis has shown that the management of European fish stocks is characterized, in part, by a lack of flexibility and transparency in the allocation of fishing quotas, leading to conflict and mistrust among resource users and interest groups. First and foremost, there are diverse system understandings and the resulting different conceptualizations of system components, system functioning and system dynamics (*various system thinking*). In the past and still today, there is a lack of recognition of this knowledge diversity and suggestions on how to implement this in management (insufficient implementation). This aspect reflects a past development that is not sustainable and develops into a picture that is nowadays characterized by mistrust and a lack of acceptance of management decisions (*lack of trust*). To ensure a sustainable exploitation of natural resources, and in our case fish stocks in EU waters, there is a need to redesign the participation processes within the management system. There is a huge spectrum of different types of knowledge or 'knowledges' generated by various user and interest groups. In order to reverse the resulting *downward loop* of management development, it is necessary to recognize and integrate these knowledge types into the management process (*diverse knowledge types*). This step should be followed by a participatory process involving different users as well as interest groups to gather their perspectives on the system itself and management (*joint negotiation*). The main objective consists of building or rebuilding trust between the different stakeholders in the system with the intention to develop integrated management decisions and consequently to ensure a sustainable use of natural resources (*increase in trust*).

The Theoretical and Methodological Entrance to the Multifaceted Species Cod

The basic assumption that human activity affects nature and therefore fish [2] opened up the possibility to theoretically study cod in its entirety and to explore its diversity from different angles. However, in order to turn cod into a manageable species, a legitimate scientific classification is developed which provides the basis for fisheries management not only of WB cod. However, there is a growing interest in understanding cod not only from the scientific perspective but also in attributing a growing role to stakeholders' framings of the system. This assumption that cod is not a homogeneous object and cannot exclusively be classified by science has provided space to think about cod in a more comprehensive way. The idea of the so-called "cod multiple" [12,31,42] provided the opportunity to comprehensively understand this species, to enlarge and discuss problems revolving around this stock. This theoretical approach allowed us to reframe cod from different biological, economic and social perspectives.

The aspect to understand management as co-construction and to negotiate and involve different 'knowledges' [21] encouraged us to explicitly focus in our approach on the investigation of the different 'knowledges', the framing of science and management. This now enabled us to provide food for thought that could help to make management more participatory and thus represent a contribution to the sustainable use of WB cod in particular and natural resources in general. However, it should be realized that integrating more and different 'knowledges' does not automatically improve the interaction between different stakeholders and increase the acceptance of management decisions as well as their implementation in practice. However, the awareness of the different 'knowledges' and their backgrounds can lead to the support of better mutual understanding which can be understood as a first step to manage the system and its components in a more sustainable way.

In this context, it is relevant to emphasize that knowledge about and framings of a system can be generated and determined through multiple ways (e.g., experiences and analysis). In general, different understandings and framings of a system can be explained by the fact that people interact in very different ways with the system itself or system components such as fish species that are, for example, directly (practicing fishing) or indirectly (modeling fish distribution) related to the biological system. These different ways of generating knowledge lead stakeholders to develop different perspectives on and understandings of the biological 'workings' of natural resources—or in our case, WB cod [68]—and the resulting management options [17].

It has, moreover, been shown that there are different ways and practices of scientists and fishers to frame the state of fish stocks. While a fisher trusts his on-board equipment to iteratively follow fish to catch it (i.e., fine spatial scale and local) and observes stock from their on-boat or practice perspective, researchers use scientifically standardized routes to estimate stock size through scientifically sound and robust epistemologies (i.e., large spatial scale and universal) [69–72]. The assessment of and knowledge about stock size is thus not only determined by different technologies but rather by the background of different epistemologies, rationales, practices and approaches. These aspects cause variations in the framing of problems, meaning not only which problem is perceived, but how it is constructed, socially embedded and what finally has to be done about it. Diverse epistemologies are important as they allow a fish stock to be explored at different scales, providing a comprehensive picture of it as well as its surrounding system [71]. The intent, therefore, should be to acknowledge different epistemologies and indicate that natural resource management should incorporate a broader variation of 'knowledges' to reflect current ecological, social and economic changes [25,73–75] and what to do in relation to them.

In order to ultimately reveal, explore and recognize these 'knowledges', it is important to consider how stakeholders can be effectively involved in the context of natural resource management and at what levels this can take place. This process can be organized and designed in many different ways, depending on the organizational level, but also on the resources available (e.g., time), as well as the specific intention of the stakeholder participation and the intended forms of possible interaction see [74,76].

In the context of European fisheries management, there are numerous considerations of co-management approaches, but the attempt to implement them seems to be blocked in parts by top-down driven management [77]. However, there are two EU initiatives that have been established to institutionalize and thus strengthen stakeholder participation at regional (e.g., AC, Advisory Council) and local levels (e.g., FLAG, Fisheries Local Actions Groups) [50,78–80].

ACs were implemented with the aim to increase involvement of various groups in fisheries management (e.g., commercial fisheries and NGOs) to support discussion across stakeholders and develop various ways of cooperation [49,50,78,81]. The main task of ACs consists of formulating recommendations for the European Commission on aspects of the European fisheries management [50]. These include advice on the compliance with socioeconomic aspects of the management (e.g., implementation of new fishing gear) or simplification of rules for commercial fisheries [78]. It should be noted that these recommendations by the ACs only have a consultative function and are not subject to any implementation obligation. This kind of stakeholder involvement in fisheries management could be seen as a positive first step. However, there is also criticism with regard to the ACs (i) due to the unequal distribution of representatives given the majority of fisheries representatives (60:40, i.e., fishing industry:other groups), (ii) to limited attendance due to resources such as time or money and (iii) to the difficulties of finding consensus due to diverse regional and local issues [48,50,81,82].

FLAGs, unlike ACs, are based at the local level and involve not only fisheries and eNGOs but also the public and private organizations [78,79]. The goal here is to design joint strategies that benefit the development of local fish communities (e.g., an app to support direct marketing for local fish) [80]. While ACs tend to involve large-scale fisheries, FLAGs are more likely to involve small-scale fisheries [78]. As far as the influence of FLAGs on decision-making processes is concerned, they can rather be understood as offering a possibility for co-management, which is strongly dependent on local realities and willingness. Linke and Bruckmeier (2015) show examples in which FLAGs clearly distances themselves from political activities, while others want to actively influence politics and its actions. For some FLAGs, direct participation in local decision-making is even described, through which, e.g., spatial planning processes could be influenced by fisheries [78]. In this context, it is important to note that a FLAG can be related to different topics such as (i) society and culture, (ii) added value to fisheries, (iii) environment, (iv) diversification and (v) governance. The latter objective aims to strengthen the role of fishing communities in the local development and governance of local fisheries resources, thus giving fishers a voice in local decision making and resource management [80]. In this regard, Miret-Pistor et al. (2020) noted that only a few of the reviewed projects focused on this objective. However, other overarching goals of FLAGs would also contribute to governance [79], although a critical review reveals that the focus is only on knowledge sharing and not on actual power sharing.

It should be noted that there are already initiatives established by the EU that enable the participation of various stakeholders, which, unfortunately, only provide for limited power sharing. In general, however, it must be stated that communication and interaction between resource users and interest groups in many ways is a first step toward a jointly managed resource. However, this needs to be socially institutionalized in order to build trust at the lowest level and thus create acceptance of, for example, management decisions in the second step. This engagement with resource users and stakeholders is time intensive and requires a lot of care to lay the foundation for trust, not only between stakeholder and scientist but also with the stakeholder group itself. Time-wise, this step is often underestimated, due to projects being set up for too short a time, which does not allow firm social structures to be built up. Approaches to highlighting in this context are Community of Practice [83] or Living Lab [84]. Both approaches focus on a similar start (e.g., topic and, if applicable, conflict shared by the stakeholders) and the establishment of defined ways of working to create an initially informal social institution [83,84]. A positive aspect to be emphasized is a given long-term planning capability (e.g., by long-term funding), which helps to establish a social system in a multifaceted exchange with the stakeholders on the ground. What is missing here, as already described in parts for ACs and FLAGs, is the "real" power to concretely influence and change management design and measures. Of course, it is possible to involve mayors or ministers, but again, there is no general guarantee that developed proposals for change in natural resource management will actually be implemented.

Lastly, it is important to note that, especially in the context of EU management, there are multiple ways to involve stakeholders in fisheries management, but in most cases, this form of involvement is limited to knowledge sharing rather than stakeholder empowerment.

5. Conclusions

To conclude, we have highlighted the different stakeholder 'knowledges' and perspectives that frame Western Baltic cod and its surrounding systems. Likewise, we exposed the time dimensions that permeate WB cod at the scientific, political, administrative and social levels, leading not least to divergent temporal frames that have created conflicts or, as in our case, harden them.

As to the present state, it seems that a kind of endless and rather unsuccessful loop has developed over the recent decade that is calling for integrated action more than ever. Top-down EU fisheries management has contributed to overfishing (and stock depletion), in which fishing pressures (e.g., catch quota) have been too high and predictions have been false due to model uncertainty and environmental change [39]. This resulted in a lack in trust among fishers, politicians and scientists.

Therefore, actions that increase stakeholder involvement at multiple levels of governance, i.e., local, national, and supranational, have the potential to promote confidence in and acceptance of management measures, one of the keystones of achieving a sustainable exploitation of marine resources. This shift would mainly address the aspect that management needs to be designed in a more social way, meaning to be more participatory in terms of negotiation while acknowledging the various 'knowledges' and perspectives on the 'cod-multiple'. Our study hence emphasizes the need to better implement ecosystem-based management in EU fisheries of which a social-ecological system approach is a key component [85–87]. Even if this path requires more time and financial resources, it can address the sustainability goals set within the EU [88].

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su132112229/s1. Accompanying our manuscript, we present additional information on the stock assessment of Western Baltic cod and measures taken to manage this stock sustainably. The document also includes the interview guide consisting of questions on ecology, management, economy, communication as well as conclusion and ideas for solutions. Also included are the detailed descriptions of the three categories knowledge, management and science and their empirical subcategories, as collectively identified during interview analysis.

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References

1. Berkes, F. *Sacred Ecology*, 2nd ed.; Routledge: New York, NY, USA, 2008; p. 394.
2. Pálsson, G. Nature and society in the age of postmodernity. In *Reimagining Political Ecology*; Biersack, A., Greenberg, J.B., Eds.; Durham University Press: Durham, NC, USA, 2006; pp. 70–93.
3. Johnson, P.J.; Hersoug, B. Local empowerment through the creation of coastal space. *Ecol. Soc.* **2014**, *19*, 1–7. [CrossRef]
4. Latour, B. *An Inquiry into Modes of Existence: An Anthropology of the Moderns*; Harvard University Press: Cambridge, MA, USA, 2018; p. 489.
5. Latour, B. *Reassembling the Social: An Introduction to Actor-Network-Theory*; Oxford University Press: Oxford, UK, 2007; p. 312.
6. Jefferson, R.; McKinley, E.; Capstick, S.; Fletcher, S.; Griffine, H.; Milanese, M. Understanding audiences: Making public perceptions research matter to marine conservation. *Ocean Coast. Manag.* **2015**, *115*, 61–70. [CrossRef]
7. Dobson, A. *Citizenship and Environment*; Oxford University Press: Oxford, UK, 2004; p. 240.
8. Dobson, A.; Bell, D. (Eds.) *Environmental Citizenship*; MIT Press: Cambridge, MA, USA, 2005; p. 296.
9. Fletcher, S.; Jefferson, R.L.; McKinley, E. Saving the shallows: Focusing marine conservation where people might care. *Aquat. Conserv.* **2012**, *22*, 7–10. [CrossRef]
10. Guest, H.; Lotze, H.L.; Wallace, D. Youth and the sea: Ocean literacy in Nova Scotia, Canada. *Mar. Policy* **2015**, *58*, 98–107. [CrossRef]
11. Berkes, F.; Nayak, P.K. Role of communities in fisheries management: One would first need to imagine it. *Marit. Stud.* **2018**, *17*, 4. [CrossRef]
12. Probyn, E. *Eating the Ocean*; Duke University Press: Durham, NC, USA, 2016; p. 202.
13. Voyer, M.; Gollan, N.; Barclay, K.; Gladstone, W. 'It's part of me': Understanding the values, images and principles of costal users and their influence on the social acceptability of MPAs. *Mar. Policy* **2015**, *52*, 93–102. [CrossRef]
14. Hannigan, J. Toward a sociology of oceans. *Can. Rev. Sociol.* **2017**, *54*, 8–27. [CrossRef] [PubMed]
15. Yates, K.L.; Clarke, B.; Thurstan, R.H. Purpose vs performance: What does marine protected area success look like? *Environ. Sci. Policy* **2019**, *92*, 76–86. [CrossRef]
16. Pita, C.; Pierce, G.J.; Theodossiou, I.; Macpherson, K. An overview of commercial fishers' attitudes towards marine protected areas. *Hydrobiologia* **2011**, *670*, 273–281. [CrossRef]
17. Schwermer, H.; Aminpour, P.; Reza, C.; Funk, S.; Möllmann, M.; Gray, S. Modeling and understanding social-ecological knowledge diversity. *Conserv. Sci. Pract.* **2021**, *3*, e396. [CrossRef]
18. Yates, K.L. View from the wheelhouse: Perceptions on marine management from the fishing community and suggestions for improvement. *Mar. Policy* **2014**, *48*, 39–50. [CrossRef]
19. McKinley, E.; Fletcher, S. Improving marine environmental health through marine citizenship: A call for debate. *Mar. Policy* **2012**, *36*, 839–843. [CrossRef]
20. Moon, K.; Cvitanovic, C.; Blackman, D.; Scales, I.; Browne, N. Five questions to understand epistemology and its influence on integrative marine research. *Front. Mar. Sci.* **2021**, *8*, 173. [CrossRef]
21. Alexander, K.A.; Hobday, A.J.; Cvitanovic, C.; Ogier, E.; Nash, K.L.; Cottrell, R.S.; Fleming, A.; Fudge, M.; Fulton, E.A.; Frusher, S.; et al. Progress in integrating natural and social science in marine ecosystem-based management research. *Mar. Freshw. Res.* **2019**, *70*, 71–83. [CrossRef]
22. Danovitch, J.H.; Keil, F. Should you ask a fisherman or a biologist? Developmental shifts in ways of clustering knowledge. *Child Dev.* **2004**, *75*, 918–931. [CrossRef] [PubMed]
23. Moreno-Báez, M.; Orr, B.J.; Cudney-Bueno, R.; Shaw, W. Using fishers' local knowledge to aid management at regional scales: Spatial distribution of small-scale fisheries in the Northern Gulf of California, Mexico. *Bull. Mar. Sci.* **2010**, *86*, 339–353.
24. Teel, T.L.; Anderson, C.B.; Burgman, M.A.; Cinner, J.; Clark, D.; Estévez, R.A. Publishing social science research in conservation biology to move beyond biology. *Conserv. Biol.* **2018**, *32*, 6–8. [CrossRef]
25. Stephenson, R.L.; Paul, S.; Pastoors, M.A.; Kraan, M.; Holm, P.; Wiber, M.; Benson, A. Integrating fishers' knowledge research in science and management. *ICES J. Mar. Sci.* **2016**, *73*, 1459–1465. [CrossRef]
26. Moon, K.; Browne, N.K. Developing shared qualitative models for complex systems. *Conserv. Biol.* **2021**, *35*, 1039–1050. [CrossRef] [PubMed]
27. Murdoch, J.; Clark, J. Sustainable knowledge. *Geoforum* **1994**, *25*, 115–132. [CrossRef]
28. Clark, J.; Murdoch, J. Local knowledge and the precarious extension of scientific networks: A reflection on three case studies. *Sociol. Rural.* **1997**, *37*, 38–60. [CrossRef]
29. Amariglio, J. Poststructuralism. In *The Handbook of Economic Methodology*; Davis, J.B., Hands, D.W., Maki, U., Eds.; Edward Elgar: London, UK, 1998; pp. 382–388.
30. Latour, B. *We Have Never Been Modern*; Harvard University Press: Cambridge, MA, USA, 1993; p. 168.
31. Law, J. *After Method. Mess in Social Science Research*; Routledge: London, UK, 2004; p. 200.

32. Abram, S.; Lien, M.E. Performing nature at World's ends. *Ethnos* **2011**, *76*, 3–18. [CrossRef]
33. Lien, M.E.; Law, J. 'Emergent aliens': On salmon, nature, and their enactment. *Ethnos* **2011**, *76*, 65–87. [CrossRef]
34. Todd, Z. Fish pluralities: Human-animal relations and sites of engagement in Paulatuuq, Arctic Canada. *Inuit Stud.* **2014**, *38*, 217–238. [CrossRef]
35. Holm, P. Which way is up on Callon? In *Do Economists Make Markets? On the Performativity of Economics*; MacKenzie, L.S.D., Muniesa, F., Eds.; Princeton University Press: Princeton, NJ, USA, 2007; pp. 225–243.
36. Eden, S. Counting fish: Performative data, anglers' knowledge-practices and environmental measurement. *Geoforum* **2012**, *43*, 1014–1023. [CrossRef]
37. Bavington, D. Managing to endanger: Creating manageable cod fisheries in Newfoundland and Labrador, Canada. *Marit. Stud.* **2009**, *7*, 99–121.
38. Bear, C.; Eden, S. Thinking like a fish? Engaging with nonhuman difference through recreational angling. *Environ. Plan D* **2011**, *29*, 336–352. [CrossRef]
39. Möllmann, C.; Cormon, X.; Funk, F.; Otto, S.; Schmidt, J.; Schwermer, H.; Sguotti, C.; Voss, R.; Quaas, M. Tipping point realized in cod fishery. *Sci. Rep.* **2021**, *11*, 14259. [CrossRef] [PubMed]
40. Funk, S.; Frelat, R.; Möllmann, C.; Krumme, U. The forgotten feeding ground: Patterns in seasonal and depth-specific food intake of adult cod Gadus morhua in the western Baltic Sea. *J. Fish Biol.* **2021**, *98*, 3. [CrossRef] [PubMed]
41. Döring, R.; Berkenhagen, J.; Hentsch, S.; Kraus, G. Small-Scale Fisheries in Germany: A Disappearing Profession? In *Small-Scale Fisheries in Europe: Status, Resilience and Governance*; Pascual-Fernández, J., Pita, C., Bavinck, M., Eds.; MARE Publication Series; Springer: Cham, The Netherlands, 2020; Volume 23. [CrossRef]
42. Mol, A. *The Body Multiple. Ontology in Medical Practice*; Duke University Press: Durham, NC, USA; p. 216.
43. Ingold, T. *The Life of Lines*; Routledge: London, UK, 2015; p. 184.
44. Klenk, N. From network to meshwork: Becoming attuned to difference in transdisciplinary environmental research encounters. *Environ. Sci. Policy* **2018**, *89*, 315–321. [CrossRef]
45. Barclay, K.; Voyer, M.; Mazur, N.; Payne, A.M.; Mauli, S.; Kinch, J.; Fabinyi, M.; Smith, G. The importance of qualitative social research for effective fisheries management. *Fish. Res.* **2017**, *186*, 426–438. [CrossRef]
46. Schreier, M. *Content Analysis in Practice*; Sage: London, UK, 2012; pp. 171–183.
47. Prior, L. *Using Documents in Social Research*; Sage: London, UK, 2003; p. 210.
48. Burns, T.R.; Stöhr, C. Power, knowledge, and conflict in the shaping of commons governance. The case of EU Baltic fisheries. *ISAC* **2011**, *5*, 233–258. [CrossRef]
49. Long, R. The Role of Regional Advisory Councils in the European Common Fisheries Policy: Legal Constraints and Future Options. *Int. J. Mar. Coast. Law* **2009**, *25*, 289–346. [CrossRef]
50. Linke, S.; Jentoft, S. Ideals, realities and paradoxes of stakeholder participation in EU fisheries governance. *Environ. Sociol.* **2016**, *2*, 144–154. [CrossRef]
51. ICES. *Baltic Fisheries Assessment Working Group (WGBFAS)*; ICES Scientific Reports; ICES: Copenhagen, Denmark, 2019. [CrossRef]
52. King, N.; Horrocks, C.; Brooks, J. *Interviews in Qualitative Research*, 2nd ed.; Sage: London, UK, 2018; p. 360.
53. Suri, H. Purposeful Sampling in Qualitative Research Synthesis. *Qual. Res. J.* **2011**, *11*, 63–75. [CrossRef]
54. Palinkas, L.A.; Horwitz, S.M.; Green, C.A.; Wisdom, J.P.; Duan, N.; Hoagwood, K. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Adm. Policy Ment. Health* **2015**, *42*, 533–544. [CrossRef]
55. Herzog, H. On Home Turf: Interview Location and its Social Meaning. In *Qualitative Sociology*, 2nd ed.; Gubrium, J.F., Holstein, J.A., Marvasti, A.B., McKinney, K.D., Eds.; Sage: London, UK, 2005; Volume 28, pp. 25–47.
56. Cresswell, J.; Cresswell, D. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed.; Sage: London, UK, 2018; p. 304.
57. Stamenova, K.; Hinshelwood, R. (Eds.) *Methods of Research into the Unconscious: Applying Psychoanalytical Ideas to Social Science*; Routledge: Abington, UK; New York, NY, USA, 2018; p. 282.
58. Charmaz, K. *Constructing Grounded Theory*; Sage: London, UK, 2006; p. 222.
59. Corbin, J.; Strauss, A. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 3rd ed.; Sage: London, UK, 2008; p. 379.
60. Saldana, J. *The Coding Manual for Qualitative Researchers*, 3rd, ed.; Sage: London, UK, 2015; p. 366.
61. Gläser, J.; Laudel, G. *Experteninterviews und Qualitative Inhaltsanalyse*, 4th ed.; Springer: Wiesbaden, Germany, 2010; p. 352.
62. EC. *Regulation (EU) 2016/1139 of the European Parliament and of the Council of 6 July 2016 Establishing a Multiannual Plan for the Stocks of Cod, Herring and Sprat in the Baltic Sea and the Fisheries Exploiting Those Stocks, Amending Council Regulation (EC) No 2187/2005 and Repealing Council Regulation (EC) No 1098/2007*; EC: Brussels, Belgium, 2016.
63. Knight, F.H. *Risk, Uncertainty and Profit*; Courier Dover Publications: Mineola, NY, USA, 1921.
64. Lempert, R.J.; Collins, M.T. Managing the risk of uncertain threshold responses: Comparison of robust, optimum, and precautionary approaches. *Risk Anal. Int. J.* **2007**, *27*, 1009–1026. [CrossRef]
65. Hadjimichael, A.; Reed, P.M.; Quinn, J.D. Navigating deeply uncertain tradeoffs in harvested predator-prey systems. *Complexity* **2020**, *4170453*, 18. [CrossRef]
66. Marchau, V.A.; Walker, W.E.; Bloemen, P.J.; Popper, S.W. *Decision Making under Deep Uncertainty: From Theory to Practice*; Springer: Cham, The Netherlands, 2019; p. 405.

67. Quinn, J.D.; Reed, P.M.; Keller, K. Direct policy search for robust multi-objective management of deeply uncertain socio-ecological tipping points. *Environ. Model. Softw.* **2017**, *92*, 125–141. [CrossRef]
68. Funk, S.; Krumme, U.; Temming, A.; Möllmann, C. Gillnet fishers' knowledge reveals seasonality in depth and habitat use of cod (Gadus morhua) in the Western Baltic Sea. *ICES J. Mar. Sci.* **2020**, *77*, 1816–1829. [CrossRef]
69. Pálsson, G. Learning by fishing: Practical engagement and environmental concerns. In *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*; Berkes, F., Folke, C., Colding, J., Eds.; Cambridge University Press: Cambridge, MA, USA, 1998; pp. 48–66.
70. Haggan, N.; Neis, B.; Baird, I. Introduction. In *Fishers' Knowledge in Fisheries Science and Management*; Haggan, N., Neis, B., Baird, I., Eds.; UNESCO: Paris, France, 2007; pp. 14–20.
71. Daw, T.M. *How Fishers Count: Engaging with Fishers' Knowledge in Fisheries Science and Management*; Newcastle University: Newcastle, UK, 2008.
72. Van Hoof, L.; Kraan, M.; Visser, N.M.; Avoyan, E.; Batsleer, J.; Trapman, B. Muddying the waters of the Landing Obligation: How Multi-level governance structures can obscure policy implementation. In *The European Landing Obligation. Reducing Discards in Complex, Multi-Species and Multi-Jurisdictional Fisheries*; Uhlmann, S.S., Ulrich, C., Kennelly, S.J., Eds.; Springer: Berlin/Heidelberg, Germany, 2019; pp. 179–196. [CrossRef]
73. Folke, C. Traditional knowledge in social–ecological systems. *Ecol. Soc.* **2004**, *9*, 7. [CrossRef]
74. Reed, M.S. Stakeholder participation for environmental management: A literature review. *Biol. Conserv.* **2008**, *141*, 2417–2431. [CrossRef]
75. Steins, N.; Kraan, M.L.; van der Reijden, K.J.; Quirijns, F.J.; van Broekhoven, W.; Poos, J.J. Integrating collaborative research in marine science: Recommendations from an evaluation of evolving science-industry partnerships in Dutch demersal fisheries. *Fish Fish.* **2019**, *21*, 146–161. [CrossRef]
76. Arnstein, S.R. A ladder of citizen participation. *J. Am. Plan. Assoc.* **1969**, *35*, 216–224. [CrossRef]
77. Degnbol, D.; Wilson, D.C. Spatial planning on the North Sea: A case of cross-scale linkages. *Mar. Policy* **2008**, *32*, 189–200. [CrossRef]
78. Linke, S.; Bruckmeier, K. Co-management in fisheries—Experiences and changing approaches in Europe. *Ocean Coast. Manag.* **2015**, *104*, 170–181. [CrossRef]
79. Miret-Pastor, L.; Svels, K.; Freeman, R. Towards territorial development in fisheries areas: A typology of projects funded by Fisheries Local Action Groups. *Mar. Policy* **2020**, *119*, 104111. [CrossRef]
80. EC. FARNET. Fisheries Areas Network. 2021. Available online: https://webgate.ec.europa.eu/fpfis/cms/farnet2/node_en (accessed on 12 July 2021).
81. Linke, S.; Dreyer, M.; Sellke, P. The Regional Advisory Councils. What is their potential to incorporate stakeholder knowledge into fisheries governance? *AMBIO* **2011**, *40*, 133–143. [CrossRef] [PubMed]
82. Linke, S.; Jentoft, S. Exploring the phronetic dimension of stakeholders' knowledge in EU fisheries governance. *Mar. Policy* **2014**, *47*, 153–161. [CrossRef]
83. Wenger, E. *Communities of Practice. Learning, Meaning, and Identity*; Cambridge University Press: Cambridge, MA, USA, 1998; p. 336.
84. Lupp, G.; Zingraff-Hamed, A.; Huang, J.J.; Oen, A.; Pauleit, S. Living Labs—A Concept for Co-Designing Nature-Based Solutions. *Sustainability* **2021**, *13*, 3012. [CrossRef]
85. Long, R.; Charles, A.; Stephenson, R.L. Key principles of ecosystem-based management: The fishermen's perspective. *Fish Fish.* **2015**, *18*, 244–253. [CrossRef]
86. Levin, P.; Breslow, S.J.; Harvey, C.J.; Norman, K.; Poe, M.; Williams, G.D.; Plummer, M.L. Conceptualization of Social-Ecological Systems of the California Current: An Examination of Interdisciplinary Science Supporting Ecosystem-Based Management. *Coast. Manag.* **2016**, *44*, 1–12. [CrossRef]
87. Piet, G.; Delacámara, G.; Kraan, M.; Röckmann, C.; Lago, M. Advancing Aquatic Ecosystem-Based Management with Full Consideration of the Social-Ecological System. In *Ecosystem-Based Management, Ecosystem Services and Aquatic Biodiversity. Theory, Tools and Applications*; O'Higgins, T.G., Lago, M., DeWitt, T.H., Eds.; Springer: Berlin/Heidelberg, Germany, 2020.
88. EC. *Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy, Amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and Repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC*; EC: Brussels, Belgium, 2013.

Supplementary Material

Western Baltic cod (WBC) stock status and management measures taken

In recent years the development of this stock has been strongly influenced in a negative way, particularly by climatic change effects (Drinkwater 2005, Hüssy et al. 2011, Stiasny et al. 2016, Voss et al. 2019) and continued overfishing (Sellke et al. 2016). According to scientific findings within our period of investigation (2017-2018), the fishing mortality (F) as well as the spawning stock biomass (SSB) were outside safe biological limits within both reference years: F was above FMSY (MSY = maximum sustainable yield; fishing pressure at sustainable level) and SSB was below the reference point called MSY Btrigger (ICES 2017, ICES 2018). It should also be mentioned that SSB has been below the reference level since 2008, as well as F, which was significantly above FMSY (ICES 2017, ICES 2018). Furthermore, the level of recruitment (R, i.e., number of young fishes enter the fishery) has been low since 1999 and, according to scientific estimates, it is assessed to be at lowest level of the time series in 2016 (ICES 2017, ICES 2018). Based on scientific calculations, a strong decrease of the cod catch quota for Western Baltic cod was set at EU level resulting in a reduction of catches by 60% compared to 2015 (EC 2016). As commercial fisheries are directly dependent on the level of the quota, this reduction also led to a considerable loss of fishers' income. Based on an estimated stock development, a roll-over period was negotiated for 2018 meaning a no further decrease or increase of the catch quota of Western Baltic cod (EC 2017).

Additionally, since 2017, the removal of cod by recreational fisheries has been considered in the fisheries stock assessment for Western Baltic cod. According to scientific calculations, recreational fisheries contribute significantly to the overall fishing mortality and were consequently significant compared to the catches from commercial fisheries (Strehlow et al. 2012, Eero et al. 2014). A so-called bag limit was introduced regulating anglers' removal by a fixed daily catch limit of 5 specimens, or 3 during the eight-week closure period between February to April (EC 2016, EC 2017). The latter was established politically in order i) to protect the Western Baltic cod stock from possible disturbance during spawning aggregations and thus ii) contribute to stock recovery (EC 2016, EC 2017).

Table A1. List of questions asked within each interview. The order of asked questions was dependent on the interviewees' expertise. Hereby, the interview guide consisted of five different thematic blocks: ecology, management, economy, communication as well as conclusion and solution. For the questions Ec1, Ec2 (economics) and C1 (communication) additional scale questions were used, which asked for further knowledge about economics and communication.

Id	Questions
Ecology	
Unlike in most marine areas, the marine fish species in the brackish water sea Baltic Sea are strongly dependent on environmental conditions such as salinity, temperature, oxygen content. In addition to these environmental factors, economic sectors such as fishing or tourism also influence fish stocks like cod.	
E1	What is your current state of the cod stock in the Western Baltic Sea? Would you rate the stock as endangered?
E2	Do you believe that a good environmental status can be achieved by 2020?
E3	How do you evaluate the influence of climate change on marine fish stocks and in particular on the stock situation of Western Baltic cod?
E4	Do you think that seabirds, such as cormorants and marine mammals (e.g. porpoises and seals) may have a negative impact on cod stocks in the Western Baltic Sea?
E5	Do you think that recreational fisheries have a negative impact on the stock size of the Western Baltic cod?
Management	
The stock of cod in the Western Baltic Sea is currently managed accordingly to a multi-annual plan. In addition to the Total Allowable Catches (TACs), this plan provides further restrictions on fishing activities. The aim is to manage the stock according to the maximum sustainable yield (MSY).	
M1	How would you define a good status for a fish stock?
M2	Do you currently consider the Western Baltic cod stock to be sustainably managed?
	a) Do you think the MSY approach is appropriate?
	b) Is it possible to achieve the management target by 2020?
M3	How would you explain to a student the way of allocating catch quotas in a comprehensible way?
M4	How would you evaluate the current fisheries management of the EU?
	a) In your opinion, what are the biggest problems and uncertainties in the management of Western Baltic cod?
	b) Do they consider the EU's sanctioning potential to be too low?
M5	Do you trust the calculation on the basis of which the fishing quotas are allocated & if yes/no why/why not?
M6	What do you think about the fact that the fishing quotas, and therefore the fisheries, are currently much less restricted than suggested by scientists?

M7	Can you comprehend the implementation of "bag limits" and fishing ban zones for angling in the current state of the stock? Do you think that these will lead to a recovery of the stock?
M8	Which stakeholders do you consider to have the greatest influence on the size of fishing quotas and on the management of fish stocks in general?
M9	Who do you think should take on which tasks in fisheries management?
M10	What do you say to the following quotation: "Fish has a lobby, fishers don't!"
M11	Should fisheries representatives be given more decision-making power in fisheries management?
M12	Do you believe that a reduction in fleet capacity will be necessary to protect the stock?
M13	Do you see the scrapping premium as an appropriate measure to protect the cod stock in the Western Baltic Sea?
M14	How do you assess the benefits of alternative fishing methods (e.g. modified nets to avoid by-catch species)?
M14	Do you see the business concept of 'Kutterfisch', i.e. one company controls production, processing and marketing, as a potential business model for the fishing companies managing the western Baltic cod stock?

Economy (Ec)

Cod and herring are considered to be the "bread fish" for Schleswig-Holstein (cod) and Mecklenburg-Vorpommern (herring). Fishers here are dependent on the income from fisheries on these species.

Ec1	How do you assess the economic importance of the Western Baltic cod stock both nationally and internationally?
Ec2	Assess the economic damage caused by the management measure now and in the future: a) bag limit b) fishing prohibited zones

Communication

During the master class, we dealt intensively with a number of different media contributions. Each of these articles provides an exciting insight into the cooperation but also into the dependencies of the stakeholders involved.

C1	How do you perceive and evaluate the dialogue between stakeholders involved in the fisheries management of Western Baltic cod (e.g. between scientists and representatives of angling and commercial fisheries)?
C2	Please describe possible reasons for a disrupted communication.
C3	If you have a suggestion for improving communication between stakeholders - what might it be?

Conclusion & solution (CS)

CS1	What do you think has gone wrong in the past with the management of EU fish stocks in general and of Western Baltic cod in particular?

CS2	If you had to give an assessment, how do you estimate the involvement of the relevant stakeholders in the current stock situation of Western Baltic cod?
CS3	What would be your personal first/important measure that would contribute to improving the cod stock situation in the Western Baltic?
CS4	What do you think has a higher priority? The state of the stock or the economic security of fisheries?
CS5	How could you foresee a balance between protection and economic consequences?
CS6	Is a sustainable fishery at all possible for you while protecting a stock?

Table A2a. Knowledge describes everything that the interviewees know, and which cannot be predominantly assigned to the EU fisheries management. This comprises a total of 10 different knowledge types, which e.g. are related to a spatial component (i.e., local knowledge), temporal component (i.e., historical knowledge, future knowledge) or knowledge that could be explicitly assigned to a specific stakeholder group (i.e., fishers' knowledge, anglers knowledge).

General categories	Type	Description
Local knowledge	Local ecological knowledge	Biological knowledge with local reference; knowledge of biological processes (i.e., abiotic and biotic factors at local level), e.g., fish species distribution in the Greifswald Bay area or an oxygen depletion event in Kiel Fjord
	Local economic knowledge	Economic knowledge with a local reference, e.g. marketing strategy of fisheries cooperative or side-business of fishers in summer (i.e. tourist trips). The economic term includes commercial fisheries (catch, processing), tourism and recreational fisheries
Tacit knowledge	Tacit knowledge	Knowledge of the experienced in the personal or work context. The own experiences are the main focus here and refer secondarily to other types of knowledge, e.g., interaction with other stakeholders via mail (institutional knowledge) or provided information about fish distribution by fishers (fishers' knowledge)
Ecological knowledge	Baltic Sea ecosystem	Knowledge of the ecosystem which is not clearly assigned to flora & fauna or influencing factors on Baltic Sea ecosystem, e.g., distribution of fish (in general) in response to climate change
	Flora and fauna of Baltic Sea ecosystem	Biological relationships, i.e. descriptions of flora and fauna of the ecosystem, e.g. explicit knowledge on Baltic Sea fish species as well as existence of vegetation in certain areas (e.g., bank area)
	Abiotic factors of Baltic Sea ecosystem	Knowledge about abiotic influences on the ecosystem, including human-induced factors (e.g. commercial fishery, agriculture), e.g., the influence of agriculture or fishery on the ecosystem health
	Cod	Biological knowledge that concerns the species cod including the evaluation of the biological condition of cod based on its recruitment or length distribution
	Influences on cod	Biological knowledge concerning impacts on cod; knowledge about abiotic (e.g., temperature or oxygen conditions), biotic (e.g., predator-prey relationship) and anthropogenic influences (e.g., commercial fisheries, recreational fisheries)
Historical knowledge	Baltic Sea ecosystem	Past biological processes and values related to the Baltic Sea ecosystem, i.e. past inflow events from the North Sea or past abundance of seals within the Baltic Sea
	Cod	Knowledge about cod refers to processes from the past, e.g., stock development or reproductive behavior in the past (i.e., beginning of sexual maturity)
	Economy	Past economic processes including market price of cod or the social status of the fisher in the community
	Others	Includes all contents which could not be assigned to the categories Baltic Sea, cod and economy, e.g. past institutional structures

Future knowledge	Baltic Sea ecosystem	Knowledge about future events and effects on the Baltic Sea ecosystem, which are based on assumptions supported by knowledge from the past and present (e.g., future climate events)
	Cod	Knowledge about future events and effects on cod, which are based on assumptions supported by knowledge from the past and present (e.g., future stock development)
Economic knowledge	Cod	Description of the economic importance of the Western Baltic cod stock, i.e. regional importance (i.e., cultural status) compared to its world market importance (i.e., market price)
	Commercial fisheries	Includes all economic contents in connection with commercial fisheries, including fish processing and certification processes
	Others	Includes all economic contents which cannot be assigned to the categories cod and commercial fisheries, i.e., buyer behaviour or the economic importance of other sectors like tourism and recreational fisheries
Institutional knowledge	Structure	Structural setup of institutions involved, processes and communication channels (e.g., round tables)
	Content	Stakeholder knowledge, statements and opinions on e.g., commercial fisheries, NGO, management, tourism
Fishers knowledge	Fisheries observation knowledge	Fisheries knowledge goes back to fishers as a profession and their practice of fishing (fisheries representatives are excluded); fishers provide information about the fishery (e.g., catches, length frequency)
	Fishers' experimental knowledge	Fishers' knowledge is based on being a fisher as a profession and fishers' practice of fishing (fisheries representatives are excluded); unique knowledge of the fishers that derives from fishing as a social practice
Angler knowledge		Contents which are mentioned related to recreational fisheries (i.e., fishing gear) and management measures (i.e., bag limit)
Non-knowledge	Non-knowledge (reference)	Statement that the interviewee does not know something, but refers directly to persons, institutions or stakeholder groups who possess that knowledge (e.g. I don't know, but XY knows!"); reference to science is excluded
	Non-knowledge (no reference)	Statement that the interviewee does not know something, and makes no reference to persons, institutions or stakeholder groups who might have knowledge about this ("I don't know!")

Table A2b. Knowledge-science describes the acquisition of knowledge by the interviewee, which is scientific consensus. This appropriation can be acquired through listening or reading. Further, knowledge-science is defined by reference to the scientific community. This category often appears in connection with the legitimation of non-knowledge.

General categories	Type	Description
	Non-knowledge	Interviewee does not know something, but refers to science that could give the answer; e.g., no knowledge about explicit numbers on the cod stock but reference to scientists
	Tacit knowledge	Tacit knowledge of the interviewee, which is scientifically grounded, e.g., stock assessment data
	Science reference	Reference to a scientific source (e.g., data of stock assessment) to answer the question

Table A3. Category science contains all quotes that explicitly refer to or mention science in its broadest sense. A total of 9 different sub-categories were found providing a rich conceptual landscape about how the different actors conceive the rationales of science and its perceived role by the interview partners.

General categories	Type	Description
Science	Scientists	Scientists mentioned and referred by interview partners
	Scientific institutions	Scientific Institutions mentioned by interviewees
	Scientific disciplines	Disciplines referred to as important for the cod problem
Scientific epistemology	System understanding of cod	Usefulness of a systems understanding of cod in the positive and negative sense as assessed by the interview partner
	Problem of system dynamics	Aspects of complexities and interactions within systems as described by the interview partner
	Weakness of models and modelling	Limits and limitations of models as seen through the interviewee's eyes
	Methodological gaps	Methodological problems in research as depicted by interview partners
	Empirical principles	Perceived or experienced ways of interpreting results taken from data analysis as witnessed by the interviewee
Science and Society	Trust in science	Ascribed relevance to science and its results for society by the partner
	Scientific uncertainty	Attributed uncertainty of scientific results and procedures as assessed by the interview partner
	Scientific predictability	Perceived accuracy of predictions as perceived by the interview partner
	Data availability and generation	Quest for more data instead of conceptual improvement of models

Table A4a. Management and its list of subcategories primarily concerned with the fisheries management of the European Union. These were further subdivided into a spatial classification (EU, federal and state level), the description of the management (e.g. reference points, conservations measures) and its problems and improvements (EU=European Union, TAC=Total Allowable Catch, MSY=Maximum Sustainable Yield, Blim=biomass limit reference point, BLE=Bundesanstalt für Landwirtschaft und Ernährung (Federal Office for Agriculture and Food), MOFI=Mobile Fisheries Log app, ICES=International Council for the Exploration of the Sea).

General categories	Type	Description
Levels	EU level	Management in relation to the European Union; policies on EU level (e.g., Common Fisheries Policy) and EU competence (e.g., consultancy and determination of quota by the European Council and Commission, respectively)
	Federal level	Management in connection with Germany; contents on federal level and responsibility of the German government (e.g. enforcement of regulations)
	State level	Management on the level of federal states; contents on state level and responsibility of the federal states (i.e., Schleswig-Holstein, Mecklenburg-Vorpommern)
Description of the EU fisheries management	Management system - general	Includes everything mentioned in the context of the current EU fisheries management, i.e. measures, multi-annual plans, quota
	Management system - TAC	Knowledge of the management system; this can range from very simple to very complex structures. The statements here refer mainly to system behind the allocation of the quota like the scientific advice from ICES given to the European Commission
	Reference points	Contains everything mentioned about reference points (MSY, Blim, etc.), as well as the definition of the good environmental status
	Stakeholder opinion	Returns whether the interviewees classify the current management as sufficient for the stock to recover
	Fishers direct implementation	Management content that directly affects the commercial fishers, e.g., catch reports, BLE app (MOFI app)
	Controls	Presence and implementation of controls within the commercial fishery, i.e., implementation of the control regulation
	Conservation measures	Conservation measures that have been implemented to protect the cod stock like set-aside premiums, landing obligation
	Alternative fishing gears	Statements on alternative catch techniques (i.e., selective gear), as well as on possible technical developments
	Bag limit	Contents and judgement on the subject of the bag limit, i.e. effectiveness of this management measure in order to ensure cod stock recovery
	Reduction of fleet capacity	Statements and judgements on the management measure fleet reduction
	Subsidies	Includes statements and judgement on subsidies, e.g. scrappage bonus, set-aside premium
Participation	Stakeholders - general	Contains everything mentioned concerning the participation of the stakeholders involved in the EU fisheries management (e.g., the inclusion on several policy levels)

	Stakeholder responsibilities	Assignment of tasks and position of stakeholders, e.g. task of the fisheries committee to find compromises between economic and fishers' livelihood trade-off
	Regional Advisory councils	Management in the context of regional areas; responsibilities and stakeholder participation of EU countries in the EU fisheries management; here, Baltic Sea Advisory Council
	Commercial fisheries	Contents, which were mentioned in the context of fishers' participation in the EU fisheries management, e.g., how and who to include
	Recreational fisheries	Participation of recreational fisheries in the EU fisheries management, e.g. inclusion in the discussion about measures to conserve spawning cod
	Science	Participation of science in the fisheries management, e.g. in which way to include science
	Communication	General statements regarding communication between stakeholders in the context of the EU fisheries management like an extended exchange between stakeholders on EU and national level
Impacts	Impact on cod	Impacts on the cod stock through the fisheries management, e.g., the amount of allowed and used catch within the different fisheries
	Recreational fisheries	Specific impacts of recreational fisheries on the cod stock (i.e., the amount of cod fished
	Impact on management	Any impact on the management, including the influence by various stakeholders like the commercial fisheries lobby
Problems	Management system	General problems (e.g., actions like the decrease of fishing pressure were taken too late) regarding the EU fisheries management system
	TAC	Problems (e.g., distribution among recreational and commercial fisheries) related to TAC, including the distribution of the quota
	Controls	Problems occurring in the context of the measure control like the complete enforcement
	Multi annual plan	Includes the issues of multi-year plans, e.g. their inflexibility
	Ecological aspects	Includes problems raised by the lack of ecological aspects (e.g. stock in general, age structure) in the management; e.g., consider the genetic diversity of the stock for management measures
	Fishers	Problems (e.g., moratorium) that directly affect the fishers
	Scrapping bonus	Any problems related to the management measure scrappage bonus (e.g., does not have a positive effect on the cod stock)
	Reduction of fleet capacity	Problems related to the fleet capacity and its reduction like the already small size of the fleet
	Bag limit	Possible problems (i.e., measure the effect of the bag limit) that were mentioned in the context of the bag limit
	Improvements in general	Suggested improvements for and by the management including a higher flexibility for quick reactions to unplanned occurrences

Improvements		
	Long-term management	Proposal for a long-term planning (e.g. for increasing robustness), rather than annual management implementations
	TAC distribution	Improvements concerning the TAC distribution, e.g., changes in the TAC levels between commercial and recreational fisheries or taking the TAC across several years (no loss of quota for fishers)
	Trade-off between sectors	Statements regarding the balance between commercial fisheries, conservation or tourism in order to enhance the stability of a socio-ecological as well as socio-economic system
	Scientific advice	Improvements mentioned in relation to the scientific advice, e.g., EU should hold on to advised quotas
	Improvements of communication	Recommendations to improve communication between stakeholders involved in EU fisheries management like a change of existing staff or the inclusion of all stakeholders at round tables

Table A4b. Management-knowledge describes all content of the interviews that explicitly refer to category management and are primarily aimed at the interviewees' knowledge of EU fisheries management, i.e. management in general (e.g. participation by stakeholder groups), explicit management measures (e.g. catch quota, scrapping premium) or knowledge types with focus on EU fisheries management (e.g. historical knowledge) are addressed (EU=European Union, MSY=Maximum Sustainable Yield, TAC=Total Allowable Catch). It should be highlighted that only this subcategory was subject to a different coding procedure. Based on author knowledge, all relevant management measures according to Western Baltic cod were noted and finer categorized if necessary. Furthermore, central knowledge types from the categorization of knowledge were used and applied including historical knowledge, tacit knowledge, local knowledge, non-knowledge and fishers' knowledge.

