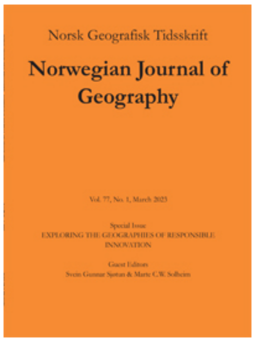

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Inclusion in the global innovation system for CRISPR salmon in Norway

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ABSTRACT
The aim of the paper is to determine how inclusion, as understood in the literature on responsible research and innovation (RRI), should be acknowledged in the global innovation system in Norway for CRISPR salmon. The authors conceptualize inclusion from a systems perspective (i.e., systemic inclusion) and use global innovation systems (GIS) as a conceptual framework. The analysis is based on an actor-network map comprising innovation projects and actors drawn from empirical data by applying socio-technical configuration analysis (STCA). The authors find that inclusion should be addressed by acknowledging that CRISPR salmon innovation is performed in a market-anchored GIS. This means that "footloose" knowledge should be prioritized in order to understand the problems that CRISPR innovation aims to tackle and the type of risks that it implies, but also that local valuations should be prioritized in order to build a functional legal and market structure along with local social concerns. The authors conclude that the approach is necessary because although it is recognized that the inclusion of new and diverse perspectives needs to be done strategically when innovating with CRISPR technology, there is no clear rationale that can help when defining a strategy for who should be included and why.

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Introduction

In May 2021, the European Commission proposed a new plan for a "sustainable blue economy" as part of the European Union's Green Deal (European Commission 2021). The plan aims to reduce the climate impact of fisheries and aquaculture by calling for investment in innovative technologies that will ensure sustainable food production. This is relevant for the Norwegian salmon farming industry because the industry is plagued by issues related to environmental impact and fish welfare. These issues must be addressed if production is to increase in a sustainable manner (Bailey & Eggereide 2020), and if Norway wants to maintain its current entrepreneurial and moral global lead in the industry (EY 2020). Taking a "responsible innovation" approach, which is understood in the EU context in terms of responsible research and innovation (RRI) (von Schomberg 2011; Stilgoe et al. 2013), could provide needed direction in Norwegian aquaculture innovation in a way that would address such sustainability challenges.

Various innovations have been aimed at addressing the Norwegian salmon farming industry's sustainability issues with differing degrees of "radicalness" to facilitate industrial renewal (Fløysand & Jakobsen 2017). Several infrastructure innovation projects have been proposed and are now being implemented to produce salmon in the open ocean or on land, such as the Spidercage and the Marine Donut (Fiskeridirektoratet n.d.). In addition, large-scale digital innovations are being introduced for fish health control, ecosystem overview, and the effectivization of feed distribution (GSI 2021). One of the most radical innovations is gene editing with CRISPR, a technology with the "potential for novel, ground-breaking

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solutions" (Myskja & Myhr 2020, 2601), which aims to replace technologies that represent a high risk for the environment or animal welfare (Veterinærinstituttet 2021). However, given CIRSPR's groundbreaking implications for Norway's salmon farming industry and the market, firms innovating with CRISPR may have to deal with legislative and commercial obstacles due to regulations and consumer skepticism. One way of dealing with such obstacles in accordance with RRI is strategically to include stakeholders in the innovation process (Callegari & Mikhailova 2021). Nevertheless, there are no clear answers concerning what such strategies imply and how strategic stakeholders should be included. This is an important issue because firms have been shown to be highly skeptical towards being inclusive, as doing so can have negative consequences for competition and even restrain innovation (Brand & Blok 2019). Thus, there is a need for a better understanding of how firms can more systematically consider inclusion in accordance with RRI (Scholten & Blok 2015).

To account for regulatory challenges and to obtain social license to use CRISPR in today's diverse stakeholder reality, we argue that firms must acknowledge inclusion by understanding the rationale of the multiscalar innovation system in which they operate. By "rationale," we refer to the set of reasons or logic formed behind an innovation system that determines the way in which actors, networks, and institutions relate (Witt & Redding 2009). Furthermore, the term "systemic inclusion" is borrowed from organizational studies and it encompasses the idea of when all actors feel safe, engaged, respected, and valued within a system (Taylor 2017). In our case, understanding the rationale for systemic inclusion means determining (1) how to consider inclusion, (2) what inclusion means (i.e., who to include), and (3) its potential consequences. Hence, our aim is to understand the rationale that is defined within the context in which the premises for inclusion are created. We address these questions by focusing on the spatial configurations and relations that are formed when actors, networks, and institutions work together using global innovation systems (GIS) (Binz & Truffer 2017) as a conceptual framework.