General categories	Type	Description
Management	Structure	Management on structural basis including different guidelines or reference values (e.g., MSY). Statements are excluded if they can be clearly assigned to a management measure (e.g. catch quota, scrapping bonus)
	Participation	Participation on international, national and regional level by stakeholder groups in the EU fisheries management of Western Baltic cod
	Ecology	Knowledge about management in connection with ecological concerns, e.g., knowledge about the fish species cod or the ecosystem
TAC	Structure	Structural characteristics, i.e. legal requirements for the implementation of this measure, including the distribution of the quota, the amount of the set quota
	Ecological impact	Ecological impacts related to the TAC, e.g., impact on the stock in terms of a decreased catch quota (stock recovery)
	Economic impact	Economic effects due to the fishing quota as a management measure; effects refer to the fishing sector in general (e.g., less income due to a decrease in TAC) and in particular to certification processes (e.g., loss of certification license)
Bag limit	Structure	Structural characteristics of the bag limit, including legal requirements for the implementation, e.g., to what amount the removal is limited or the origin of the defined reference value
	Ecological impact	Ecological impact of the bag limit, e.g. the effect on the stock in terms of a reduction of the bag limit resulting in a stock recovery
	Economic impact	Economic effects through the bag limit; effects refer mainly to the fishing and tourism sectors, e.g. the reduction of anglers through fewer fishing opportunities and the resulting decline in the tourism sector (including bed occupancy, restaurant visits)
Reduction of fleet capacity	Structure	Description of the legal requirements defining this measure, including a description of the ships affected by fleet capacity reduction
	Economic impact	Description of economic impacts, i.e. impacts relating exclusively to the fisheries sector (e.g., loss of fishing boats)
Scrapping bonus	Structure	Description of the legal requirements defining this measure, including a description of the ships affected by the scrapping bonus

	Economic impact	Description of economic impacts, i.e. impacts relating exclusively to the fisheries sector (e.g., loss of fishing boats)
Alternative fishing opportunities	Structure	Description of the legal requirements by which the management measure is defined and determined, e.g. description of different alternative fishing gear (e.g., cock pots, fish traps)
	Ecological impact	Ecological effects caused by the use of alternative fishing gear; these effects must be considered for the entire ecosystem or individual ecosystem components, e.g. reduction of by-catch (e.g., harbor porpoise, seal)
	Economic impact	Economic impacts due to the use of alternative fishing gear. These effects are mainly to be considered for the commercial fisheries sector (e.g., investment by commercial fisheries related to higher costs)
Seasonal closing	Structure	Description of the legal requirements by which the management measure is defined and determined, e.g. description of time limits as well as fishing activities that are excluded from the closed season
	Ecological impact	Ecological effects through the establishment of closed seasons, e.g. stock recovery due to the reduction of fishing pressure within a defined period of time (i.e. during the spawning season)
	Economic impact	Economic effects caused by the implementation of closed seasons, e.g. reduction of fishing effort and resulting loss of income
Historical knowledge	TAC	Past catch quota concerns; including content on the distribution mechanism of the catch quota (relative stability by a 15% barrier) or catch quotas allocated in the past
	Reduction of fleet capacity	Historical knowledge related to reduction of fleet capacity; this includes e.g. past performance of the commercial fisheries fleet
	Alternative fishing gears	Knowledge of past alternative fishing gears, e.g. size selection of fish
Tacit knowledge	TAC, bag limit	Experience (personal, working context) in connection with the EU fisheries management of the Western Baltic Sea cod; here in particular related to TAC and bag limit
Local knowledge		Management contents with local reference, e.g. size of the local commercial fishery fleet or effects by the bag limit particularly in Heiligenhafen
Non-knowledge	Non-knowledge - reference	Non-knowledge in the context of EU fisheries management; contents which clearly show that there is no knowledge and no reference to corresponding responsibilities (e.g., stakeholder groups). Usually this classification is accompanied by "I do not know"!
	Non-knowledge - no reference	Non-knowledge in the context of EU fisheries management, i.e., "I do not know, but XY knows." No knowledge but reference to corresponding responsibilities (e.g., stakeholder groups)
Fishers' knowledge		Fishers' knowledge with management reference; here fisheries management of Western Baltic cod, i.e. fishers' information concerning data related to stock assessment

Supplementary References

1. Drinkwater, K. F. The response of Atlantic cod (*Gadus morhua*) to future climate change. ICES J. Mar. Sci. 2005; 62, 7, pp. 1327-1337. doi:10.1016/j.icesjms.2005.05.015.
2. Hüssy, K. Review of western Baltic cod (*Gadus morhua*) recruitment dynamics. ICES J. Mar. Sci. 2011; 68, 7, pp. 1459–1471. doi:10.1093/icesjms/fsr088.
3. Stiansny, M. H., Mittermayer F. H., Sswat, M., Voss, R., Jutfelt, F., Chierici, M., Puvanendran, V., Mortensen, A., Reusch, T. B. H., & Clemmesen, C. Ocean Acidification Effects on Atlantic Cod Larval Survival and Recruitment to the Fished Population. Plos One 2016; 11, 8, e0155448 doi:10.1371/journal.pone.0155448.
4. Voss, R., Quaas, M. F., Stiasny, M. H., Hänsel, M., Stecher Justiniano Pinto, G. A., Lehmann, A., Reusch, T. B. H., & Schmidt J. O. Ecological-economic sustainability of the Baltic cod fisheries under ocean warming and acidification. J. Environ. Manage. 2019; 238, pp. 110-118. doi:10.1016/j.jenvman.2019.02.105.
5. Sellke, P., Dreyer, M., & Linke, S. Fisheries: A Case Study of Baltic Sea Environmental Governance. In Environmental Governance of the Baltic Sea, Gilek, M., Karlsson, M., Linke, S., & Smolanz, K., Eds.; Springer: Switzerland 2016; 10, pp. 45-71.
6. ICES. ICES Advice on fishing opportunities, catch, and effort. Baltic Sea ecoregion. Cod (*Gadus morhua*) in subdivisions 22–24, western Baltic stock (western Baltic Sea). Copenhagen, Denmark 2017. doi:10.17895/ices.pub.3095.
7. ICES. ICES Advice on fishing opportunities, catch, and effort. Baltic Sea ecoregion. Cod (*Gadus morhua*) in subdivisions 22–24, western Baltic stock (western Baltic Sea). Copenhagen, Denmark 2018. doi:10.17895/ices.pub.4377.
8. EC. Council Regulation (EU) 2016/1903 of 28 October 2016 fixing for 2017 the fishing opportunities for certain fish stocks and groups of fish stocks applicable in the Baltic Sea and amending Regulation (EU) 2016/72, Brussels, Belgium 2016.
9. EC. Council Regulation (EU) 2017/1970 of 27 October 2017 fixing for 2018 the fishing opportunities for certain fish stocks and groups of fish stocks applicable in the Baltic Sea and amending Regulation (EU) 2017/127, Brussels, Belgium 2017.
10. Strehlow, H. V., Schultz, N., Zimmermann, C., & Hammer, C. Cod catches taken by the German recreational fishery in the western Baltic Sea, 2005–2010: implications for stock assessment and management. ICES J. Mar. Sci. 2010; 69, 10, pp. 1769-1780. doi:10.1093/icesjms/fss152.
11. Eero, M., Strehlow, H. V., Adams, C. M., & Vinther, M. Does recreational catch impact the TAC for commercial fisheries? ICES J. Mar. Sci. 2014; 72, 2, pp. 450-457. doi:10.1093/icesjms/fsu121.

STUDY IV

Do social identity and cognitive diversity correlate in environmental stakeholders?

PLOS ONE

RESEARCH ARTICLE

Do social identity and cognitive diversity correlate in environmental stakeholders? A novel approach to measuring cognitive distance within and between groups

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Abstract

Groups with higher cognitive diversity, i.e. variations in how people think and solve problems, are thought to contribute to improved performance in complex problem-solving. However, embracing or even engineering adequate cognitive diversity is not straightforward and may even jeopardize social inclusion. In response, those that want to promote cognitive diversity might make a simplified assumption that there exists a link between identity diversity, i.e. range of social characteristics, and variations in how people perceive and solve problems. If this assumption holds true, incorporating diverse identities may concurrently achieve cognitive diversity to the extent essential for complex problem-solving, while social inclusion is explicitly acknowledged. However, currently there is a lack of empirical evidence to support this hypothesis in the context of complex social-ecological systems—a system wherein human and environmental dimensions are interdependent, where common-pool resources are used or managed by multiple types of stakeholders. Using a fisheries example, we examine the relationship between resource stakeholders' identities and their cognitive diversity. We used cognitive mapping techniques in conjunction with network analysis to measure cognitive distances within and between stakeholders of various social types (i.e., identities). Our results empirically show that groups with higher identity diversity also demonstrate more cognitive diversity, evidenced by disparate characteristics of their cognitive maps that represent their understanding of fishery dynamics. These findings have important implications for sustainable management of common-pool resources, where the inclusion of diverse stakeholders is routine, while our study shows it may also achieve higher cognitive coverage that can potentially lead to more complete, accurate, and innovative understanding of complex resource dynamics.

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Introduction

Diversity is a term generally used to identify differences between individuals or describe instances of being composed of differing elements or including different qualities. Depending on the type of differences by which the diversity is determined, people can be categorized under demographic, cultural, political, occupational, intellectual, or many other categories. As a guiding principle, these dimensions can be dichotomized into two overarching kinds of diversity: (a) *identity diversity* and (b) *cognitive diversity* [1–3].

Identity diversity—also known as *surface-level* diversity—refers to differences in a set of subjective characteristics that are apparent across individuals or groups [2]. As such, many social categories or deductive specifications that are explicitly defined by demographic, socio-economic, cultural, political, or any other salient features of the individuals fall into identity diversity. These are factors that are generally considered observable (think demographic categories), and often perceptible by those who seek or care about diversity and inclusion [4].

On the other hand, cognitive diversity—also known as *deep-level* diversity—refers to differences in how people represent, think about, and solve problems [2]. Hong and Page (2004) refer to this kind of diversity as *functional differences* and explain how it might be determined by measuring variations in people's perspectives (i.e., how they represent a problem) and heuristics (i.e. how they find solutions to a problem) (also see [5]). This kind of diversity has been suggested to be a critical driver of improving group performance in complex problem-solving [6–8]. Three mostly cited problem-solving benefits associated with cognitive diversity are i) augmentation (i.e., the generation of a larger pool of knowledge), ii) purification (i.e., the cancelation and refinement of errors and inaccuracies mostly in predictions), and iii) recombination (i.e., the emergence of innovative solutions as a result of higher possibility for permutation and combination of knowledge) [6, 9–11]. Accordingly, since human societies face more complex problems today, cognitive diversity becomes a vital ingredient in contemporary problem-solving.

Despite these benefits, achieving cognitive diversity is not always straightforward because such differences across groups and individuals are not immediately observable or readily detectable [12]. Instead, to assess cognitive diversity, researchers need to dive deeper into invisible variations in personality, intellectual abilities, and cognitive characteristics of individuals using intelligence tests [13], psychological and neuropsychological assessments [14], mental modeling techniques [15], or cognitive ability tests [16]. Yet, seeking and embracing cognitive diversity does not necessarily satisfy the full inclusion of diverse social identities [2, 17], which can be problematic wherein social inclusion is vital to achieving ethical goals such as achieving social equity and resolving conflicts in areas like participatory governance [18].

However, the inverse may possibly be true—that is, some sort of identity diversity can congruently achieve beneficial cognitive diversity [19, 20]. Under certain circumstances, incorporating diverse identities into problem-solving may concurrently encourage cognitive diversity which is beneficial to groups' problem-solving capability, while it also satisfies the social equity goals. While it does not appear to be an unreasonable assumption in some cases (e.g., particularly those cases wherein some salient differences that determine identity diversity are of high problem-solving relevance) [21], the literature around "diversity" is still open to debate about the relationship between identity and cognitive diversity. In fact there is evidence to the contrary, that is, that identity diversity does not always contribute to beneficial cognitive diversity [2, 3, 17].

Regardless of these controversies, in many cases, achieving both kinds of diversity at the same time or what has been referred to as "congruence between surface and deep-level characteristics"—has been thought to be a major success [2]. Despite practical challenges, implementing this congruency has been recommended in multi-stakeholder governance and management systems such as common-pool resources and environmental assessments [18]. Understanding diversity within stakeholders who interact with natural resource systems, therefore, serves as a great case study to evaluate these congruencies since they typically involve multiple stakeholders and require the participation of socially diverse groups in dialogue, deliberation, decision-making, and adaptive co-management [22]. This inclusive participation of socially diverse groups of stakeholders in decision-making and policy development processes instills stakeholders' sense of ownership of the decisions, helps them address conflicts and build shared understandings, thereby improving the legitimacy of natural resource management strategies [23, 24]. It, thus, constitutes an important component of improving decision-making and social and environmental sustainability [25].

In addition, natural resource systems are composed of both social components (i.e., human-related factors like consumption, regulations and conservation) and ecological components (i.e., nature-related factors like ecosystem health, resource abundance, productivity), as well as their feedback interactions (e.g., the impact of consumptions or regulations on resource dynamics or the impact of degraded ecosystem productivity on human well-being). These so-called social-ecological interdependences commonly lead to complex system behaviors and dynamics that are hard to predict [26, 27]. As a result, understanding and managing natural resource systems typically entails the participation of cognitively diverse individuals who bring a wider range of perspectives and heuristics to the table, and their diverse knowledge pool can lead to a greater cognitive coverage and a boosted problem-solving capability [7, 8, 28, 29].

Here we explore whether *congruence* exist in groups with diverse environmental stakeholders who self-identify themselves in different professional roles, each represents a certain type of human-nature interactions. We hypothesized that these different social identities are associated with distinct cognitive spaces and knowledge (i.e. there exist a correlation between surface and deep-level diversities in environmental stakeholders).

We build this hypothesis on prior theoretical and empirical evidence describing that different social groups of resource stakeholders (e.g. fishermen, hunters, scientists, policymakers, and managers) interact differently with natural and social dimensions of ecosystems at different time and spatial scales. Such different social groups may also be subjected to diverging beliefs and values [30], disparate experiences with the nature [28], differences in preferred adaptation strategies and management policies [31], and are thought to build in their minds diverse cognitive representations (i.e., mental models) of the system that reflect their specific interests and interactions.

To empirically support our hypothesis, we use a fisheries example where multiple groups of stakeholders interact differently with a natural ecosystem (i.e., a common-pool resource system). Our case is the Western Baltic cod (*Gadus morhua*) in Germany. Western Baltic cod is of crucial importance for regional ecosystems and constitute a vital component of coastal economies [32, 33] (a more detailed explanation of the case study is provided in S1 File). Cod is known as one of the species in high demand and plays a key role in the Baltic Sea, environmentally, socially and economically [34]. Here, we focus on stakeholder groups who are differently affected by or involved in fisheries management and therefore represent varying interdependences with the natural ecosystem (S1 File).

We use a semi-quantitative cognitive mapping technique called Fuzzy Cognitive Mapping (FCM) [35, 36] in conjunction with network analysis to develop a novel approach to measuring cognitive distances within and between social groups of stakeholders (i.e. individuals with diverse roles and resource use). Finally, analyzing the congruence of differences in stakeholders' identities and features of their cognitive maps can empirically demonstrate the potential proximity of surface and deep-level diversities among environmental stakeholders.

Methods

Data collection

Mental models and fuzzy cognitive maps. To measure variation in stakeholders' perceptions and understanding of the complex social- ecological relationships (i.e. deep-level diversity), we collected individual mental models about fisheries ecosystem dynamics and management from fisheries stakeholders. Theoreticians have hypothesized that humans develop in their mind simplified internal representations of the complex reality that allow them to perceive the world around them [15]. Individuals who observe, interact with, and experience the world around them can concurrently develop an internal model of the external world to understand it and predict how it functions [37]. These so-called mental models represent patterns of perceived cause-and-effect relationships among various concepts that are built through reasoning and thus shape the basis for problem-solving and decision-making [38]. Importantly, these mental models can be elicited through cognitive mapping techniques [39]. Cognitive maps are graphical representations of mental models in the form of directed networks where nodes represent concepts and edges show the causal relationships between them (see S1 File for more details).

Here we used Fuzzy Cognitive Mapping (FCM) [35]—an enhanced form of cognitive maps which mathematically and graphically model system components (nodes), their causal relationships (edges), and the strength of these relationships using a normalized quantitative parameterization of causal magnitudes. In an FCM, edges are characterized by a normalized number in the interval of [-1, +1], corresponding to the strength and sign of causal relationships between nodes, thereby forming a weighted directed graph [40]. These weighted directed graphs can be analyzed using network analysis through measures and algorithms related to node connectivity, graph distances, their adjacency matrices similarity, and graph clustering [41].

Cognitive map elicitation. Five relevant stakeholder types were identified in a stakeholder analysis: Local fisheries (including commercial and recreational fishers) (33.3%), representatives of tourism industry (12.1%), Non-governmental organizations (NGOs) (18.2%), managers and policymakers (18.2%), and scientific experts (18.2%). Two key criteria were applied to sample study participants (N = 33) using a purposeful sampling strategy: stakeholders needed to be affiliated with a German institution either through their job or honorary position, and have been active (involved or affected) in the cod fishery in the Western Baltic Sea for more than 5 years (see the description of interviewed stakeholders in S1 File). The first criterion is based on the intention of a national survey, whereas the second one was chosen as a reference point to ensure that the interviewees have established themselves in their position (job, volunteer) and are familiar with the subject of cod fishery in the Western Baltic Sea. Both criteria led to the exclusion of some actors, including stakeholders from the fishing industry or people who have only recently started working on this topic, for example, trainees.

We elicited stakeholders' FCMs through semi-structured interview processes. This study was conducted with approval of University of Hamburg, and informed consent was acquired from all participants. All subjects gave their informed consent via email for inclusion before they participated in the study. The study was hence conducted in accordance with the Declaration of Helsinki. Individuals were asked to identify relevant concepts (i.e., system components) and their causal relationships, from which they then drew a concept map representing their mental models about Western Baltic cod ecosystem and fisheries management. This process included routine FCM data collection practices with open-ended concepts [42]. Participants' cognitive maps were qualitatively homogenized (i.e., using the same terminology for concepts that have the same meaning across all individual maps; see refs.[43, 44] for more detail about qualitative homogenization and standardization process) and digitized after the interview (i.e. maps were converted to digital weighted directed graphs and corresponding adjacency matrices using www.mentalmodeler.org) and sent back to the interviewees for validation. We described in details the cognitive map elicitation protocol elsewhere [45] and in S1 File.

Data analysis

Comparing graphs. Following the qualitative homogenization of FCMs and standardization of terminologies used to describe their concepts, we conducted a subsequent level of homogenization called quantitative homogenization: FCM adjacency matrices were brought to the same size and thus included information about every unique concept that was mentioned in any of the contributing FCMs. By doing this, all adjacency matrices were adjusted to have the same size in favor of matrix comparability—for each individual FCM, the absent nodes not mentioned in the original map were added but left unconnected to other nodes.

To measure cognitive diversity in a group, we determine how dissimilar the cognitive maps of the group members are by measuring the average of their pairwise distances. To quantify the distance between cognitive maps, we perform network comparisons of FCMs. Each FCM is a directed, weighted graph $G(V,E)$, with V being the set of nodes (i.e. set of homogenized concepts mentioned by all individuals) and E being the set of edges (i.e., causal connections). We compute the distance between a pair of FCMs by taking into account two measures:

(a) The distance between the dichotomized adjacency matrices of their graphs:

The dichotomized adjacency matrix A^d of a graph G is a $n \times n$ square matrix, where n is the number of nodes, and the elements of the matrix $[a_{ij}]$ indicate whether pairs of nodes i and j are adjacent $[a_{ij}] = 1$ or not $[a_{ij}] = 0$ in the graph. Apart from weightings, in FCMs, the presence and absence of the connections is important information which is a binomial variable (0 or 1), representing the extent to which one individual includes or excludes the directed causal relationship between two concepts when representing a complex system (independent of the sign and the strength of the relationships). One common norm used as graph distance is the Jaccard distance [46]. Given two graphs $G_1(V_1,E_1)$ and $G_2(V_2,E_2)$ with dichotomized adjacency matrices A_1^d and A_2^d, the Jaccard coefficient J is defined as $J(A_1^d, A_2^d) = \frac{A_1^d \cap A_2^d}{A_1^d \cup A_2^d}$, and their Jaccard distance is calculated as follows:

$$d_J = 1 - J(A_1^d, A_2^d) \tag{1}$$

(b) The distance between the spectra of their graphs:

The spectrum of a graph $G(V,E)$ is the set of eigenvalues of its normalized Laplacian [47, 48] and contains useful information about the principal properties and structure of a graph which has important implications for graph comparisons [48–50]. In addition, the prior study [25] demonstrated that the Euclidian distance between the spectra of two FCMs perfectly matches the distance between dynamics of causal relationships as perceived by individuals (i.e. simulation of what-if scenarios using a combination of fuzzy logic and artificial neural networks) [35, 51].

Let A_w be the undirected, weighted adjacency matrix such that the elements of $A_w = [a_{ij}] = [a_{ji}]$ indicate the edge weights between pairs of nodes i and j that are adjacent in the graph. Then the (symmetric) normalized Laplacian is defined as $L^{sym} = D^{-1/2}LD^{-1/2}$, where $L = D—A_w$, while D is the degree matrix. Importantly, all eigenvalues of the normalized Laplacian are real and non-negative [48], thereby offering a practical tool for measuring graph distances.

Given two graphs $G_1(V_1,E_1)$ and $G_2(V_2,E_2)$ we find a set of all eigenvalues for each normalized Laplacian as their spectra. Similar to the approach outlined in [52, 53], we compute the Euclidian distance between the graphs' spectra d_s as follows:

$$d_s = \sum_{i=1}^{k^*} (\lambda_{1i} - \lambda_{2i})^2 \tag{2}$$

where λ_i is the i^{th} largest eigenvalue and ($\lambda_i \geq 0$ *for* $\forall$ i). We find the smallest k such that the sum of the k largest eigenvalues constitutes at least 90% of the sum of all of the eigenvalues. If the values of k are different between the two graphs, we use the smaller one k^*.

These two measures of graph distance are complementary as they take into account the structural properties that are characterized by either edge directionality or edge weights. Thus, to jointly acknowledge the weight and directionality of causal connections in FCMs, we define the cognitive distance between two FCMs as follows:

$$CD = \frac{d_s}{1 - d_J} \times \varphi \tag{3}$$

were φ is the standardization coefficient for mapping CD to a normalized range between [0,1].

All individual cognitive maps were converted into adjacency matrices and the cognitive distances between any pairs of maps were computed using Eq 3. For each identifiable social group (e.g., fishers, managers, NGOs, tourism, and experts) we make two sets of cognitive distances: the *intra-group* set including the cognitive distances between any pairs of socially homogeneous individuals who share the same social category (e.g., a pair of fishers), and the *inter-group* set including the cognitive distances between any pairs of socially diverse individuals who do not share the same social category (e.g., a pair of one fisher and one manager). Independent sample t-tests were used to compare the means of cognitive distances in intra-group and inter-group sets. This helped us determine whether or not inter-group distances were longer than intra-group distances—that is, the cognitive diversity amongst socially diverse individuals was statistically significantly higher than the cognitive diversity in socially homogeneous ones. Despite the fact that independent-samples t tests were shown to be reasonably robust to Type I and Type II errors when the normality assumption was violated [54], we conduct an additional non-parametric test to determine the significance of differences. We use the non-parametric Wilcoxon-Mann-Whitney (or U) test to compare differences between *intra-group* and *inter-group* sets of cognitive distances with the assumption that they are independent, but not normally distributed.

Monte-Carlo method. We then used the Monte-Carlo method (MCM), wherein the virtual FCMs were randomly reproduced from the probability distributions of stakeholder-driven cognitive maps. That is, virtual agents with a defined identity (e.g., fisher, manager, etc.) were computationally generated, such that their cognitive maps were randomly drawn from the probability distribution of FCMs elicited from actual individuals of that social type [8]. For each group g with K individuals $i = 1,\ldots,k$, the set of all unique edges mentioned by these individuals is $\{E\}$:

$$\{E\} = \cup_{i=1}^{k} \{E^i\} \tag{4}$$

$$for\ \forall\ e \in \{E\}, \quad \pi_e = \frac{1}{K} \sum_{i=1}^{K} X_e^i \tag{5}$$

Where π_e is the frequency of edge e in group g, $\{E^i\}$ is the set of edges included in the FCM of individual i, and $X_e^i = 1$ if e is in $\{E^i\}$, ($X_e^i = 0$, otherwise). Then, a random FCM is generated in two steps: First, a random set of edges is drawn such that the probability that the generated FCM includes edge e is determined by a Bernoulli distribution, $Pr(X_e = 1) \sim Bern(\pi_e)$; and second, the weight of edge e in a random FCM $w(e)$ is determined by a random normal distribution:

$$w(e) \sim N(\mu_e, \sigma_e) \quad (6)$$

Where μ_e and σ_e are the mean and standard deviation of weights assigned to edge e by all individuals in group g whose FCMs include e. Although, this process of random FCM generation uses edges-probability distribution (instead of nodes-probability distribution), which represents the likelihood that two-nodes co-occur, and at the same time, they are adjacent, it does not take into account the probability that two edges with a shared source node co-occur in a map. One possible solution to this limitation is to keep at least a memory order of one and hence using a Markov-Chain Monte-Carlo (MCMC) of memory 1 in which the random matrix is reproduced while representing a memory with respect to the number of first neighbors that each node has. However, this requires a relatively large sample of observations (i.e., collected FCMs), which in many cases, is not achievable due to the fact that FCM interviews are typically time and resource demanding.

Importantly, the MCM helps us regenerate virtual samples of stakeholders that artificially represent various levels of identity diversity, thereby enabling us to carry out a probabilistic examination of how identity diversity correlates with cognitive diversity. Using MCM we built 100 replicates of our FCM sample. Each reproduced sample has $N = 33$ individuals (to resemble actual sample size) with a random combination of virtual agents from different social categories (i.e. individuals of different types). For each random replicate, 1000 bootstrap resamples were used to estimate the 95% confidence interval.

To measure the identity diversity of each reproduced sample we used Shannon's entropy index (H) [55]. The Shannon's entropy index takes into account both the richness (i.e., how many unique identities exist in a sample) and the evenness (i.e., how even the proportions of stakeholder identities are in a sample), and thus provides useful information about identity diversity. Fig 1 displays four illustrative samples of size 10 with different richness and evenness. We calculate identity diversity in each sample using the following equations:

$$H = -\sum_i p_i \times Ln(p_i), \quad p_i = \frac{n_i}{N} \quad (7)$$

$$D = \frac{e^H}{\max(r)} \quad (8)$$

where H is the Shannon's entropy index, n_i is the number of individuals of type i, N is the sample size, D is the identity diversity, and $max(r)$ is the maximum possible richness (i.e. maximum possible number of unique types) in a sample, which is 5 in our case. D is a number between [0,1] with values closer to one representing higher diversity. In addition, we define cognitive diversity as the mean of pairwise cognitive distances (CD) (see Eq 3) between any two individuals within the sample. Finally, the correlation between identity diversity and cognitive diversity is calculated using Pearson correlation coefficient.

Last but not least, we drew on network theory and cognitive map analyses of perceived causation [56] to cluster FCMs using their network micro-motifs (i.e., micro-structures that are constructed by two or three nodes and some unique patterns of connections between them,

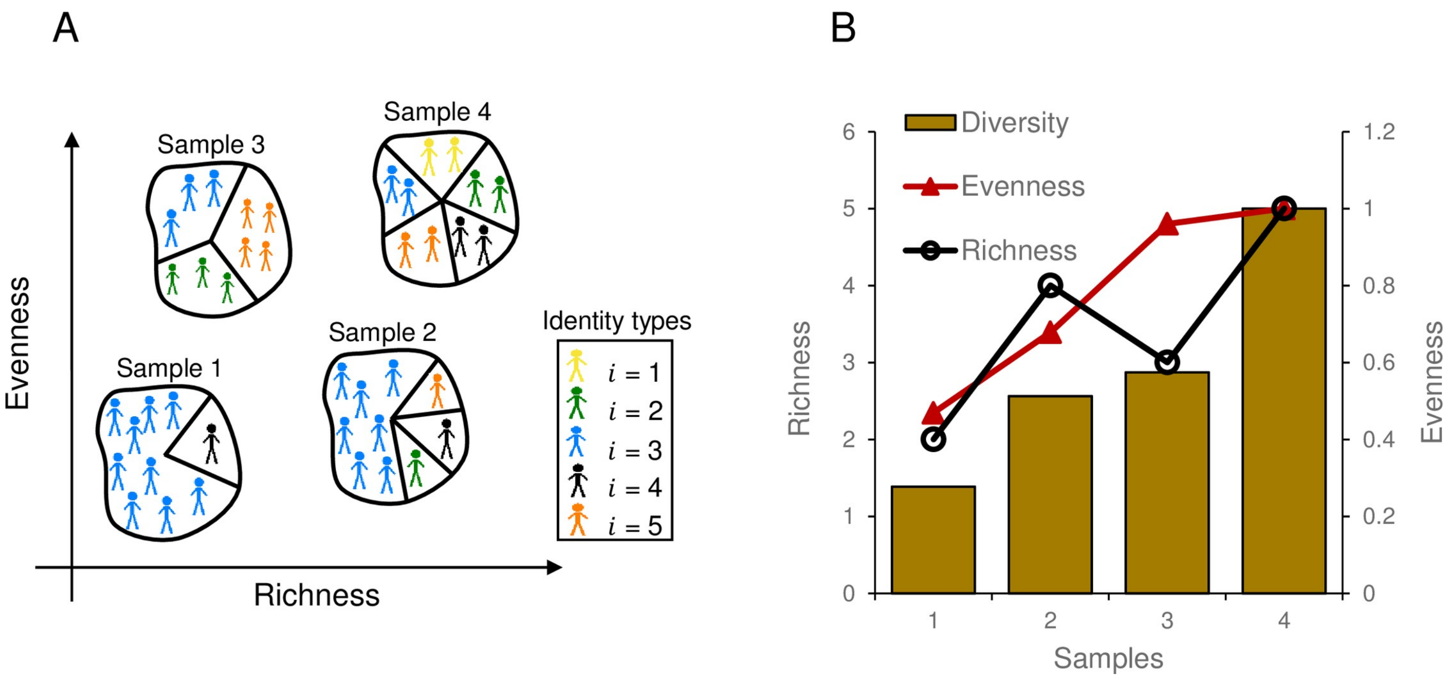

Fig 1. Illustrative samples of individuals with different levels of richness and evenness. Four hypothetical examples with low-to-high levels of richness and evenness are shown in (A). The calculated identity diversity with regards to each sample's richness, evenness, and their influence on the level of diversity is shown in (B). Samples' diversity was calculated using an information theoretic measure built on Shannon's entropy formula.

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which shape the underlying elements of perceived causation in a cognitive map). The frequency distribution of these micro motifs in one cognitive map—also known as directed graphlets of size two and three—can provide useful information about how one individual sees the causal interdependencies and can be used as a tool for deep-level comparisons [51]. Theoretical and empirical studies have frequently suggested the use of seven simple micro-motifs (Fig 2) to exemplify common patterns of perceived causation [56–62]. We combined Principle Component Analysis (PCA) and K-mean clustering to develop an unsupervised learning algorithm that clusters individuals based on their frequency distributions of these 7 micro-motifs and no pre-defined labeling. We also clustered the individuals based on their pre-defined identities (i.e. social types labeling). Analyzing and visualizing the alignment between identity-based clustering and micro-motif-based clustering helped us further examine the proximity of surface and deep level diversities.

Results

Intra versus inter-group cognitive distances

We collected 33 FCMs through semi-structured interviews with stakeholders (see S1 File). Five social groups (i.e. types) of stakeholders participated in our study. Fig 3 illustrates the comparison of intra-group versus inter-group pairwise cognitive distances (see Eq 3). Independent sample t-tests were used to compare the means, and p-values demonstrate significance of their difference. In all five socially distinguishable groups of stakeholders (Fig 3A–3E) the mean of inter-group cognitive distances is longer than the mean of intra-group cognitive distances, and in three groups (i.e., NGOs, tourism, and experts) these differences are statistically significant at the level of $p < 0.05$. It is visible from the Fig 3F that, once all individuals are combined, the cognitive diversity (measured by the mean of cognitive distance between any pairs of

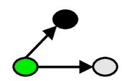
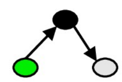
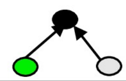
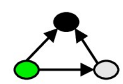
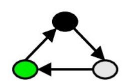
Typology of causality	Corresponding network structure (Graphlet)	Micro-motifs	Details
Direct Dependence	Simple Directed Edge		One node affects an adjacent node
Bi-directionality	Closed Pair		One node affects and simultaneously is affected by an adjacent node
Multiple Effects	Linear Triplet (Source)		Two non-adjacent nodes are affected by a shared adjacent node
Indirect Effect	Linear Triplet (Passer/Flipper)		One node affects a non-adjacent node throw a third node that mediates the effect
Multiple Causes	Linear Triplet (Sink)		Two non-adjacent nodes affect a shared adjacent node
Moderated Effect	Closed Triplet (Feedforward)		One node affects an adjacent node while it simultaneously affects that node throw a third node.
Feedback Loop	Closed Triplet (Feedback)		Three adjacent nodes affect one another through a cycle, either clockwise or counter-clockwise

Fig 2. Seven micro-motifs and their corresponding network structure (Graphlet). These micro-motifs exemplifying common patterns of perceived causation in cognitive maps.

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individuals) amongst socially diverse individuals (i.e. inter-group pairs) is statistically significantly higher than the cognitive diversity in socially homogeneous ones (i.e., intra-group pairs). Additionally, the results of nonparametric Wilcoxon-Mann-Whitney *U* test further supported the findings that the mean of inter-group cognitive distances was statistically significantly larger than the mean of intra-group distances ($p = 0.04$), even if the the normality assumptions were violated.

Correlation of identity and cognitive diversity

Next, we examined the correlation of identity and cognitive diversity using the MCM. Fig 4 shows the result of 100 randomly generated samples of stochastic agents (i.e. artificial individuals who own randomly-generated cognitive maps drawn from the probability distribution of actual FCMs). These random samples represent different levels of identity diversity determined by Eq 8. Pearson correlation coefficient of 0.74 revealed a positive association between samples' identity diversity and the mean of pairwise cognitive distances among agents' cognitive maps. That is, samples high in identity diversity are 74% probable to show high cognitive diversity (each sample was bootstrapped 1,000 times to estimate 95% confidence interval).

Proximity of surface and deep-level clusters

In addition, we compared the results of two clustering algorisms: one based on predefined socially distinguishable labels (i.e. identity), and the other one based on an unsupervised

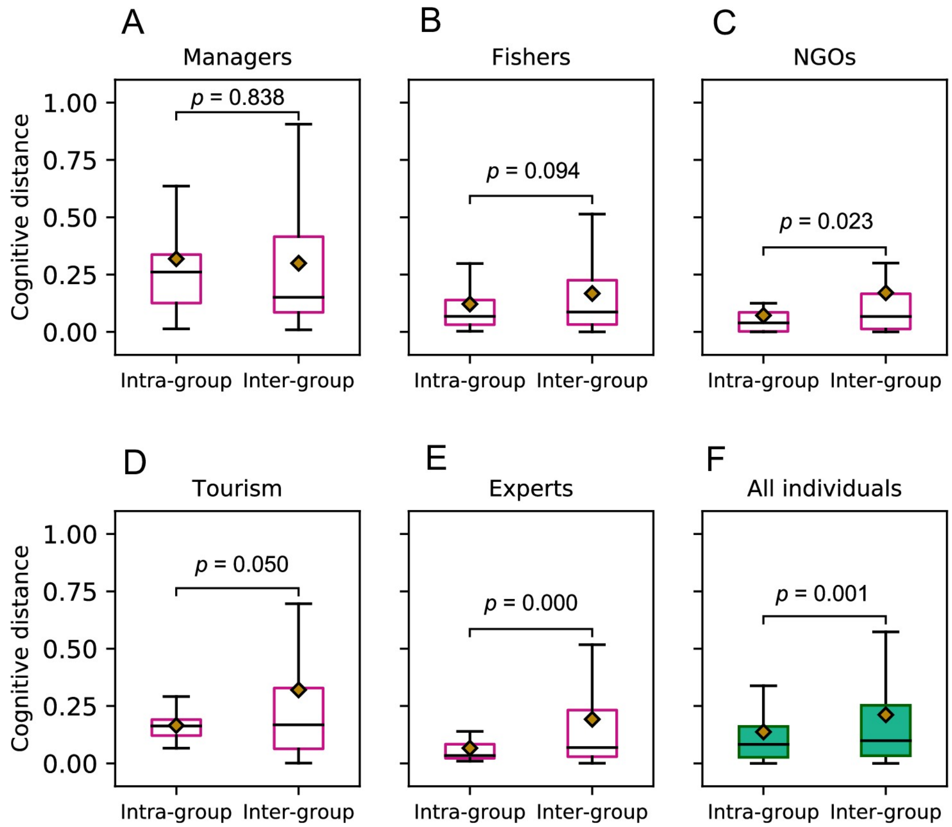

Fig 3. Comparison of intra-group (i.e., within social groups of stakeholders) versus inter-group (i.e., between social groups of stakeholders) pairwise cognitive distances. Independent sample t-tests were used to compare the means, and *p*-values demonstrate significance of their difference. (A-E) show the distribution of inter-group versus intra-group cognitive distances for five social groups of stakeholders. Overall results for all individuals is shown in (F). Note that in (F) the nonparametric Wilcoxon-Mann-Whitney *U* test is also significant ($p = 0.04$).

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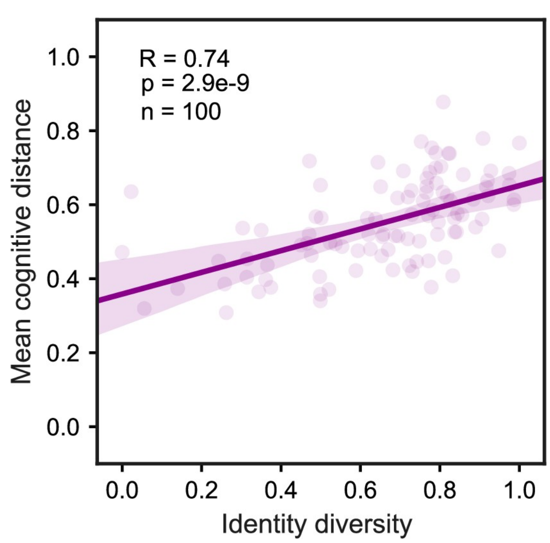

Fig 4. Correlation between identity and cognitive diversity. The figure shows the result of 100 randomly generated samples of size N = 33 individuals. The shaded area represents 95% confidence interval estimated by bootstrapping the sample 1000 times.

https://doi.org/10.1371/journal.pone.0244907.g004 dimension reduction technique (i.e., a PCA) that transforms cognitive maps from their 7-dimensional micro-motif space (see Fig 2) to a 2-dimensional principle component space, where clusters are determined by k-nearest neighbors (based on their Euclidian distance). Fig 4A and 4B illustrate the results of these two clustering algorithms for a randomly reproduced sample of size 1,000 (with 200 individuals for each of five social groups). It is visible from these figures that individuals who are similarly clustered by their predefined social identities are more likely to be in the same cognitive neighborhood that represents a prevailing cluster of individuals who are closely matching in terms of how they perceive causal interdependences. Fig 5C shows the probability of possible concurrencies formed by the categories of two clustering algorithms. Interestingly, for each cognitive cluster, there exists one and only one dominating social cluster (i.e. identity) whose concurrency probability is greater than 0.5, meaning that the overwhelming majority of individuals within a cognitive cluster share the same social identity. These findings revealed that environmental stakeholders demonstrate distinguishable differences in discrete aspects of their cognitive models (i.e., deep-level clusters) that are most probably aligned with the way they could have been distinguished by their disparate social identities (i.e., surface-level clusters). Consequently, these perfect alignments demonstrate the strong likelihood of congruence of surface and deep level diversities in environmental stakeholders.

Discussion

The importance of diversity, in general can be seen across systems, from ecosystems [63] to economic systems [64], and also extends to norms regarding social inclusion and social equity [65, 66]. In each case, diversity is considered to make systems more adaptable and resilient to changes. Here we extend this general notion of the diversity bonus [4] and provide evidence of the hypothesized correlation between identity diversity (surface) and cognitive diversity (deep). Our data provide empirical evidence that the inclusion of diverse stakeholder groups in natural resource problem-solving has implications for better understanding the complexity of natural resource systems since different social groups interact within these systems somewhat similarly by group, but distinct across groups providing more opportunities for full cognitive coverage [8]. While the literature on collaborative natural resource management has for some time promoted the inclusion of diverse stakeholder groups and public participation for improved decision-making [18], the diversity of knowledge systems that these different social groups bring with them has been largely assumed, rather than empirically evaluated with some exceptions [67].

Combining approaches from network science, graph theory, and cognitive mapping, we explored the relationship between social identity and cognitive diversity in environmental stakeholders who interact with a common pool resource system. For this, we collected stakeholders' cognitive maps using FCM—a weighted, directed graph that visualizes people's mental models that represents how each individual perceives causal interdependencies to explain the complex real world they interact with. In this study we used a case of Western Baltic cod in Germany and collected FCMs from five groups of stakeholders whose identities are socially distinguishable (i.e., social categories that are identified by their distinct roles and types of resource use which specify how they interact with the fisheries ecosystem and its resources).

Our data indicate that individuals whose identities (i.e., social categories) vary and demonstrate variations at surface-level, also develop cognitive maps that are more likely to demonstrate diverging network structural aspects as determined by their longer cognitive distances—a quantitative measure to represent cognitive, deep-level variations base on cognitive map characteristics. We developed a novel measure of cognitive distance which simultaneously

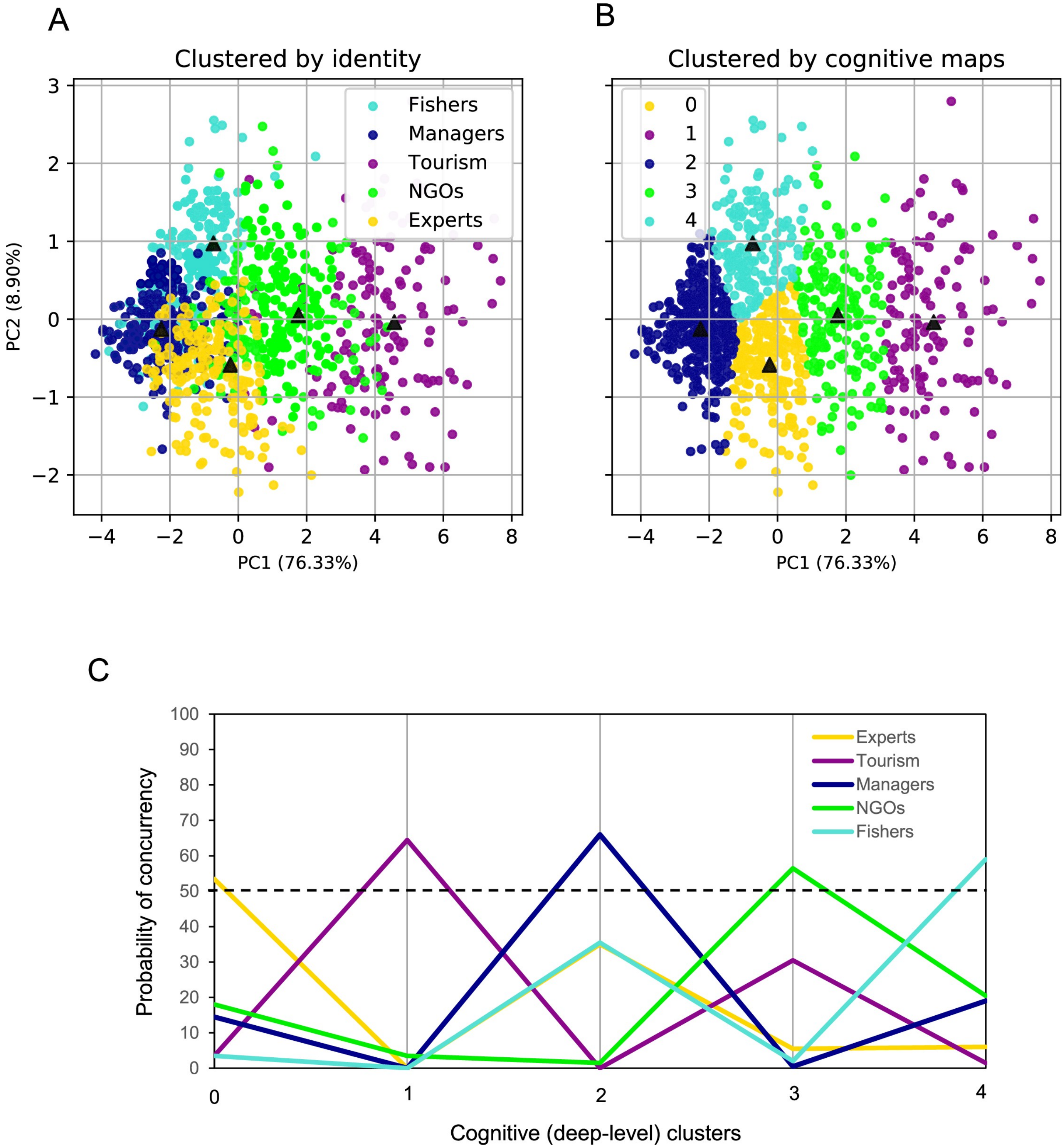

Fig 5. The proximity of identity and cognitive diversities based on micro-motifs in cognitive maps. Principle component analysis was performed on the seven dimensions of micro-motif frequencies in 1000 random cognitive maps (with 200 individual maps were re-produced form the probability distribution of cognitive maps of each of the five social groups). Two principle components were retained, cumulatively explaining about 85% of variance. Individual maps are illustrated by points in a 2-dimensional principle component scatter plot where points are clustered by their predefined social identities in (A) and by a K-Mean clustering algorithm using the Euclidian distances between points in (B). Black triangles in (A) and (B) illustrate the center of the clusters based on K-nearest neighborhood. The probability of concurrencies of social identities and cognitive clusters is shown in (C).

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takes into account dissimilarities in graph and spectral-graph metrics to provide useful insights about how individuals' cognitive maps (i.e., mental models) differ at the macro scale (metrics that represent a graph as a whole). These methods for comparing FCMs prove to produce useful information about how individuals represent different mental models and how they vary in perceiving the dynamics of the system they represent (e.g. [8, 25]).

Despite the benefits of using spectral methods such as the eigenvalue similarity index we used in the current study, we should warn the readers of some of the drawbacks associated with the use of spectral methods in comparing graphs (e.g., dependence on the matrix representation and abnormal sensitivity, such that small changes in the graph's structure can produce large changes in the spectrum) [51]. Thus, before using this approach, we encourage readers to evaluate the sensitivity of the spectra of their observed sample of FCMs to small changes (e.g. through a repetitive process of random small alterations, such as random removal or extension of nodes and edges). We, also encourage readers to replicate our study by using other methods for comparing graphs and conclude which approaches most appropriately fit their study.

Yet, it is also interesting to consider the variations of cognitive maps at the micro scale. To that end, we examined the distribution of certain directed graphlets in cognitive maps (i.e. micro-motifs) that represent common patterns of perceived causalities and are building blocks of causal reasoning [56]. This micro-motif comparisons, too, showed the proximity of identity and cognitive diversities (Fig 5). While conventional graphlet methods for network comparisons such as Relative Graphlet Frequency distance (RGF-distance) [68] or Graphlet Degree Distribution agreement (GDD-agreement) [69] use all 2-5-node Graphlets, our approach only takes into account those micro-motifs that represent common typology of perceived causation and have important relevance to comparing cognitive maps (see Fig 2).

Trade-offs in measuring knowledge diversity

Currently, there are several methods that exist to elicit and compare knowledge diversity, each with trade-offs. For example, "Cultural Consensus" theory [70] is a relatively straightforward way to understanding within and across group differences, often measured through evaluating individuals' responses to a series of related questions where norms and shared beliefs can be assessed through aggregate responses [71]. While these methods have been widely used, many questions posed to individuals exist at a broad-level and often force participants to select binary responses (true/false). Additionally, qualitative approaches, such as applying emergent coding rubrics to concept maps or narratives are also common [72]. While these approaches provide rich data, analyzing and coding qualitative concept maps take considerable time and are resources that might not be available with larger datasets. Finally, FCM as a semi-quantitative assessment, such as the approach we use here, has been popular in recent years. Gray et al. (2014) point out, however, that there are considerable trade-offs in how these cognitive maps are collected: are concepts/elements in the model pre-defined?, are these maps the result of an interviewer leading the process of map development or are crowdsourced freely, or are they a mix of data collection methods? Each decision a researcher makes in the data collection process will influence the analytical options available to the researchers and should be considered fully in the design of studies seeking to elicit, capture and integrate or compare individual knowledge [42].

In the context of social-ecological systems, and in contrast to our findings, Stier et al. (2017) found that experts can exhibit cognitively diverse views and perceptions about the structure of a complex ecosystem (e.g., marine food web), independent of commonly identified "bins" of expertise (e.g., local, scientific, traditional) [17]. That is, the identity and cognitive diversities may not necessarily co-occur. The authors of that study have contended that individuals' demographics and background may not explain differences in perceptions of complex ecosystem structure as evidenced by lack of variations in their cognitive maps.

We argue that such findings might be influenced by the methodological biases resulting from highly standardized elicitation methods where cognitive maps are constructed using predefined standardized concepts provided by researchers. In such cases, representation of individuals' cognitive maps is significantly influenced by researchers' presumptions or limitations; consequently, true cognitive diversity is less likely to be fully captured. Therefore, we decided to provide more flexibility and elicited cognitive maps while individuals were able to freely brainstorm, represent concepts, and draw connections between them with no influence from researchers and facilitators. This decentralized process allows individuals to freely represent their internal perceptions and system knowledge, and therefore it increases the probability that a wider spectrum of knowledge diversity (i.e., cognitive coverage) is sampled. In addition, conventional methods to compare FCMs (e.g. methods described in [51]) which were used by prior studies (e.g., [17]), take into account fewer structural metrics mainly obtained by comparing the value of network global statistics, such as the density, number of receiver/driver/ordinary nodes, complexity index, hierarchy index, and the centrality of particular nodes. Except for the centrality, these metrics do not consider the correspondence between nodes—that is, two FCMs with different set of nodes, (i.e., different qualitative compositions) may be considered very similar only because they have the same number of nodes or how these nodes are connected to each other matches across two FCMs (i.e., apples and oranges considered similar because they both have round shapes). These limitations may impact the results of previous studies. Here we addressed these limitations by introducing a novel approach to measuring cognitive distances within and between groups of stakeholders.

Conclusion

In sum, our approach produces a more inclusive set of insights into understanding and measuring within group and between group knowledge variations, which has three important implications: First, measuring within group cognitive distances has implications for how we understand similarities and knowledge homogeneity within "social groups", which enables innovative approaches to measuring culture (shared ideas and knowledge) and group-specific cognitive biases or alternatively, identifying different types of expertise (e.g. commercial fishermen may have more expertise about biological or market-related aspects of a fishery compared to other groups). As our study supports, individuals form the same social group hold more similar knowledge, and this might be attributed to their shared experiences, beliefs and values; the routine set of human-environment interactions they adopt in their day-to-day life; and a more frequent exposure to the same information sources and social network (e.g., shared media and news outlets). They, therefore, build in their minds cognitively more homogenous understanding of the complex ecosystem dynamics compared to the members of other social groups. Our novel approach of measuring within group shared knowledge helps us to understand how different social groups construct their specific cultural spaces about the environment which, in turn, lead stakeholders to behave/adapt in a certain way in response to environmental and social changes.

Second, measuring across group cognitive distances has implications for understanding how incorporating diverse knowledge and perceptions from across groups may ensure problem-adequate solutions, reaching knowledge saturation points, and the achievement of more complete "cognitive coverage". Knowledge held by stakeholders varies across social groups, yet suggesting that different types of stakeholders hold complementary perceptions of complex social-ecological interdependencies. Our approach of measuring between group cognitive distances ensures that we bring in adequate knowledge diversity from across multiple stakeholder groups to harness their collective intelligence. Nevertheless, we did not evaluate whether more diverse groups improve group task performance.

Finally, our findings have applications for designing inclusive processes and adaptive co-management practices [23]. Such approaches encourage the participation and involvement of relevant stakeholders and may enhance the credibility and legitimization of management strategies while resource users, managers, NGOs, policymakers, and scientists bridge their divides and jointly agree on possible management actions for uncertain ecosystems [73]. Furthermore, to achieve knowledge co-production, inclusive processes with buy-in from diverse individuals should also guarantee an increase in the total pool of available knowledge and cognitive coverage. Our study assures that involving diverse groups of stakeholders into adaptive co-management can also achieve knowledge co-production: the "Iterative and collaborative processes involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future" [24]. However, it worth noting that inclusion of diverse stakeholder groups with diverging perspectives and knowledge, if not properly harnessed, may undermine the success of co-management and knowledge co-production processes as conflicts may arise. Importantly, dialogue between different stakeholder groups needs to be mediated and stakeholder engagement requires extensive facilitation, such that conflicting representations of the system/problem does not reduce the effectiveness or the value of diversity, but guarantees the creation of between-group synergies.

Supporting information

S1 File. This file includes supporting materials, figures and tables for "Do social identity and cognitive diversity correlate in environmental stakeholders? A novel approach to measuring cognitive distance within and between groups."
(PDF)

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Author Contributions

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References

1. Page SE. Making the difference: Applying a logic of diversity. Acad Manag Perspect. 2007; 21: 6–20.
2. Phillips KW, Loyd DL. When surface and deep-level diversity collide: The effects on dissenting group members. Organ Behav Hum Decis Process. 2006; 99: 143–160.
3. de Oliveira S, Nisbett RE. Demographically diverse crowds are typically not much wiser than homogeneous crowds. Proc Natl Acad Sci. 2018; 115: 2066–2071. https://doi.org/10.1073/pnas.1717632115 PMID: 29440376
4. Page SE. The diversity bonus: How great teams pay off in the knowledge economy. Princeton University Press; 2019.
5. Page SE. The difference: How the power of diversity creates better groups, firms, schools, and societies-new edition. Princeton University Press; 2008.
6. Hong L, Page SE. Groups of diverse problem solvers can outperform groups of high-ability problem solvers. Proc Natl Acad Sci. 2004; 101: 16385–16389. https://doi.org/10.1073/pnas.0403723101 PMID: 15534225
7. Baggio JA, Freeman J, Coyle TR, Nguyen TT, Hancock D, Elpers KE, et al. The importance of cognitive diversity for sustaining the commons. Nat Commun. 2019; 10: 1–11. https://doi.org/10.1038/s41467-018-07882-8 PMID: 30602773
8. Aminpour P, Gray S, Singer A, Scyphers S, Jetter A, Jordan R, et al. The diversity bonus in pooling local knowledge about complex problems. Proc Natl Acad Sci U S A. https://doi.org/10.1073/pnas.2016887118 PMID: 33495329
9. Kao AB, Berdahl AM, Hartnett AT, Lutz MJ, Bak-Coleman JB, Ioannou CC, et al. Counteracting estimation bias and social influence to improve the wisdom of crowds. J R Soc Interface. 2018; 15: 20180130. https://doi.org/10.1098/rsif.2018.0130 PMID: 29669894
10. Bernstein E, Shore J, Lazer D. How intermittent breaks in interaction improve collective intelligence. Proc Natl Acad Sci. 2018; 115: 8734–8739. https://doi.org/10.1073/pnas.1802407115 PMID: 30104371
11. Reynolds A, Lewis D. Teams solve problems faster when they're more cognitively diverse. Harv Bus Rev. 2017;30.
12. Horwitz SK, Horwitz IB. The effects of team diversity on team outcomes: A meta-analytic review of team demography. J Manage. 2007; 33: 987–1015.
13. Woolley AW, Chabris CF, Pentland A, Hashmi N, Malone TW. Evidence for a collective intelligence factor in the performance of human groups. Science (80-). 2010; 330: 686–688. https://doi.org/10.1126/science.1193147 PMID: 20929725
14. Camara WJ, Nathan JS, Puente AE. Psychological test usage: Implications in professional psychology. Prof Psychol Res Pract. 2000; 31: 141.
15. Johnson-Laird PN. Mental models and human reasoning. Proc Natl Acad Sci. 2010; 107: 18243–18250. https://doi.org/10.1073/pnas.1012933107 PMID: 20956326
16. Chan D, Schmitt N, DeShon RP, Clause CS, Delbridge K. Reactions to cognitive ability tests: the relationships between race, test performance, face validity perceptions, and test-taking motivation. J Appl Psychol. 1997; 82: 300. https://doi.org/10.1037/0021-9010.82.2.300 PMID: 9109288
17. Stier AC, Samhouri JF, Gray S, Martone RG, Mach ME, Halpern BS, et al. Integrating expert perceptions into food web conservation and management. Conserv Lett. 2017; 10: 67–76.
18. Stern PC, Dietz T. Public participation in environmental assessment and decision making. National Academies Press Washington, DC; 2008.
19. Jackson SE, Ruderman MN. Diversity in work teams: Research paradigms for a changing workplace. American Psychological Association; 1995.
20. Gaither SE, Apfelbaum EP, Birnbaum HJ, Babbitt LG, Sommers SR. Mere membership in racially diverse groups reduces conformity. Soc Psychol Personal Sci. 2018; 9: 402–410.
21. Kearney E, Gebert D, Voelpel SC. When and how diversity benefits teams: The importance of team members' need for cognition. Acad Manag J. 2009; 52: 581–598.
22. Adams WM, Brockington D, Dyson J, Vira B. Managing tragedies: understanding conflict over common pool resources. Science (80-). 2003; 302: 1915–1916. https://doi.org/10.1126/science.1087771 PMID: 14671288

23. Armitage D, Berkes F, Doubleday N. Adaptive co-management: collaboration, learning, and multi-level governance. UBC Press; 2010.

24. Norström A V, Cvitanovic C, Löf MF, West S, Wyborn C, Balvanera P, et al. Principles for knowledge co-production in sustainability research. Nat Sustain. 2020; 1–9.

25. Aminpour P, Gray SA, Jetter AJ, Introne JE, Singer A, Arlinghaus R. Wisdom of stakeholder crowds in complex social—ecological systems. Nat Sustain. 2020; 1–9.

26. Levin S, Xepapadeas T, Crépin AS, Norberg J, De Zeeuw A, Folke C, et al. Social-ecological systems as complex adaptive systems: Modeling and policy implications. Environ Dev Econ. 2013; 18: 111–132. https://doi.org/10.1017/S1355770X12000460

27. Ostrom E. A general framework for analyzing sustainability of social-ecological systems. Science (80-). 2009; 325: 419–422. https://doi.org/10.1126/science.1172133 PMID: 19628857

28. Freeman J, Baggio JA, Coyle TR. Social and general intelligence improves collective action in a common pool resource system. Proc Natl Acad Sci. 2020; 117: 7712–7718. https://doi.org/10.1073/pnas.1915824117 PMID: 32209670

29. Gray S, Aminpour P, Reza C, Scyphers S, Grabowski J, Murphy JR, et al. Harnessing the Collective Intelligence of Stakeholders for Conservation. Front Ecol Environ. 2020.

30. St John FA V, Steadman J, Austen G, Redpath SM. Value diversity and conservation conflict: Lessons from the management of red grouse and hen harriers in England. People Nat. 2019; 1: 6–17.

31. Otto-Banaszak I, Matczak P, Wesseler J, Wechsung F. Different perceptions of adaptation to climate change: a mental model approach applied to the evidence from expert interviews. Reg Environ Chang. 2011; 11: 217–228.

32. Voss R, Quaas MF, Stiasny MH, Hänsel M, Pinto GASJ, Lehmann A, et al. Ecological-economic sustainability of the Baltic cod fisheries under ocean warming and acidification. J Environ Manage. 2019; 238: 110–118. https://doi.org/10.1016/j.jenvman.2019.02.105 PMID: 30849595

33. Funk S, Krumme U, Temming A, Möllmann C. Gillnet fishers' knowledge reveals seasonality in depth and habitat use of cod (Gadus morhua) in the Western Baltic Sea. ICES J Mar Sci. 2020. https://doi.org/10.1093/icesjms/fsaa227 PMID: 33814897

34. McQueen K, Casini M, Dolk B, Haase S, Hemmer-Hansen J, Hilvarsson A, et al. Regional and stock-specific differences in contemporary growth of Baltic cod revealed through tag-recapture data. ICES J Mar Sci. 2020. https://doi.org/10.1093/icesjms/fsaa227 PMID: 33814897

35. Kosko B. Fuzzy cognitive maps. Int J Man Mach Stud. 1986; 24: 65–75.

36. Jetter AJ, Kok K. Fuzzy Cognitive Maps for futures studies—A methodological assessment of concepts and methods. Futures. 2014; 61: 45–57.

37. Mohammed S, Dumville BC. Team mental models in a team knowledge framework: Expanding theory and measurement across disciplinary boundaries. J Organ Behav Int J Ind Occup Organ Psychol Behav. 2001; 22: 89–106.

38. Johnson-Laird PN. Mental models: Towards a cognitive science of language, inference, and consciousness. Harvard University Press; 1983.

39. Eden C. On the nature of cognitive maps. J Manag Stud. 1992; 29: 261–265.

40. Gray SA, Gray S, De Kok JL, Helfgott AER, O'Dwyer B, Jordan R, et al. Using fuzzy cognitive mapping as a participatory approach to analyze change, preferred states, and perceived resilience of social-ecological systems. Ecol Soc. 2015;20.

41. Savić M, Ivanović M, Jain LC. Fundamentals of Complex Network Analysis. Complex Networks in Software, Knowledge, and Social Systems. Cham: Springer International Publishing; 2019. pp. 17–56. https://doi.org/10.1007/978-3-319-91196-0_2

42. Gray SA, Zanre E, Gray SRJ. Fuzzy cognitive maps as representations of mental models and group beliefs. Fuzzy cognitive maps for applied sciences and engineering. Springer; 2014. pp. 29–48.

43. Olazabal M, Neumann MB, Foudi S, Chiabai A. Transparency and reproducibility in participatory systems modelling: the case of fuzzy cognitive mapping. Syst Res Behav Sci. 2018; 35: 791–810.

44. Siqueiros-García JM, Lerner AM, Eakin HC, Hernández Aguilar B. A standardization process for mental model analysis in socio-ecological systems. Environ Model Softw. 2019; 112: 108–111. https://doi.org/10.1016/j.envsoft.2018.11.016

45. Schwermer H, Aminpour P, Reza C, Funk S, Möllmann C, Gray SA. Modeling and Understanding Social-Ecological Knowledge Diversity. Conserv Sci Pract.

46. Tantardini M, Ieva F, Tajoli L, Piccardi C. Comparing methods for comparing networks. Sci Rep. 2019; 9: 1–19. https://doi.org/10.1038/s41598-018-37186-2 PMID: 30626917

47. Cohen-Steiner D, Kong W, Sohler C, Valiant G. Approximating the spectrum of a graph. Proceedings of the 24th acm sigkdd international conference on knowledge discovery & data mining. 2018. pp. 1263–1271.

48. Chung FRK, Graham FC. Spectral graph theory. American Mathematical Soc.; 1997.

49. Bollobás B. Modern graph theory. Springer Science & Business Media; 2013.

50. Newman M. Networks: An Introduction. OUP Oxford; 2010. Available: https://books.google.com/books?id=-DgTDAAAQBAJ.

51. Özesmi U, Özesmi SL. Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. Ecol Modell. 2004; 176: 43–64.

52. Koutra D, Parikh A, Ramdas A, Xiang J. Algorithms for graph similarity and subgraph matching. Proc Ecol Inference Conf. 2011.

53. Gera R, Alonso L, Crawford B, House J, Mendez-Bermudez JA, Knuth T, et al. Identifying network structure similarity using spectral graph theory. Appl Netw Sci. 2018; 3: 2. https://doi.org/10.1007/s41109-017-0042-3 PMID: 30839726

54. Sawilowsky SS, Blair RC. A more realistic look at the robustness and type II error properties of the t test to departures from population normality. Psychol Bull. 1992; 111: 352.

55. Shannon CE. A mathematical theory of communication. Bell Syst Tech J. 1948; 27: 379–423.

56. Levy MA, Lubell MN, McRoberts N. The structure of mental models of sustainable agriculture. Nat Sustain. 2018; 1: 413–420.

57. Grotzer TA, Shane Tutwiler M. Simplifying Causal Complexity: How Interactions Between Modes of Causal Induction and Information Availability Lead to Heuristic-Driven Reasoning. Mind, Brain, Educ. 2014; 8: 97–114. https://doi.org/10.1111/mbe.12054

58. White PA. Naive ecology: Causal judgments about a simple ecosystem. Br J Psychol. 1997; 88: 219–233. https://doi.org/10.1111/j.2044-8295.1997.tb02631.x

59. Trope Y, Liberman N. Construal-Level Theory of Psychological Distance. Psychol Rev. 2010; 117: 440–463. https://doi.org/10.1037/a0018963 PMID: 20438233

60. Halbrendt J, Gray SA, Crow S, Radovich T, Kimura AH, Tamang BB. Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture. Glob Environ Chang. 2014; 28: 50–62.

61. Olazabal M, Chiabai A, Foudi S, Neumann MB. Emergence of new knowledge for climate change adaptation. Environ Sci Policy. 2018; 83: 46–53.

62. Hamilton M, Salerno J, Fischer AP. Cognition of complexity and trade-offs in a wildfire-prone social-ecological system. Environ Res Lett. 2019; 14: 125017.

63. Oliver TH, Heard MS, Isaac NJB, Roy DB, Procter D, Eigenbrod F, et al. Biodiversity and resilience of ecosystem functions. Trends Ecol Evol. 2015; 30: 673–684. https://doi.org/10.1016/j.tree.2015.08.009 PMID: 26437633

64. Duchek S, Raetze S, Scheuch I. The role of diversity in organizational resilience: a theoretical framework. Bus Res. 2020; 13: 387–423.

65. O'Brien KR, Scheffer M, Van Nes EH, der Lee R. How to break the cycle of low workforce diversity: A model for change. PLoS One. 2015; 10: e0133208. https://doi.org/10.1371/journal.pone.0133208 PMID: 26217957

66. Potvin DA, Burdfield-Steel E, Potvin JM, Heap SM. Diversity begets diversity: A global perspective on gender equality in scientific society leadership. PLoS One. 2018; 13: e0197280. https://doi.org/10.1371/journal.pone.0197280 PMID: 29847591

67. Gray S, Chan A, Clark D, Jordan R. Modeling the integration of stakeholder knowledge in social—ecological decision-making: benefits and limitations to knowledge diversity. Ecol Modell. 2012; 229: 88–96.

68. Pržulj N, Corneil DG, Jurisica I. Modeling interactome: scale-free or geometric? Bioinformatics. 2004; 20: 3508–3515. https://doi.org/10.1093/bioinformatics/bth436 PMID: 15284103

69. Pržulj N. Biological network comparison using graphlet degree distribution. Bioinformatics. 2007; 23: e177—e183. https://doi.org/10.1093/bioinformatics/btl301 PMID: 17237089

70. Romney AK, Weller SC, Batchelder WH. Culture as consensus: A theory of culture and informant accuracy. Am Anthropol. 1986; 88: 313–338.

71. Paolisso M. Cultural models and cultural consensus of Chesapeake Bay blue crab and oyster fisheries. Napa Bull. 2007; 28: 123–135.

72. Greene BA, Lubin IA, Slater JL, Walden SE. Mapping changes in science teachers' content knowledge: Concept maps and authentic professional development. J Sci Educ Technol. 2013; 22: 287–299.

73. Plummer R, Crona B, Armitage DR, Olsson P, Tengö M, Yudina O. Adaptive comanagement: a systematic review and analysis. Ecol Soc. 2012;17.

The case of Western Baltic cod

Cod of the Western Baltic Sea (Fig. S1) is not only ecologically of great importance (i.e., predator-prey relationships), also the commercial fishery, which is dependent on this species, shapes the area of the North German Baltic Sea coast and thus provides a high socio-cultural variety. In addition, tourism and especially recreational fisheries are main components of the region, i.e. anglers come from all over Germany to the Baltic Sea coast to catch for cod and thus have a great influence on the characteristics of this region.

However, the state of the stock is currently outside safe biological limits (ICES, 2019). In order to ensure a sustainable management of commercial fish stocks like cod in the Western Baltic Sea, the European Union (EU) has implemented various management measures within the framework of the Common Fisheries Policy (EC, 2013; EC, 2016). These include, in particular, the so-called total allowable catch quotas (i.e., TACs). In the specific case of Western Baltic cod and due to its low stock size, also recreational fisheries are regulated by a fixed daily catch limit since 2017 (i.e., bag-limit).

However, the level of these two management measures is controversially discussed. Stakeholders involved (i.e., managers, scientists, environmental organizations) or directly affected (i.e. commercial fishery, recreational fishery, tourism) have partially strongly divergent perceptions on the cause of the stock status and so of the appropriate measures which need to be taken in terms of stock recovery. This state of affairs continues to these days and has led to hardening fronts between these groups.

In order to investigate how these different perceptions are described and structured, we have collected and analyzed mental models of different stakeholders from 5 groups, i.e. commercial and recreational fisheries, NGOs, tourism, scientific experts and management agencies (Table S1).

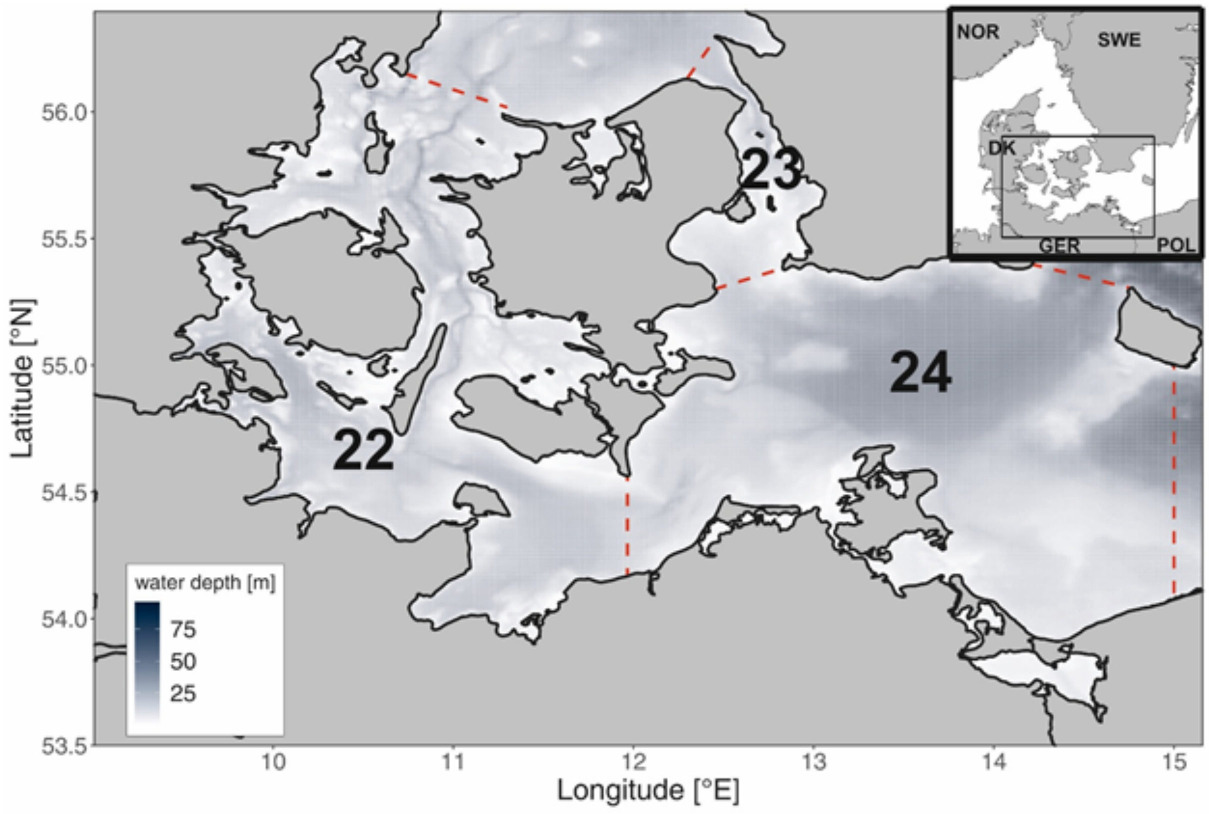

Fig S1. Map of the Baltic Sea region. This map shows the different subdivisions (SD) set by the FAO. The Western Baltic Sea and thus the distribution area of Western Baltic cod is represented by SD22-24, i.e. the Belts Sea (SD22), the Sound (SD23), and the Arkona Sea (SD24). Here, the region of interest is the German coast within SD22-24. [Funk, 2020]

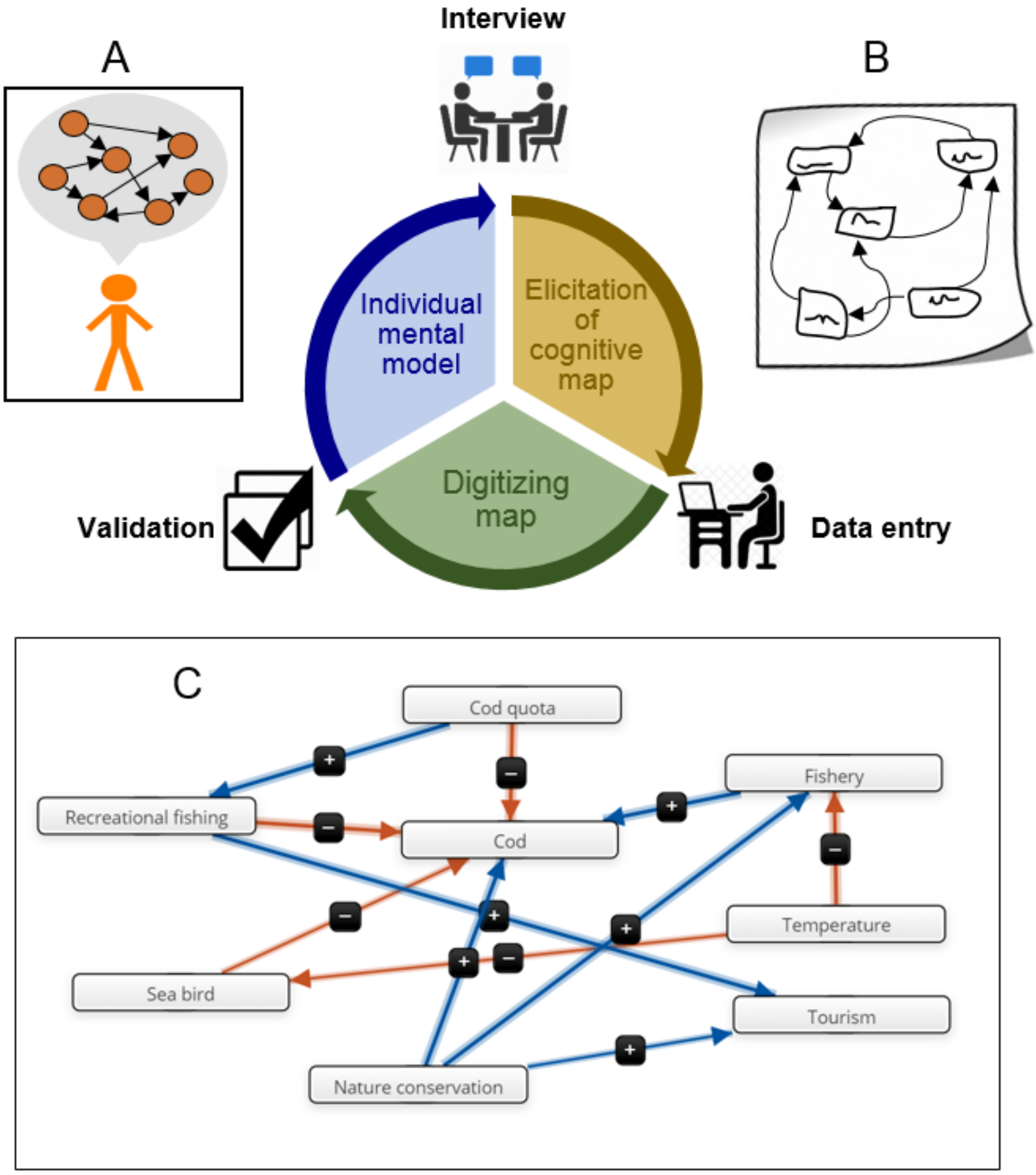

Fig S2. Cognitive map elicitation. (A) shows how an individual constructed a mental model in their head. They then participated in an interview process where individuals were asked to identify relevant concepts (i.e., system components) and their causal relationships, from which they then drew a concept map representing their mental models about Western Baltic cod ecosystem and fisheries management (B). Participants' cognitive maps were digitized after the interview (i.e. maps were converted to digital weighted directed graphs using www.mentalmodeler.org) (C) and sent back to the interviewees for validation.

Table S1. In order to evaluate the perception of the social-ecological system (SES) of the Western Baltic cod fisheries from the perspective of different stakeholders, participants from 5 relevant groups were interviewed (NGO=non-governmental organization, Com Fish=commercial fisheries representatives, MV=Mecklenburg-Western Pomerania, Rec Fish=recreational fisheries representatives, SH=Schleswig-Holstein).

Stakeholder group	Description	%
Com Fish & Rec Fish	Representatives of i) commercial fisheries at national and state level (i.e., manager of fishing cooperative, commercial fishers from MV and SH) and ii) Representative of the recreational fisheries at national and state level with focus on sea angling	33,3
NGO	Representatives of i) marine protection of the Baltic Sea at regional, national and international level, ii) local fisheries in SH and iii) certification of commercial fisheries	18.2
Managers	Officials focusing on i) catch quotas, ii) fisheries management at international and national level, and iii) nature conservation as well as iv) angling tourism at regional level	18.2
Scientific experts	Academics with research focus on i) economy of commercial fisheries, ii) Baltic fish ecology, iii) Baltic fisheries management and iv) gear development in fisheries	18.2
Tourism	Members of tourism associations at regional level with focus on i) the promotion of regional angling tourism or ii) tourism activities in nature, as well as iii) manager of a fishing store	12.1

Additional references

EC (2013). Regulation (EU) No 1380/2013 of the European Parliament and of the council of 11 December 2013 on the Common Fisheries Policy, amending Council Regulations (EC) No 1954/2003 and (EC) No 1224/2009 and repealing Council Regulations (EC) No 2371/2002 and (EC) No 639/2004 and Council Decision 2004/585/EC.

EC (2016). Regulation (EU) 2016/1139 of the European Parliament and of the Council of 6 July 2016 establishing a multiannual plan for the stocks of cod, herring and sprat in the Baltic Sea and the fisheries exploiting those stocks, amending Council Regulation (EC) No 2187/2005 and repealing Council Regulation (EC) No 1098/2007.

Funk, S. 2020. Spatio-temporal distribution, food intake and growth of cod (Gadus morhua L.) in the Western Baltic Sea. (Doctoral thesis, University of Hamburg, Germany).

ICES (2019). ICES Advice on fishing opportunities, catch, and effort Baltic Sea ecoregion. Cod (*Gadus morhua*) in subdivisions 22–24, western Baltic stock (western Baltic Sea). Copenhagen.

Considering humans as part of the ecosystem has significantly increased in importance in recent decades. The understanding of a system as a social-ecological system (SES), i.e. the emphasis that not only ecological components interact within in a system, but also social components influence ecological ones and vice versa, has become increasingly important (Ostrom 2009, Partelow 2018). Particularly in natural resource management (Reed 2008, Long et al. 2015, Stephenson et al. 2016, Alexander et al. 2019) and concerning governance issues (Jentoft & Chuenpagdee 2009, Burns et al. 2011, Birnbaum 2015), this understanding goes hand-in-hand with the inclusion of resource users and interest groups, so-called stakeholders, who are part of, influenced by, dependent on, or affect the system.

Today, the involvement of multiple stakeholder groups is an important pillar in fisheries legislation worldwide (e.g., European Union, EC 2013), United States of America (Jones & Seara, 2020)), and has become increasingly important in scientific research (e.g., Mackinson et al. 2010, Aanesen et al. 2014, Steins et al. 2019). The latter addresses, for example, stakeholder perceptions (Gray et al. 2012) and the exploration as well as integration of different knowledge types into fisheries management (Folke 2004, Daw 2008, Figus et al. 2017, Steins et al. 2019). Moreover, studies on the structure of social networks in the context of stakeholders involved in or affected by environmental management are of central importance exploring, for example, questions of power and interdependence (Bodin & Crona 2009, Bodin et al. 2019). This is accompanied by concerns about the ‘appropriate’ inclusion of resource users and interest groups in institutional structures of natural resource management and its underlying governance (Burns & Stöhr 2011, Birnbaum 2015, Stepanova 2019).

In natural resource management and governance, it is crucial to know i) who the relevant stakeholders are, how they perceive the SES they are part of and what knowledge informs this understanding, ii) how stakeholders are incorporated into the management network and what structures characterize them, and iii) how a common-pool resource, such as a fish stock, can be managed by multiple stakeholders with what structures need to be in place to do so (i.e., knowledge and power-sharing).

We conducted a literature review to answer the above questions, with the objective of examining how stakeholders are generally defined, who is considered a relevant stakeholder in the context of coastal and marine fisheries management, how their methodological involvement is described, and what the underlying intention is (**Study I**). At the time of data collection, there was a sharp increase in the number of scientific papers addressing the topic of stakeholder participation. We disclosed that many papers lack a more precise definition of who is considered a stakeholder and what is understood by participation. A particularly critical aspect is that in half of the studies, stakeholders were only used for research purposes and actual participation in the sense of the definition (participation with the aim of contributing to management) has not taken place. Moreover, we found that in some cases stakeholders involved are not or only vaguely described (e.g., term stakeholder is often used as a buzzword only) resulting in reduced reproducibility and limited opportunities for further research.

Using an online survey questionnaire, we conducted a comprehensive identification of stakeholders affected by and involved in the Western Baltic (WB) cod fisheries. Based on various categories, we selected from these a number of stakeholders representing commercial fisheries, recreational fisheries, environmental non-governmental organizations (eNGOs), tourism, administration, and science. In total, we conducted 33 interviews with relevant stakeholders of the WB cod fisheries system. To reveal the individual perceptions on WB cod fisheries, we used the mental model approach that has been established in SES research (**Study II**). The results of the study show a different understanding of the system among all six stakeholder types. Both social and environmental system components differ in their number in the overall system, and in their individually defined definitions and units of measures. The latter was determined to enable a dynamic mapping of the system. It should be particularly emphasized that the definitions and units of measure of the social components vary to some extent significantly between the stakeholder groups, but also within the respective groups. There is a need to take differing perceptions of a multitude of stakeholders involved in natural research management into account. This is to promote understanding between the various groups, but more importantly to increase the acceptance of management decisions to enable the sustainable exploitation of natural resources such as fish stocks.

We conducted further interviews with relevant representatives from commercial fisheries, eNGOs, recreational fisheries and administration, with the aim to explore WB cod in the context of its underlying fisheries management, and to learn the different stakeholders' description and perception of problems and improvements (**Study III**). Here, we identified a comprehensive range of knowledge types (e.g., tacit knowledge, local ecological knowledge, non-knowledge) representing WB cod in its multi-faceted aspects. It can also be seen that, especially the perceptions of the current stock (here related to the stock recruitment) and even more so in the perception of its future development opinions differ greatly, ranging from "cod is on the mend" to "on the verge of collapse". Our comprehensive analysis also shows the multi-layered uncertainties in WB cod evaluation and its related influencing parameters, such as climate and marine mammals. Furthermore, this study shows strong stakeholder criticism towards EU fisheries management, not only from the perspective of commercial fisheries (e.g., short-term measures, insufficient catch quotas) but also from the perspective of eNGOs (e.g., nontransparency of quota setting with regard to scientific advice) and science (e.g., lack in implementation of MSY levels). But concerns are also raised by stakeholder groups regarding science, which acts as an advisory body for fisheries management, by all stakeholder groups, implying scientific evidence is too insecure to provide precise stock assessments (e.g., natural mortality rate of cod). Recognition and integration of multiple types of knowledge in fisheries management can enhance sustainable use of natural resources by increasing trust among stakeholders and thus the acceptance of management decisions. Institutionalization of participatory processes, especially at the local level, is necessary to recognize knowledge-sharing across multiple stakeholders, and to initiate power-sharing to involve resource users and interest groups in the management of WB cod.

We explored the relationship between social identity and cognitive diversity among stakeholders (e.g., commercial fisheries, eNGOs, administration) interacting with a shared resource system through the combination of approaches from complex network science, graph theory, and cognitive mapping (**Study IV**). The results suggest that groups with greater identity diversity also exhibit greater cognitive diversity, as evidenced by different characteristics of their cognitive maps representing their understanding of the WB cod fisheries system. Specifically, cognitive distances between groups are greater than cognitive distances within groups. Moreover, cognitive diversity of socially diverse individuals (i.e., intergroup pairs) is shown to be statistically significantly higher than cognitive diversity of socially homogeneous individuals (i.e., intragroup pairs). Our study shows that higher cognitive coverage may lead to a more complete, accurate, and innovative understanding of the complex resource dynamics of the WB cod. Thus, the measurement of cognitive distances may contribute to the understanding of similarities within social groups, and enable innovative approaches to measure group-specific cognitive biases as well as to identify different knowledge types. Involving diverse stakeholders in natural resource management can therefore contribute to a better understanding of the complexity of resource systems and may help to address and solve conflicts.

The wickedness in fisheries management

Natural resource management is generally characterized by a multitude of affected and involved stakeholders such as diverging perceptions of the resource condition and the surrounding system (e.g., system components and their interactions) and the respective management (e.g., number and strength of management measures) (Jones & Seara 2020). Diverse knowledge and assumptions, as well as economic dependencies and cultural identities, frame this complexity and transform natural resources such as fish stocks into a dynamic and complex system that makes it difficult to implement the 'right' management, making fisheries management a 'wicked problem' (Jentoft & Chuenpagdee 2009, DeFries & Nagendra 2017, Jones & Seara 2020, Hare 2020).

Rittel and Webber (1973) introduced the term 'wicked problem', meaning a complex and tricky problem that is symptom and cause of other problems, difficult to grasp and solve in its entirety, not least due to the large numbers of involved stakeholder and their diverging perceptions, knowledge or interests (Jentoft & Chuenpagdee 2009, Hare 2020). The definition of a problem, as Jentorf and Chuenpagdee (2009) argued, is already a 'wicked problem', arising from the multitude of stakeholders involved in the management, their interaction and their construction of the system as well as its components. Study II and III show in part very different designs of the Western Baltic (WB) cod fisheries system and its underlying management. Marine mammals (e.g., seal, harbor porpoise) and seabirds (e.g., cormorant), which are described and incorporated into the system as protected goods on the one hand, are characterized as enemies of the fisheries on the other hand. An increasing population of seals, harbor porpoise and cormorants means loss of income and more work for the fisher, if they end up being caught as bycatch. Conversely, stakeholders from environmental non-governmental organizations (eNGOs), for example, describe the increasing population of marine mammals and seabirds as a positive impact on the ecosystem and as sign of a good environmental status. The construction of the problem i) the negative impact of marine mammals and birds on catch, and ii) the negative impact of the fisheries on marine mammals indicates one of the many 'wicked problems' in fisheries management of the WB cod. Thus, the definition of the problem itself is subject to individual descriptions and integrations into the respective system, which slows down or even hinders the identification of appropriate measures to address the problem (Jentoft & Chuenpagdee 2009, Hare 2020). High variability in the definition of system components and their measurable integration into the WB cod fisheries system itself must also be emphasized here (results from Study II). The social components in particular are subject to high variability, indicating the complexity of managing a social-ecological system.

Especially, the integration of the fisheries sector into the system reveals intriguing insights into the system understanding in general and the entire problem domain. In terms of interaction with other system components, it makes a big difference whether the focus of the fisheries is on the gear (e.g., trawl, gillnet), the type of income (e.g., primary or secondary), or even the impact on the system (e.g., industrial fisheries). While gear may have an impact on other ecological components, such as harbor porpoise (e.g., bycatch), fisheries, when defined by its income type solely, does not necessarily have an impact on the named species. Even whether a stakeholder is talking about predation on a fish stock in general, or about predation by marine mammals or by seabirds, seals, harbor porpoises, or cormorants indicates a great diversity in the perception of the system, its interactions and dynamics. Most significantly, it demonstrates potential problems in interaction (and communication) between stakeholders that could pose challenges to management (Burns & Stöhr 2011, Aanesen et al. 2014).

The results of the mental model study also display differences in the identification of system components and their interactions, including definitions and units of measure of components, between and within the relevant stakeholder groups such as commercial fisheries, eNGO and administration. Deciding who is a stakeholder in fisheries management thus affects how the system is generally framed, what problems are defined and characterized in the process, and what recommendations for management measures are made (Burns & Stöhr 2011, Kraan et al. 2014, Aanesen et al. 2014, Stephenson et al. 2016, Jones & Seara 2020). General, stakeholder involvement has positive effects, such as complementing scientific information with local ecological knowledge (LEK), traditional ecological knowledge (TEK) (Folke 2004) or fishers' ecological knowledge (FEK) (Daw 2008, Figus et al. 2017, Funk et al. 2020). But it can also slow down or even hinder the finding of solutions due to different perceptions on a problem or conflict and the management measures to be taken (Aanesen et al. 2014, Long et al. 2015, Linke & Jentoft 2016).

Fisheries management is already complex enough to promote sustainable management (Levin et al. 2013, Aanesen et al. 2014). In addition, new measures may also lead to the involvement of additional resource users or interest groups, increasing the complexity of fisheries management. Using the example of the WB cod, the implementation of the so-called bag limit in 2017, through which the recreational fisheries as well as the tourism sector became involved in the fisheries management discussion as further stakeholder groups, can be highlighted here (Eero et al. 2014, EC 2016). This complexity in understanding the system (including its interactions and dynamics), and differences in the value of the group-specific interaction with the system and the criticism of its measures taken, is clearly evident in the results from the mental model analysis (Study II) and the comprehensive analysis of expert interviews (Study III). At first glance, both recreational and commercial fisheries seem to have similar interests in the system: i) the removal of fish, ii) the closeness to nature, and iii) the freedom that everyone can enjoy with it. However, when it comes to finding a common solution to restore sustainable management of the WB stock, both groups accuse each other of overfishing the stock in the past. It is said, that recreational fisheries is the least harmful method of catching fish, whereas trawl or gillnet fisheries negatively affects marine ecosystems through destroying bottom-dwelling organisms or bycatch of marine mammals, respectively. The commercial fisheries, on the contrary, argues that they earn their salary by catching fish, but recreational fisheries is only considered a hobby, which should be taken into account when implementing appropriate management measures. In addition, there is the economic value of fishing and tourism compared to commercial fisheries. According to stakeholders, angling tourism can generate five times as much as the commercial fisheries. Yet the tradition and culture of the fisheries sector shape and characterize many regions along the Western Baltic coast and contribute to the economic value of the regions.

Moreover, climate change and its impact on marine ecosystems, such as the species shifts and thus new species in the respective system (Pinsky et al. 2020), raise new questions towards fisheries management (Möllmann et al. 2021) and may lead to increasing complexity and the difficulty taking appropriate measures (Levin et al. 2013, Pinsky et al. 2018, Bruckmeier 2019, Maureaud et al. 2020). Maureaud et al. (2020) indicate that EU fish stocks are already managed by several countries through the classification of management areas, but the management of transboundary migratory species requires special adaptations such as temporal and spatial monitoring of species, by combining several regional surveys. The study by Möllmann et al. (2021), with a specific focus on the WB cod, shows that decades of overfishing and the effects of climate change led to a tipping point in the WB cod fisheries, which poses new challenges for the management of this species and its fisheries.

In a nutshell, a variety of different 'wicked problems' were identified in fisheries management of WB cod: i) the definition of a problem, ii) the definition of system components and their interactions as well as its variations across and within relevant stakeholder groups, and iii) additional management measures or stressors. In this context, it should be emphasized that these are only some of many 'wicked problems' in the management of fish stocks. Consequently, 'wicked problems' in fisheries management become a constant challenge for managers and policy makers, with the assumption that it is difficult or in some cases even impossible to find an appropriate solution for everyone (Jentoft & Chuenpagdee 2009, Hare 2020). Hereby, each solution benefits one or multiple groups, but in the course of fish stock management it never benefits all, as the interest in and the knowledge about the system its components are sometimes very heterogeneous (Aanesen et al. 2014, Aminpour et al. 2020). Thus, it is the task of managers and policy makers to achieve a balance between ecology, economy and social issues to, for example, align sustainable fish status, the safety of the fisheries sector with the prevention of cultural identity of local communities.

Conflict resolution through stakeholder engagement

'Wicked problems' can, by definition, generate long-lasting conflicts because the solution to a problem itself is not easily achieved, and in some cases even impossible (Adams et al. 2003, Jentoft & Chuenpagdee 2009, Hare 2020). Since natural resources are used by stakeholders with heterogeneous interests, values, beliefs, and interdependencies (Binder et al. 2013, Sterling et al. 2017, Arlinghaus et al. 2021), conflicts can be seen as a natural part along with their use and management (Adams et al. 2003, Jentoft 2017, Stepanova 2019). This can lead to divergent perceptions about the system, its interactions, and its dynamics (Gray et al. 2012, Aminpour et al. 2020), causing differences in the understanding of existing problems (e.g., declining fish stocks) and management actions to be taken to, for example, manage a fish stock back to a sustainable state (Adams et al. 2003, Steins et al. 2019, Van Hoof et al. 2019).

Conflicts are here defined as non-violent (e.g., not determined by wars) and in parts coastal and locally specific (Stepanova 2019). In the context of natural resource management, these conflicts can be diverse, complex and in parts interlocked (Bruckmeier 2019, Dahlet et al. 2021). According to Bruckmeier (2019), resource and spatial conflicts can be categorized as follows: (i) conflicts over soil, water, air pollution, and other environmental damage; (ii) conflicts within and between different interest groups sharing the same resource; (iii) conflicts over access to and use of natural resources; (iv) conflicts caused by illegal use of natural resources or land (Bruckmeier 2019, Mendenhall et al. 2020, Arlinghaus et al. 2021).

The Western Baltic Sea (WBS), and in particular WB cod fisheries system is complex and further characterized by multiple conflicts for space and resources existing among stakeholder groups that are part of the system (e.g., Burns & Stöhr 2011, Arlinghaus et al. 2021). However, due to the declining biomass of main target species, for example WB cod (ICES 2021, Möllmann et al. 2021), the resource fish is becoming limited and conflicts over resource and space continue to increase (Mendenhall et al. 2020, Arlinghaus et al. 2021). In this regard, the WBS is characterized by a multitude of affected and involved stakeholder groups and thus by different interests regarding the resource and the space, but also by diverging perceptions about existing conflicts, and how they should be solved (Jones & Seara 2020). The problems and associated tensions between commercial fisheries, recreational fisheries and eNGOs have dominated the WBS for decades (Arlinghaus et al. 2021), but conflicts have greatly intensified due to the impact of climate change as well as declining yields in fisheries (Blenckner et al. 2015, Möllmann et al. 2021). Conflicts have also become increasingly serious within the fisheries sector in recent years, for example, between high-seas and small-scale coastal fisheries, as well as between full-time and part-time fishers. Resource scarcity, not only for cod, the increasing designation of marine protected areas and wind parks and the thus reduced space in which fishers can pursue their craft, are just some of the reasons.

As described earlier, conflicts are part of a system in which a resource is shared and interests are not homogeneous in this regard (Adams et al. 2003, Stepanova 2019). Hence approaches need to be formulated when these conflicts hinder the implementation of management measures and thus limit the sustainable exploitation of resources. Therefore, direct engagement with resource users and interest groups is needed to address these conflicts and to formulate possible solutions and adaptation options (Gray et al. 2012, Jentoft 2017). The objectives of conflict management can be either short-term or long-term, but should be understood as a continuous interactive process linked to the management of natural resources (Stepanova 2019, Steins et al. 2019). In this course, stakeholder engagement can be distinguished between formal (e.g., EU advisory councils) and informal (e.g., mediation, stakeholder dialogues) forms as well as between knowledge-sharing and power-sharing (Linke & Bruckmeier 2015, Stepanova 2019, Miret-Pastor et al. 2020) (Figure 5).

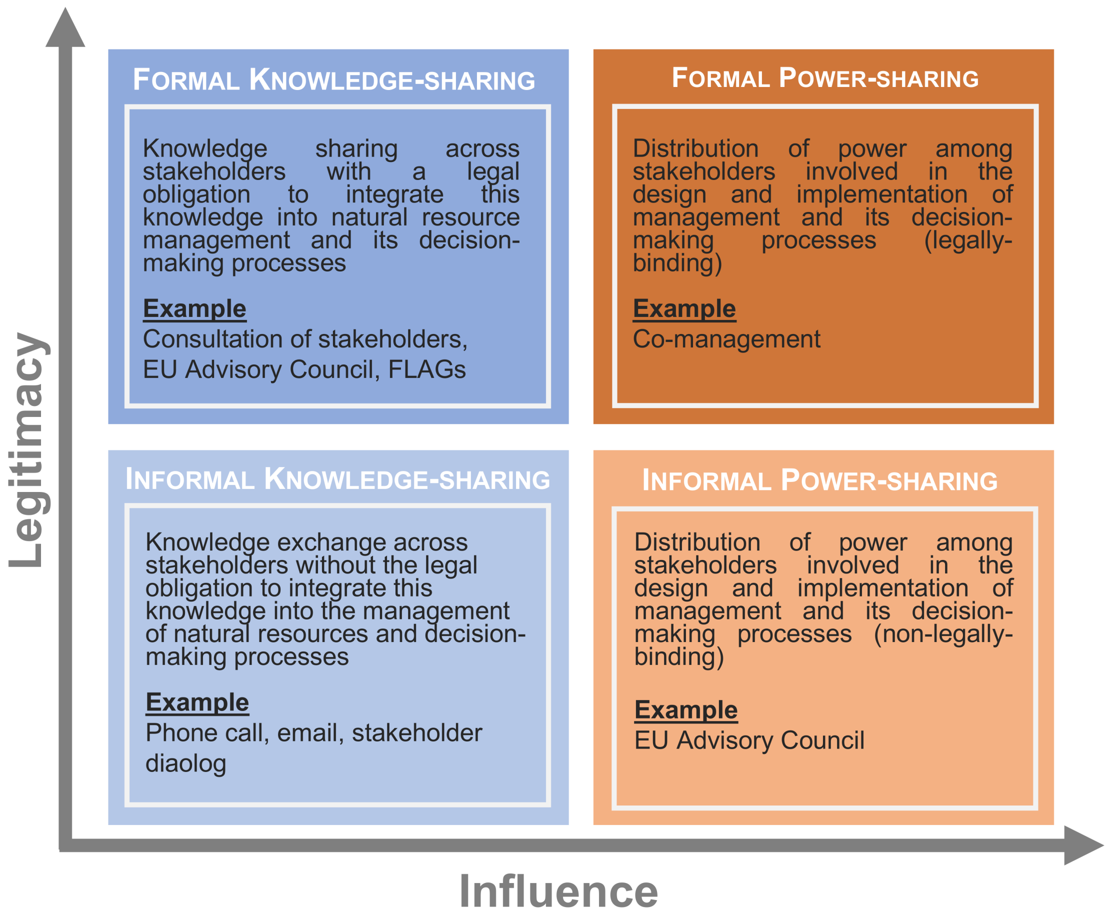

Figure 5. Conflict resolution through stakeholder engagement. Simplified figure using the example of EU fisheries, showing the different forms of conflict resolution in management and decision-making processes: i) informal knowledge sharing (light blue), ii) informal power sharing (light orange), iii) formal knowledge sharing (blue), and iv) formal power sharing (orange) (EU=European Union, FLAGs=Fisheries Local Action Groups).