Although actors, especially firms, may not be ultimately interested in making the innovation system more inclusive (Blok et al. 2015), adopting a GIS perspective on inclusion can help firms to understand the rationale of the innovation system in which they operate. Consequently, firms can determinate what and which key actors to include in the innovation process, as well as how to include them. In addition, we apply the premises of RRI to develop further the way in which "value assessments"[1] are conceived within GIS. This is of interest because the literature on innovation systems has been criticized for not addressing what is referred to as the "harmony fallacy," where there is a need to analyze stakeholders' diverse and conflictive intentions when aiming for innovation (Heiberg & Truffer 2022). As a result, the proposed analysis should be of interest to firms because it may help them to identify and manage conflicts concerning legal obstacles or ethical controversies. These aspects are difficult to identify through normal market assessments and consumer surveys. To our knowledge, no study has provided practical suggestions for inclusion by aiming to understand the rationale behind an innovation system in the way we propose. Accordingly, the research question we ask is: *How should inclusion, as understood within RRI, be acknowledged in the global innovation system for CRISPR salmon in Norway ?* First, we address this question with a brief explanation of GIS to clarify what we mean by systemic inclusion, and how the perspectives of RRI can be applied. Thereafter, we construct an actor-network map with empirical data, and subsequently define the type of GIS formed by CRISPR salmon innovations. Finally, we respond to our research question with empirical data and discuss possible implications for the development of CRISPR innovation within the Norwegian context.

Theoretical framework

Innovation systems and inclusion

A system of innovation "comprises all determinants of the innovation process, that is, all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations" (Sternberg 2011, 39). Following this idea, Arocena et al. (2018, 95) state that an "inclusive innovation system is a system that includes the explicit mandate of orienting the production and use of knowledge toward social inclusion." Thus, an inclusive innovation system, or systemic inclusion, is not only about accounting for a larger number of actors or a larger diversity of ideas, but also involves incorporating them into the system in a functional and integral way. Such a system perspective on inclusion allows us to understand that just because more or new actors/ideas are considered in the innovation process, it does not mean that they are properly included in it. In other

[1]While the term 'valuations' is normally used within GIS literature, hereafter we use the term 'value assessments' to avoid the risk of valuations being read as meaning assessment of the monetary value of innovations.

words, a well-functioning inclusive innovation system implies that all actors have the mechanisms to give and obtain knowledge they have and need in order to express their ideas. If an innovation system is not inclusive, any attempt to incorporate an actor/idea into an innovation process will be worthless because it will be limited or rejected by the system.

Having a system perspective on inclusion can help firms to recognize early warnings of potential conflicts regarding commercialization or future change of regulations. In addition, it can assist firms to be equipped in terms of knowing how to deal with such issues (Warnke et al. 2016). By having a more holistic understanding of inclusion, firms can recognize actors or ideas that are outside the innovation process as such, and probably would have been ignored or not identified. The latter occurs when the significance of some actors, such as certain consumer organizations or governmental institutions, may be difficult to recognize in the innovation process itself, but it becomes crucial once an innovation is commercialized or regulated. Thus, analyzing the degree to which an innovation system is inclusive will allow firms to define strategies for intervention at an early stage. For example, firms could include key stakeholders by giving them early access to scientific knowledge that is difficult to understand when making risk assessments.

Thus, the major challenge is to understand how inclusion can be analyzed within an innovation system, particularly when actors are dispersed in different geographical places and spaces, where complex relations are created. In addressing the innovation system to acknowledge inclusion properly, it is necessary to have a theoretical and methodological strategy to help us to understand the rules of the system. Thus, there is a need for a conceptual framework that can help to define the key spatial configurations and relations that influence how inclusion is formed within an innovation system, such as considering the kind of system resources that are generated between actors, networks, and institutions, and finding the logic that forms them. For these reasons, and the fact that the salmon farming industry is of global dimensions, we propose the use of GIS as a basis for making this analysis.

GIS

As proposed by Binz & Truffer (2017), GIS is a conceptual framework designed to understand the global dimensions of an innovation system. The framework consists of two conceptual elements: subsystems and structural couplings. Subsystems are formed by actors generating the same type of system resources, which means that they do not need to be bounded to territorial limits. The concept of system resources is divided into two main modes: knowledge creation, which is referred to as the "innovation mode," and investment mobilization, market formation, and technology legitimation, which together are referred to as the "valuation mode." Each modes can be either local or global. Actors that make local value assessments are those that define the place-based criteria for local markets, policies, and ethical concerns, whereas those that make global value assessments aim for standardization of values. Actors that generate local knowledge refer to those applying synthetic place-based knowledge, whereas actors that generate global knowledge refer to "footloose" knowledge (Plum & Hassink 2011). The combinations of these system resources can result in four different GIS configurations: footloose GIS, market-anchored GIS, spatially sticky CIS, and production-anchored GIS. Structural couplings are the connections between actors located in different subsystems. They show the way in which subsystems relate to each other. A detailed explanation of both how GIS are constructed and the modes is provided by Binz & Truffer (2020).