Numerous studies in the context of fisheries research demonstrate that the disclosure and recognition of knowledge between stakeholders can help to reveal the different perspectives on the system (Stier et al. 2016, Stephenson et al. 2016), and thus increase the acceptance of management decisions which contributes to sustainable use of natural resources (Aanesen et al. 2014, Jones & Seara 2020) (Figure 5, informal knowledge-sharing, formal knowledge-sharing). Through a participatory modeling approach, as well as conducting interviews, we revealed diverse knowledge types and demonstrated various perspectives on the WB fisheries system and its underlying management (informal knowledge-sharing). Moreover, we have been interviewing both local and national stakeholders, allowing us to view the system, its interaction and dynamics from different levels of governance. But, the integration of such knowledge, which is considered relevant to support sustainability, is not necessarily implemented in management or decision-making processes (Linke & Bruckmeier 2015, Stephenson et al. 2016). In particular, traditional ecological knowledge (TEK), local ecological knowledge (LEK) and fishers' ecological knowledge (FEK) provide valuable information about the system and its dynamics, essential for the implementation and outcome of management (Jentoft et al. 1998, Folke 2004, Jentoft & Chuenpagdee 2009, Steins et al. 2019, Funk et al. 2020). The disclosure of this knowledge can be achieved not least by a constant exchange among stakeholders, based on trust and respect. However, the integration of knowledge cannot be reached through goodwill and participation alone; institutionalization (legal-binding) is necessary to support the power relations between stakeholders being part of decision-making processes (Stepanova 2019). In general, and not on a case-by-case basis, it is only through power-sharing (informal power-sharing, formal power-sharing) that a greater influence on decision-making processes through stakeholder engagement can be assumed (Figure 5) (Linke & Bruckmeier 2015). Particularly noteworthy is the legal-binding power-sharing, as understood in the concept of co-management (e.g., Murunga et al. 2021), where responsibilities for management are decentralized and assigned to resource users and interest groups at various governance levels, but usually at the local level (e.g., Jentoft et al. 1998, Linke & Bruckmeier 2015). Co-management of fisheries resources has only limited experience in Europe, and in the specific case of WB fisheries, this approach is open to debate - mainly because top-down European fisheries management exists, with some of its laws and principles dating back to the 1980s (e.g., relative stability) (Baudron et al. 2020, Morin 2020). Moreover, by construct of the EU, fisheries resources are managed communally, meaning by more than one country and thus various values, norms and interests associated to the fish stocks and its surrounded system exist. In the case of the WB cod, besides Germany, Denmark, Estonia, Finland, Lithuania, Latvia, Poland and Sweden have a share of the total quota. As the concept of the relative stability is very outdated (Baudron et al. 2020, Morin 2020), some EU member states, for example Denmark, allow to trade quotas individually (ITQs = individual transferable quotas) (i.e., form of formal power-sharing) (Merayo et al. 2018). In Germany, however, this is prohibited by law, but could be a first right step to give more decision power to the commercial fisheries about 'their' fishing opportunities. Merayo et al. (2018) criticize that the approach of ITQs is exclusively economically driven, leaving out environmental and social sustainability. In addition, only economically well-established fishing companies would benefit, disadvantaging small-scale fisheries that are rich in tradition and culture (Merayo et al. 2018). However, there are approaches within the EU fisheries management to promote a stronger involvement of stakeholders and thus contribute not least to conflict resolution (e.g., Advisory Councils (ACs), Fisheries Local Action Groups (FLAGs)). With the establishment of ACs, for example, the EU created an instrument at regional level which promotes the dialogue and knowledge transfer between stakeholders of diverse groups (formal knowledge-sharing) (Linke et al. 2011, Linke & Jentoft 2016). The institutionalization of stakeholder engagement is intended to address conflicts between various stakeholder groups and countries which may lead to increased acceptance of the management measures imposed by the EU (Linke et al. 2011, Linke & Jentoft 2016). Critically, however, 60% of the seats are allocated to the fishing industry and the remaining 40% to other groups, such as recreational fisheries, small-scale fisheries and environmental and nature conservation organizations (Linke & Bruckmeier 2015, Linke & Jentoft 2016). Very clearly, there is an informal power-sharing i) within the different fisheries sectors (fishing industry vs. small-scale fisheries), but also ii) between the fishing industry and conservation organizations. This circumstance subordinates the contribution of knowledge by stakeholders with fewer seats (informal power) and empowers the knowledge of the fishing industry. However, even if knowledge-sharing between the stakeholders participating in the AC is legally binding through the Common Fisheries Policy (CFP), it must be critically emphasized that the implementation in management or decision-making processes is lacking (Linke & Bruckmeier 2015, Linke & Jentoft 2016).

To summarize, the EU fisheries management is constructed in such a way in which the following forms of conflict resolution can be found at EU, national and local level: informal knowledge-sharing, formal knowledge-sharing, as well as informal power-sharing. Legal-binding power-sharing, as it is appealed in co-management approaches, is not existent (Linke & Bruckmeier 2015, Linke & Jentoft 2016). And thus, instruments like ACs remain fig leaves of politics, giving the impression that resource users or interest groups can actually contribute and influence decision-making processes.

Conflict resolution of natural resources in general, and specifically of WB cod, should not be approached with the goal of resolving the conflict in its entirety; rather, goals should be formulated in stages that are adaptable to potential new challenges or stakeholders involved in the conflict (Stepanova 2019). Given the norms, values, and cultural realities of local communities along coastal areas, the approach to conflict resolution should be considered on a case-specific basis (Sterling et al. 2017). In doing so, it is first and foremost important to get a picture of the conflict(s) surrounding the social-ecological system, meaning i) which conflict needs to be resolved, ii) are there multiple conflicts intertwined, iii) which groups are involved in this conflict, iv) have there already been initiatives to support conflict resolution, v) how long has the conflict existed and how hardened is it possibly (Mendenhall et al. 2020, Dahlet et al. 2021, Arlinghaus et al. 2021). The methods of conflict resolution are diverse, ranging from mediation to participatory modeling and Bayesian Belief Networks (Haapasaari et al. 2012, Gray et al. 2014, Stier et al. 2016). Games and simulations can also help to look at the system from a different perspective and contribute to a common understanding across stakeholders (see Edwards et al. 2019). However, a cooperative, collaborative and participatory way of working with stakeholders is essential to promote knowledge-sharing, joint learning and, last but not least, the building or strengthening of trust, thus contributing to conflict resolution (Stepanova 2019). Conflict resolution should be given time and space to, among other things, develop a common understanding of the conflict in order to build trust and be able to formulate goal-oriented solutions across the various stakeholders involved in the conflict. However, conflicts can also be framed as an opportunity in terms of managing an SES in which stakeholders can both learn and find common solutions (Lopes et al. 2017).

5. CONCLUSION

The Western Baltic fisheries are changing: the stock size of important target species such as herring and cod are decreasing, causing a progressive decline of the fisheries and its lack of young fishers, leading to the possible loss of tradition and culture and the knowledge associated with it, meaning the eventual restructuring of fishing communities along the coast.

This thesis focuses on the so-called bread winning fish of the German fisheries – Western Baltic (WB) cod. Using various methods such as participatory modeling, expert interviews, and network analysis, my co-authors and I not only explored the diverse knowledge about the WB cod from the perspective of various stakeholders, but rather this work shows how multifaceted WB cod, its fisheries, and the surrounding system are. A large number of stakeholders are part of this system and thus indirectly and directly involved in its changes. We presented the different problems and conflicts around the system WB cod fisheries, identified and framed by the different stakeholders. Diverging opinions about the fisheries management in general and its success exist, but we have also been able to reveal various resource and spatial conflicts that relate to the system under focus.

However, we have also shown that the WB cod fisheries system is complex and that stakeholder involvement can be beneficial in exploring this complexity. With disclosing and acknowledging these various system components, interactions and dynamics, trust among stakeholders could be strengthened and thus promote the success of various management measures. The involvement of user and interest groups should not focus exclusively on the disclosure of knowledge, its recognition and the goal of a common understanding. Rather, there is a need for additional instances in the future resulting in the participation of stakeholders in decision-making processes. At the various governance levels (e.g., local level), the focus today is only on the knowledge transfer, while power-sharing is still treated step-motherly in the case of Baltic fisheries management.

The Western Baltic Sea is a dynamic system and the adaptation to its current ecological, social and economic development seems now more important than ever, in order not to lose the fisheries sector and various elements associated with it. But this adaptation requires a transdisciplinary approach - which depends not least on the willingness of the stakeholder to participate and on the possibilities to shape this adaptation.

References

Aanesen, M., Armstrong, C. W., Bloomfield, H. J., & Röckmann, C. 2014. What does stakeholder involvement mean for fisheries management. Ecol. Soc., 19, 4, 35. doi:10.5751/ES-06947-190435

Adams, W. M., Brockington, D., Dyson, J., & Vira, B. 2003. Managing the tragedies. Understanding conflicts over common pool resources. *Science*, 302, 1915-1916. doi:10.1126/science.1087771

Alexander, K. A., Hobday, A. J., Cvitanovic, C., Ogier, E., Nash, K. L., Cottrell, R. S., …, & Watson, R. A. 2019. Progress in integrating natural and social science in marine ecosystem-based management research. Mar. Freshw. Res., 70, 71-83

Aminpour, P., Gray, S. A., Jetter, A. J., Instrone, J. E., Singer, A., & Arlinghaus, R. 2020. Wisdom of stakeholder crowds in complex social-ecological systems. Nat. Sustain., doi:10.1038/s41893-019-0467-z

Arlinghaus, R., Lucas, J., Weltersbach, M. S., Kömle, D., Winkler, H. M., Riepe, C., Kühn, C., Strehlow, H. V. 2021. Niche overlap among anglers, fishers and cormorants and their removals of fish biomass: A case from brackish lagoon ecosystems in the southern Baltic Sea. Fish. Res., 238, 105894. doi:10.1016/j.fishres.2021.105894

Baudron, A. R., Brunel, T., Blachet, M.-A., Hidalgo, M., Chust, G., Brown, E. J., …, & Fernander, P. G. (2020). Changing fish distributions challenge the effective management of European fisheries. Ecography, 43, 494-505. doi:10.1111/ecog.04864

Binder, C. R., Hinkel, J., Bots, P. W. G., & Pahl-Wostl, C. 2013. Comparison of Frameworks for Analyzing Social-ecological Systems. Ecol. Soc., 18, 4. doi:10.5751/ES-05551-180426

Birnbaum, S. 2015. Environmental Co-governance, Legitimacy, and the Quest for Compliance: When and Why Is Stakeholder Participation Desirable? J. Environ. Policy Plan. doi:10.1080/1523908X.2015.1077440

Blenckner, T. Llope, M., Möllmann, C., Voss, R., Quaas, M. F., Casini, M., …, & Stenseth N. C. 2015. Climate and fishing steer ecosystem regeneration to uncertain economic futures. Proc. R. Soc. B, 282, 1803, 20142809. doi:10.1098/rspb.2014.2809

Bodin, Ö., & Crona, B. I. 2009. The role of social networks in natural resource governance: What relational patterns make a difference? Glob Environ Change, 19, 366-374. doi:10.1016/j.gloenvcha.2009.05.002

Bodin, Ö., Baird, J., Schultz, L., Plummer, R., & Armintage, D. 2019. The impacts of trust, cost and risk on collaboration in environmental governance. People nat. (Hoboken), 00, 1-16

Bruckmeier, K. 2019. Environmental conflicts. Towards theoretical analyses of social-ecological systems. In: Olsson, E. G. A., & Gooch, P. (ed). Natural resource conflicts and sustainable development. Routledge

Burns, T. R., & Stöhr, C. 2011. Power, knowledge, and conflict in the shaping of commons governance. The case of EU Baltic fisheries. Int. J. Commons, 5, 2, 233-258

Dahlet, L. I., Himes-Cornell, A., & Metzner, R. 2021. Fisheries conflicts as drivers of social transformation. Curr. Opin. Environ. Sustainability, 53, 9-19. doi:10.1016/j.cosust.2021.03.011

Daw, T. M. 2008. How fishers count: engaging with fishers` knowledge in fisheries science and management. Newcastle University, United Kingdom

DeFries, R., & Nagendra, H. 2017. Ecosystem management as a wicked problem. Science, 356, 265-270

EC. 2013. Regulation (EU) No 1380/2013 of the European Parliament and of the council of 11 December 2013 on the Common Fisheries Policy. Brussels, Belgium

EC. 2016. Council Regulation (EU) 2016/1903 of 28 October 2016 fixing for 2017 the fishing opportunities for certain fish stocks and groups of fish stocks applicable in the Baltic Sea and amending Regulation (EU) 2016/72, Brussels, Belgium

Edwards, P., Sharma-Wallace, L., Wreford, A., Holt, L., Cradock-Henry, N. A., Flood, S., & Velarde, S. J. 2019. Tools for adaptive governance for complex social-ecological systems: a review of role-playing-games as serious games at the community-policy interface. Environ. Res. Lett., 14, 113002. doi: 10.1088/1748-9326/ab4036

Eero, M., Strehlow, H. V., Adams, C. M., & Vinther, M. 2014. Does recreational catch impact the TAC for commercial fisheries? ICES J. Mar. Sci., 72, 2, 450-457. doi:10.1093/icesjms/fsu121

Figus, E., Carothers, C., & Beaudreau, A. H. 2017. Using local ecological knowledge to inform fisheries assessment: measuring agreement among Polish fishermen about the abundance and condition of Baltic cod (*Gadus morhua*). ICES J. Mar. Sci. doi:10.1093/icesjms/fsx061

Folke, C. 2004. Traditional knowledge in social–ecological systems. Ecol. Soc., 9, 3, 7

Funk, S., Krumme, U., Temming, A., & Möllmann, C. 2020. Gillnet fishers' knowledge reveals seasonality in depth and habitat use of cod (Gadus morhua) in the Western Baltic Sea. ICES J. Mar. Sci., 77, 5, 1816-1829, fsaa071. doi:10.1093/icesjms/fsaa071

Gray, S., Chan, A., Clark, D., & Jordan, R. C. 2012. Integrating stakeholder knowledge in social-ecological system decision-making: Benefits and limitations to knowledge diversity. Ecol Modell, 229, 88-96. doi:10.1016/j.ecolmodel.2011.09.011

Gray, S., Gagnon, A. S., Gray, S. A., O`Dwyer, B., Mahony, C., Muir, D., ..., & Gault, J. 2014. Are local coastal managers detecting the problem? Assessing stakeholder perception of climate vulnerability using Fuzzy Cognitive Mapping. Ocean Coast Manag, 94, 74-89. doi:10.1016/j.ocecoaman.2013.11.008

Haapasaari, P., Mäntyniemi, S., & Kuikka, S. 2012. Baltic Herring Fisheries Management: Stakeholder Views to Frame the Problem. Ecol. Soc. 17, 3, 36. doi:10.5751/ES-04907-170336

Hare, J. 2020. Ten lessons from the frontlines of science in support of fisheries management. ICES J. Mar. Sci., 77, 3, 870-877. doi:10.1093/icesjms/fsaa025

ICES. 2021. Cod (*Gadus morhua*) in subdivisions 22–24, western Baltic stock (western Baltic Sea). doi: 10.17895/ices.advice.7744

Jentoft, S., McCay, B. J., & Wilson, D. C. 1998. Social theory and fisheries co-management. Mar Policy, 22, 4-5, 423-436

Jentoft, S., & Chuenpagdee, R. 2009. Fisheries and coastal governance as a wicked problem. Mar Policy, 33, 553-560. doi:10.1016/j.marpol.2008.12.002

Jentoft, S. 2017. Small-scale fisheries within maritime spatial planning: knowledge integration and power. J. Environ. Policy Plan., 19, 3. doi:10.1080/1523908X.2017.1304210

Jones, K., & Seara, T. 2020. Integrating Stakeholders' Perceptions into Decision-Making for Ecosystem-Based Fisheries Management. Coastal Management, 48, 4, 275-288. doi:10.1080/08920753.2020.1773211

Kraan, M., Hendriksen, A., van Hoof, L., van Leeuwen, J., & Jouanneau, C. 2014. How to dance? The tango of stakeholder involvement in marine governance research. Mar Policy, 50, 347-352. doi:10.1016/j.marpol.2014.05.010

Levin, S., Xepapadeas, T., Crépin, A.-S., Norberg, J., de Zeeuw, A., Folke, C., …, & Walker, B. 2013. Social-ecological systems as complex adaptive systems: modeling and policy implications. Environment and Development Economics, 18, 2, 111-132. doi:10.1017/S1355770X12000460

Linke, S., Dreyer, M., & Sellke, P. 2011. The Regional Advisory Councils. What is their potential to incorporate stakeholder knowledge into fisheries governance? AMBIO, 40, 133-143. doi:10.1007/s13280-010-0125-1

Linke, S., & Bruckmeier, K. 2015. Co-management in fisheries – Experiences and changing approaches in Europe. Ocean Coast Manag, 104, 170-181. doi:10.1016/j.ocecoaman.2014.11.017.

Linke, S., & Jentoft, S. 2016. Ideals, realities and paradoxes of stakeholder participation in EU fisheries governance. Environ. Sociol., 2, 2, 144-154. doi:1080/23251042.2016.1155792

Long, R. D., Charles, A., & Stephenson, R. L. 2015. Key principles of marine ecosystem-based management. Mar Policy, 57, 53-60

Lopes, P. F., M., Mendes, L., Fonseca, V., & Villasante, S. 2017. Tourism as a driver of conflicts and changes in fisheries value chains in Marine Protected Areas. J. Environ. Manage., 200, 123-134. doi: 10.1016/j.jenvman.2017.05.080

Mackinson, S., Wilson, D. C., Galiay, P., & Deas, B. 2010. Engaging stakeholders in fisheries and marine research. Mar Policy, 35, 18-24. doi:10.1016/j.marpol.2010.07.003

Mendenhall, E., Hendrix, C., Nyman, E., Roberts, P. M., Hoopes J. R., Watson, J. R., …, & Sumaila, U. R. 2020. Climate change increases the risk of fisheries conflict. Mar Policy, 117, 103954. doi:10.1016/j.marpol.2020.103954

Merayo, E., Nielsen, R., Hoff, A., & Nielsen, M. 2018. Are individual transferable quotas an adequate solution to overfishing and overcapacity? Evidence from Danish fisheries. Mar Policy, 87, 167-176. doi:10.1016/j.marpol.2017.08.032

Miret-Pastor, L., Svels, K., & Freeman, R. 2020. Towards territorial development in fisheries areas: A typology of projects funded by Fisheries Local Action Groups. Mar Policy, 104111. doi:10.1016/j.marpol.2020.104111

Möllmann, C., Cormon, X., Funk, F., Otto, S., Schmidt, J., Schwermer, H., …, & Quaas, M. 2021. Tipping point realized in cod fishery. Sci. Rep., 11, 14259. doi:10.1038/s41598-021-93843-z

Morin, M. 2020. The fisheries resources in the European Union. The distribution of TACs: principle of relative stability and quota-hopping. Mar Policy, 24, 265-273

Murunga, M., Partelow, S., & Breckwoldt, A. 2021. Drivers of collective action and role of conflict in Kenyan fisheries co-management. World Dev, 141, 105413. doi:10.1016/j.worlddev.2021.105413

Ostrom, E. 2009. A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science, 325, 5939, 419-422. doi:10.1126/science.1172133

Partelow, S. 2018. A review of the social-ecological systems framework: applications, methods, modifications, and challenges. Ecol. Soc., 23, 4, 36. doi:10.5751/ES-10594-230436

Pinsky, M. L., Reygondeau, G., Caddell, R., Palacios-Abrantes, J., Spijkers, J., & Cheung, W. W. L. 2018. Preparing ocean governance for species on the move. Science, 360, 6394, 1189-1191. doi:10.1126/science.aat2360

Pinsky, M. L., Selden, R. L., & Kitchel, Z. J. 2020. Climate-driven shifts in marine species ranges: Scaling from organisms to communities. Ann Rev Mar Sci, 12, 1, 153-179. doi:10.1146/annurev-marine-010419-010916

Reed, M. S. 2008. Stakeholder participation for environmental management: A literature review. Biol. Conserv., 141, 2417-2431. doi:10.1016/j.biocon.2008.07.014

Rittel, H. W. J., & Webber, M. M. 1973. Dilemmas in a general theory of planning. Policy Sci., 4, 155-169

Steins, N., Kraan, M. L., van der Reijden, K. J., Quirijns, F. J., van Broekhoven, W., & Poos, J. J. 2019. Integrating collaborative research in marine science: Recommendations from an evaluation of evolving science-industry partnerships in Dutch demersal fisheries. Fish Fish (Oxf), 21, 1, 146-161. doi:10.1111/faf.12423

Stepanova, O. 2019. Power and knowledge use in coastal conflict resolution. In: Olsson, E. G. A., & Gooch, P. (ed). Natural resource conflicts and sustainable development. Routledge

Stephenson, R.L., Paul, S., Pastoors, M. A., Kraan, M., Holm, P., Wiber, M., Mackinson, S., …, & Benson, A. 2016. Integrating fishers' knowledge research in science and management. ICES J. Mar. Sci., 73, 6, 1459-1465. doi:10.1093/icesjms/fsw025

Sterling, E., Filardi, C., Toomey, A., Sigouin, A., Betley E., Gazit, N., …, & Jupiter, S. 2017. Biocultural approaches to well-being and sustainability indicators across scales. Nat. Ecol. Evol., 1,12, 1798-1806. doi:10.1038/s41559-017-0349-6.hal-02107213

Stier, A. C., Samhouri, J. F., Gray, S., Martone, R. G., Mach, M. E., Halpern, B. S., …, & Levin, P. S. 2016. Integrating Expert Perceptions into Food Web Conservation and Management. Conservation Letters, 0, 0, 1-10. doi:10.1111/conl.12245

Van Hoof, L., Kraan, M., Visser N. M., Avoyan E., Batsleer, J., & Trapman, B. 2019. Muddying the waters of the Landing Obligation: How Multi-level governance structures can obscure policy implementation. In: Uhlmann, S. S., Ulrich, C., & Kennelly, S. J. (ed). The European Landing Obligation. Reducing discards in complex, multi-species and multi-jurisdictional fisheries. Springer, 179-196. doi:10.1007/978-3-030-03308-8

Supplementary Material I

Survey – Social network structures of Western Baltic cod fisheries

Supplementary Material II

Booklet – Perception on SES Western Baltic cod fisheries

SUPPLEMENTARY MATERIAL I

Social network structures of Western Baltic cod fisheries

DER FORSCHUNG | DER LEHRE | DER BILDUNG

- Capturing social network structures –

The interaction and dependence of involved social groups in the management of Western Baltic cod

Dear study participant,

in the context of my PhD thesis I am dealing with the fisheries management of cod (*Gadus morhua*) in the Western Baltic Sea and the network structures of involved stakeholders.

The purpose of this questionnaire is to identify those German stakeholders or stakeholders from abroad (with German representation) and to analyze their network. In particular, I am interested in how the individual institutions are connected to each other.

Answering the questionnaire will not take more than **10 minutes** of your time!

In order to maintain anonymity, your data will of course be treated confidentially. Should you wish to receive the results of the research, you will have the opportunity to enter your e-mail address at the end of the questionnaire (note: by entering your e-mail address, no references to the completed questionnaire will be stored).

Thank you for your participation and support.

Heike Schwermer.

Contact person

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22767 Hamburg
Tel.: 04042838 - 6658
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Definition of relevant terms

Network

"From the perspective of social network analysis, networks are defined as actors who are connected to each other through relationships," (Kilduff & Tsai 2003).[1]

Institutions

"Institutions are the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions and codes of conduct) and formal rules (constructions, laws, property rights)," *(North 2003)*[2]*.*

According to this, an institution describes the formal and informal rules of a society that define incentive structures for political, economic and social interaction.

For the sake of simplicity, within the questionnaire the following terms are grouped under institution: ministry, agency, board, university, institute, institution, federal government, association, community. Commercial fisheries and recreational fisheries are also described here by the term institution.

Interest group

The term interest group covers the institutions that represent similar to the same interests. In the following questionnaire, six interest groups are distinguished: science, environmental non-governmental groups, commercial fisheries, tourism, politics and administration.

[1] Kilduff M., Tsai W. (2003). Social networks and organizations. SAGE publications.

[2] North D. C. (1991). Institutions. Journal Article. The Journal of Economic Perspectives. Vol. 5, No. 1: 97-112.

1. **To which of the interest groups mentioned here do you count your employer?**

Note: Please only choose an interest group.

A. Science
B. eNGO
C. Commercial fisheries
D. Tourism
E. Politics
F. Administration
G. Others:

2. **And to which interest group do you personally belong?**

Note: Please only choose an interest group.

A. Science
B. eNGO
C. Commercial fisheries
D. Tourism
E. Politics
F. Administration
G. Others:

3. **How long have you been employed in the interest group you named in question 1?**

Note: The time of your professional training is not considered here.

A. < 1 year
B. 1 – 5 years
C. 6 – 10 years
D. 11 – 15 years
E. 16 – 20 years
F. > 20 years

4. **In addition to the classification of your employer in the corresponding interest group, the information in which institution you are employed is particularly valuable for us.**

We would therefore be very pleased if you would note the name of your employer or the fisheries cooperatives you belong to, below:

5. **Please list the institutions you cooperate with most frequently in a professional context.**

Note: Name a maximum of 10 German institutions or institutions abroad with German representation.

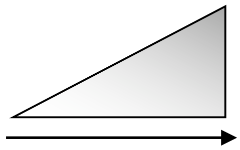
1. ______________________________ **6.** ______________________________
2. ______________________________ **7.** ______________________________
3. ______________________________ **8.** ______________________________
4. ______________________________ **9.** ______________________________
5. ______________________________ **10.** ______________________________

6. In the following possible institutions in Germany and abroad (with German representation) are listed.

Please indicate which of the statements applies to the respective institution:

(0) Institution is known to me by name.
(1) The institution's tasks and focus are known to me.
(2) Cooperation with this institution has already taken place.
(3) A cooperation is currently taking place.

Note: The order in which the institutions are listed is based on a rough classification (i.e., interest group), but not on a gradation of importance.



Institution	0	1	2	3	Not known
ICES					
Christian-Albrechts Universität					
IFM GEOMAR					
Institut für Hydrobiologie und Fischereiwissenschaften					
Thünen Institut für Ostseefischerei, Rostock					
Landesforschungsanstalt M-V					
Baltic Sea Advisory Council					
Greenpeace					
World Wildlife Fund for Nature (WWF)					
Naturschutzbund (NABU) e.V.					
Bund für Umwelt und Naturschutz Deutschland e.V. (BUND)					
EUCC - Die Küsten Union Deutschland e.V.					
Deutscher Naturschutzring e.V.					
Marine Stewardship Council					
European Anglers Alliance					
AktivRegion Ostseeküste e.V.					
Commercial fisheries					
Recreational fisheries					
Deutscher Fischereiverband e.V.					

Landesfischereiverband S-H e.V.					
Landesfischereiverband M-V e.V.					
Verband der Deutschen Kutter- und Küstenfischerei e.V.					
Landesverband der Kutter- und Küstenfischer M-V e.V.					
Deutscher Angelfischerverband e.V.					
Deutscher Meeresangelverband e.V.					
Angler Verband S-H e.V., Uetersen					
Landesanglerverband M-V e.V.					
HELCOM, Helsinki (FIN)					
Europäische Union (EU), Brüssel (BEL)					
EU Ministerrat, Brüssel (BEL)					
EU Parlament, Brüssel (BEL)					
EU Kommission, Brüssel (BEL)					
Bundesregierung, Berlin					
Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB), Berlin					
Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB)					
Ministerium für Ernährung, Landwirtschaft und Umwelt und ländliche Räume S-H					
Landesamt für Landwirtschaft, Umwelt & ländliche Räume S-H					
Landwirtschaftskammer S-H					
Ministerium für Landwirtschaft, Umwelt und Verbraucherschutz M-V					
Landesamt für Landwirtschaft, Lebensmittelsicherheit und Fischerei M-V					
Wasserschutzpolizei					
Umweltbundesamt					
Bundesamt für Naturschutz, Putbus (Vilm)					
Bundesanstalt für Landwirtschaft und Ernährung, Hamburg					
Ministerium für Wirtschaft, Verkehr, Arbeit, Technologie und Tourismus S-H					
Tourismusagentur S-H					
Ministerium für Wirtschaft, Arbeit und Gesundheit M-V					
Tourismusverband M-V e.V.					

7. please name other possible institutions in Germany or abroad (with German representation).

Please indicate which of the statements applies to the respective institution:

(0) Institution is known to me by name.

(1) The institution's tasks and focus are known to me.
(2) Cooperation with this institution has already taken place.
(3) A cooperation is currently taking place.

Note: Please move to the next question if you can't think of any other institution.

1	0	1	2	3
2				
3				
4				
5				
6				
7				
8				
9				
10				

8. With regard to the management of cod in the Western Baltic Sea, which institutions should cooperate more closely in the future?

Sample: Institution 1 - Institution 2

Note: Only use the institution that has already been mentioned in the questionnaire.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________
11. ______________________________
12. ______________________________
13. ______________________________
14. ______________________________
15. ______________________________

9. And with which institutions would you like to cooperate more strongly in future?

Note: Only use the institution that has already been mentioned in the questionnaire.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

10. Would you like to be informed about the research results?

Please enter your email address below:

I would like to thank you for your participation and your contribution to our research project.

You now have the opportunity to note comments or question:

SUPPLEMENTARY MATERIAL II

Perception on SES Western Baltic cod fisheries

Erfassung des sozial-ökologischen Systems mittels mentaler Modelle

Der westliche Ostseedorsch

Herausgeber

Universität Hamburg
Institut für Marine Ökosystem- und Fischereiwissenschaften
Große Elbstraße 133
22767 Hamburg

Redaktion und Bearbeitung

Heike Schwermer




Liebe Interviewte,

noch einmal möchten wir uns herzlich für Ihre Teilnahme an dem Projekt „Erfassung des sozial-ökologischen Netzwerkes des Westlichen Ostseedorsches mittels mentaler Modelle“ bedanken. Erst durch Ihr hohes Engagement und die Möglichkeit, uns an Ihrem mentalen Modell teilhaben zu lassen, konnte die Erhebung in diesem Maße erfolgreich durchgeführt werden.

Nun möchten wir Ihnen die Ergebnisse aus den anderen Interviews nicht vorenthalten und hoffen Ihnen durch diese Zusammenfassung einen guten Einblick in die mentalen Modelle der anderen Interviewten zu geben. Wie sehen also Vertreter*innen „meiner“ Gruppe das sozial-ökologische System des Westlichen Ostseedorsches? Wie nehmen Vertreter*innen anderer Gruppen das System wahr? Was beeinflusst die Komponenten Dorsch, Fischerei und Dorschquote?

Dieses Dokument ist so aufgebaut, dass wir Ihnen zunächst das methodische Vorgehen beschreiben (Seite 6). Im Anschluss werden wir Ihnen erste Ergebnisse aus einer derzeit verfassten Publikation präsentieren (Seite 9). Aufgeteilt nach den verschiedenen Interessengruppen (Fischerei, Freizeitfischerei, Umweltschutz, Verwaltung, Tourismus und Wissenschaft) finden Sie dann eine Vielzahl der Modelle ab Seite 14 .

Wir haben versucht Ihnen einen möglichst tiefen Blick in die Ergebnisse zu geben. Sollten von Ihrer Seite noch Anregungen oder Fragen bestehen, so kontaktieren Sie mich sehr gerne unter der unten genannten Adresse.

Wir wünschen Ihnen einen interessanten Einblick,

Prof. Christian Möllmann, Raissa Borgmann & Heike Schwermer

Kontakt

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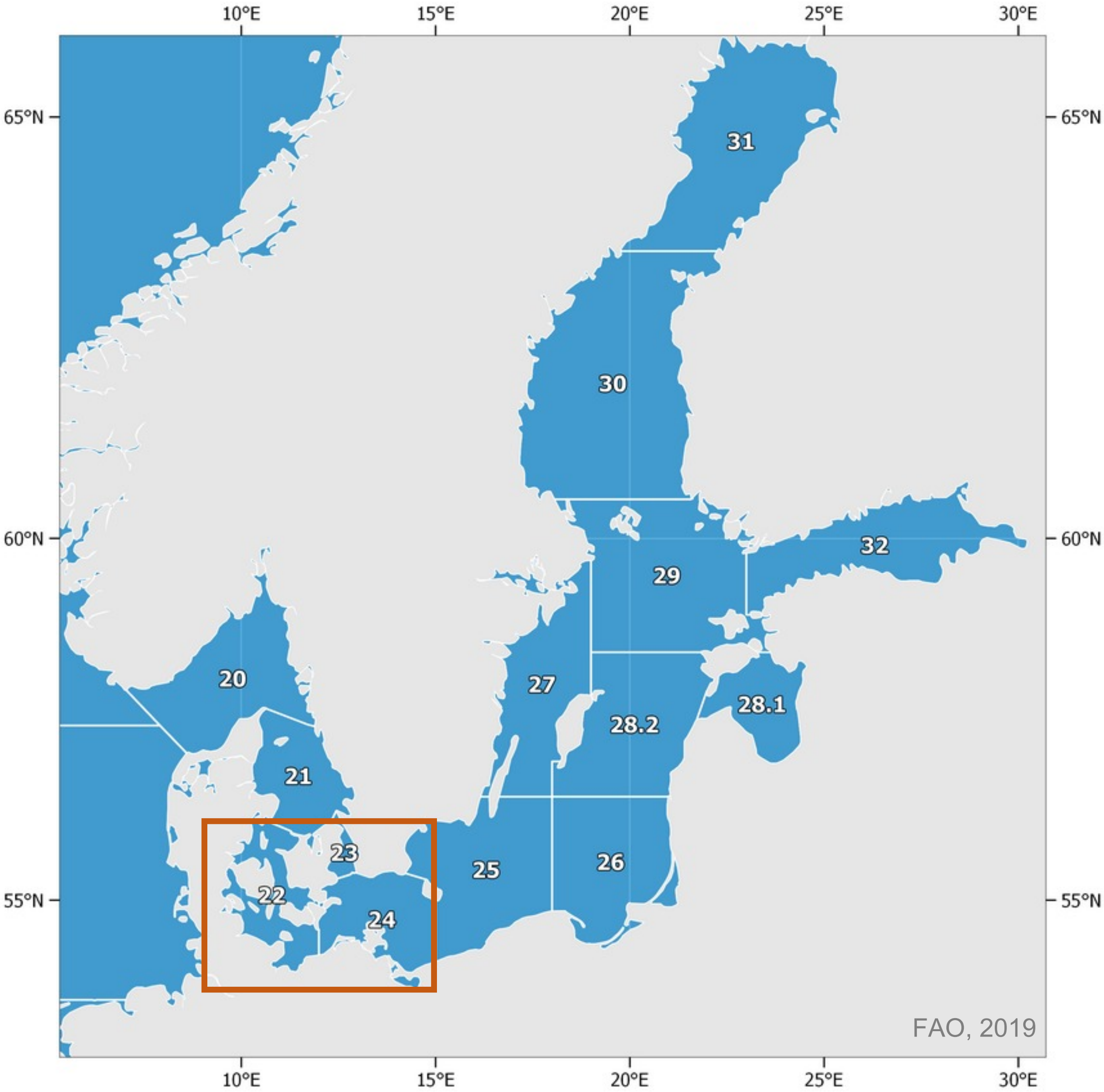
DBU
Deutsche Bundesstiftung Umwelt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Januar 2019

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

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Schritte	Beschreibung
1. Vorbereitung	Eine Woche im Voraus erhielten die Beteiligten ein Handout, welches das Ziel des Projekts erläuterte und eine Erklärung zu sozial-ökologischen Systemen und mentalen Modellen gab. Ferner wurde das Vorgehen der Datenerhebung beschrieben und eine Definition der drei Ausgangskomponenten Dorsch, Fischerei und Fangquote beigefügt.
2. Erklärung	Zu Beginn eines jeden halbstrukturierten Interviews gingen wir das Handout durch und beschrieben ausführlich, wie wir bzgl. der Erfassung des mentalen Modells vorgehen werden; nach der Projektbeschreibung zu Beginn wurden die Interviewten gebeten, sich vorzustellen und zu beschreiben, wie Ihre Arbeit mit Dorsch in der westlichen Ostsee in der Vergangenheit aussah und wie lange sie hierzu schon arbeiten.
3. Identifizierung	Um die Erhebung ihres mentalen Modells zu starten, wurden den Interviewten zwei Fragen gestellt, : 1. Wenn Sie an den Kabeljau in der westlichen Ostsee denken, welche Komponenten kommen Ihnen in den Sinn? (Definition der Komponenten); 2. Wie ist das Verhältnis zwischen diesen Komponenten? (Beschreibung der Verbindungen zwischen Komponenten). Die Komponenten (max. 20) konnten entweder sozialer, ökologischer oder ökonomischer Natur sein.
4. Mapping	Das Vorgehen hinsichtlich der Visualisierung des mentalen Modells war den Interviewten überlassen; a) alle Komponenten aufschreiben und anschließend miteinander verbinden; b) Fragen 1 und 2 kombinieren. Hierbei war es wichtig, dass eine Definition der Komponenten sowie die Maßeinheit dieser beschrieben wurde. Um die Beziehung zwischen Komponente A und B zu beschreiben, muss von einer Erhöhung der beeinflussenden Komponente A ausgegangen werden, um die Wirkung auf die beeinflussenden Komponente B zu beschreiben. Hierbei kann es entweder zu einer Erhöhung (+) oder einer Absinkung (-) dieser kommen. Am Ende des Mappings wurde dem Interviewten eine Liste von Komponenten (Prädation, Beute, Umweltfaktoren, andere Fische, Freizeitfischerei, Tourismus und eNGO) vorgelegt. Diese basieren auf einem Vorabtest mit Wissenschaftlern der Universität Hamburg. Die Komponenten wurden immer in der gleichen Reihenfolge vorgeschlagen und konnten entweder akzeptiert oder abgelehnt werden. Für die Erstellung der mentalen Modelle wurden folgende Materialien verwendet: a) Whiteboard, b) Tafelmarker, c) laminierte Komponentenkarten (vordefiniert, leer).
5. Kommunikation	Drei Tage nach dem Interview wurde dem Befragten eine digitalisierte Version des eigenen mentalen Modells per E-Mail zugesandt; zur Visualisierung verwendeten wir die Software *MentalModeler*. Die Befragten hatten die Möglichkeit, ihr mentales Modell zu ändern oder zu erweitern.

1. Datenerhebung

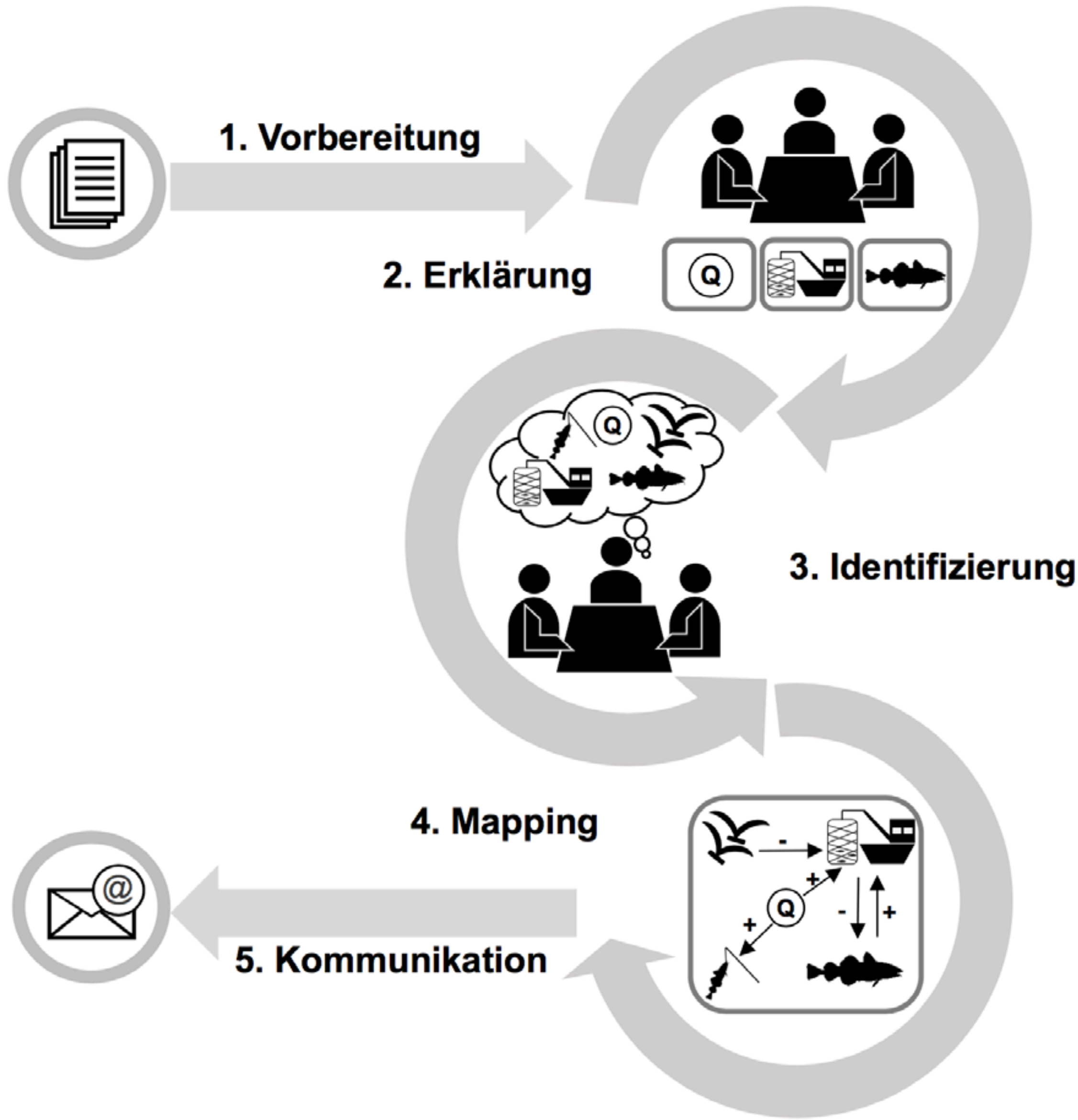
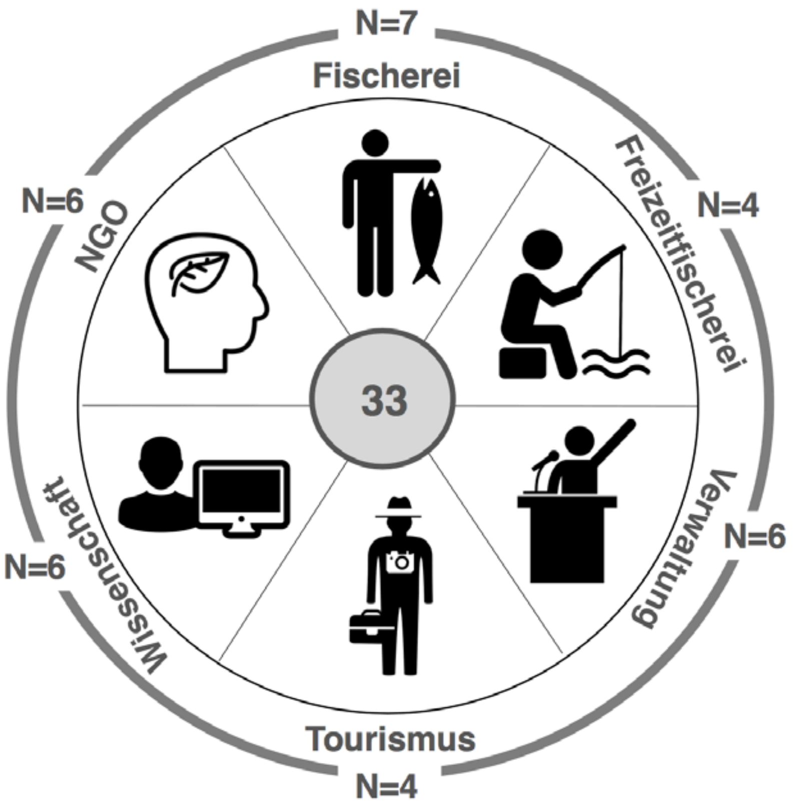


Abbildung 2.
Der 5-stufige Ansatz wurde verwendet, um die Wahrnehmung (mentale Modelle) der Interviewten in Bezug auf das sozial-ökologische System des westlichen Ostseedorsches zu beschreiben: 1. Vorbereitung (Handout: Vorbereitung auf die Datenerhebung), 2. Erklärung (Beschreibung aller wichtigen Informationen für die Datenerhebung), 3. Identifizierung (Aktivierung des mentalen Modells des Interviewten), 4. Mapping (Graphische Darstellung des mentalen Modells des Interviewten durch Komponenten und Beziehungen) und 5. Kommunikation (digitalisierte Karte wurde an den Interviewten geschickt, um nach Änderungen und/oder Zufriedenheit zu fragen).

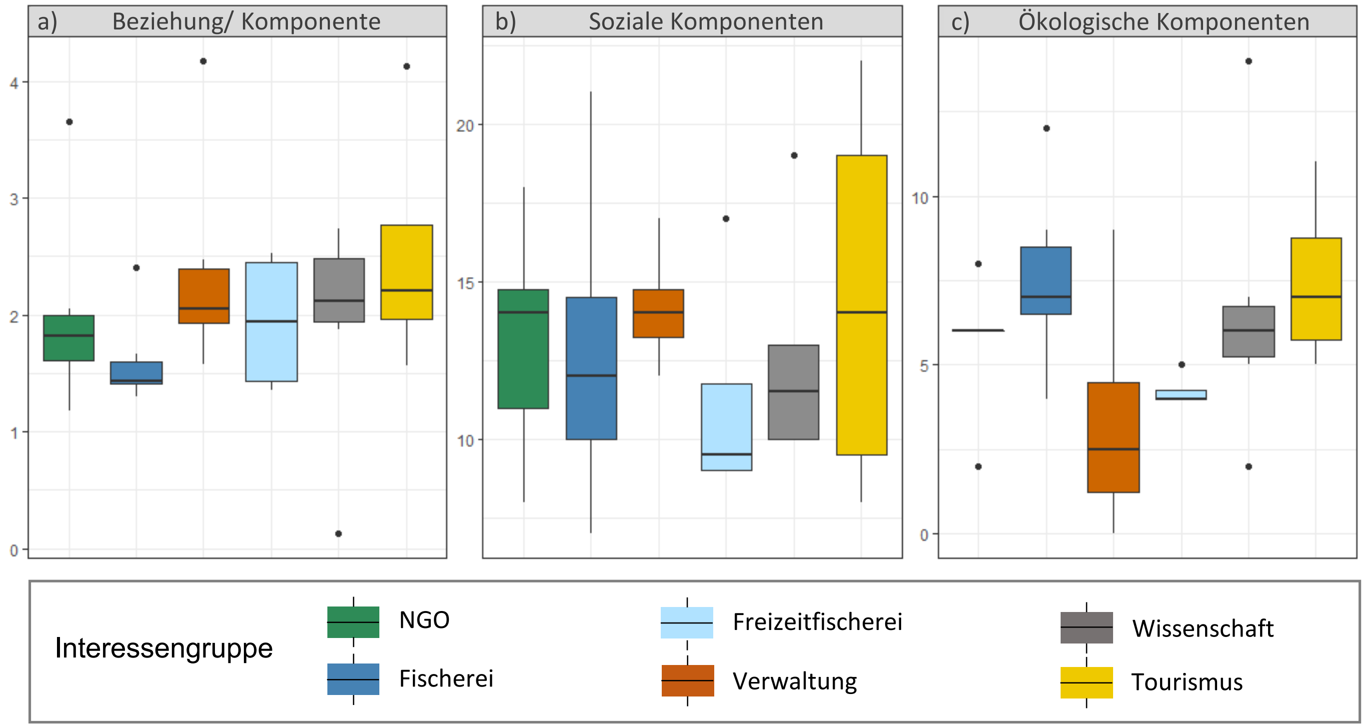
Interviewpartner*innen

Im Zeitraum vom 09.02.–10.04.2019 führten wir eine Datenerhebung durch, die zum Ziel hatte, die Wahrnehmung verschiedener Interessenvertreter*innen auf das sozial-ökologischen Systems des westlichen Ostseedorschs zu erfassen. Die Auswahl der Interviewten basiert auf fünf von uns festgelegten Kriterien: i) Interviewte ist Teil einer deutschen Institution/Verein, ii) Interviewte hat an der vorangegangenen Studie zur sozialen Netzwerkanalyse der Dorschfischerei in der westlichen Ostsee teilgenommen, iii) Interviewte besitzt eine langjährige Erfahrung (> 5Jahre) auf dem untersuchten Gebiet, iv) Job-Position und v) Interviewte ist verfügbar in dem von uns festgesetzten Zeitraum. Mindestens vier der beschriebenen Kategorien musste hierbei erfüllt sein.
Die 33 Interviewten dieser Studie sind Vertreter*innen aus 6 Interessensgruppen: Fischerei, Freizeitfischerei, Verwaltung, Tourismus, Wissenschaft sowie Umweltschutz. Jede Gruppe ist hierbei durch ein sogenanntes Piktogramm dargestellt und wir Sie durch das Dokument begleiten.



2. Ergebnisse

A Strukturelle Analyse



Im Zuge der Auswertung haben wir sowohl eine strukturelle Analyse der mentalen Modelle wie auch eine inhaltliche Analyse dieser durchgeführt.
Die Analyse der Struktur wird hier beispielhaft durch die Maße a) Beziehung/Komponente, b) Anzahl sozialer Komponenten sowie c) Anzahl ökologischer Komponenten dargestellt. Eine umfassende Strukturanalyse wurde von Raissa Borgmann vorgenommen und umfasst neben einer Netzwerkanalyse vor allem eine Clusteranalyse.

Was wird deutlich?

Weder zwischen den Gruppen noch innerhalb der betrachteten Gruppen sind klare Muster zu erkennen.
Das heißt, es gibt keine Gruppe, die sich durch das Verhältnis Beziehung zu Komponente, Anzahl sozialer oder Anzahl ökologischer Komponenten von den anderen stark unterscheidet. Auch die Clusteranalyse zeigt, dass es keine klaren Muster hinsichtlich der Struktur der mentalen Modelle gibt.

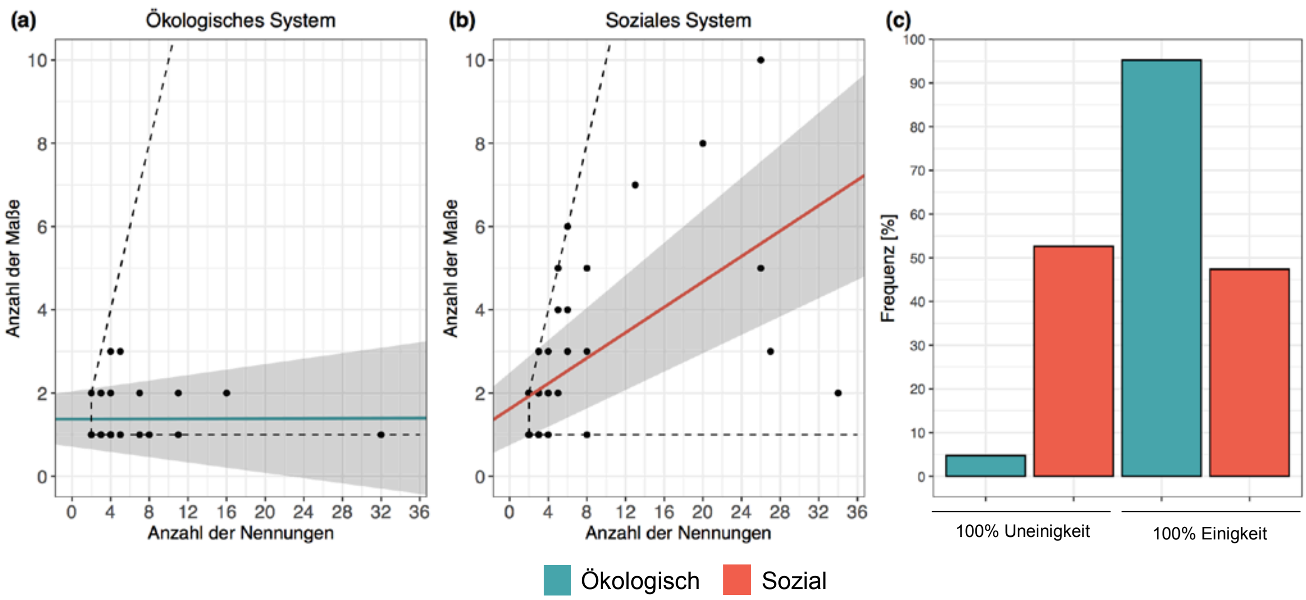
Komponenten und die verwendeten Synonyme

Alle mentalen Modelle sind in diesem Dokument in der Form, räumlich wie auch in der sprachlichen Formulierung dargestellt, wie sie durch die Interviewten festgelegt wurden.
Interessant ist, dass für einige Komponenten mehrere Begriffe definiert wurden, d.h. a) Verwendung der Mehrzahl, b) Ergänzung durch weitere Begriffe, c) Begriff als Person oder aber d) Verwendung eines „neuen“ Begriffs. Folgende Tabelle zeigt Ihnen einige dieser Komponenten:

Komponente	Synonyme
Freizeitfischerei	Angelfischerei Angler Brandungsangler Freizeitfischer Freizeitangler
eNGO	U-NGO Ökogruppen Naturschutzverbände Verbände Naturschutz
Wissenschaft	Wissenschaftler Wissenschaft, Forschung Wissenschaft (Daten, Modelle) Forschungsinstitute Wissenschaftsapparat
Arbeitsplätze	Jobs (Fisch) Humankapital
Salzwassereinstrom	Salzwassereinstrom (O2) Salzwassereinströme Einstrom Nordseewassereinstrom Wasseraustausch Nordsee Hydrologie Wetter, Wasseraustausch
Nahrung	Nahrungsangebot (Adult) Nahrungsangebot (Larven) Nahrungsorganismen Nahrung für Dorsch
Prädation	Prädatoren Räuber Fressfeinde Fraßfeinde (Fische) Fraßfeinde (Meeressäuger)
Temperatur	Erwärmung Ostsee Klima, Wassertemperatur Wassertemperatur Umwelteinfluss Klimaerwärmung

2. Ergebnisse

B Inhaltliche Analyse

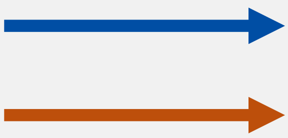


Die inhaltliche Analyse basiert auf einer qualitativen wie auch einer quantitativen Auswertung der mentalen Modelle. Wir haben die Messgröße, welche für die jeweilige Komponente individuell durch jeden Interviewten definiert wurde, genutzt, um eine Aussage darüber zu treffen, inwieweit ein gleiches Systemverständnis zwischen den Interviewten besteht.
Die Abbildung zeigt eine Unterteilung in die Komponenten des a) ökologischen Systems sowie des b) sozialen Systems. Die gestrichelten Linien begrenzen genau den Bereich, für den ein unterschiedliches Verständnis der Komponentenmessgrößen vorliegt. Besteht ein gleiches Verständnis so liegen die Datenpunkte auf x=1.
In c) ist der prozentuale Anteil der sozialen wie auch ökologischen Komponenten dargestellt, für welche ein nicht gleiches (100% Uneinigkeit, links) und ein gleiches (100% Einigkeit, rechts) Verständnis vorliegt.

<u>Was wird deutlich?</u>
Das Verständnis über die Funktion der ökologischen Komponenten ist über alle Gruppen deutlich größer als das über der sozialen Komponenten.
Lediglich für eine ökologische Komponente (Altersstruktur des Dorsches) liegen verschiedene Messgrößen vor (1. Anzahl der großen und alten Dorsche, 2. Stärke der Durchmischung).

Wie lese und interpretiere ich ein mentales Modell?

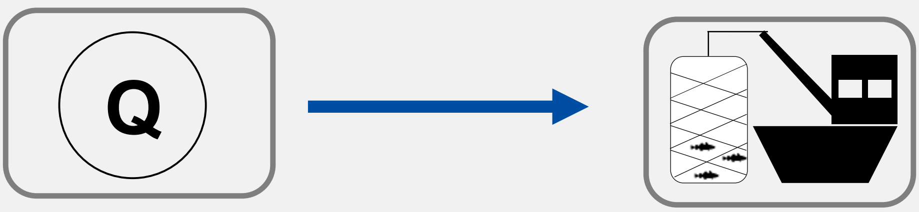
Jedes Modell wird beschrieben durch i) Komponenten sowie ii) deren Beziehungen zueinander. Hierbei kann eine Komponente mehrere andere beeinflussen oder durch diese beeinflusst werden.
Die (digitalisierten) Modelle in dieser Dokumentation sind durch farbige Pfeile gekennzeichnet und beschreiben sich wie folgt:



Zunahme der Komponente

Abnahme der Komponente

Um die Beziehung zwischen den Komponenten zu verstehen, ist jede dieser durch eine Messgröße definiert. Diese Messgröße wurde individuell durch die Interviewten festgelegt und wird für jedes der hier aufgeführten Modelle tabellarisch dargestellt. Es ist immer von einer Zunahme der einflussnehmenden Größe auszugehen, um die Wirkung auf die beeinflussende Komponente zu beschreiben. Folgendes Beispiel:



Durch einen Anstieg der Fangquote (A) des westlichen Ostseedorschs, darf mehr gefangen werden, wodurch der Umsatz, in der Fischerei (B) steigt.

A) Fangquote wird gemessen an der Höhe der Fangquote.
B) Fischerei misst sich an dem Umsatz der durch den Fang von Fisch generiert wird.

2. Ergebnisse

Auf den folgenden Seiten finden Sie eine Vielzahl der (digitalisierten) mentalen Modelle. Bevor die einzelnen Modelle präsentiert und entsprechend ihrer Hauptcharakteristika beschrieben werden, wird Ihnen ein kurzer Überblick über die relevanten Gruppen Fischerei, Freizeitfischerei, Umweltschutz, Tourismus, Verwaltung und Wissenschaft gegeben. Hierbei soll kurz auf die Fragen „Wie beschreibt sich die Gruppe?“ und „Was sind die am häufigsten genannten Komponenten der Gruppe?“ eingegangen werden.

Im Anschluss an diese Kurzbeschreibung wird dann im Detail jedes der einzelnen Modelle aufgeführt. Zu jedem Modell finden Sie neben Eckdaten aus der strukturelle Analyse eine Tabelle, welche die Komponenten und die Messgrößen (individuell durch den Interviewten definiert) aufzeigt. Erst hierdurch können die Modelle in ihrer Dynamik verstanden und nachvollzogen werden.
Durch diese Form der Darstellung wollen wir Ihnen die Möglichkeit geben, die Wahrnehmungen und Sichtweisen anderer Vertreter*innen Ihrer Interessengruppe, aber auch die der Vertreter*innen anderer Gruppen, nachzuvollziehen.

1. Welche Komponenten werden genannt?
2. In welcher Beziehung stehen die genannten Komponenten zueinander?
3. Welche Komponenten sowie deren Definitionen gleichen denen aus meinem Modell und in welcher Beziehung stehen sie zu anderen Komponenten des Systems?

<u>Interessengruppen</u>


Fischerei, Seite 14

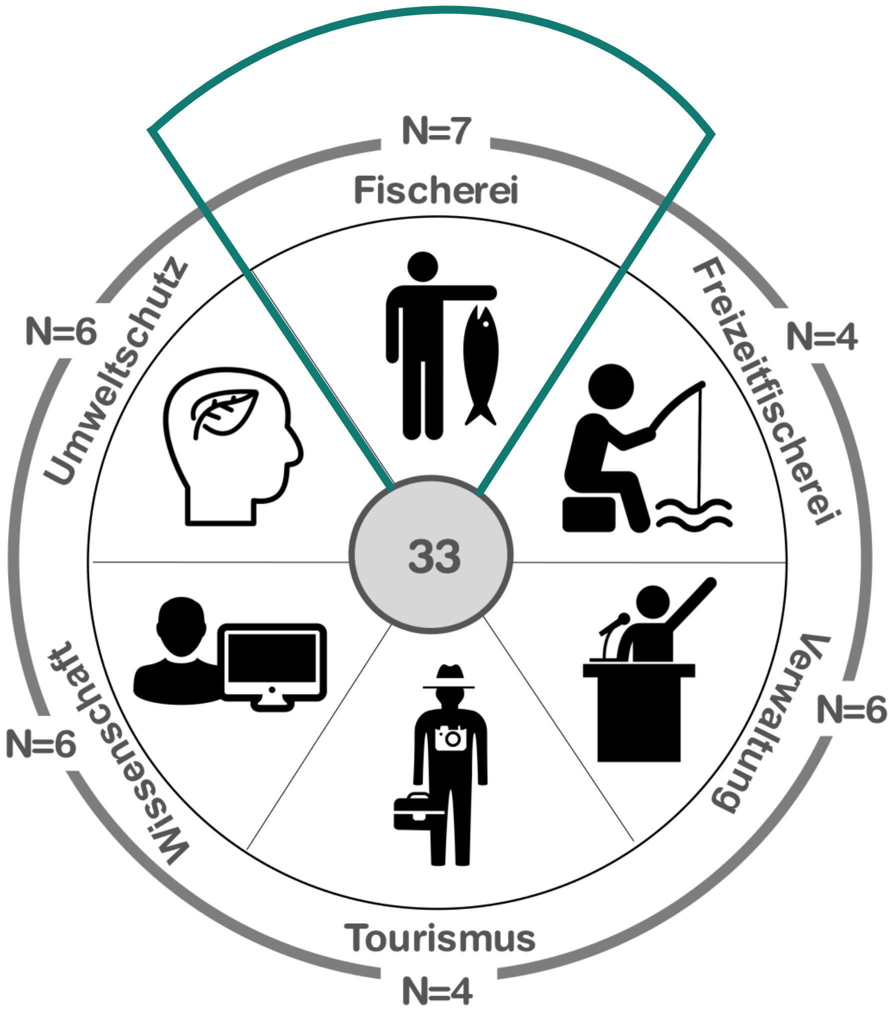

Umweltschutz, Seite 41


Verwaltung, Seite 71


Freizeitfischerei, Seite 31


Tourismus, Seite 53


Wissenschaft, Seite 71



Wir haben **7 Interviews** mit Vertretern*innen aus der Gruppe *Fischerei* geführt.
Hierbei wurden insgesamt 142 Komponenten definiert (Mittel: 20 Komponenten pro Interview).

2.1 Fischerei

Tourismus, **Nahrung** und **Freizeitfischerei** sind die am häufigsten genannten Komponenten in der Gruppe *Fischerei*.

Durch einen Anstieg der Touristen (Komponente: Tourismus) werden sowohl in der Freizeitfischerei (auch: Angelfischerei) wie auch in der Fischerei höhere Umsätze erzielt. Ferner kommt es durch mehr Angler auch zu einer Stärkung der Eigenvermarktung (auch: Selbstvermarktung).

Nahrung (auch: Nahrungsangebot (Adulte, Larven)) hingegen wirkt sich positiv auf den Dorschbestand aus, sprich: je mehr Nahrung, desto höher die Dorschbiomasse. Eine Erhöhung der Umweltfaktoren Temperatur, Sauerstoff- und Salzgehalt resultieren in erhöhten Nahrungsmengen.

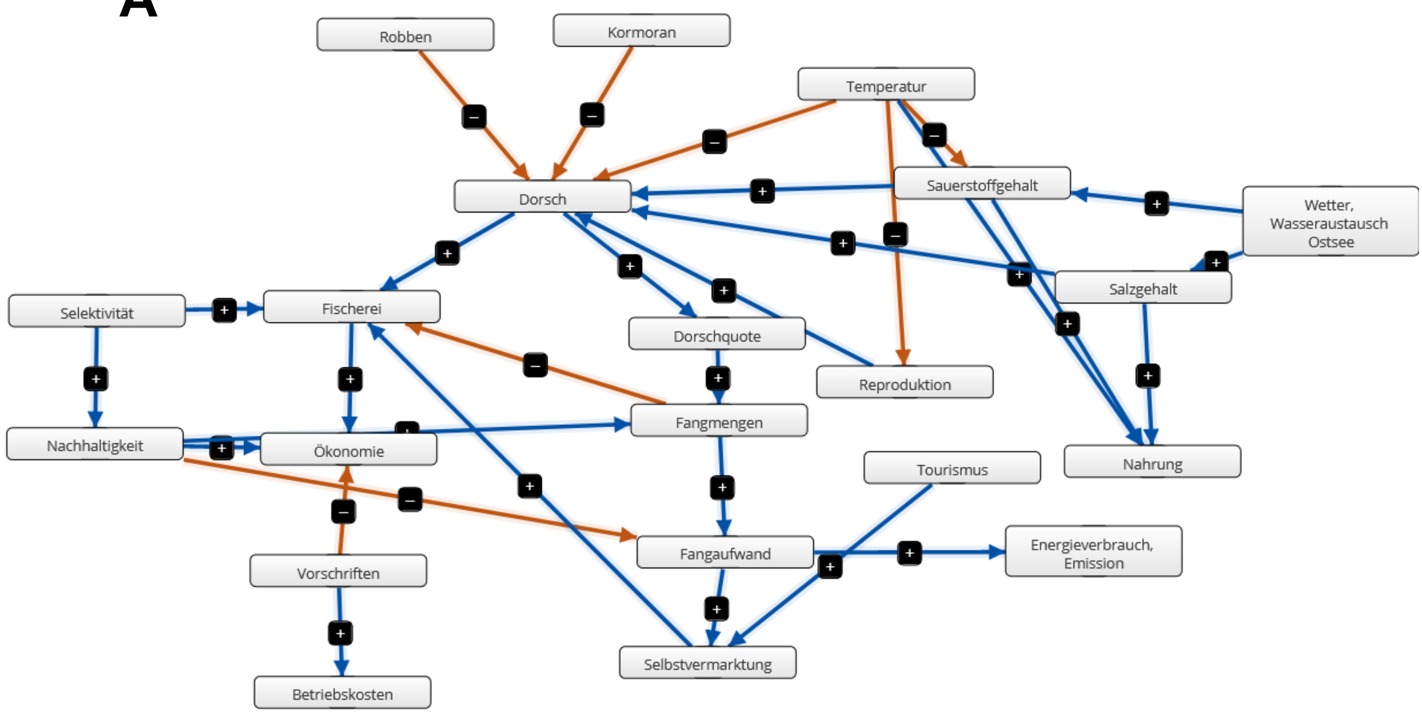
Freizeitfischerei (auch: Angelfischerei, Angler) wirkt als konkurrierender Nutzer, heißt: je höhe die Entnahmen durch Angler, je niedriger auch der Dorschbestand. Dieses bedingt geringe Fangmengen für die Fischerei. Eine Erhöhung der Dorschquote, und eine damit einhergehende Erhöhung des Bag limits bedingen hingegen die Zunahme an Anglern.

Komponente	Anzahl
Tourismus	7
Nahrung	5
Freizeitfischerei	5
Umweltorganisation	4
Salzgehalt	4
Salzwassereinstrom	4



2.1 Fischerei

A



<u>Zentralste Komponenten</u>

1. Dorsch
2. Fischerei
3. Sauerstoff, Nachhaltigkeit, Fangmengen, Fangaufwand

<u>Informationen zum Netzwerk</u>

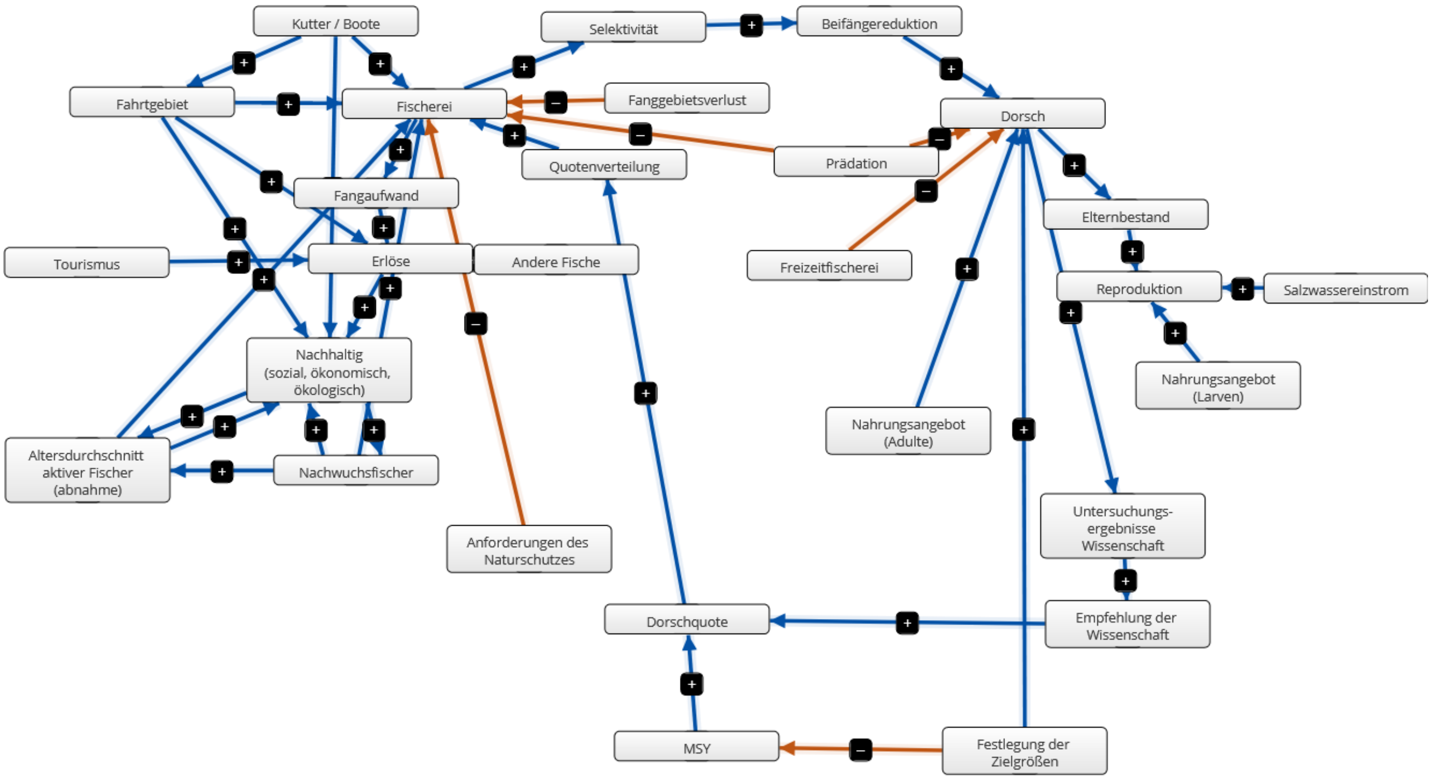
Anzahl Komponenten - 21
- Sozial - 12
- Ökologisch - 9

Anzahl der Beziehungen - 30

Komponente	Messgröße	
Betriebskosten	Höhe der Betriebskosten	Sozial
Dorschquote	Höhe der Fangquote	
Energieverbrauch, Emissionen	Höhe des Energieverbauchs	
Fangaufwand	Höhe des Fangaufwandes	
Fangmengen	Höhe der Fangmenge	
Fischerei	Höhe der Umsätze in der Fischerei	
Nachhaltigkeit	Höhe der selektiven Entnahme	
Ökonomie	Höhe der Wertschöpfung	
Selbstvermarktung	Menge der selbstvermarkteten Fische	
Selektivität	Höhe der selektiven Entnahme	
Tourismus	Anzahl der Touristen	
Vorschriften	Anzahl der Vorschriften	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Kormoran	Anzahl der Kormorane	
Nahrung	Menge an Nahrung	
Reproduktion	Anzahl der Rekruten	
Robben	Anzahl der Robben	
Salzgehalt	Höhe des Salzgehaltes	
Sauerstoffgehalt	Höhe des Sauerstoffgehaltes	
Temperatur	Höhe der Temperatur	
Wetter, Wasseraustausch	Häufigkeit der Einstromevents aus Nordsee	

2.1 Fischerei

B



Zentralste Komponenten

1. Fischerei
2. Dorsch
3. Nachhaltig (sozial, ökologisch, ökonomisch)

Informationen zum Netzwerk

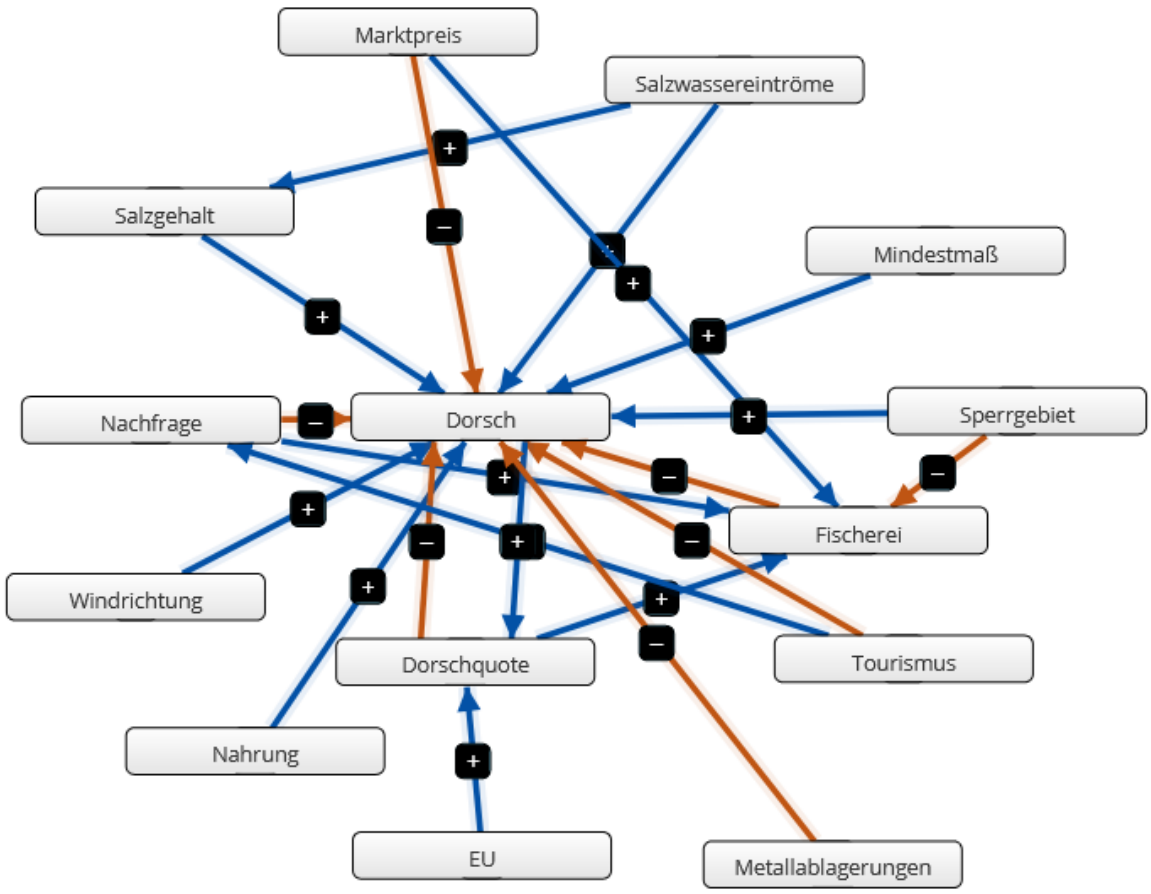
Anzahl Komponenten - 28
- Sozial - 21
- Ökologisch - 7

Anzahl der Beziehungen - 39

Komponente	Messgröße	
Anforderung Naturschutz	Stärke der Naturschutzanforderung	Sozial
Beifangreduktion	Menge der reduzierten Beifänge	
Dorschquote	Höhe der Fangquote	
Durchschnittsalter Fischer	Stärke der Altersverteilung	
Empfehlung Wissenschaft	Höhe der wissen. Empfehlung	
Erlöse	Höhe des Umsatz	
Fahrtgebiet	Fläche des Fahrtgebietes	
Fangaufwand	Höhe des Fangaufwandes	
Fanggebietsverlust	Höhe der Verlustfläche	
Festlegung Zielgröße	Höhe des $B_{MSY\text{-}trigger}$	
Fischerei	Anzahl der Fischer	
Freizeitfischerei	Anzahl der Angler	
Kutter, Boote	Alter und Größe der Kutter, Boote	
MSY	Höhe des F_{MSY}	
Nachhaltigkeit	Höhe der Nachhaltigkeit im Sinne sozial, ökologisch oder ökonomisch	
Nachwuchsfischer	Anzahl an Nachwuchsfischern	
Selektivität	Höhe der Selektivität (Fanggerät, Netz)	
Tourismus	Anzahl Touristen	
Quotenverteilung	Höhe der verteilten Quote	
Untersuchungsergebnisse (Wissenschaft)	Größe der beprobten Dorschmenge	
Andere Fische	Anzahl der anderen Fische	Ökologisch
Dorsch	Laicherbiomasse (SSB)	
Elternbestand (Dorsch)	Laicherbiomasse (SSB)	
Nahrungsangebot (Larven)	Menge an Nahrung	
Nahrungsangebot (Adulte)	Menge an Nahrung	
Prädation	Anzahl der Prädatoren	
Reproduktion	Anzahl der Rekruten	
Salzwassereinstrom	Häufigkeit der Salzwassereinströme	

2.1 Fischerei

C



<u>Zentralste Komponenten</u>

1. Dorsch
2. Fischerei
3. Dorschquote

<u>Informationen zum Netzwerk</u>

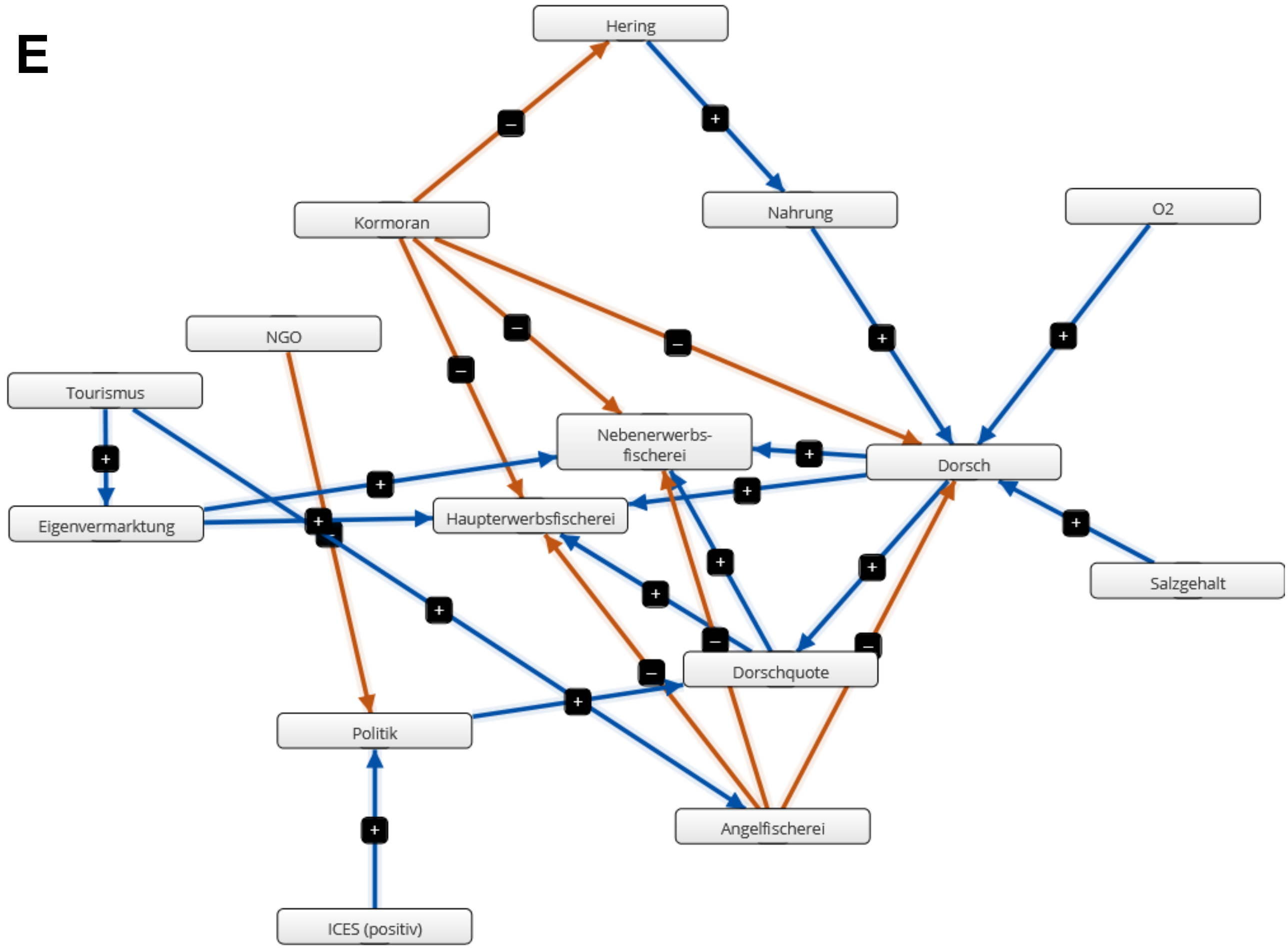
Anzahl Komponenten - 14
Sozial - 7
Ökologisch - 7

Anzahl der Beziehungen - 20

Komponente	Messgröße	
Dorschquote	Höhe der Fangquote	Sozial
EU	Durchsetzungsvermögen der EU	
Fischerei	Intensität der Fischerei	
Marktpreis	Höhe des Marktpreises	
Mindestmaß	Höhe des Mindestmaßes in cm	
Nachfrage	Höhe der Nachfrage nach Dorsch	
Sperrgebiet	Fläche des Sperrgebietes	
Tourismus	Anzahl der Touristen	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Metallablagerungen	Höhe der Metallablagerungen	
Nahrung	Menge an Nahrung	
Salzgehalt	Höhe des Salzgehaltes	
Salzwassereinströme	Anzahl der Salzwassereinströme	
Windrichtung	Dauer und Stärke der östlichen Winde	

2.1 Fischerei

E



Zentralste Komponenten

1. Dorsch
2. Haupterwerbsfischerei
3. Nebenerwerbsfischerei

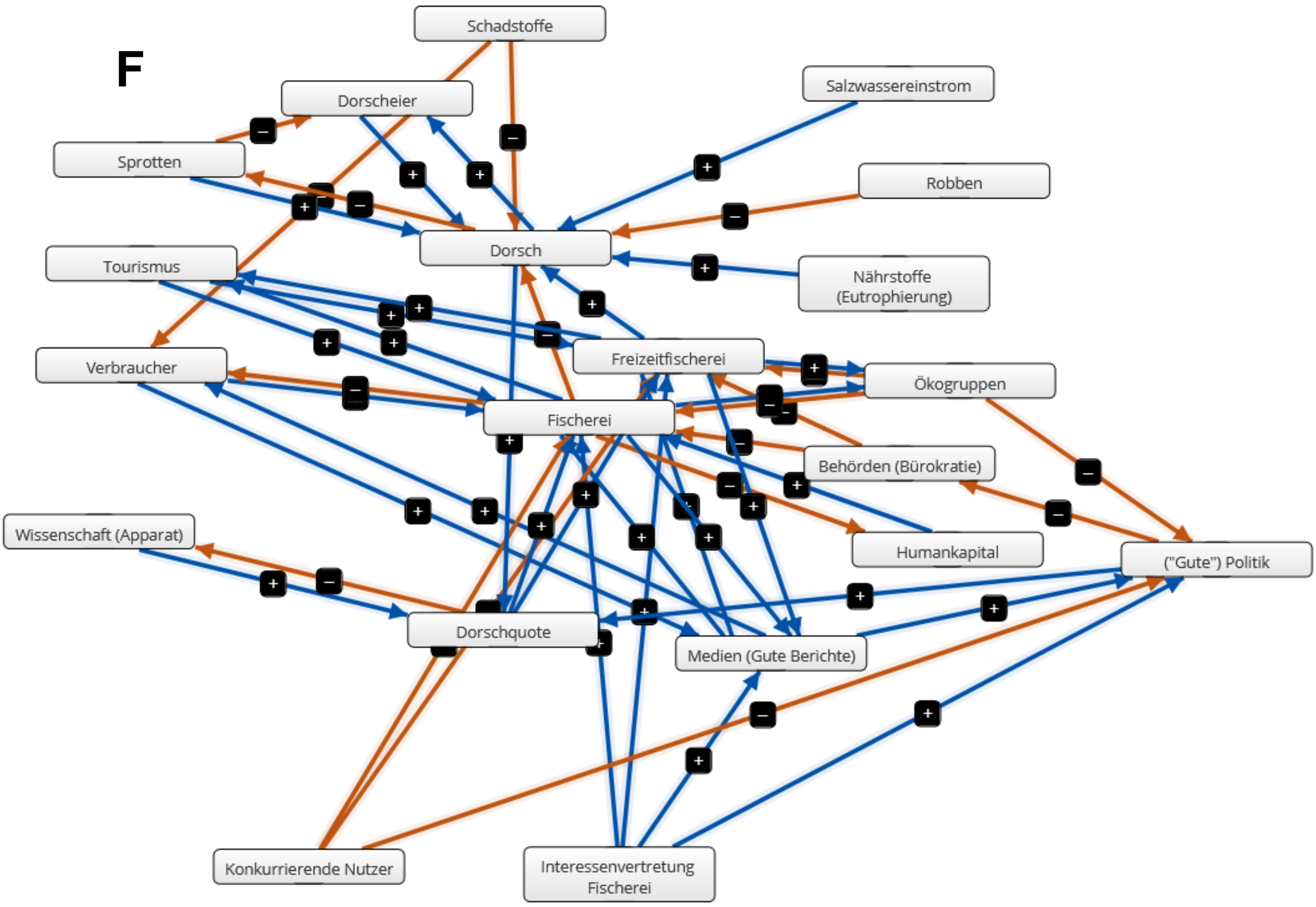
Informationen zum Netzwerk

Anzahl Komponenten - 15
- Sozial - 9
- Ökologisch - 6

Anzahl der Beziehungen - 23

Komponente	Messgröße	
Angelfischerei	Höhe der Entnahme durch Angler	Sozial
Dorschquote	Höhe der Fangquote	Sozial
Eigenvermarktung	Menge an eigenvermarkteten Produkten	Sozial
Haupterwerbsfischerei	Höhe des Umsatzes	Sozial
ICES (positv)	Höhe der Empfehlung	Sozial
Nebenerwerbsfischerei	Höhe des Umsatzes	Sozial
NGO	Höhe des Einflusses von NGOs	Sozial
Politik	Stärke der wirtschaftlichen Orientierung	Sozial
Tourismus	Anzahl der Touristen	Sozial
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Hering	Anzahl der Heringe	Ökologisch
Kormoran	Anzahl der Kormorane	Ökologisch
Nahrung	Verfügbarkeit der Nahrung	Ökologisch
O2	Höhe des Sauerstoffgehaltes	Ökologisch
Salzgehalt	Höhe des Salzgehaltes	Ökologisch

2.1 Fischerei



Zentralste Komponenten

1. Fischerei
2. Dorsch
3. Freizeitfischerei

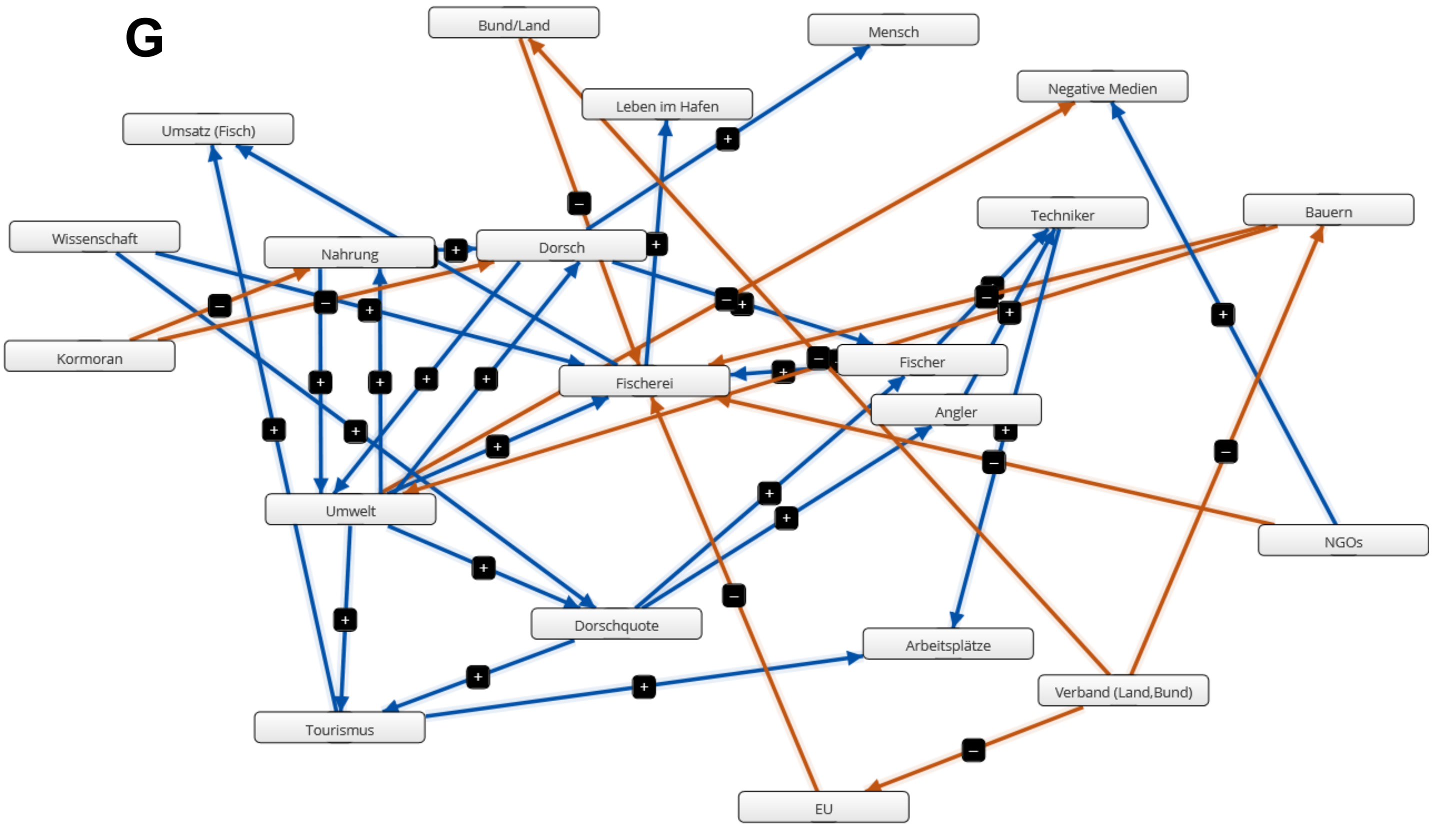
Informationen zum Netzwerk

Anzahl Komponenten - 20
- Sozial - 12
- Ökologisch - 8

Anzahl der Beziehungen - 48

Komponente	Messgröße	
Behörden	Höhe des bürokratischen Aufwandes	Sozial
Dorschquote	Höhe der Fangquote	
Fischerei	Stärke des Vorhandenseins einer Fischerei	
Freizeitfischerei	Anzahl der Angler	
Gute Medienberichte	Anzahl guter Berichte im Sinne der Fischerei	
(„Gute“) Politik	Stärke der Politik im Sinne der Fischerei	
Humankapital	Höhe der verfügbaren Arbeitskräfte	
Interessenvertretung Fischerei	Stärke der Interessenvertretung	
Konkurrierende Nutzer	Anzahl konkurrierender Nutzer (u.a. Windpark)	
Ökogruppen	Stärke des Aktionismusses der Ökogruppen	
Tourismus	Anzahl der Touristen	
Verbraucher	Anzahl der Verbraucher	
Wissenschaftsapparat	Höhe der Datenmenge	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Dorscheier	Anzahl der Dorscheier	
Nährstoffe (Eutrophierung)	Menge an eingetragenen Nährstoffen	
Robben	Anzahl der Robben	
Salzwassereintrom (O2)	Häufigkeit der Salzwassereinströme	
Schadstoffe	Höhe der Schadstoffbelastung	
Sprotte	Anzahl der Sprotten	

2.1 Fischerei



Zentralste Komponenten

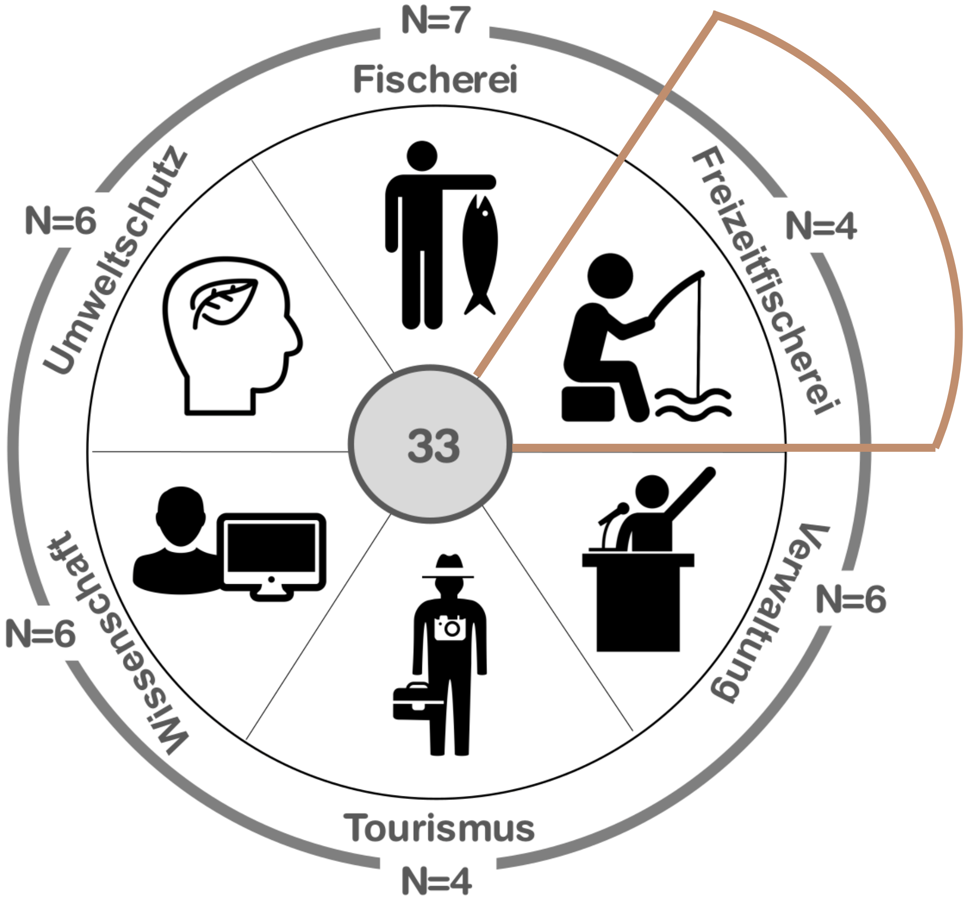
1. Fischerei
2. Umwelt
3. Dorsch

Informationen zum Netzwerk

Anzahl Komponenten - 21
- Sozial - 17
- Ökologisch - 4

Anzahl der Beziehungen - 35

Komponente	Messgröße	
Angler	Anzahl der Angler	Sozial
Arbeitsplätze	Anzahl der Arbeitsplätze	
Bauern	Höhe der Nährstoffeinträge	
Bund (Land)	Höhe des bürokratischen Aufwandes	
Dorschquote	Höhe der Fangquote	
EU	Höhe des bürokratischen Aufwandes	
Fischer	Anzahl der Fischer	
Fischerei	Grad des Wohlergehens der Fischerei	
Leben im Hafen	Anzahl der unterschiedlichen Betriebe (Vielfalt im Hafen)	
Mensch	Anzahl der Konsumenten	
Negative Medien	Anzahl der negativen Pressemitteilungen	
NGOs	Stärke des Aktivismusses	
Techniker	Anzahl der Aufträge für den Betriebe	
Tourismus	Anzahl der Touristen	
Umsatz (Fisch)	Höhe des Umsatzes in der Fischerei	
Verband (Land, Bund)	Stärke der Vertretung	
Wissenschaft	Höhe der Empfehlung	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Kormoran	Anzahl der Kormorane	
Nahrung	Menge an Nahrung	
Umwelt	Höhe der Qualität des Umweltzustandes	



Wir haben **4 Interviews** mit Vertretern*innen aus der Gruppe *Freizeit-fischerei* geführt. Hierbei wurden insgesamt 62 Komponenten definiert (Mittel: 16 Komponenten pro Interview.

2.2 Freizeitfischerei

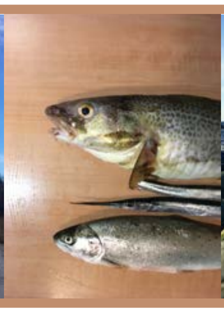
Prädation und **Freizeitfischerei** sind die am häufigsten genannten Komponenten in der Gruppe *Freizeitfischerei*. Hierbei ist zu erwähnen, dass für ein mentales Modell der Begriff Freizeitfischerei in Freizeitfischerei (Ufer) und Freizeitfischerei (Boot) unterteilt wurde.

Durch mehr Freizeitfischerei (auch Angler, Angelfischerei, gemessen an Anzahl der Angler) steigt der Umsatz in den Angelshops (auch: Fachgeschäfte). Zudem wirkt sich eine Zunahme der Angler positiv auf den Tourismus aus, sprich: mehr Angler, mehr Touristen.

Die Prädation (auch: Fressfeinde, Prädatoren, gemessen an der Anzahl der Prädatoren) wirken am stärksten auf den Dorschbestand, d.h. durch eine steigende Anzahl der Prädatoren, welche den Dorsch fressen, sinkt die Biomasse des Dorschbestandes. Dieses wirkt sich ebenfalls negativ, u.a. auf die Fischerei sowie Freizeitfischerei aus.

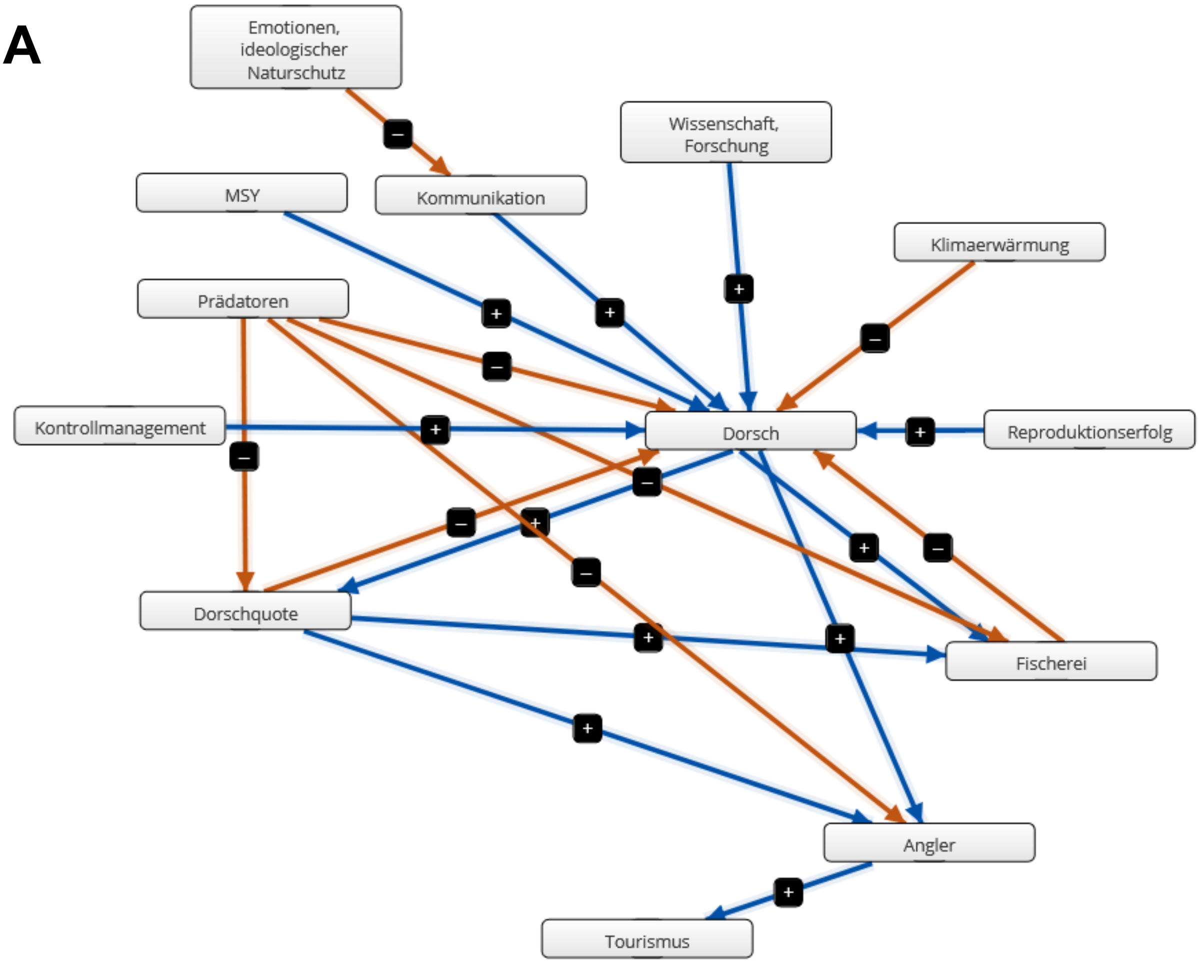
Komponente	Anzahl
Freizeitfischerei	4
Prädation	3
Angelshops	2
Umweltfaktoren	2
Sauerstoff, Salzgehalt	2
Nahrung	2
Tourismus	2






2.2 Freizeitfischerei

A



<u>Zentralste Komponenten</u>

1. Dorsch
2. Dorschquote
3. Fischerei, Prädatoren, Angler

<u>Informationen zum Netzwerk</u>

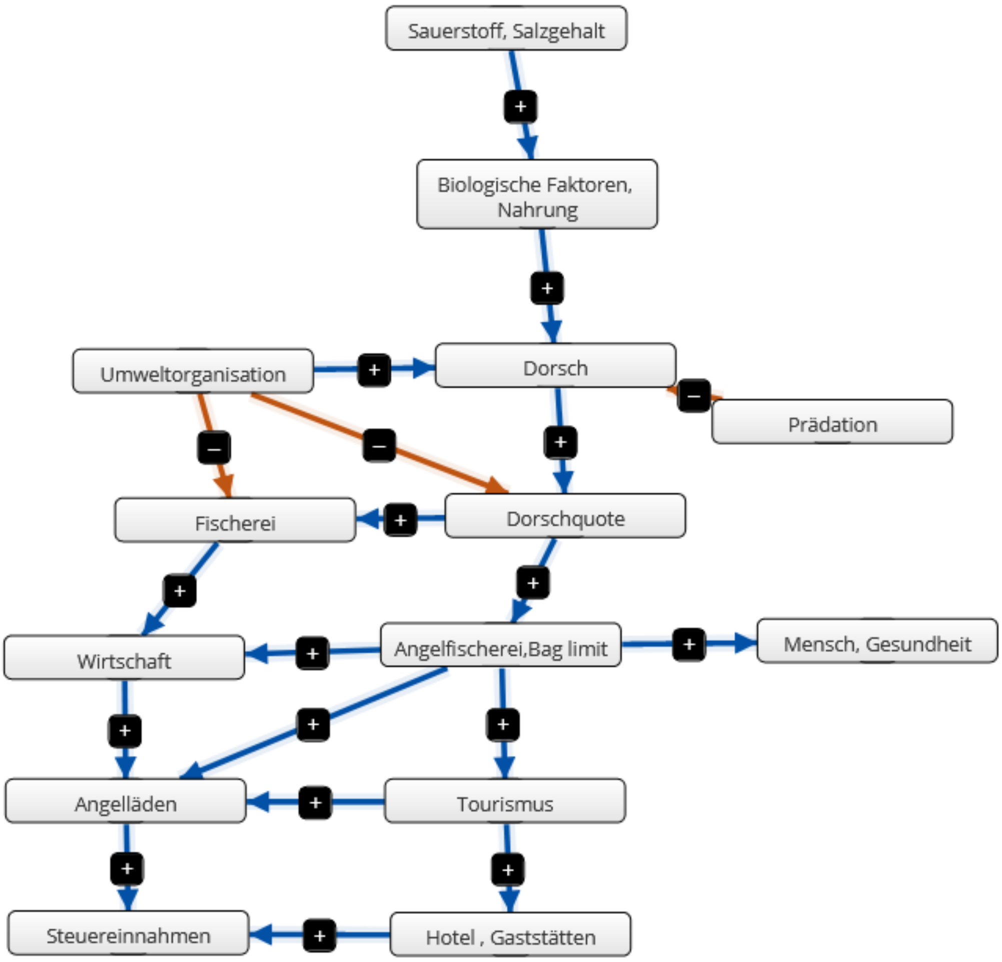
Anzahl Komponenten - 13
Sozial - 9
Ökologisch - 4

Anzahl der Beziehungen - 19

Komponente	Messgröße	
Angler	Anzahl der Angler an der Küste	
Dorschquote	Höhe der Fangquote	
Fischerei	Höhe der Fangmengen	
Kontrollmanagement	Anzahl und Intensität der Kontrollen	
MSY	Stärke der Einhaltung des MSY	Sozial
Naturschutz (ideologisch)	Stärke der emotionalen Besetzung des Naturschutzes	
Wissenschaft, Forschung	Anzahl der Beprobungen	
Tourismus	Anzahl der Touristen	
Kommunikation	Stärke der Kommunikation zw. den Beteiligten	
Dorsch	Laicherbiomasse (SSB)	
Klimaerwärmung	Höhe der Temperatur	Ökologisch
Prädatoren	Anzahl der Prädatoren	
Reproduktionserfolg	Anzahl der Rekruten	

2.2 Freizeitfischerei

B



<u>Zentralste Komponenten</u>

1. Angelfischerei, Bag limit
2. Dorsch, Dorschquote, Angelläden

<u>Informationen zum Netzwerk</u>

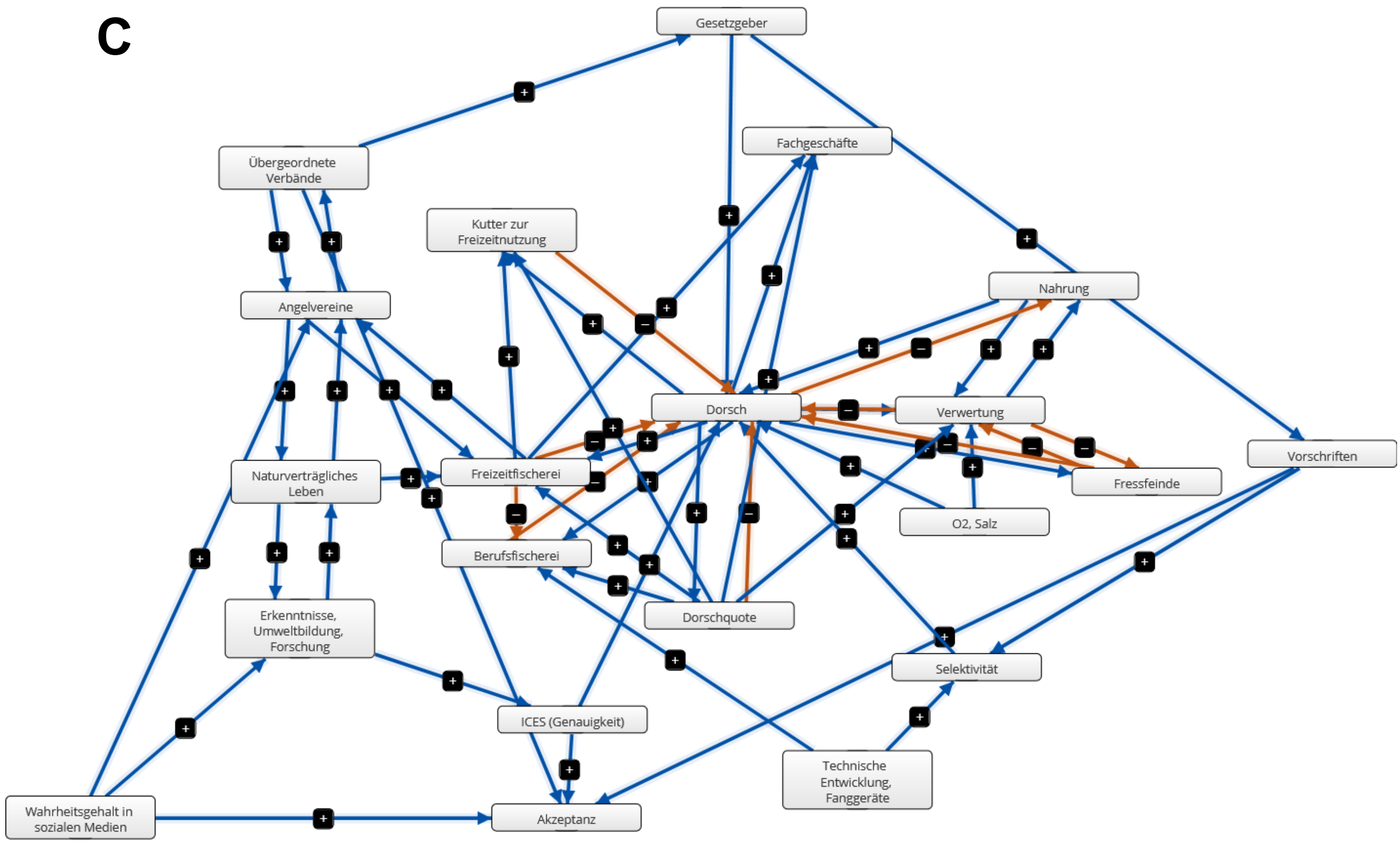
Anzahl Komponenten - 14
- Sozial - 10
- Ökologisch - 4

Anzahl der Beziehungen - 19

Komponente	Messgröße	
Angelfischerei, Bag limit	Anzahl der Angler und Höhe des Bag limits	Sozial
Angelläden	Höhe des Umsatzes	
Dorschquote	Höhe der Fangquote	
Fischerei	Höhe der Fangmengen	
Hotel, Gaststätten	Höhe des Umsatzes in Hotel und Gaststätten	
Mensch, Gesundheit	Grad der menschlichen Gesundheit	
Steuereinnahmen	Höhe der Steuereinnahmen	
Tourismus	Anzahl der Touristen	
Umweltorganisation	Stärker der ideologischen Ausrichtung (Fanatismus)	
Wirtschaft	Höhe des Umsatz	
Biologische Faktoren, Nahrung	Grad des Gesundheitszustandes des Gewässers und Menge an Nahrung	Ökologisch
Dorsch	Laicherbiomasse (SSB)	
Prädation	Anzahl der Prädatoren	
Sauerstoffgehalt, Salzgehalt	Höhe des Sauerstoff- und Salzgehalts	

2.2 Freizeitfischerei

C



<u>Zentralste Komponenten</u>

1. Dorsch
2. Freizeitfischerei
3. Angelvereine, Dorschquote

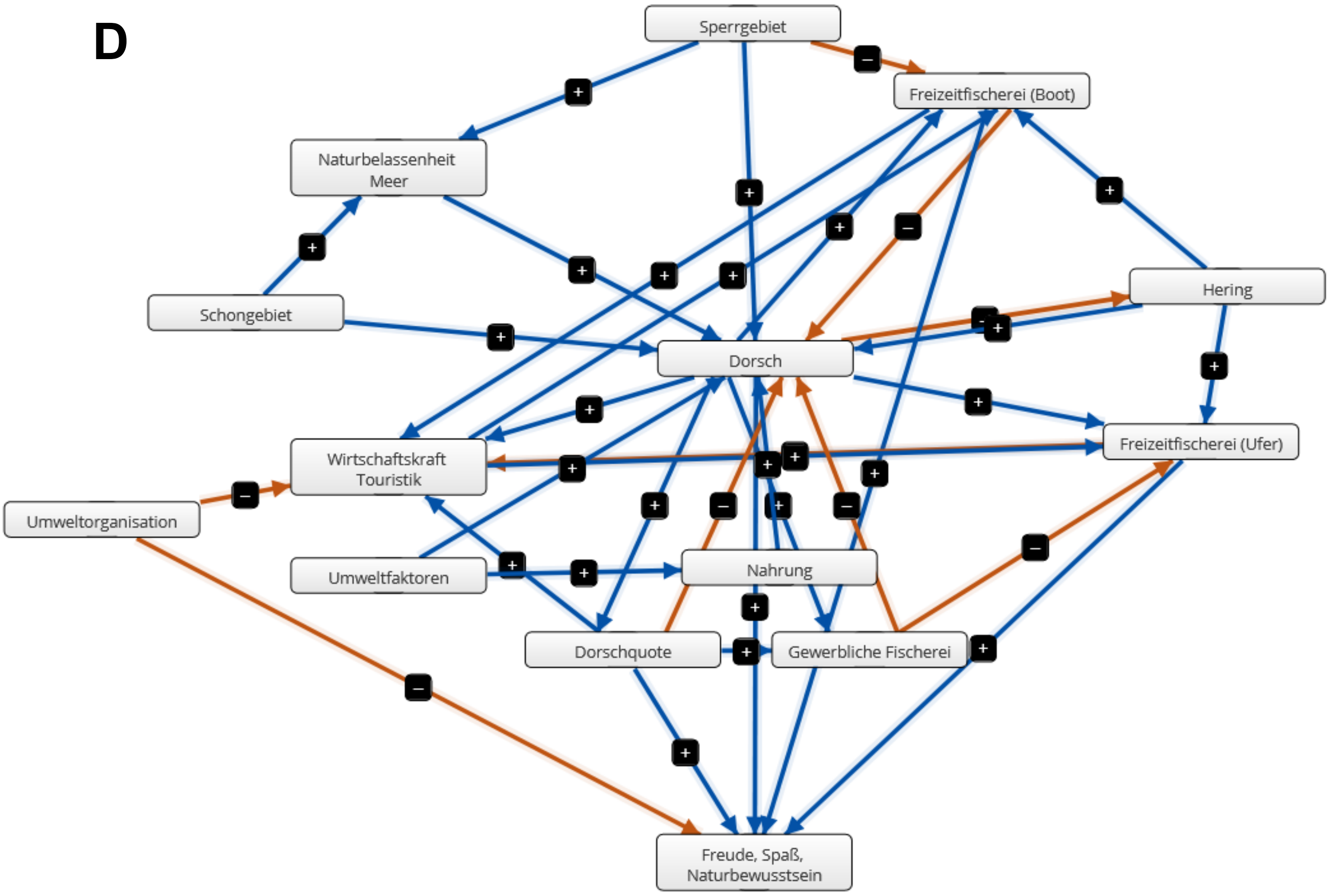
<u>Informationen zum Netzwerk</u>

Anzahl Komponenten - 21
- Sozial - 17
- Ökologisch - 4

Anzahl der Beziehungen - 53

Komponente	Messgröße	
Akzeptanz	Höhe der Akzeptanz	Sozial
Angelvereine	Anzahl der Angelvereine	Sozial
Berufsfischerei	Höhe der Fangmenge	Sozial
Dorschquote	Höhe der Fangquote	Sozial
Erkenntnisse, Umweltbildung, Forschung	Anzahl der Erkenntnisse aus Forschung, Höhe der Umweltbildung	Sozial
Fachgeschäfte	Höhe der Wahrscheinlichkeit der Erhaltung	Sozial
Freizeitfischerei	Anzahl der Angler	Sozial
Gesetzgeber	Höhe der Qualität der gesetzgebenden Arbeit	Sozial
ICES (Genauigkeit)	Höhe der Genauigkeit der Empfehlung	Sozial
Kutter zur Freizeitnutzung	Höhe der Wahrscheinlichkeit der Erhaltung	Sozial
Naturverträglich leben	Höhe des Interesses an einem naturverträglichem Leben	Sozial
Selektivität	Höhe der Selektivität	Sozial
Technische Entwicklung	Höhe der Qualität der technischen Entwicklung	Sozial
Übergeordnete Verbände	Leistungsstärke der Verbände	Sozial
Verwertung	Menge an Fisch, welche für den privaten verzehr verwertet werden kann	Sozial
Vorschriften	Höhe der Qualität sowie Anwendbarkeit der Vorschriften	Sozial
Wahrheitsgehalt (soziale Medien)	Höhe des Wahrheitsgehaltes	Sozial
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Fressfeinde	Anzahl der Prädatoren	Ökologisch
Nahrung	Menge an Nahrung	Ökologisch
O2, Salz	Höhe des Sauerstoff- und Salzgehaltes	Ökologisch

2.2 Freizeitfischerei



<u>Zentralste Komponenten</u>

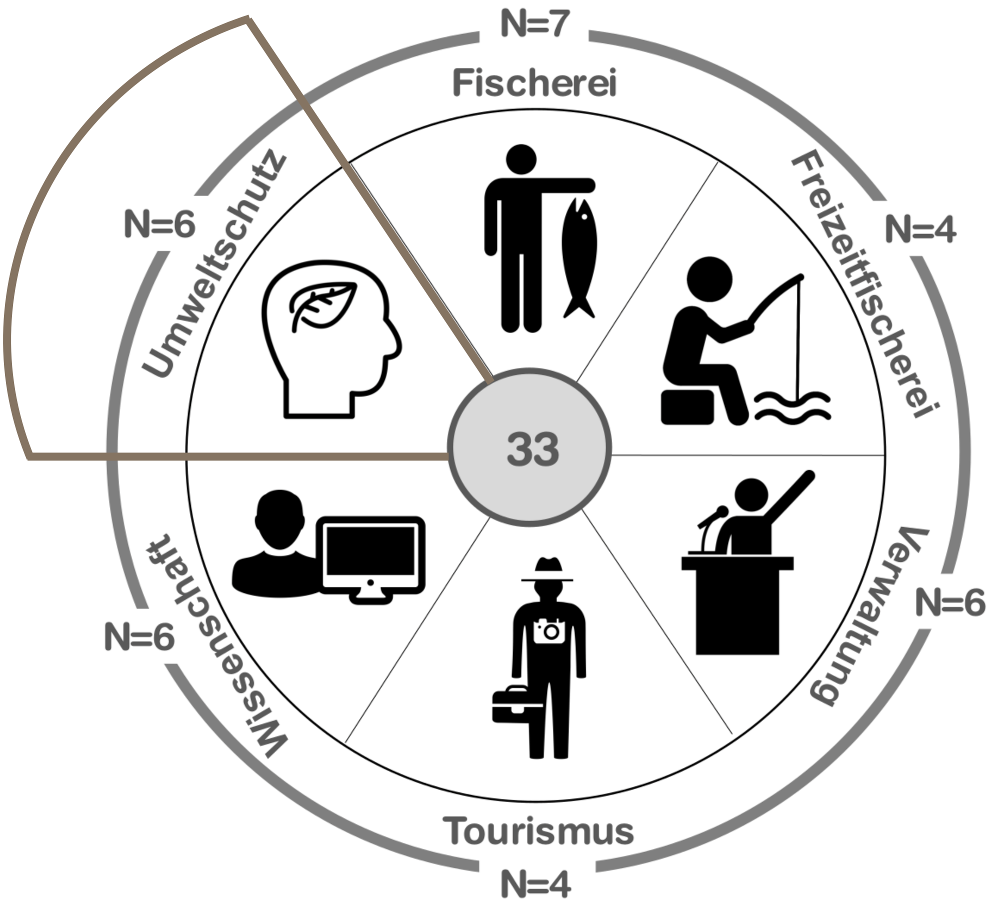
1. Dorsch
2. Wirtschaftskraft, Touristik
3. Freizeitfischerei (Boot)

<u>Informationen zum Netzwerk</u>

Anzahl Komponenten - 14
- Sozial - 9
- Ökologisch - 5

Anzahl der Beziehungen - 34

Komponente	Messgröße	
Dorschquote	Höhe der Fangquote	Sozial
Freizeitfischerei (Boot)	Anzahl der Freizeitfischer (Boot)	
Freizeitfischerei (Ufer)	Anzahl der Freizeitfischer (Ufer)	
Gewerbliche Fischerei	Intensität der Fischerei	
Schongebiet	Fläche des Schongebietes	
Spaß, Freude, Naturverbundenheit	Grad der Zufriedenheit	
Sperrgebiet	Fläche des Sperrgebietes	
Umweltorganisation	Stärke des Einflusses der Umweltorganisation	
Wirtschaftskraft (Touristik)	Höhe der Kaufkraft	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Hering	Anzahl der Heringe	
Nahrung	Menge an Nahrung	
Naturbelassenheit (Meer)	Grad der Naturbelassenheit	
Umweltfaktoren	Grad des „guten (dorschfreundlichen) Umweltzustandes“	



Wir haben **6 Interviews** mit Vertretern*innen aus der Gruppe *Umwelt-schutz* geführt. Hierbei wurden insgesamt 114 Komponenten definiert (Mittel: 19 Komponenten pro Interview).

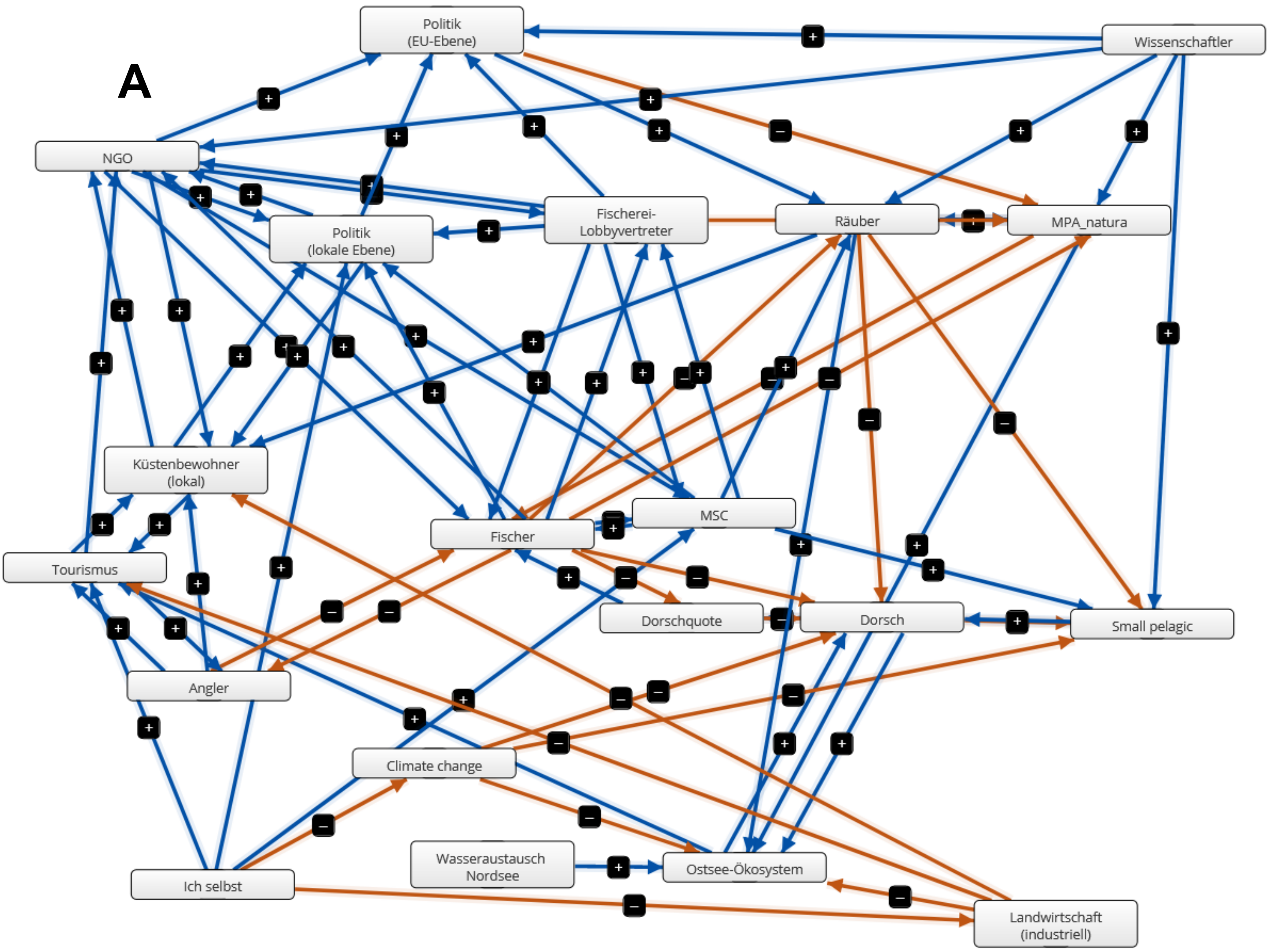
2.3 Umweltschutz

Freizeitfischerei und **Tourismus** sind die am häufigsten genannten Komponenten in der Gruppe *Umweltschutz*.
Die beeinflussende Wirkung, welche von der Freizeitfischerei ausgeht (gemessen an der Anzahl der Angler), wird am häufigsten auf den Dorschbestand beschrieben, d.h. durch eine Zunahme der Angler, welche Dorsch fischen, sinkt die Biomasse des Bestandes ab. Ferner wird durch die Hälfte der Vertreter*innen der NGOs eine konkurrierende Wirkung zwischen der Freizeitfischerei und der Fischerei definiert.
Der Tourismus wird mehrheitlich als positive Wirkungskomponente im System wahrgenommen, d.h. die Zunahme des Tourismus (gemessen an der Anzahl der Touristen) fördert den Umsatz in der Region durch u.a.) die Anzahl der Angler, ii) die Anzahl der Konsumenten von Fisch vor Ort oder aber iii) den Einfluss durch NGOs, bedingt durch den Wunsch der Touristen nach einem intakten Ökosystem und dadurch die Förderung von Naturschutz-maßnahmen.

Komponente	Anzahl
Freizeitfischerei	6
Tourismus	6
Umweltorganisation	5
Nahrung	5
Klimawandel	4
Prädation	4
Konsument	3
Marktpreis	3
Salzwassereinstrom	3
Wissenschaft	3
Wissenschaftlicher Rat	3

2.3 Umweltschutz

A



Zentralste Komponenten

1. Fischer
2. Umweltorganisation
3. Räuber

Informationen zum Netzwerk

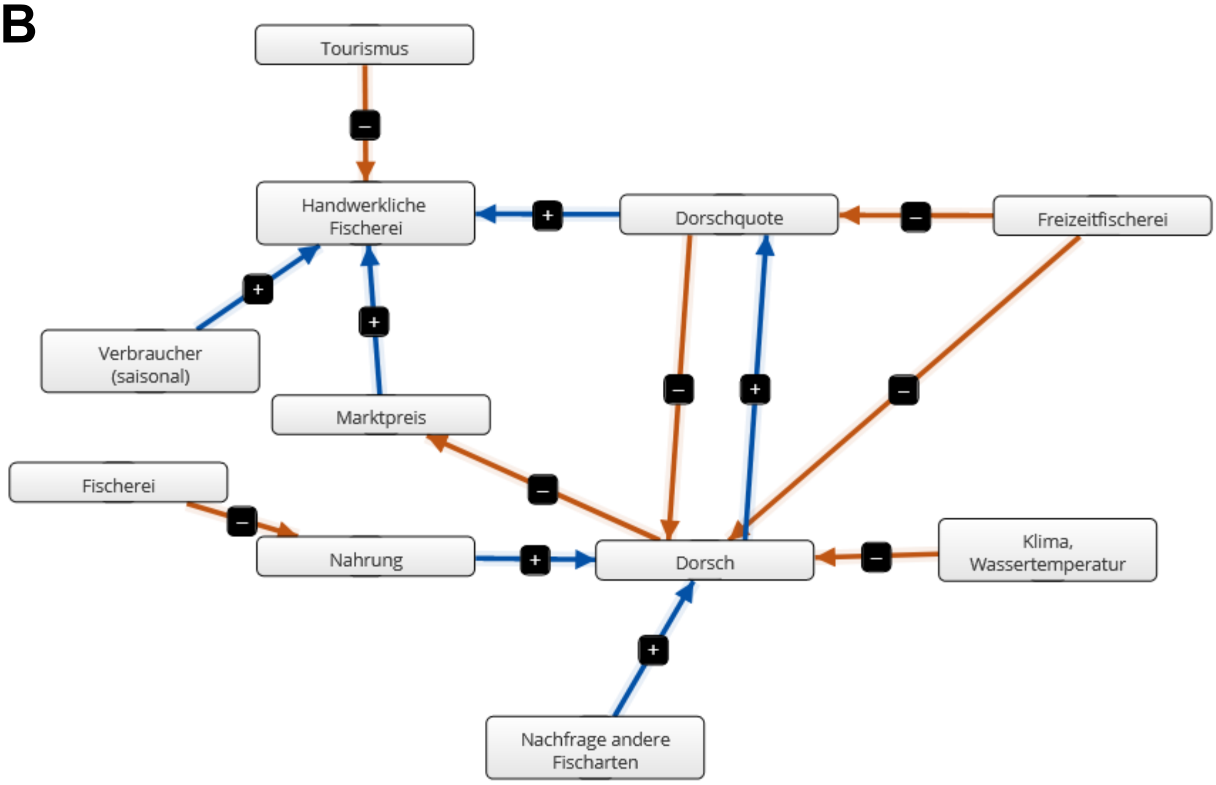
Anzahl Komponenten - 20
- Sozial - 14
- Ökologisch - 6

Anzahl der Beziehungen - 73

Komponente	Messgröße	
Angler	Anzahl der Angler	Sozial
Dorschquote	Höhe der Fangquote	
Fischer	Anzahl der Fischer	
Fischerei Lobbyvertreter	Stärke der Vertretung durch Fischereilobby	
Ich-Selbst	Stärke des Einflusses durch Ich-Selbst	
Industrielle Landwirtschaft	Menge an eingetragenen Nährstoffen	
Küstenbewohner (lokal)	Höhe des Interesses an einer intakten Umwelt	
MPA	Höhe der Qualität der ausgewiesenen Fläche	
MSC	Anzahl der Zertifizierung	
NGO	Anzahl der Mitglieder in den NGOs	
Politik (EU)	Stärke des Einflusses durch EU	
Politik (lokal)	Stärke des Einflusses der lokalen Politik	
Tourismus	Anzahl der Touristen	
Wissenschaftler	Höhe der Datenmenge	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Ostseeökosystem	Höhe des Gesundheitszustandes der Ostsee	
Räuber	Anzahl der Räuber	
Small pelagic	Anzahl der Heringe und Sprotten	
Wasseraustausch Nordsee	Häufigkeit der Einstromevents	

2.3 Umweltschutz

B



<u>Zentralste Komponenten</u>

1. Dorsch
2. Handwerkliche Fischerei
3. Dorschquote

<u>Informationen zum Netzwerk</u>

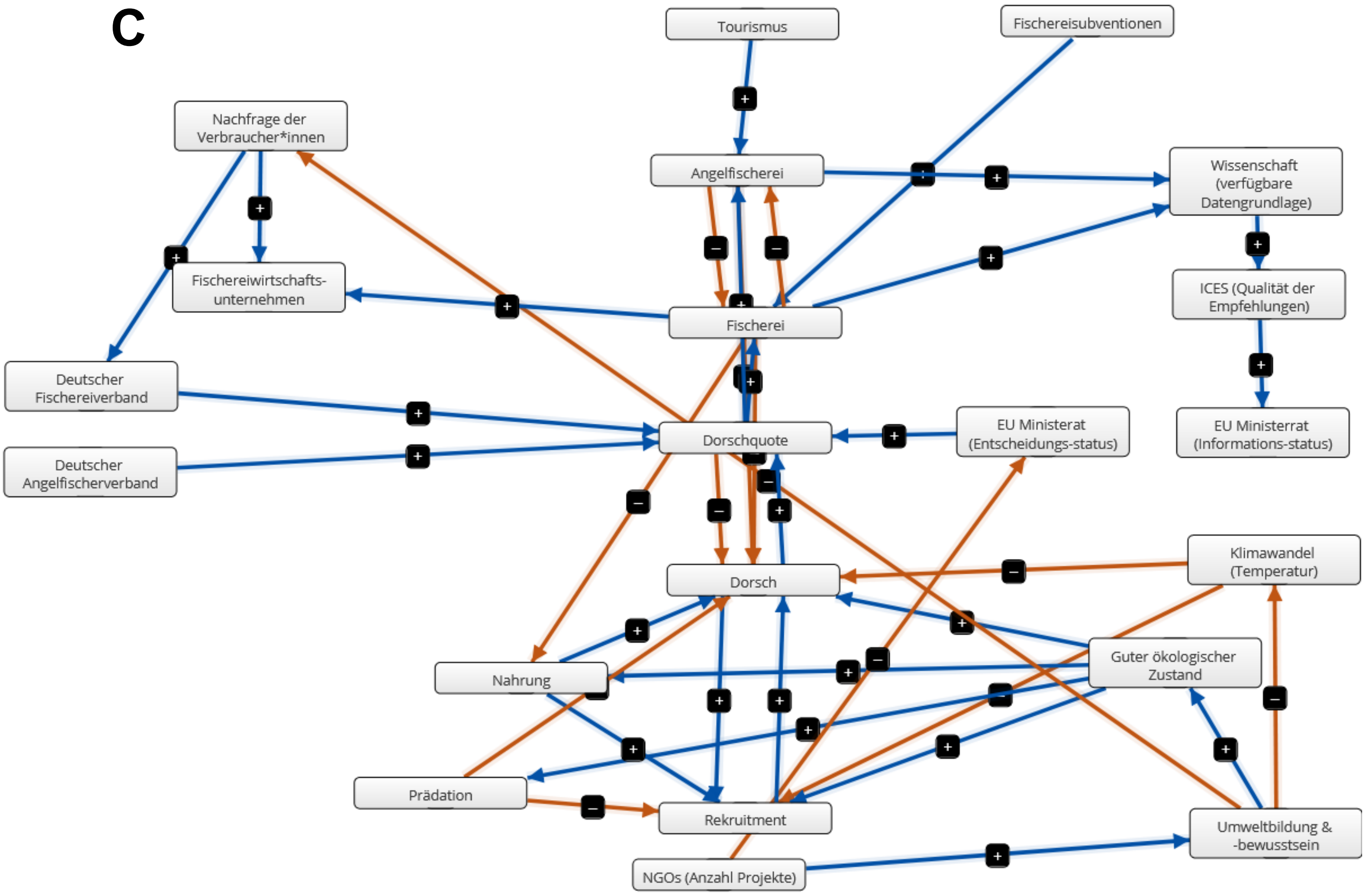
Anzahl Komponenten - 11
- Sozial - 8
- Ökologisch - 3

Anzahl der Beziehungen - 13

Komponente	Messgröße	
Dorschquote	Höhe der Fangquote	Sozial
Fischerei	Höhe der Fangmenge	
Freizeitfischerei	Anzahl der Angler	
Handwerkliche Fischerei	Höhe des Umsatzes	
Marktpreis	Höhe des Marktpreises	
Nachfrage (andere Fischarten)	Höhe der Nachfrage	
Tourismus	Anzahl der Touristen (Kiter, Motorbootfahrer)	
Verbraucher (saisonal)	Anzahl der Fischkonsumenten	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Klima, Wassertemperatur	Höhe der Temperatur	
Nahrung	Menge an Nahrung	

2.3 Umweltschutz

C



Zentralste Komponenten

1. Dorsch
2. Fischerei
3. Dorschquote

Informationen zum Netzwerk

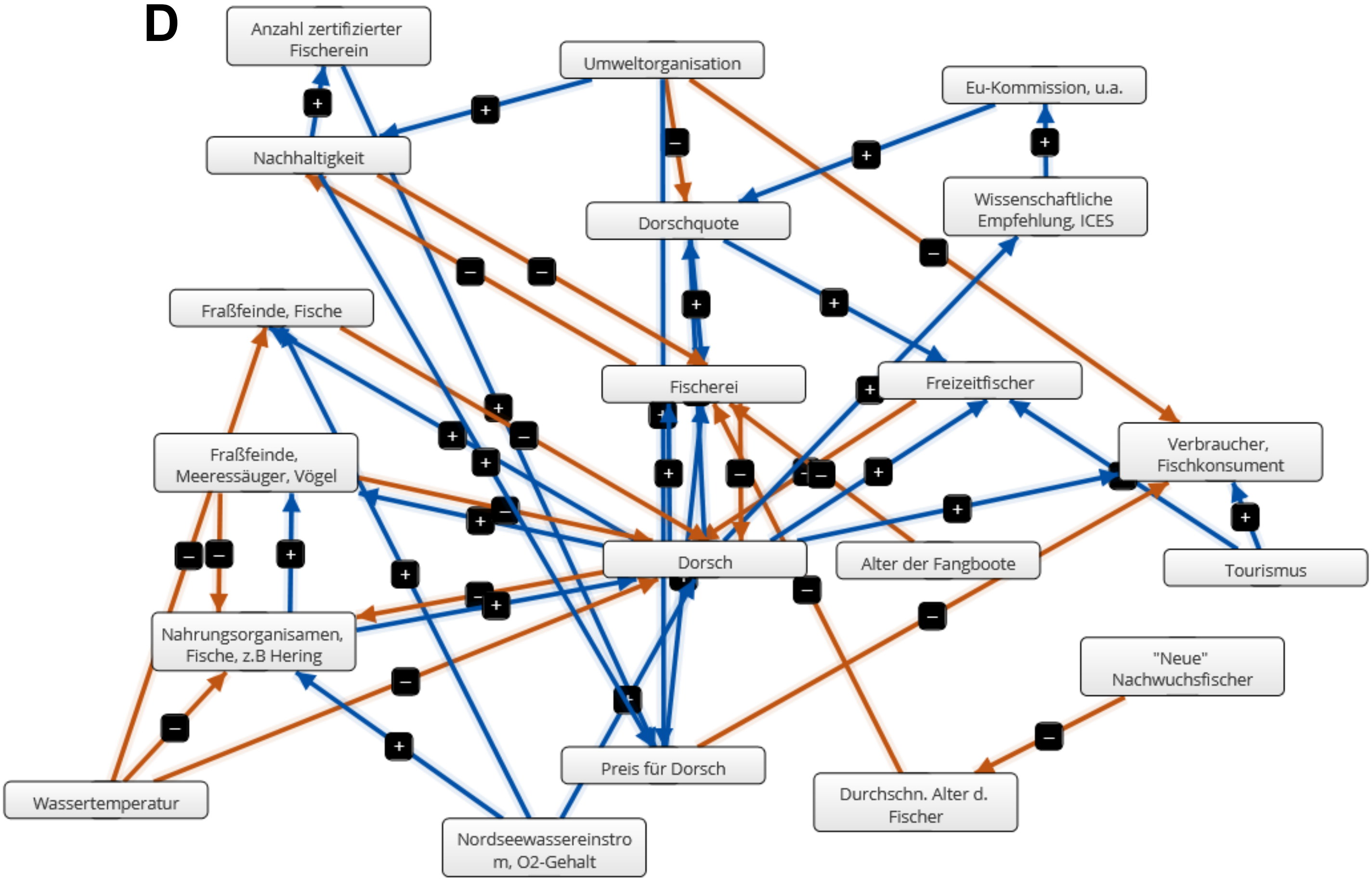
Anzahl Komponenten - 21
- Sozial - 15
- Ökologisch - 6

Anzahl der Beziehungen - 38

Komponente	Messgröße	
Angelfischerei	Menge der Entnahme durch Angler	Sozial
Deutscher Angelfischereiverband	Intensität der Lobbyarbeit	
Deutscher Fischereiverband	Intensität der Lobbyarbeit	
Dorschquote	Höhe der Fangquote	
EU Ministerrat (Entscheidungsstatus)	Nähe der Quotenfestlegung an wissenschaftlicher Empfehlung	
EU Ministerrat (Informationsstatus)	Qualität der grundlegenden wissenschaftlichen Information zur Quotensetzung	
Fischerei	Menge an angelandeten Dorschen	
Fischereisubventionen	Höhe der Subventionen	
Fischereiwirtschaftsunternehmen	Menge an gehandelten Produkten	
ICES	Qualität der Empfehlung	
Nachfrage der Verbraucher*innen	Höhe der Nachfrage nach Dorsch	
NGO	Anzahl der Projekte	
Tourismus	Anzahl der Angeltouristen	
Umweltbildung, Umweltbewusstsein	Höhe des Umweltbewusstseins	
Wissenschaft	Menge an Daten	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Guter ökologischer Zustand	Höhe der Wasserqualität	
Klimawandel, Temperatur	Höhe der Temperatur	
Nahrung	Menge an Nahrung	
Prädation	Anzahl der Prädatoren	

2.3 Umweltschutz

D



Zentralste Komponenten

1. Dorsch
2. Fischerei
3. Nahrungsorganismen (Fische, z.B. Hering)

Informationen zum Netzwerk

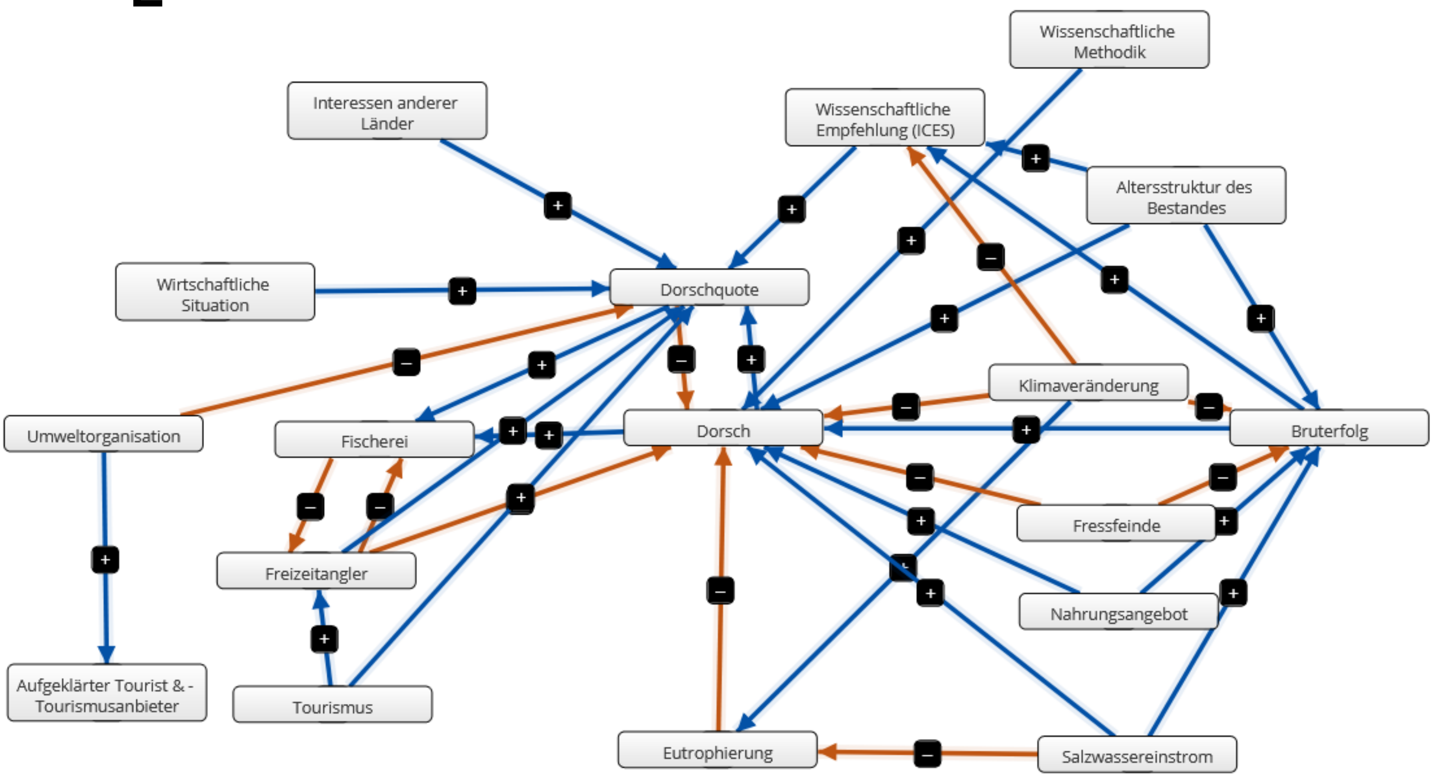
Anzahl Komponenten - 20
- Sozial - 14
- Ökologisch - 6

Anzahl der Beziehungen - 41

Komponente	Messgröße	
Alter der Fangboote	Höhe des Fangbootalters	Sozial
Anzahl zertifizierter Fischerein	Anzahl zertifizierter Fischerein	
Dorschquote	Höhe der Fangquote	
Durchschnittsalter Fischer	Höhe des Durchschnittsalters	
EU (u.a. Kommission)	Höhe der Empfehlung	
Fischerei	Intensität der Fischerei	
Freizeitfischer	Höhe der Entnahme durch Freizeitfischer	
Nachhaltigkeit	Stärke der Nachhaltigkeit	
Neue Nachwuchsfischer	Anzahl der Nachwuchsfischer	
Preis für Dorsch	Höhe des Dorschpreises	
Tourismus	Anzahl der Touristen	
Umweltorganisation	Stärke des Aktionismus der Umweltorganisation	
Verbraucher, Fischkonsument	Höhe der Konsummenge Dorsch	
Wissenschaftliche Empfehlung	Höhe der Empfehlung	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Fraßfeinde (Fische)	Anzahl der Fische	
Fraßfeinde (Meeressäuger)	Anzahl der Meeressäuger	
Nahrungsorganismen	Menge an Nahrungsorganismen	
Nordseewassereinstrom	Stärke und Häufigkeit des Nordseewassereinstromes	
Wassertemperatur	Höhe der Temperatur	

2.3 Umweltschutz

E



<u>Zentralste Komponenten</u>

1. Dorsch
2. Dorschquote
3. Bruterfolg

<u>Informationen zum Netzwerk</u>

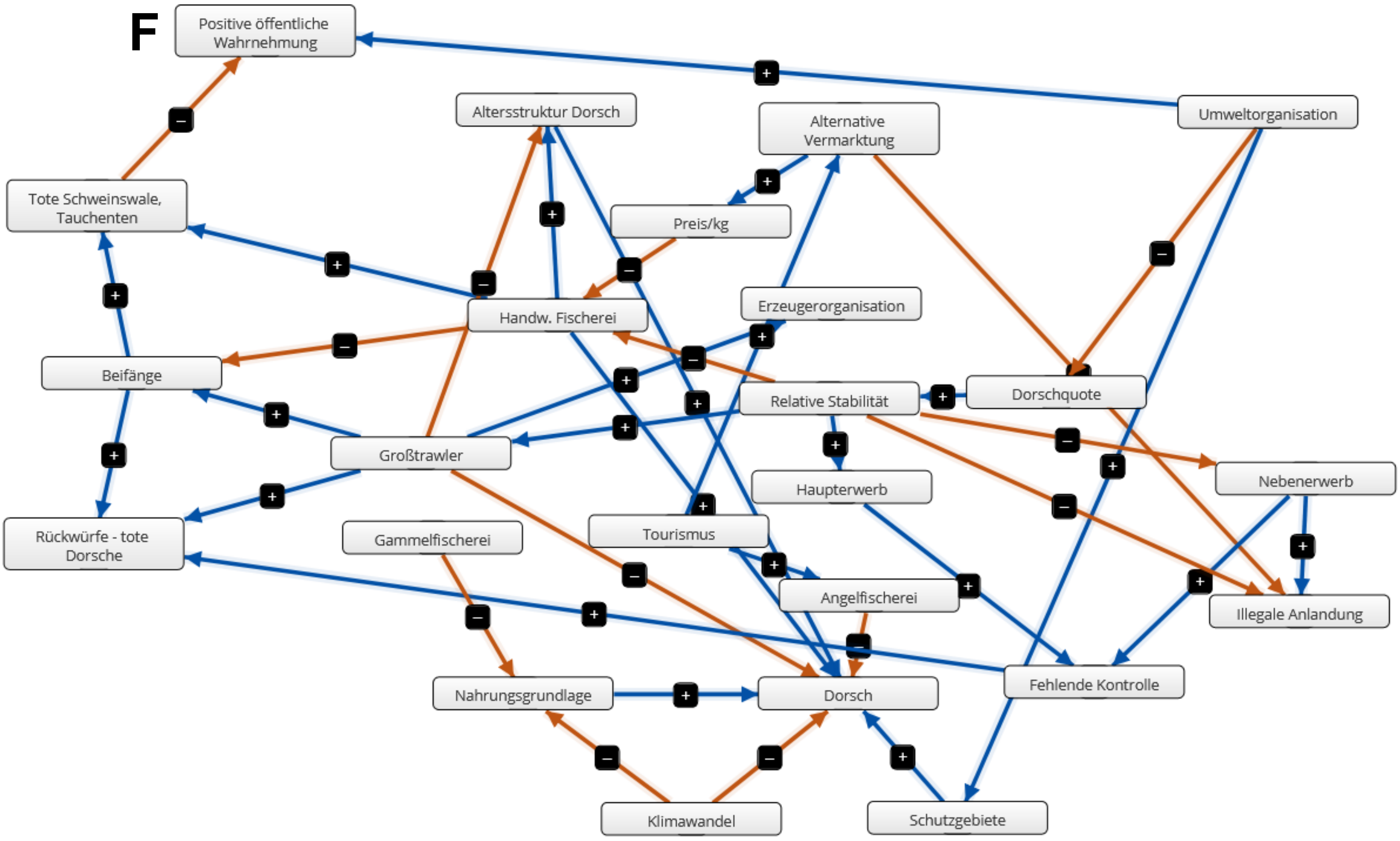
Anzahl Komponenten - 18
- Sozial - 10
- Ökologisch - 8

Anzahl der Beziehungen - 33

Komponente	Messgröße	
Aufgeklärter Tourist und Tourismusanbieter	Anzahl aufgeklärter Touristen und Tourismusanbieter	Sozial
Dorschquote	Höhe der Fangquote	
Fischerei	Höhe der Fangmenge	
Freizeitangler	Anzahl der Freizeitangler	
Interesse anderer EU Länder	Stärke des Interesses anderer EU Länder	
Tourismus	Anzahl der Vertreter und Anbieter	
Umweltorganisation	Stärke des Einflusses der Umweltorganisation	
Wirtschaftliche Situation (Fischerei)	Stärke der Fischereivertretung	
Wissenschaftliche Empfehlung	Höhe der Empfehlung	
Wissenschaftliche Methodik	Menge an Daten und „up-to-date" Datenerhebungsmethoden	
Altersstruktur	Anzahl der großen und alten Dorsche	Ökologisch
Bruterfolg	Anzahl der Nachkommen	
Dorsch	Laicherbiomasse (SSB)	
Eutrophierung	Stärke der Eutrophierung	
Fressfeinde	Anzahl der Fressfeinde	
Klimaveränderung	Höhe der Temperatur	
Nahrungsangebot	Größe des Nahrungsangebotes	
Salzwassereinstrom	Stärke und Häufigkeit des Salzwassereinstromes	

2.3 Umweltschutz

F



Zentralste Komponenten

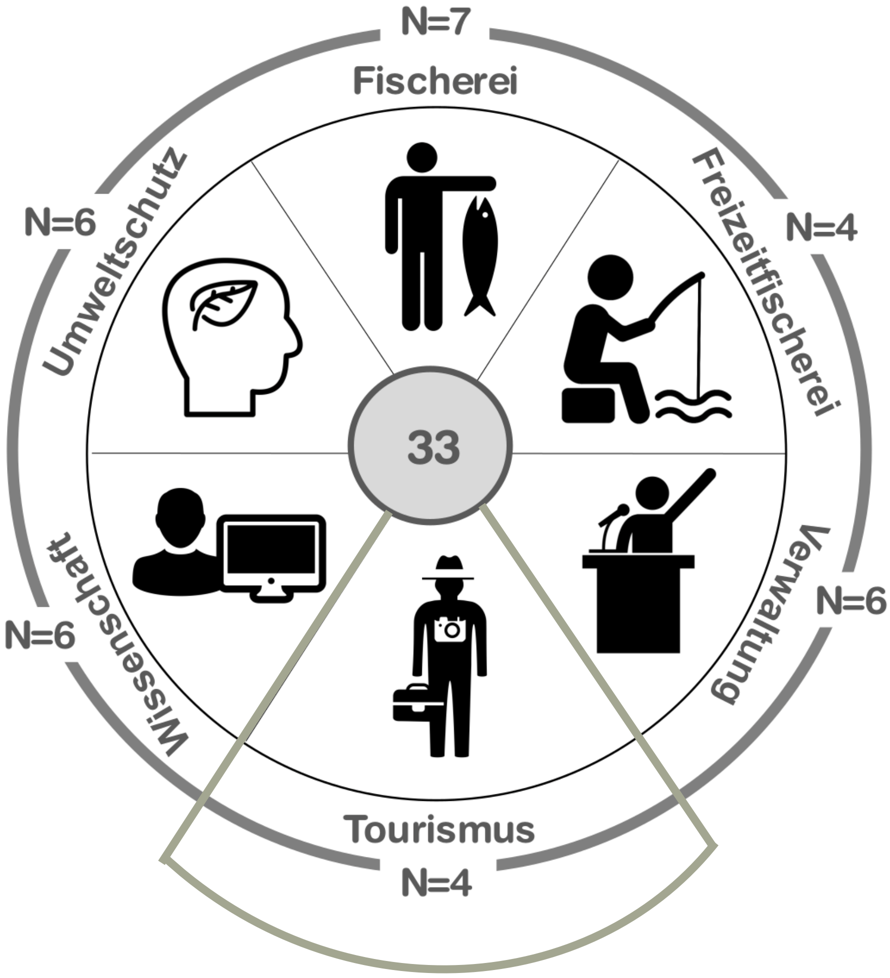
1. Dorsch
2. Handwerkliche Fischerei, Großtrawler, Relative Stabilität

Informationen zum Netzwerk

Anzahl Komponenten - 24
Sozial - 19
Ökologisch - 5

Anzahl der Beziehungen - 37

Komponente	Messgröße	
Alternative Vermarktung	Höhe der Möglichkeit alternativ zu vermarkten	Sozial
Angelfischerei	Höhe der Entnahme durch Angler	
Beifänge	Menge der Beifänge	
Dorschquote	Höhe der Fangquote	
Erzeugerorganisation	Höhe des Umsatzes	
Fehlende Kontrolle	Anzahl der Kontrollen	
Gammelfischerei	Höhe der Fangmengen und Anlandungen	
Großtrawler	Höhe der Fangmengen	
Handwerkliche Fischerei	Höhe der Fangmengen	
Haupterwerb	Anzahl der Fischer	
Illegale Anlandung	Höhe der illegalen Anlandungen	
Nebenerwerb	Anzahl der Fischer	
Positive öffentliche Wahrnehmung	Stärke der positiven öffentlichen Wahrnehmungen	
Preis/kg	Höhe des Preis/kg	
Relative Stabilität	Höhe der relativen Stabilität	
Rückwürfe tote Dorsche	Anzahl zurückgeworfener toter Dorsche	
Schutzgebiete	Anzahl der Schutzgebiete	
Tourismus	Anzahl der Touristen	
Umweltorganisation	Stärke des Einflusses	
Altersstruktur	Stärke der Durchmischung	Ökologisch
Dorsch	Laicherbiomasse (SSB)	
Klimawandel	Höhe der Temperatur	
Nahrungsgrundlage	Stärke der Verfügbarkeit der Nahrung	
Tote Schweinswale, Tauchenten	Anzahl der toten Schweinwale und Tauchenten	

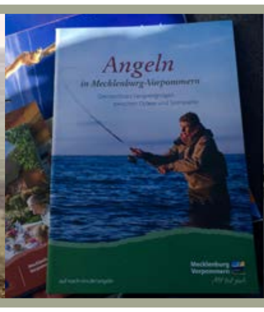


Wir haben **4 Interviews** mit Vertretern*innen aus der Gruppe *Tourismus* geführt.
Hierbei wurden insgesamt 88 Komponenten definiert (Mittel: 22 Komponenten pro Interview).

2.4 Tourismus

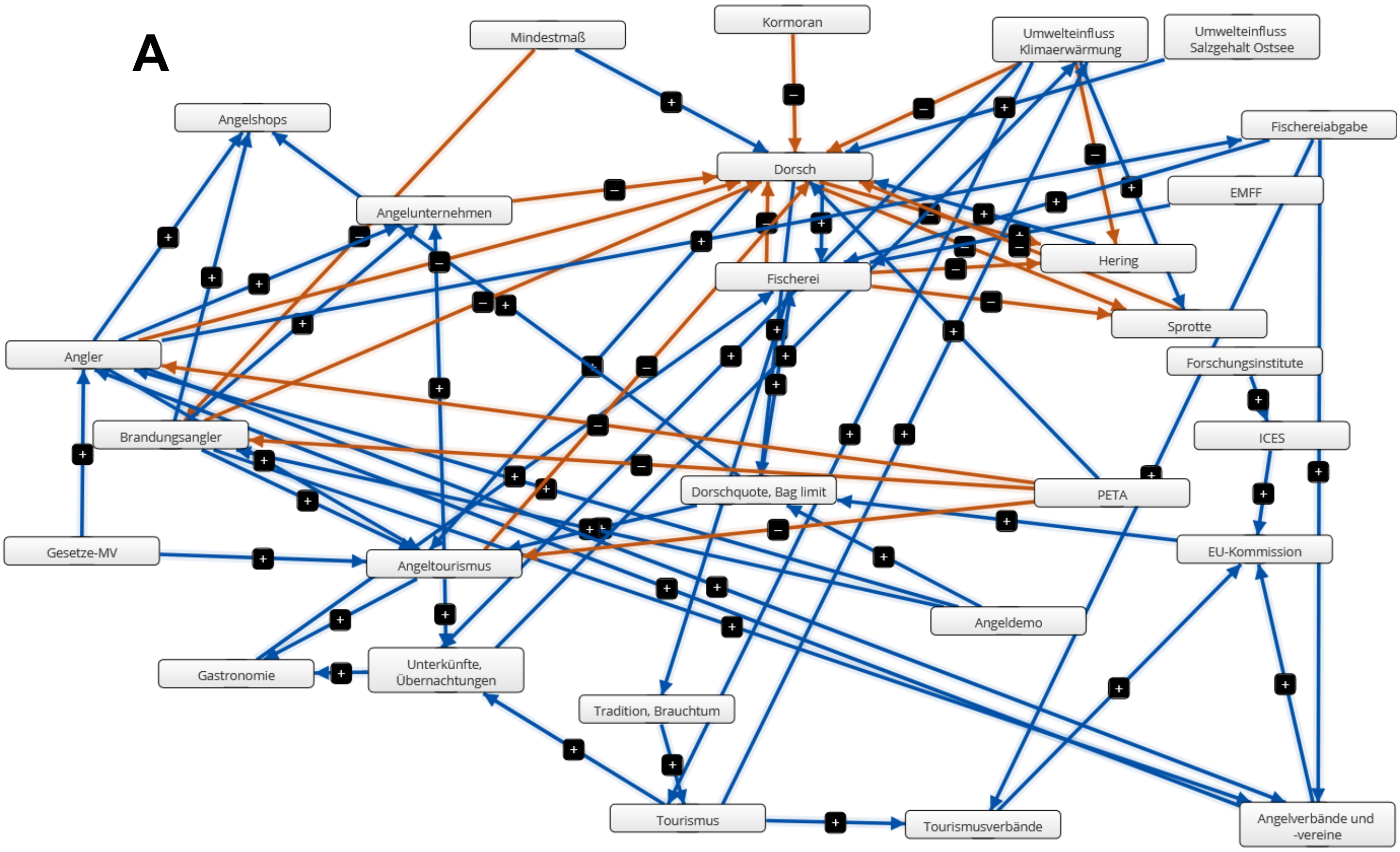
Angeltourismus, Freizeitfischerei und **Temperatur** sind die am häufigsten genannten Komponenten in der Gruppe *Tourismus*.
Der Angeltourismus (Anzahl der Angeltouristen) wird mehrheitlich aus einer ökonomischen Perspektive betrachtet; d.h. mehr Angeltouristen führen zu mehr Umsatz in der Region durch gesteigerte Steuereinnahmen, mehr Angelausfahrten, Gastronomiebesuche oder auch Übernachtungen.
Der Einfluss der Freizeitfischerei (auch: Angler, Brandungsangler) ist am größten auf den Dorschbestand, denn durch mehr Anglern und somit einer erhöhten Entnahme, nimmt die Dorschbiomasse ab.
Die Erhöhung der Temperatur bewirkt zum einen einer Verringerung des Dorsch- und Heringsbestandes sowie eine Abnahme der Nahrungsmenge, zum anderen allerdings führt ein Temperaturanstieg zu mehr Touristen und mehr Übernachtungen.

Komponente	Anzahl
Angeltourismus	3
Freizeitfischerei	3
Temperatur	3
Angelverband	2
Hering	2
Naturschutz	2
Nahrung	2
Salzgehalt	2
Wissenschaft	2
Robbe	2
Selektivität	2
Tourismus	2
Tradition & Brauchtum	2

2.4 Tourismus

A



Zentralste Komponenten

1. Dorsch
2. Angeltourismus
3. Angler

Informationen zum Netzwerk

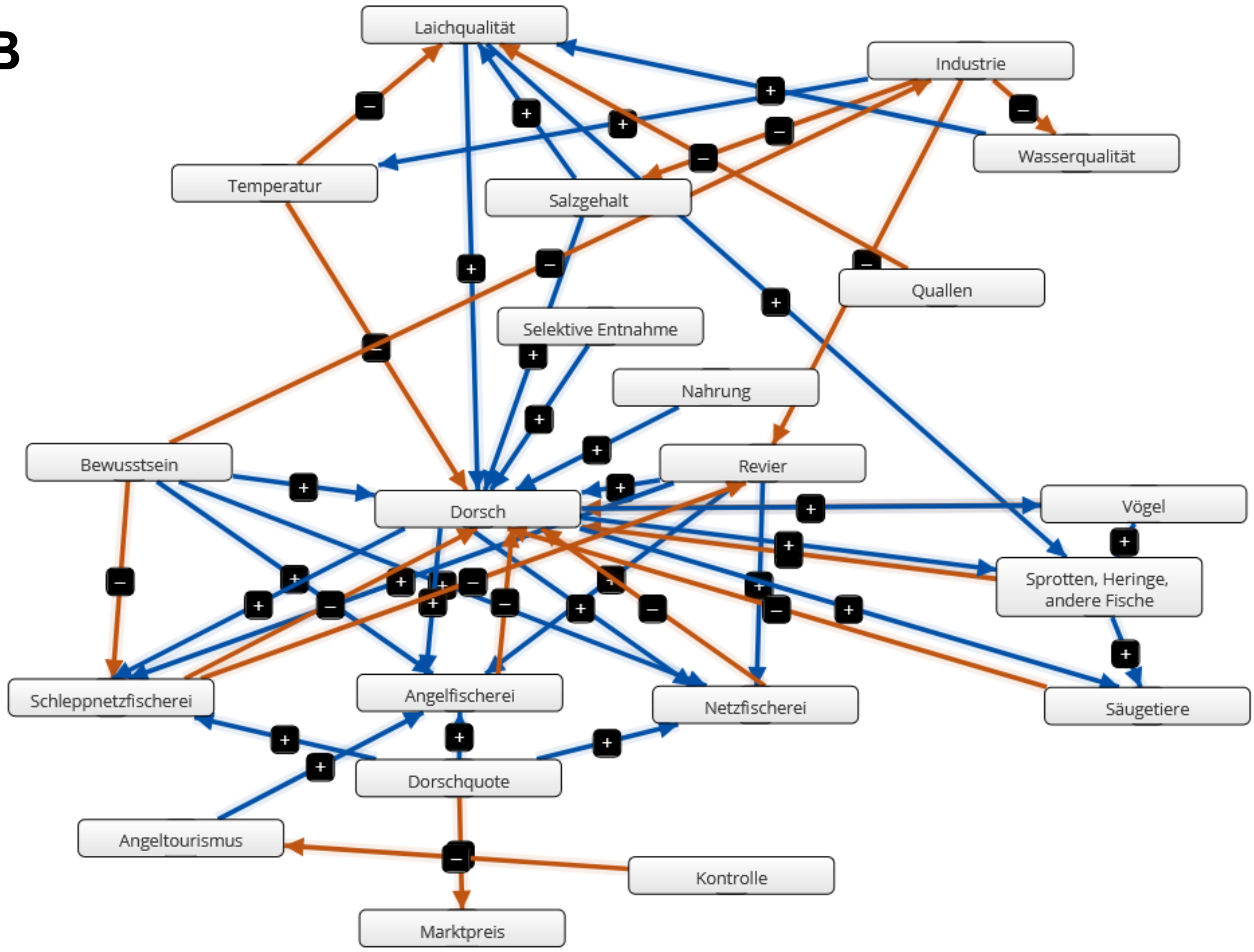
Anzahl Komponenten - 28
Sozial - 22
Ökologisch - 6

Anzahl der Beziehungen - 65

Komponente	Messgröße	
Angeltourismus	Anzahl der Angeltouristen	Sozial
Angelunternehmen	Anzahl der Ausfahrten	
Angler	Anzahl der Angler	
Angeldemo	Stärke des Einsatzes	
Angelverbände	Stärke der Lobby durch Anzahl der Vereine	
Brandungsangler	Anzahl der Brandungsangler	
Dorschquote, Bag limit	Höhe der Fangquote	
EMFF	Höhe der zur Verfügung stehenden Mittel	
EU Kommission	Höhe der Empfehlung	
Fischerei	Höhe der Fangmenge	
Fischereiabgabe	Höhe der zur Verfügung stehenden Mittel	
Forschungsinstitute	Höhe der Empfehlung	
Gastronomie	Anzahl der Gastronomiebesuche	
Gesetze (MV)	Stärke der “angelfreundlichen“ Gesetzgebung	
ICES	Höhe der Empfehlung	
Mindestmaß	Höhe des Mindestmaßes in cm	
PETA	Anzahl der negativen Pressemitteilungen	
Tourismus	Anzahl der Touristen	
Tourismusverbände	Stärke der Lobby durch Anzahl der Vereine	
Tradition, Brauchtum	Anzahl der Fischereiunternehmen	
Unterkünfte, Übernachtungen	Anzahl der Übernachtungen	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Hering	Anzahl der Heringe	
Kormoran	Anzahl der Kormorane	
Sprotte	Anzahl der Sprotten	
Umwelteinfluss, Klimaerwärmung	Höhe des Temperaturanstieges	
Umwelteinfluss, Salzgehalt	Höhe des Salzgehaltes	

2.4 Tourismus

B



Zentralste Komponenten

1. Dorsch
2. Laichqualität, Revier, Schleppnetzfischerei, Angelfischerei

Informationen zum Netzwerk

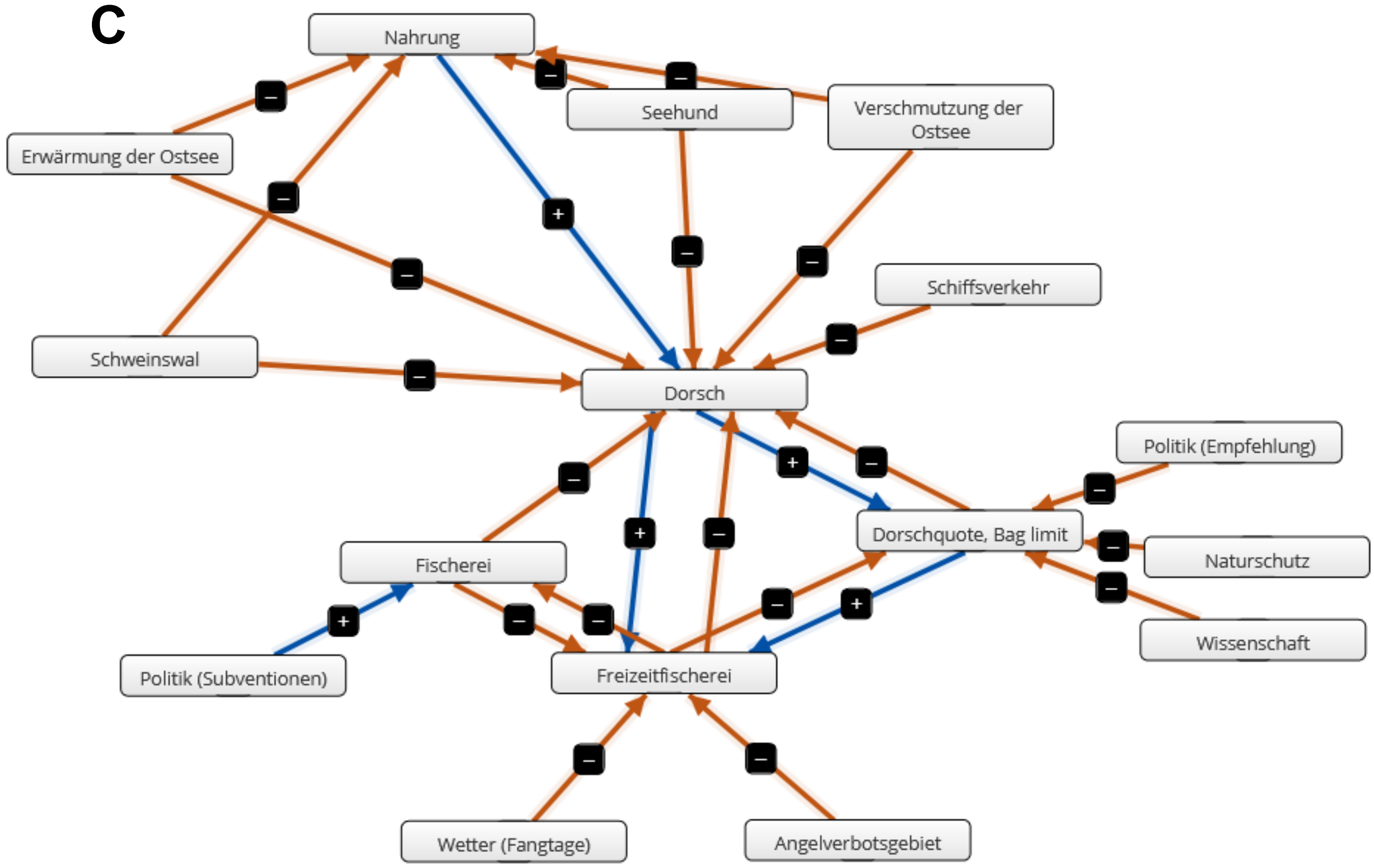
Anzahl Komponenten - 21
Sozial - 10
Ökologisch - 11

Anzahl der Beziehungen - 44

Komponente	Messgröße	
Angelfischerei	Höhe der Entnahme durch Angler	Sozial
Angeltourismus	Anzahl der Touristen	Sozial
Bewusstsein	Stärke des nachhaltigen Bewusstseins	Sozial
Dorschquote	Höhe der Fangquote	Sozial
Industrie	Stärke der industriellen Verschmutzung	Sozial
Kontrolle	Anzahl effektiver Kontrollen	Sozial
Marktpreis	Höhe des Marktpreises	Sozial
Netzfischerei	Intensität der Fischerei	Sozial
Schleppnetzfischerei	Intensität der Fischerei	Sozial
Selektive Entnahme	Häufigkeit der selektiven Entnahmen	Sozial
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Laichqualität	Anzahl der Dorscheier	Ökologisch
Nahrung	Menge an Nahrung	Ökologisch
Quallen	Menge an Quallen	Ökologisch
Revier	Größe der Fläche des Revieres (Habitat)	Ökologisch
Säugetiere	Anzahl der Robben	Ökologisch
Salzgehalt	Höhe des Salzgehaltes	Ökologisch
Sprotte, Heringe, andere Fische	Anzahl der Sprotten, Heringe und andere Fische	Ökologisch
Temperatur	Höhe der Temperatur	Ökologisch
Vögel	Anzahl der Vögel (Seevögel)	Ökologisch
Wasserqualität	Höhe der Wasserqualität	Ökologisch

2.4 Tourismus

C



<u>Zentralste Komponenten</u>

1. Dorsch
2. Freizeitfischerei
3. Dorschquote, Bag limit

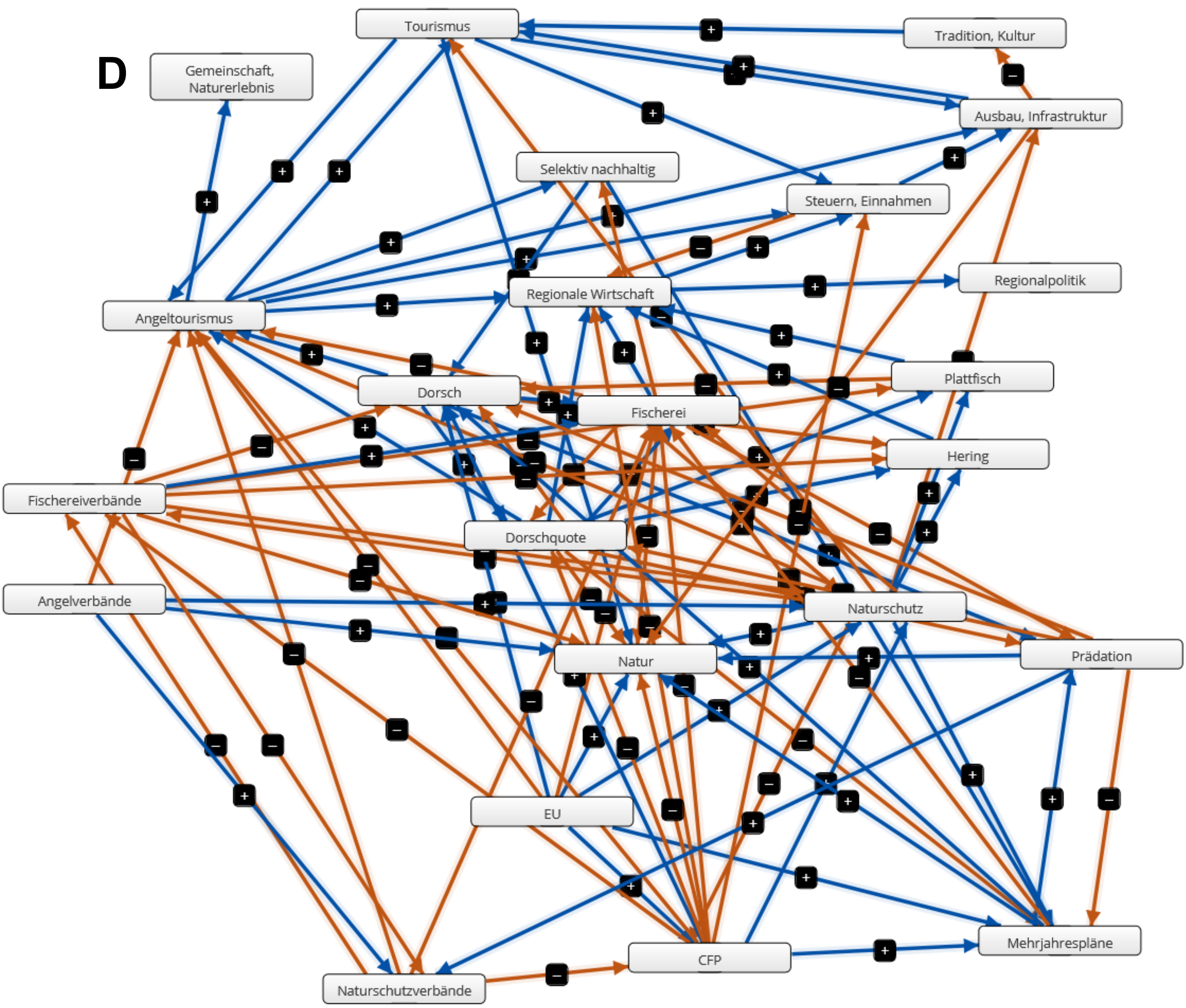
<u>Informationen zum Netzwerk</u>

Anzahl Komponenten - 16
Sozial - 8
Ökologisch - 8

Anzahl der Beziehungen - 25

Komponente	Messgröße	
Angelverbotsgebiet	Nähe des Angelverbotsgebietes zu den Angelspots	Sozial
Dorschquote, Bag limit	Höhe der Quote	
Fischerei	Intensität der Fischerei	
Freizeitfischerei	Anzahl der Angler	
Naturschutz	Stärke des Einflusses durch Naturschutz	
Politik (Empfehlung)	Stärke des Einflusses durch Politik	
Politik (Subventionen)	Höhe der Subventionen	
Schiffsverkehr	Intensität des Schiffverkehres	
Wissenschaft	Stärke des Einflusses durch Wissenschaft	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Erwärmung Ostsee	Höhe der Temperatur	
Nahrung	Menge an Nahrung	
Schweinswal	Anzahl der Schweinswale	
Seehund	Anzahl der Seehunde	
Verschmutzung Ostsee	Stärke der Verschmutzung	
Wetter, Fangtage	Anzahl der Schlechtwettertage	

2.4 Tourismus



Zentralste Komponenten

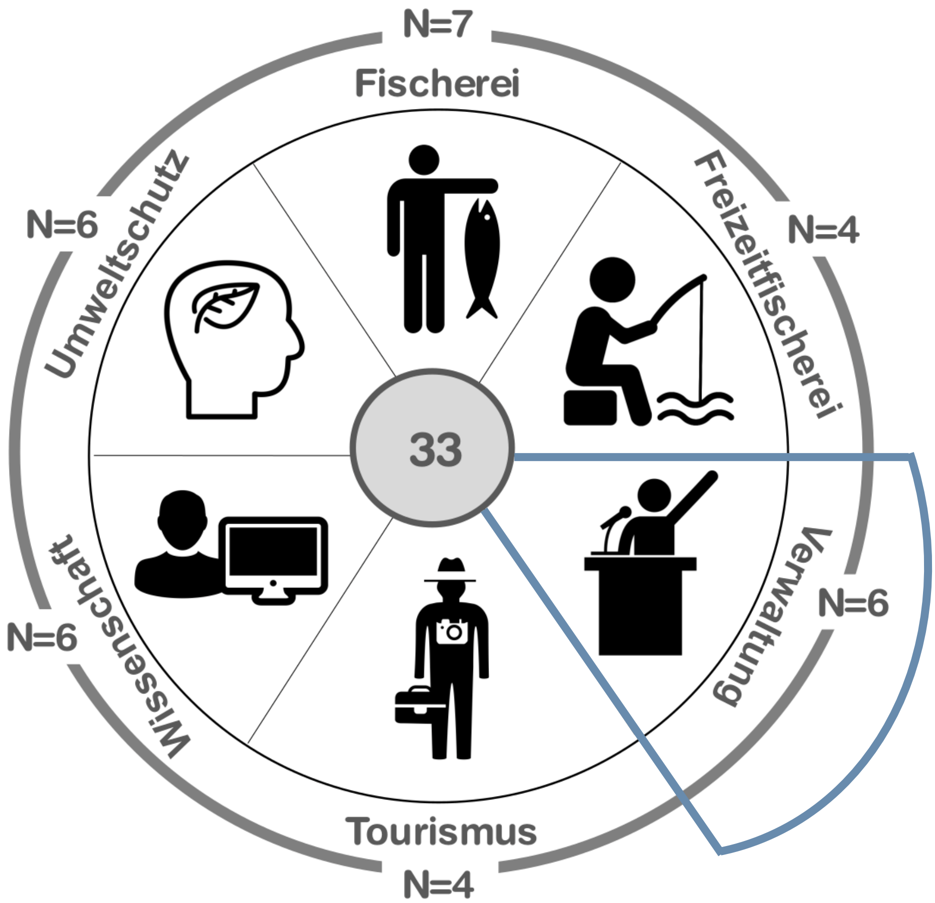
1. Angeltourismus
2. Fischerei
3. Naturschutz

Informationen zum Netzwerk

Anzahl Komponenten - 23
Sozial - 18
Ökologisch - 3

Anzahl der Beziehungen - 95

Komponente	Messgröße	
Angeltourismus	Anzahl der Angler	Sozial
Angelverbände	Stärke der Interessenvertretung	Sozial
Ausbau Infrastruktur	Anzahl der infrastrukturellen Maßnahmen	Sozial
CFP	Anzahl der umgesetzten Maßnahmen	Sozial
Dorschquote	Höhe der Fangquote	Sozial
EU	Stärke des Einflusses	Sozial
Fischerei	Höhe der Fangmengen	Sozial
Fischereiverbände	Stärke der Interessenvertretung	Sozial
Gemeinschaft, Naturerlebnis	Stärke der Gemeinschaft und des Naturerlebnisses	Sozial
Mehrjahrespläne	Stärke der Effizienz der Mehrjahrespläne	Sozial
Naturschutz	Anzahl der Maßnahmen	Sozial
Naturschutzverbände	Stärke der Interessenvertretung	Sozial
Politik (regional)	Stärke des Einflusses durch Politik auf regionaler Ebene	Sozial
Selektiv (nachhaltig)	Anzahl der selektiven Fanggeräte	Sozial
Steuereinnahme	Höhe der Steuereinnahmen	Sozial
Tourismus	Anzahl der Touristen	Sozial
Tradition, Kultur	Stärke des Vorhandenseins von Tradition und Kultur	Sozial
Wirtschaft (regional)	Höhe der Wertschöpfung	Sozial
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Hering	Anzahl der Heringe	Ökologisch
Natur	Stärke des Gesundheitszustandes	Ökologisch
Plattfische	Anzahl der Plattfische	Ökologisch
Prädation	Anzahl der Prädatoren	Ökologisch



Wir haben **6 Interviews** mit Vertretern*innen aus der Gruppe *Verwaltung* geführt.
Hierbei wurden insgesamt 104 Komponenten definiert (Mittel: 17 Komponenten pro Interview).

2.5 Verwaltung

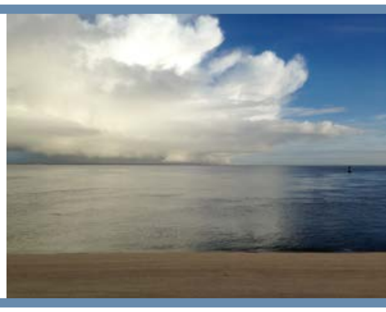
Umweltorganisation, **Freizeitfischerei** und **Wissenschaftlicher Rat** sind die am häufigsten genannten Komponenten in der Gruppe *Verwaltung*.

Umweltorganisation (auch: U-NGO, Naturschutzverbände) wirken sich durch einen zunehmenden Einfluss positiv auf Ökosystembestandteile aus, d.h. Robben, Schweinswale, Lebensraumtypen (LRT) & Riffe. Diese steigen in ihrer Anzahl oder aber ihr Schutzzustand verbessert sich. Durch das Interesse von Umweltorganisation an der Natur als Ganzes stehen diese in Konflikt mit fischereilichen Institutionen, u.a. Fischerei, Landesfischereiministerien und dem BMEL (Bundesministerium für Ernährung und Landwirtschaft).

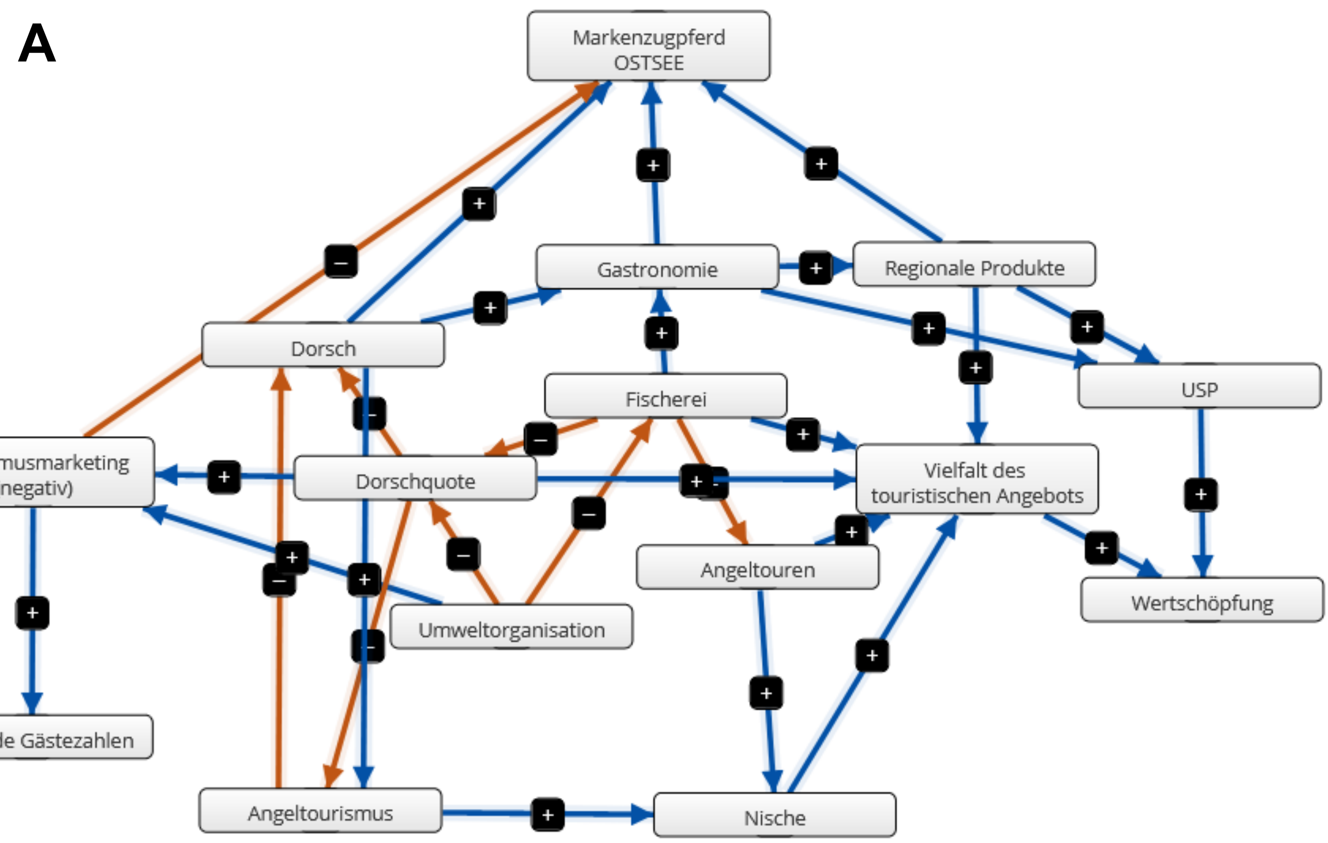
Die Freizeitfischerei (auch: Freizeitfischer) wird als konkurrierender Nutzer zur Fischerei gesehen. Zudem resultiert durch eine erhöhte Anzahl der Angler und damit einer steigende Entnahme das Absinken des Dorschbestandes.

ICES (Internationale Meeresrat) wirkt sich positiv auf den Dorschbestand aus. Durch die Fangempfehlung des ICES (gemessen an der Qualität der Forschung), wird der Dorschbestand entsprechend der Nachhaltigkeitsziele bewirtschaftet. Eine Erhöhung des Bestandes resultiert.

Komponente	Anzahl
Umweltorganisation	5
Freizeitfischerei	4
ICES	4
Tourismus	3


2.5 Verwaltung



Zentralste Komponenten

1. Dorschquote
2. Vielfalt touristisches Angebot
3. Gastronomie, Dorsch, Fischerei

Informationen zum Netzwerk

Anzahl Komponenten - 15
Sozial - 14
Ökologisch - 1

Anzahl der Beziehungen - 29

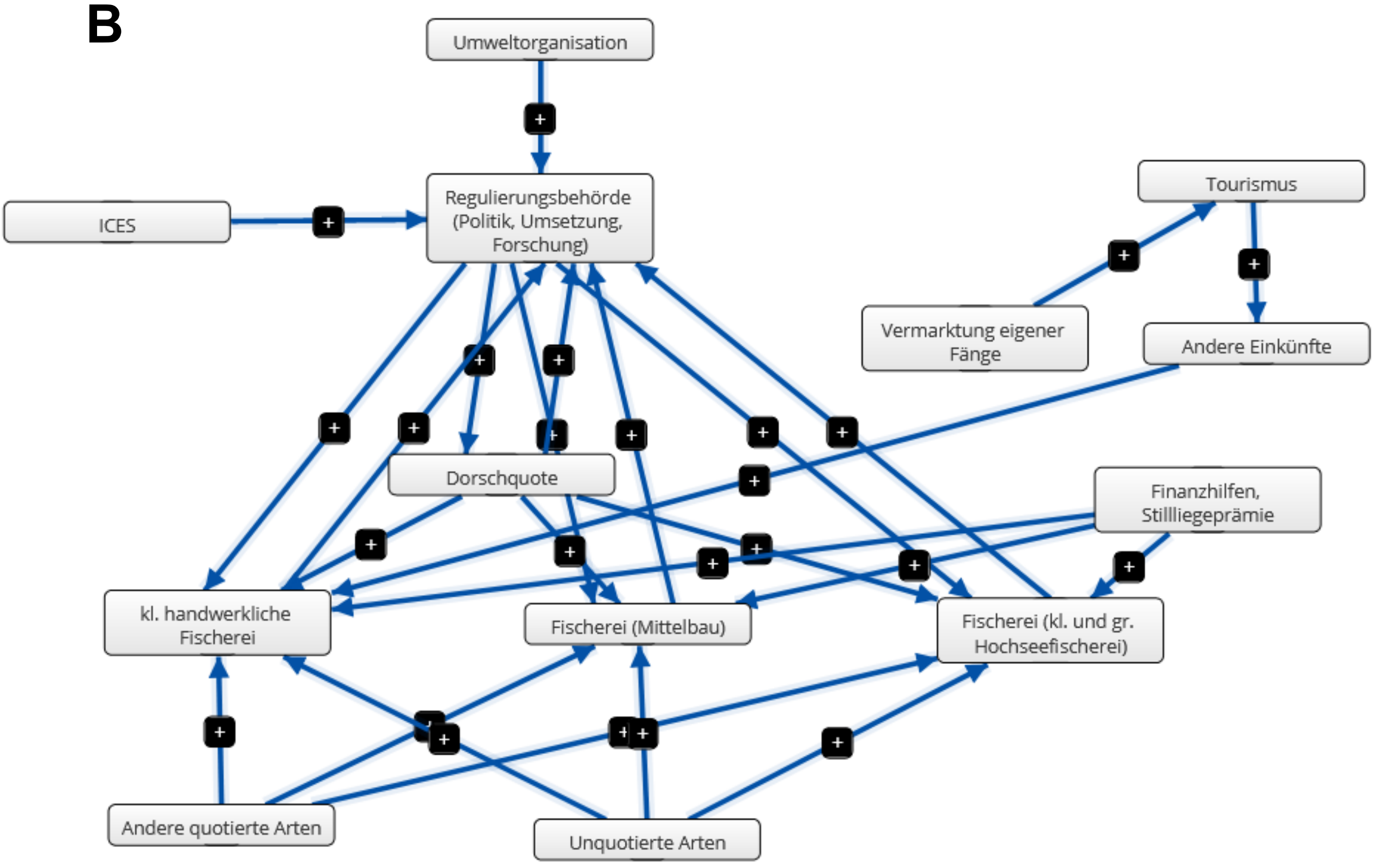
Komponente	Messgröße
Angeltouren	Anzahl der Angeltouren
Angeltourismus	Anzahl Angeltouristen
Dorschquote	Höhe der Fangquote
Fischerei	Höhe der Fangmenge
Gastronomie	Anzahl der Gastronomie
Markenzugpferd Ostsee	Höhe der Attraktivität der Ostsee
Regionale Produkte	Anzahl der regionalen Produkte
Tourismusmarketing (negativ)	Anzahl negativer Pressmittleilungen zum Thema Dorschquote
Umweltorganisation	Stärke des Einflusses der Umweltorganisation
USP (Unique Selling Point)	Höhe des Erfolges
Vielfalt touristisches Angebot	Höhe der Vielfalt des touristischen Angebots
Nische	Stärke des Bedienenes der Nische
Gästezahlen	Anzahl der Übernachtungen
Wertschöpfung	Höhe des Erlöses
Dorsch	Laicherbiomasse (SSB)

Sozial

Ökologisch

2.5 Verwaltung

B



<u>Zentralste Komponenten</u>

1. Regulierungsbehörde (Politik, Umsetzung, Forschung)
2. Kl. Handwerkliche Fischerei
3. Fischerei (Mittelbau), Fischerei (kl. Und gr. Hochseeischerei)

<u>Informationen zum Netzwerk</u>

Anzahl Komponenten - 13
Sozial - 13
Ökologisch – 0

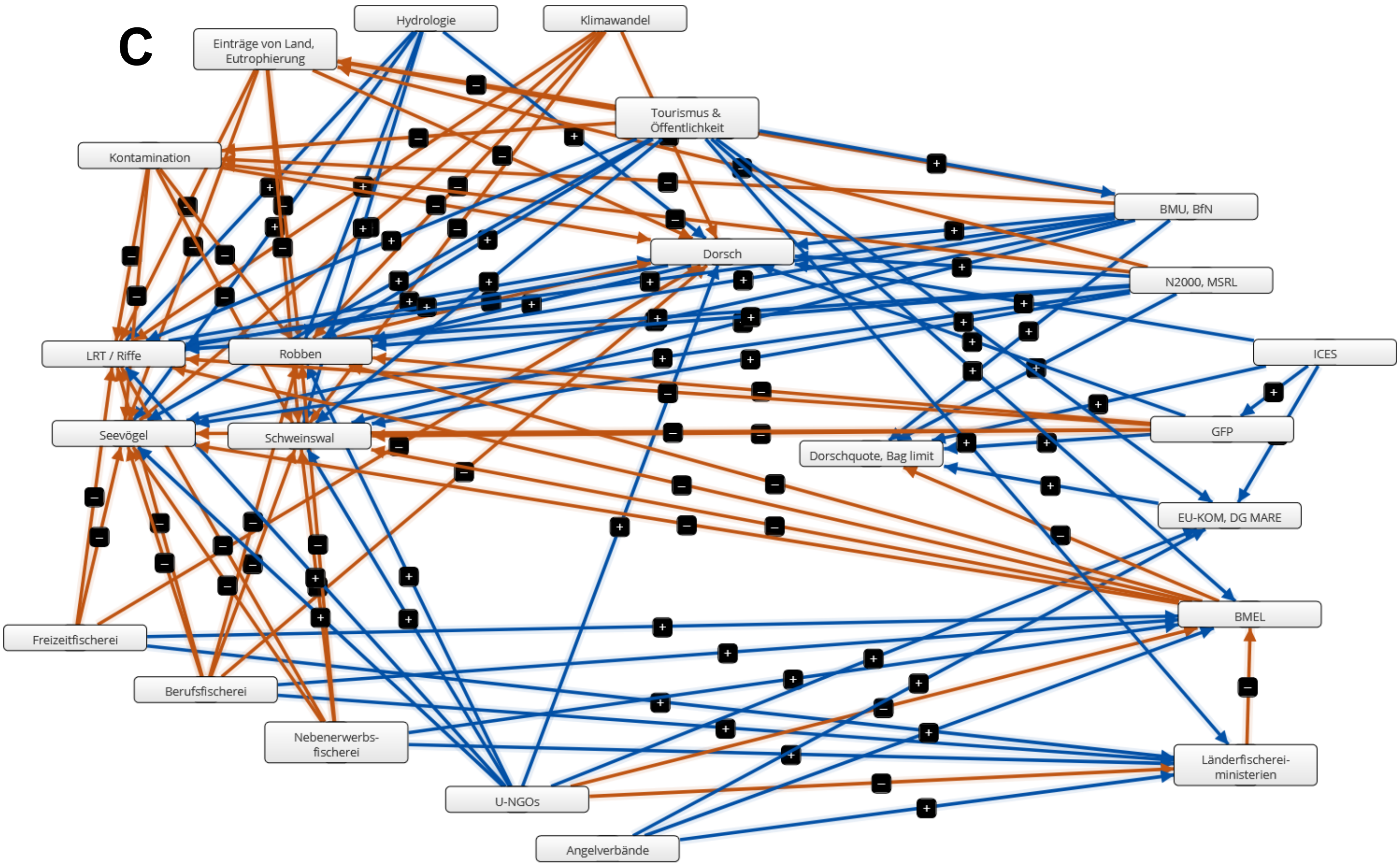
Anzahl der Beziehungen - 25

Komponente	Messgröße
Andere Einkünfte	Höhe der anderen Einkünfte (u.a. Ferien-wohnung, Verkauf von Fischbrötchen)
Andere quotierte Arten	Höhe der anderen quotierten Arten
Dorschquote	Höhe der Qualität der Fangquote
Finanzhilfen, Stillliegeprämie	Höhe der Finanzierungshilfen und Stillliegeprämien
Fischerei (kleine und große Hochseefischerei)	Höhe des Erhaltungsgrades
Fischerei (Mittelbau)	Höhe des Erhaltungsgrades
ICES	Höhe der Qualität (Menge an Daten und Qualität der Modelle)
Kl. handwerkliche Fischerei	Höhe des Erhaltungsgrades
Regulierungsbehörde (Politik, Umsetzung, Forschung)	Grad der Fischereizugewandtheit
Tourismus	Anzahl der Touristen
Umweltorganisation	Stärke des Einflusses durch Umweltorganisationen
Unquotierte Arten	Höhe der unquotierten Arten
Vermarktung eigener Fänge	Höhe der eigenen vermarkteten Fänge

Sozial

2.5 Verwaltung

C



<u>Zentralste Komponenten</u>

1. LRT, Riffe
2. Dorsch
3. Robben

<u>Informationen zum Netzwerk</u>

Anzahl Komponenten - 23

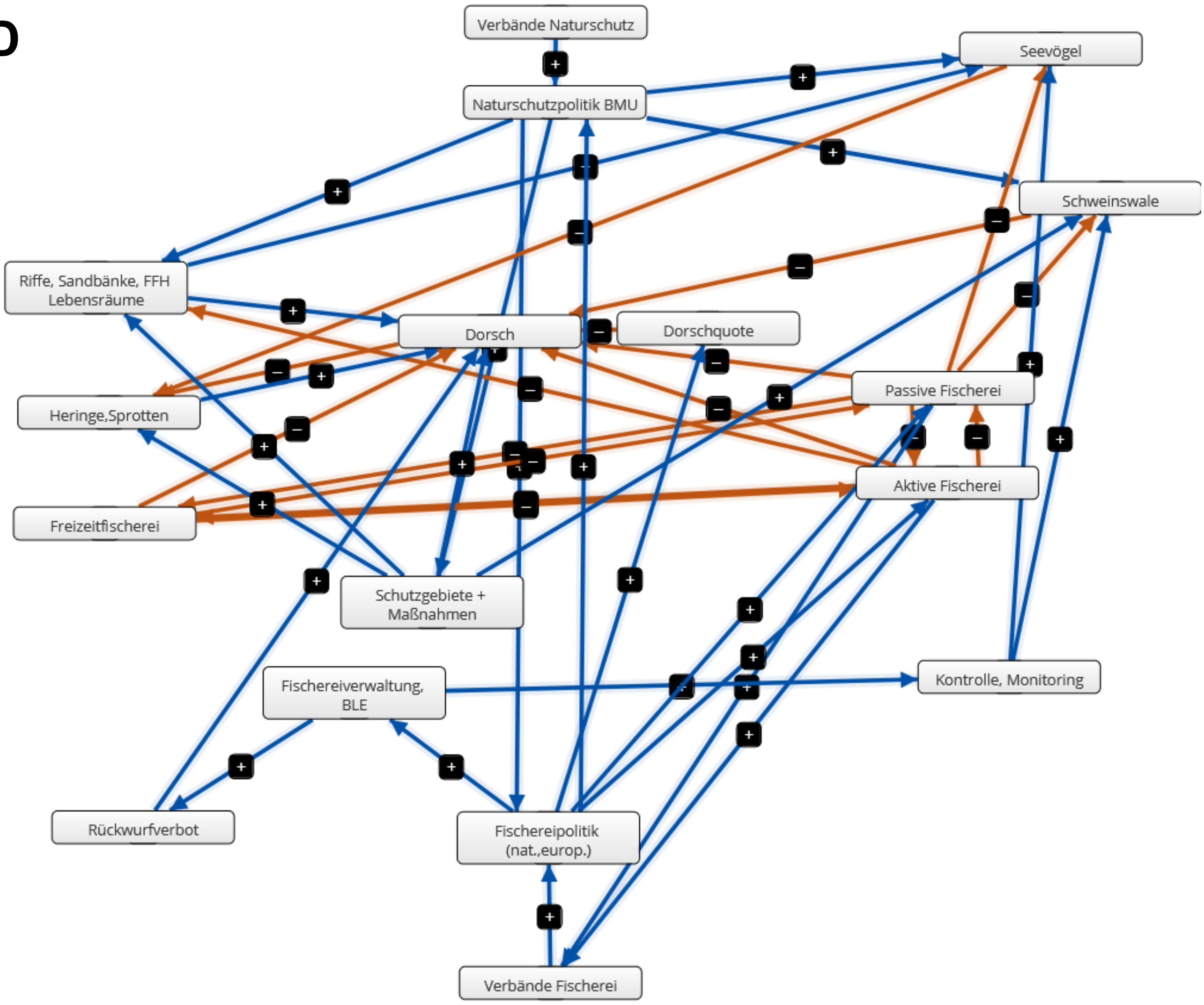
- Sozial - 14
- Ökologisch - 9

Anzahl der Beziehungen - 96

Komponente	Messgröße	
Angelverbände	Stärke der Interessenvertretung	Sozial
Berufsfischerei	Intensität der Fischerei (Fischereiaufwand)	
BMEL	Stärke des Einflusses durch BMEL	
BMU, BfN	Stärke des Einflusses durch BMU und BfN	
Dorschquote, Bag limit	Höhe der Qualität der Fangquote	
EU Kommission (EU KOM)	Stärke des Einflusses durch EU KOM	
Freizeitfischerei	Höhe der Entnahme durch Angler	
GFP	Stärke der umgesetzten Maßnahmen im Sinne der Fischerei	
ICES	Höhe der Empfehlung	
Landesfischereiministerien	Stärke der Einflussnahme im Sinne der Fischerei	
N2000, MSRL	Stärke der umgesetzten Maßnahmen	
Nebenerwerbsfischerei	Intensität der Fischerei (Fischereiaufwand)	
U-NGO	Stärke des Einflusses (politische Wahrnehmung und Einflussnahme)	
Tourismus & Öffentlichkeit	Stärke des Einflusses durch Anzahl der Touristen und andere Personen	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Einträge	Menge an landwirtschaftlichen Einträgen	
Hydrologie	Häufigkeit der Salzwassereinstromevents	
Klimawandel	Höhe der Temperatur	
Kontamination	Höhe der Belastung des Gewässers	
LRT, Riffe	Höhe der Qualität des Zustandes der Lebensraumtypen (LRT) und Riffe	
Robben	Anzahl der Robben	
Schweinswal	Anzahl der Schweinswale	
Seevögel	Anzahl der Seevögel	

2.5 Verwaltung

D



Zentralste Komponenten

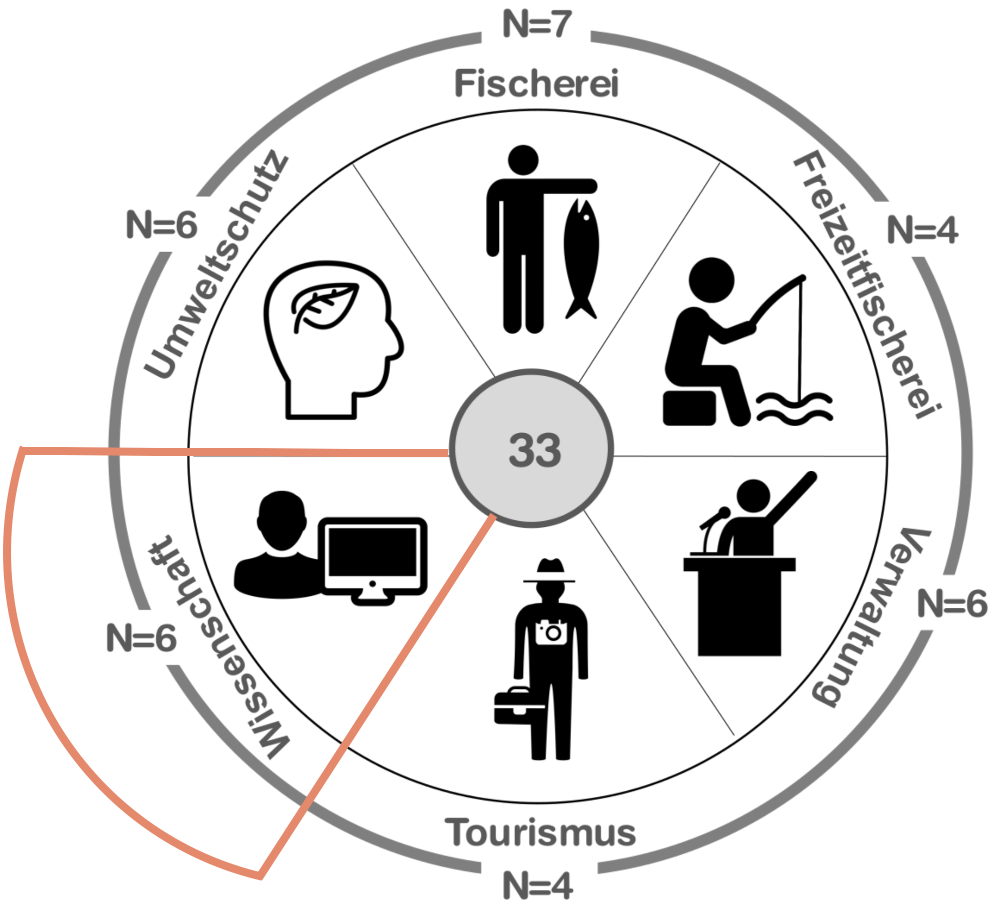
1. Dorsch
2. Passive Fischerei
3. Aktive Fischerei

Informationen zum Netzwerk

Anzahl Komponenten - 17
Sozial - 12
Ökologisch - 5

Anzahl der Beziehungen - 42

Komponente	Messgröße	
Aktive Fischerei	Anzahl der Fischer	Sozial
Dorschquote	Höhe der Fangquote	
Fischereiverbände	Stärke des Einflusses und Anzahl der Mitglieder	
Fischereipolitik	Stärke der Effektivität der fischereilichen Maßnahmen	
Fischereiverwaltung	Anzahl der umgesetzten Maßnahmen	
Freizeitfischerei	Anzahl der Angler	
Kontrolle, Monitoring	Häufigkeit der Kontrollen und Monitoring	
Naturschutzverbände	Stärke des Einflusses und Anzahl der Mitglieder	
Naturschutzpolitik	Stärke der Effektivität der Naturschutzmaßnahmen	
Passive Fischerei	Anzahl der Fischer	
Rückwurfverbot	Prozentualer Anteil der Umsetzung des Rückwurfverbotes	
Schutzgebiete	Menge der Schutzgüter	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Heringe, Sprotten	Anzahl der Heringe und Sprotten	
Riffe, Sandbänke, FHH Lebensräume	Größe und Erhaltungszustand der Lebensraumtypen	
Schweinswale	Anzahl der Schweinswale	
Seevögel	Anzahl der Seevögel	



Wir haben **6 Interviews** mit Vertretern*innen aus der Gruppe *Wissenschaft* geführt. Hierbei wurden insgesamt 115 Komponenten definiert (Mittel: 19 Komponenten pro Interview).

2.6 Wissenschaft

Freizeitfischerei und **Tourismus** sind die am häufigsten genannten Komponenten in der Gruppe *Wissenschaft*.

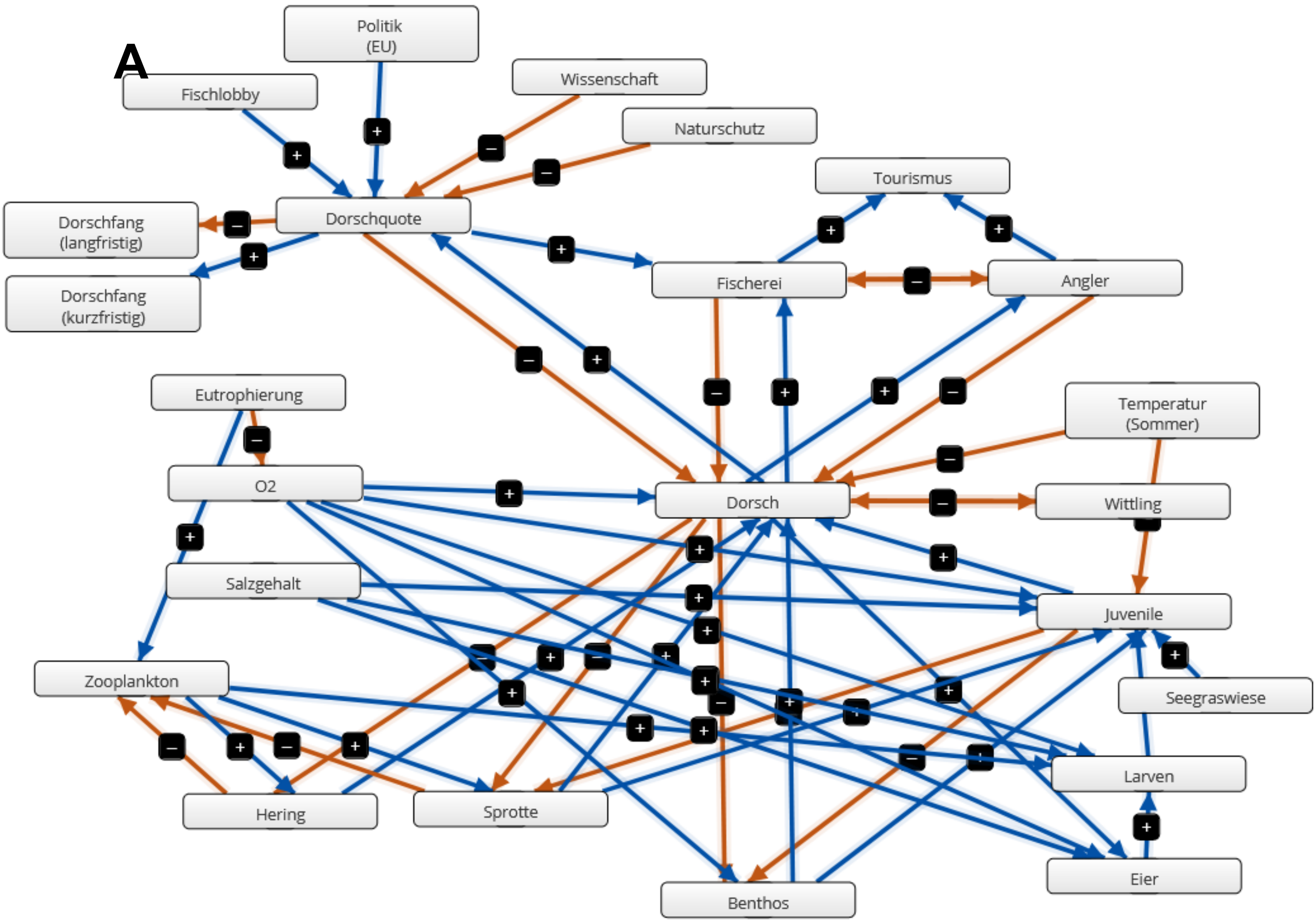
Der größte Einfluss, welcher von der Freizeitfischerei (auch: Angeln, Angler) ausgeht, ist die Abnahme des Dorschbestandes durch eine höhere Entnahme. Häufig wird auch die Beziehung zwischen Freizeitfischerei und Tourismus beschrieben; d.h. eine steigende Anzahl an Anglern wirkt sich positiv auf den Tourismus aus, u.a. durch die erhöhte Anzahl der Übernachtungen.

Der Tourismus wirkt sich zudem positiv auf die Fischerei aus, mehr Touristen bedeutet eine bessere wirtschaftliche Situation der Fischerei durch u.a. die Steigerung von alternativen Fangmöglichkeiten oder aber durch einen höheren Erhaltungsgrad bedingt durch den lokalen politischen Willen. Weiter, der Tourismus wirkt sich negativ durch eine steigende Anzahl der Touristen auf das Ostseeökosystem aus, gemeint ist hier, wenn der Tourismus nicht nachhaltig gestaltet ist, ist dies schlecht für den Gesundheitszustand des Ökosystems Ostsee.

Komponente	Anzahl
Freizeitfischerei	6
Tourismus	5
Wissenschaft	4
Umweltorganisation	3
Hering	3



2.6 Wissenschaft



<u>Zentralste Komponenten</u>

1. Dorsch
2. Juvenile
3. Dorschquote

<u>Informationen zum Netzwerk</u>

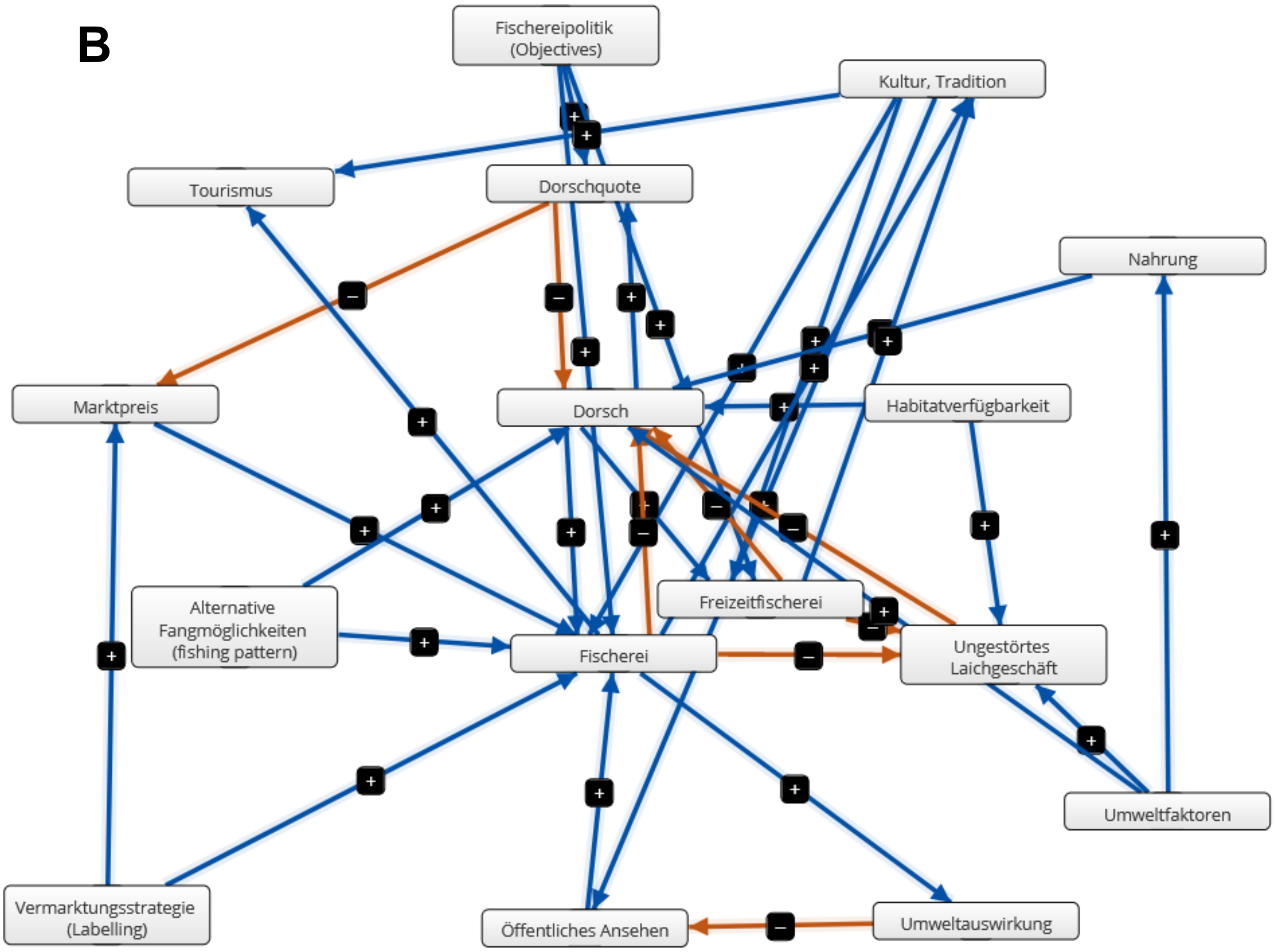
Anzahl Komponenten - 24
Sozial - 10
Ökologisch - 14

Anzahl der Beziehungen - 51

Komponente	Messgröße	
Angler	Anzahl der Angler	Sozial
Dorschfang (kurzfristig)	Höhe der Fangmenge	
Dorschfang (langfristig)	Höhe der Fangmenge	
Dorschquote	Höhe der Fangquote	
Fisch (Lobby)	Stärke des Einflusses durch die Fischereilobby	
Naturschutz	Stärke des Einflusses durch Umweltorganisationen	
Politik (EU)	Stärke des Einflusses der EU	
Tourismus	Anzahl der Touristen	
Wissenschaft	Stärke des Einflusses durch die Wissenschaft	
Benthos	Menge an Benthos	Ökologisch
Dorsch	Laicherbiomasse (SSB)	
Eier	Menge an Dorscheier	
Eutrophierung	Stärke des Ausmaßes der Eutrophierung	
Hering	Anzahl der Heringe	
Juvenile	Anzahl der juvenilen Dorsche	
Larven	Anzahl der Dorschlarven	
O2	Höhe des Sauerstoffgehaltes	
Sal. (Salinität)	Höhe des Salzgehaltes	
Seegraswiesen	Größe der Fläche der Seegraswiesen	
Sprotte	Anzahl der Sprotten	
Temperatur (Sommer)	Höhe der Temperatur (Sommer)	
Wittling	Anzahl der Wittlinge	
Zooplankton	Höhe der Qualität und der Verfügbarkeit des Zooplanktons	

2.6 Wissenschaft

B



Zentralste Komponenten

1. Fischerei
2. Dorsch
3. Freizeitfischerei, Kultur, Tradition

Informationen zum Netzwerk

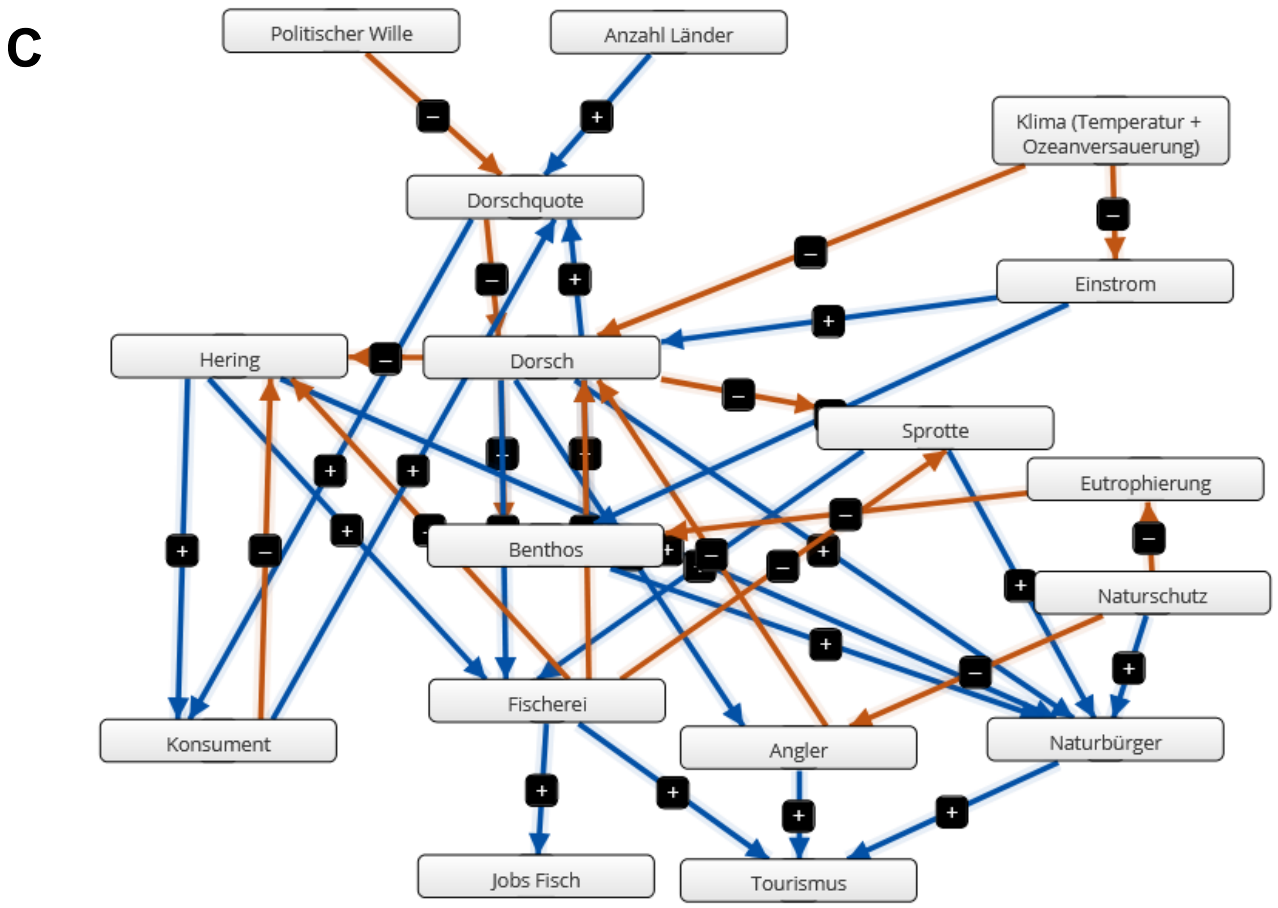
Anzahl Komponenten - 16
- Sozial - 10
- Ökologisch - 6

Anzahl der Beziehungen - 34

Komponente	Messgröße	
Alternative Fangmöglichkeiten	Anzahl der alternativen Fangmöglichkeiten	Sozial
Dorschquote	Höhe der Fangquote	Sozial
Fischerei	Höhe des ökonomischen Aufwandes	Sozial
Fischereipolitik („objectives“)	Höhe der Qualität der Fischereipolitik	Sozial
Freizeitfischerei	Anzahl der Angler	Sozial
Kultur, Tradition	Stärke der kulturellen und traditionellen Identität	Sozial
Marktpreis	Höhe des Marktpreises	Sozial
Öffentliches Ansehen	Höhe der Wertschätzung der Fischerei	Sozial
Tourismus	Anzahl der Touristen	Sozial
Vermarktungsstrategien („labelling“)	Höhe der Qualität der Vermarktungsstrategien	Sozial
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Habitatverfügbarkeit	Größe der Fläche der verfügbaren Habitate	Ökologisch
Nahrung	Menge an Nahrung	Ökologisch
Umweltauswirkungen	Stärke der Umweltauswirkungen	Ökologisch
Umweltfaktoren	Grad des Zustandes der Umweltfaktoren	Ökologisch
Ungestörtes Laichgeschäft	Stärke der Störung des Laichgeschäfts	Ökologisch

2.6 Wissenschaft

C



<u>Zentralste Komponenten</u>

1. Dorsch
2. Fischerei
3. Hering, Naturbürger

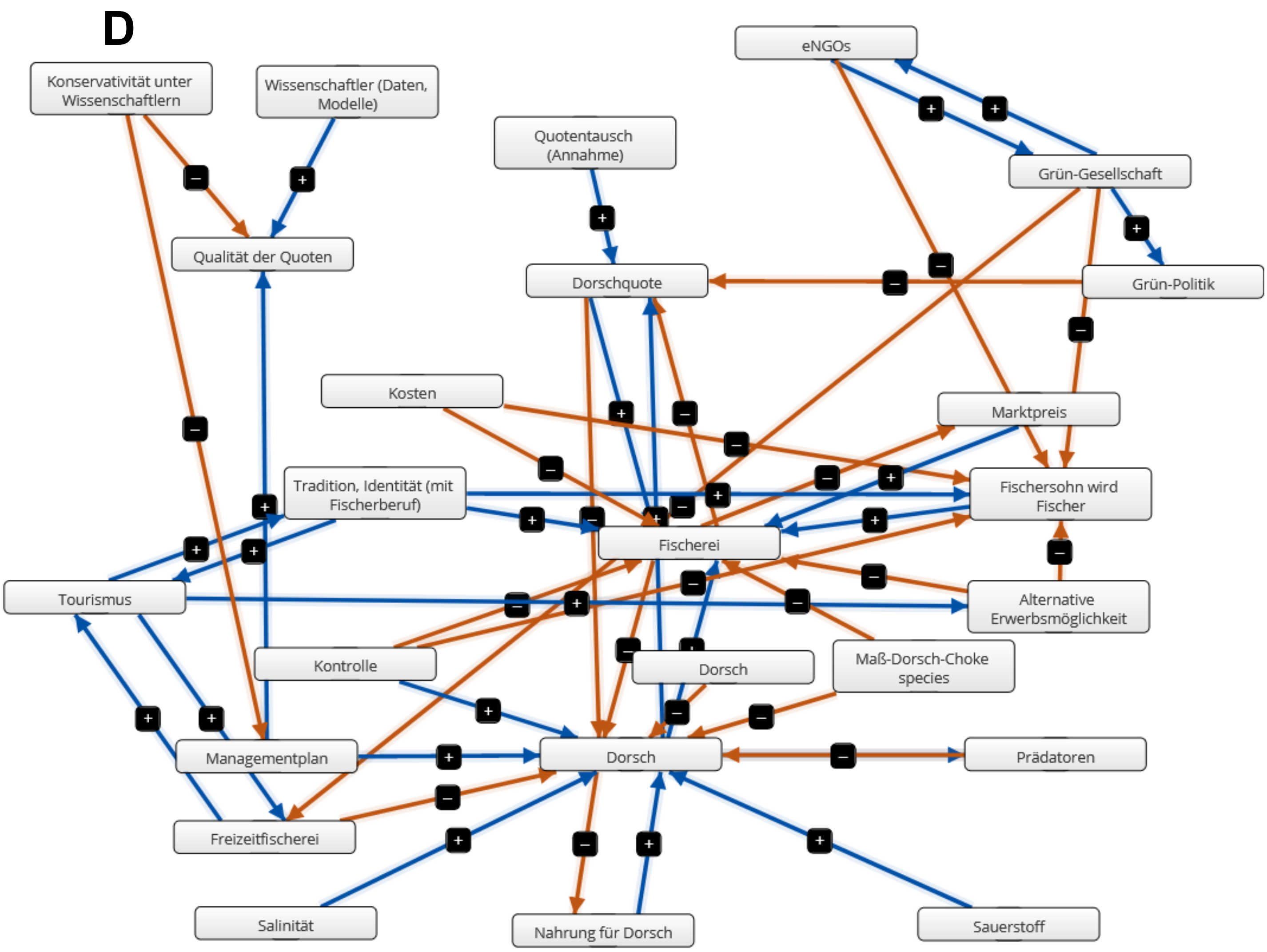
<u>Informationen zum Netzwerk</u>

Anzahl Komponenten - 17
Sozial - 10
Ökologisch - 7

Anzahl der Beziehungen - 36

Komponente	Messgröße	
Angler	Anzahl der Angler	Sozial
Anzahl Länder	Anzahl der Länder	
Dorschquote	Höhe der Fangquote	
Fischerei	Höhe der Fangmenge	
Jobs (Fisch)	Anzahl der Jobs	
Konsument	Anzahl der Konsumenten	
Naturbürger	Höhe der Zufriedenheit	
Naturschutz	Anzahl umgesetzter Maßnahmen	
Politischer Wille	Stärke des politischen Willens den Dorschbestand zu schützen	
Tourismus	Anzahl der Übernachtungen	
Benthos	Menge an Benthos	Ökologisch
Dorsch	Laicherbiomasse (SSB)	
Einstrom	Anzahl der Salzwassereinströme	
Eutrophierung	Stärke der Eutrophierung	
Hering	Anzahl der Heringe	
Klima (Temperatur, OA)	Höhe der Temperatur und Stärke der Versauerung	
Sprotte	Anzahl der Sprotten	

2.6 Wissenschaft



Zentralste Komponenten

1. Dorsch
2. Fischerei
3. Fischersohn wird Fischer

Informationen zum Netzwerk

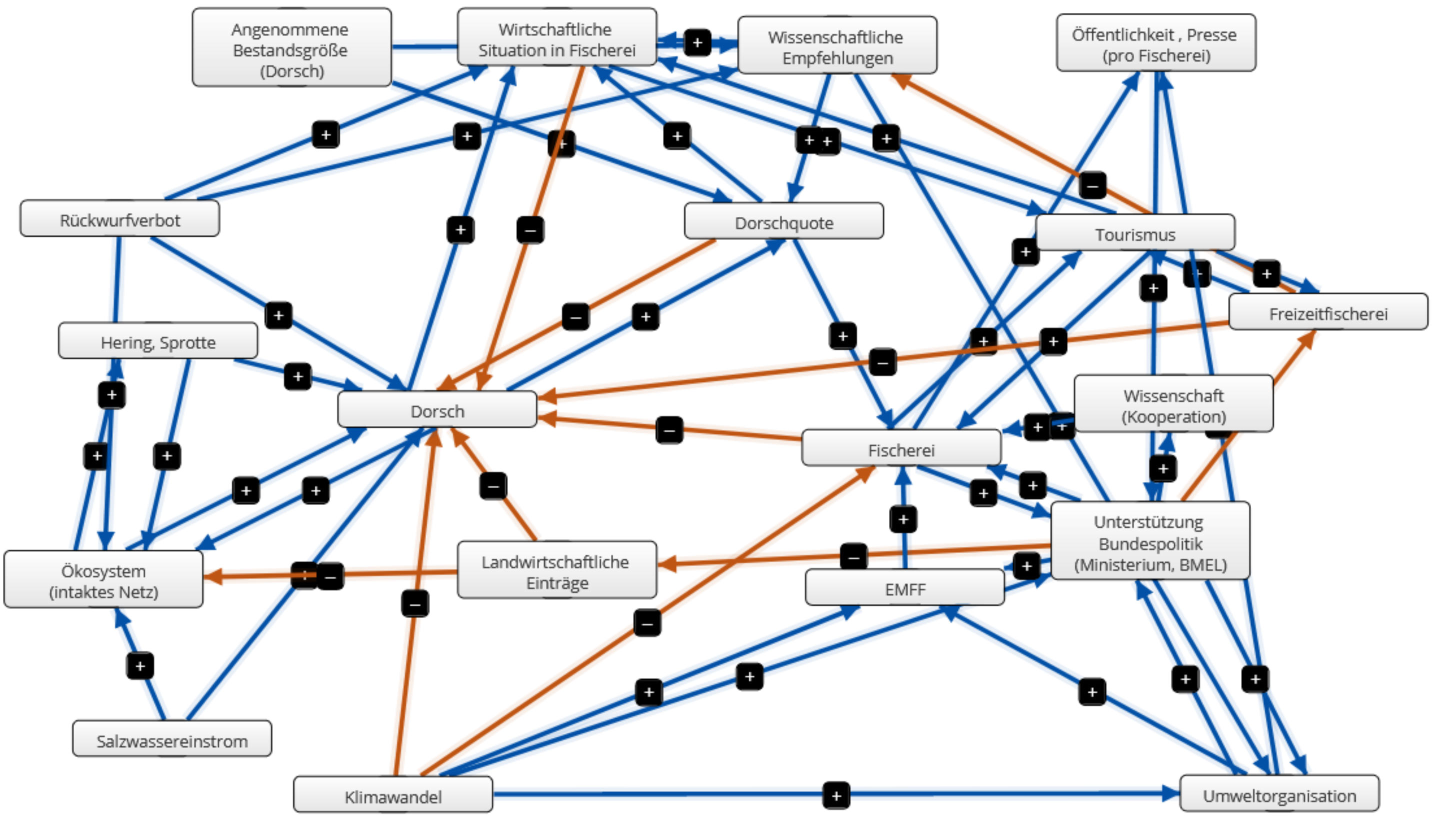
Anzahl Komponenten - 25
Sozial - 19
Ökologisch - 5

Anzahl der Beziehungen - 46

Komponente	Messgröße	
Alternative Erwerbsmöglichkeiten	Anzahl der alternativen Erwerbsmöglichkeiten	Sozial
Dorsch Choke Species	Anzahl der Dorsche als Choke Species	Sozial
Dorschquote	Höhe der Fangquote	Sozial
eNGOs	Anzahl der Mitglieder	Sozial
Fischerei	Höhe des Fischereiaufwandes	Sozial
Fischersohn zu Fischer	Höhe der Wahrscheinlichkeit das Fischersohn Fischer wird	Sozial
Freizeitfischerei	Anzahl der Angler	Sozial
Gesellschaft (Grün)	Anzahl der „grünen“ Personen in der Gesellschaft	Sozial
Identität Fischerberuf	Stärke der Identität mit dem Fischerberuf	Sozial
Konservativität Wissenschaftler	Anzahl der konservativen Wissenschaftler	Sozial
Kontrolle	Anzahl der Kontrollen	Sozial
Kosten	Höhe der Kosten für die Fischerei	Sozial
Managementplan	Höhe der Qualität des Managementplans	Sozial
Marktpreis	Höhe des Marktpreises	Sozial
Politik (Grün)	Stärke des Einflusses durch durch Anzahl „grüner“ politischer Sitze	Sozial
Quotentausch	Höhe der angenommenen getauschten Quote	Sozial
Tourismus	Anzahl der Touristen	Sozial
Wissenschaft (Daten, Modelle)	Menge der Daten und Modelle	Sozial
Qualität Quote	Höhe der Qualität der Quote	Sozial
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Nahrung für Dorsch	Menge der Nahrung	Ökologisch
Prädatoren	Anzahl der Prädatoren	Ökologisch
Salinität	Höhe des Salzgehaltes	Ökologisch
Sauerstoff	Höhe des Sauerstoffgehaltes	Ökologisch

2.6 Wissenschaft

E



Zentralste Komponenten

1. Dorsch
2. Fischerei
3. Unterstützung Bundesrepublik (BMEL)

Informationen zum Netzwerk

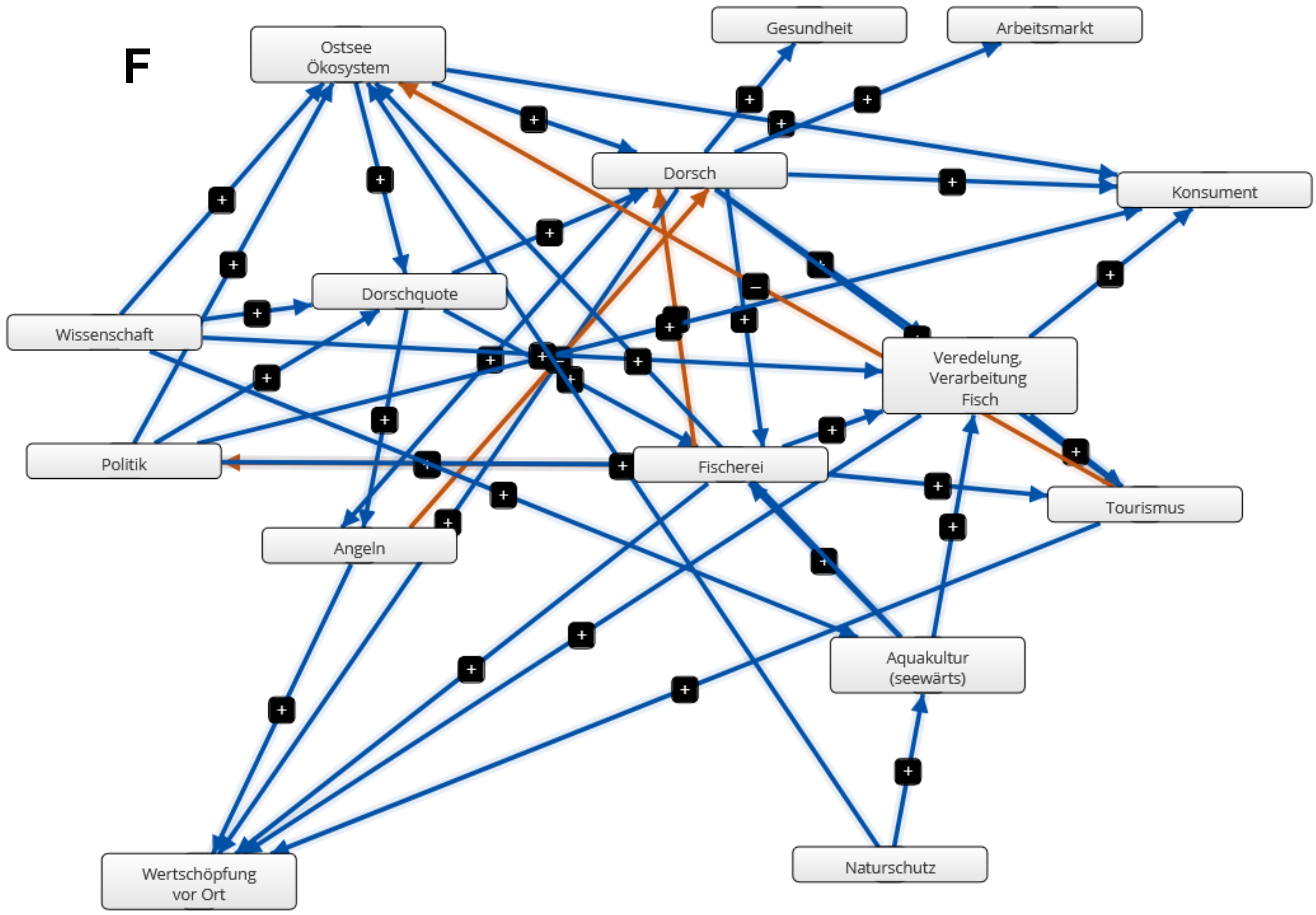
Anzahl Komponenten - 19
Sozial - 13
Ökologisch - 6

Anzahl der Beziehungen - 52

Komponente	Messgröße	
Angenommene Bestandsgröße	Höhe der angenommenen Bestandsgröße	Sozial
Bundespolitik	Stärke der Unterstützung durch die Bundesrepublik	Sozial
Dorschquote	Höhe der Fangquote	Sozial
EMFF	Höhe des Fonds	Sozial
Fischerei	Vorhandensein einer Fischerei (gemessen an der Anzahl der Boote und Fischer)	Sozial
Freizeitfischerei	Anzahl der Angler	Sozial
Öffentlichkeit (Presse pro Fisch)	Anzahl der Pressmitteilungen pro Fisch	Sozial
Rückwurfverbot	Stärke der Umsetzung des Rückwurfverbotes	Sozial
Tourismus	Anzahl der Touristen	Sozial
Umweltorganisation	Stärke des Aktivismuses	Sozial
Wirtschaftliche Situation Fischerei	Höhe des Umsatzes in der Fischerei	Sozial
Wissenschaft	Menge der finanzierten Kooperationen	Sozial
Wissenschaftliche Empfehlung	Höhe der Empfehlung	Sozial
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Hering, Sprotte	Anzahl der Heringe und Sprotten	Ökologisch
Klimawandel	Höhe der Temperatur	Ökologisch
Landwirtschaftliche Einträge	Höhe der landwirtschaftlichen Einträge	Ökologisch
Ökosystem	Grad des Zustandes des Ökosystems	Ökologisch
Salzwassereinstrom	Menge der Salzwassereinstromevents	Ökologisch

2.6 Wissenschaft

F



Zentralste Komponenten

1. Dorsch
2. Fischerei
3. Ostsee Ökosystem

Informationen zum Netzwerk

Anzahl Komponenten - 15

- Sozial - 13
- Ökologisch - 2

Anzahl der Beziehungen - 39

Komponente	Messgröße	
Angeln	Anzahl der Angler	Sozial
Aquakultur	Höhe der Qualität der Aquakultur	
Arbeitsmarkt	Anzahl der Arbeitsplätze	
Dorschquote	Höhe der Qualität der Fangquote	
Fischerei	Anzahl der Schiffe und Umsatz in der Fischerei	
Gesundheit	Grad der Gesundheit des Menschen	
Konsument	Höhe der Zufriedenheit	
Naturschutz	Höhe der Qualität des Naturschutzes	
Politik	Höhe der Qualität der Politik	
Tourismus	Anzahl der Touristen	
Veredlung Fisch	Menge der veredelten Fische	
Wertschöpfung vor Ort	Höhe des Umsatzes	
Wissenschaft	Höhe der Datenmenge	
Dorsch	Laicherbiomasse (SSB)	Ökologisch
Ostsee Ökosystem	Höhe des Gesundheitszustandes des Ostseeökosystems	

Abkürzung	Bedeutung
ICES	International Council for the Exploration of the Sea
BMEL	Bundesministerium für Ernährung und Landwirtschaft
$B_{MSY\text{-}Trigger}$	Biomasse bei höchstmöglichem Dauerertrag
BfN	Bundesamt für Naturschutz
BMU	Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit
CFP	Common Fisheries Policy
EMFF	Europäischer Meeres- und Fischereifonds
EU	Europäische Union
eNGO	Environmental non-governmental organization
F_{MSY}	Fischereiliche Sterblichkeit bei höchstmöglichem Dauerertrag
GFP	Gemeinsame Fischereipolitik
MPA	Marine Protected Areas
MSRL	Meeresstrategierahmenrichtlinie
MSY	Maximum Sustainable Yield
MSC	Marine Stewardship Council
N2000	Natura2000
NGO	Nichtregierungsorganisation
LRT	Lebensraumtypen
OA	Ocean Acidification (Ozeanversauerung)
SSB	Spawning Stock Biomass
U-NGO	Umwelt-Nichtregierungsorganisation
USP	Unique Selling Point
Zw.	Zwischen

3. Zusammenfassung

Im Zuge des Projektes wurden 33 mentale Modelle in Form von Interviews erhoben. Es zeigt sich, dass **kein Modell dem anderen gleicht**.

Die Modelle reichen von einfacheren bis sehr komplexen Darstellungen des sozial-ökologischen Systems des westlichen Ostseedorsches. Insgesamt wurden über **625 Komponenten** definiert sowie **1332 Beziehung** zwischen den Komponenten beschrieben. Die **strukturelle Analyse**, welche Raissa Borgmann in ihrer Masterarbeit durchgeführt hat, zeigt, dass es keine eindeutigen Muster weder zwischen den Gruppen noch innerhalb der Gruppen gibt.

Basierend auf der **inhaltlichen Analyse** ist interessant, dass die Komponenten sich nicht nur durch den Begriff selbst, sondern auch durch die Definition oder aber die verwendete Messgröße voneinander unterschieden. Diese Komplexität der beschriebenen Systembestandteile schafft einen umfassenden Blick auf das System aus Sicht verschiedener Akteure. Zudem fällt auf, dass eine größere Einigkeit über die Funktion ökologischer als über die sozialen Systembestandteile vorliegt. Es wurden nicht nur mehr soziale Komponenten insgesamt definiert, auch die Definition oder aber die verwendeten Messgrößen divergieren stärker als bei den ökologischen Komponenten.

Die Ergebnisse zeigen nicht nur die **Wichtigkeit der Kommunikation** zwischen Interessenvertretern*innen, sondern weisen zudem die hohe Bedeutung einer **gemeinsamen Sprache** hinsichtlich der Entwicklung gemeinsamer Lösungsstrategien zur nachhaltigen Bewirtschaftung des Bestandes des westlichen Ostseedorsches auf.

Herr Möllmann, Frau Borgmann und ich möchten uns noch einmal herzlich für Ihre Unterstützung bedanken. Wir hoffen, dass auch Ihnen die Zusammenarbeit viel Freude gemacht hat und Sie durch diese Dokumentation einen guten Einblick in unsere Forschung, aber vor allem in die Wahrnehmung verschiedener Interessenvertreter*innen bekommen haben.

Sehr gerne stehen wir Ihnen für Rückfragen zur Verfügung.

Vielen herzlichen Dank, Heike Schwermer

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22.09.2021

To whom it may concern,

I, as a native speaker (USA), hereby confirm the correctness of the language of the doctoral thesis of Heike Schwermer.

Den Burg (Texel), 22.09.2021

Dr. Myron A. Peck

Hiermit erkläre ich an Eides statt, dass ich die vorliegende Dissertationsschrift selbst verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

Hamburg, 22.10.2021

I was supported through a scholarship by Deutsche Bundesstiftung Umwelt for which I am very thankful. With the financial as well as personal support of the DBU, I was able to develop both professionally and personally. In addition, I was able to get to know many inspiring and warm personalities through my participation in three seminars as well as other events.

Thank you, DBU.

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