The application of the GIS concept is of interest because, depending on the resulting GIS configuration of an innovation, it allows us to recognize what system resources are formed, where and how they are formed, and which actors conform them. This recognition is helpful because it goes beyond a simple network analysis and provides an explanation of why key actors are important in terms of the system resources they produce. The distinction between subsystems of actors involved in knowledge creation on the one hand, and product value assessments on the other, enables us to understand the type of spatial configurations and relations that are created between different system resources. Understanding the distinction also helps to explain how knowledge creation complements strategies that target value assessments (Binz & Truffer 2020). Hence, the main contribution of GIS as a concept is how it can be used to define the type of relations that are formed between subsystems (through structural couplings), which in turn is helpful for understanding how inclusion is attained or can be better attained within the system. This is what we mean by understanding the "rationale" behind the innovation system, meaning the logic by which systemic inclusion should be performed.

The GIS framework was not originally created to address inclusion per se. Its main aim was to understand how a technology evolves within its innovation system at a global perspective in order to define the best policies needed for reinforcing or changing its development. The idea of using GIS to analyze inclusion arises from a call to expand the concept of value assessments within

GIS to more than its predominantly economic focus, a tendency for which all innovation system approaches have been criticized (Coenen & Morgan 2020). One way of achieving this is to use ideas currently discussed within the RRI literature, which has inclusion as a focus. RRI emphasizes the societal impact of research and innovation and specifically addresses ethical issues. Inclusion is seen as one of the four main pillars of RRI, with the other three being anticipation, reflexivity, and responsiveness (Stilgoe et al. 2013). von Schomberg (2011, 9) defines RRI as follows:

> a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society).

Inclusion within RRI is seen as the effort to consider new voices in the governance of research and innovation in the search for legitimacy (Thapa et al. 2019), not only to make innovation processes more ethical, but also as a way to tackle effectively the actual problems confronting the innovation system. The idea is to open the innovation process to actors who are usually absent from scientific and technological development, as a way to enrich the system with new ideas, and thus make it more resilient (van Mierlo et al. 2020). However, inclusion does not mean attempting to include every potential stakeholder in every decision, but rather it is about opening up for a greater diversity of stakeholder perspectives in specific innovation processes (which does not necessarily mean representativeness). In short, inclusion is not just about *who* to include, but is mostly about *when*, *where*, and *how* to include actors that have new and relevant perspectives (Owen et al. 2012).

Analyzing inclusion with GIS

The main idea behind analyses of inclusion by using the concept of GIS is that from an innovation system perspective inclusion can be studied through GIS by asking how the relations between subsystems affect the studied actors. The way in which knowledge and value assessments (system resources) are produced and disseminated will depend on how subsystems are formed and how the structural couplings are made. In other words, addressing inclusion in GIS is about defining the degree to which the accessibility of system resources is facilitated between the subsystems; It is about understanding who the main actors are and how they connect all others (Heiberg & Truffer 2021). In this way, one can identify which actors are not being properly included by first making a network analysis of the subsystems and then determining the type of knowledge and value assessments that are dominant or being ignored. Therefore, by analyzing the network of a particular GIS configuration, one can see that certain actors have different capabilities to express their ideas, depending on how they are connected to other actors and ideas.

In concrete terms, the first step to address inclusion through a GIS analysis is to identify the actors who are least connected to the system (Hartmann 2014). This means finding the actors who have fewer connections and/or those who depend most on intermediaries for connecting to others, both within a subsystem and between subsystems. Thus, relegated actors should be better integrated into the system, but this should not be done by just creating more links, but by understanding why and how new links should be established (Ter Wal et al. 2016). Creating more connections will not necessarily integrate actors into the system if those actors are still constrained when it cones to expressing their ethical concerns or if they are limited when it comes to obtaining different types of knowledge. Real integration will only occur if structural changes are made regarding how and why system resources do not reach actors that can transmit or translate ideas to others.

Nevertheless, the relevance of using GIS is much deeper than just the opportunity to make a network analysis of the subsystems. Defining the type of knowledge and value assessments that are at play within the system allows us to understand the rationale about inclusion that is formed in the system, which means that one can define the major trends in how knowledge and value assessments are produced in a particular GIS configuration that includes or excludes actors. This is very relevant because by understanding such rationale, one can define the premises behind how and why certain actors should or should not be included, and which strategy should be followed for including them more effectively. In this sense, it becomes important to address issues such as knowledge translation, ethical guidelines, or the formation of channels for communication, as they become part of the analysis of how an integrative innovation system should work (Arocena et al. 2018). For example, firms capable of performing the analysis and those aiming to invest in a particular technology and become involved in a specific innovation system will have an advantage when identifying power disparities or intervention strategies.

Methods

The analysis reported in this paper was based on an actor-network map created with empirical data.

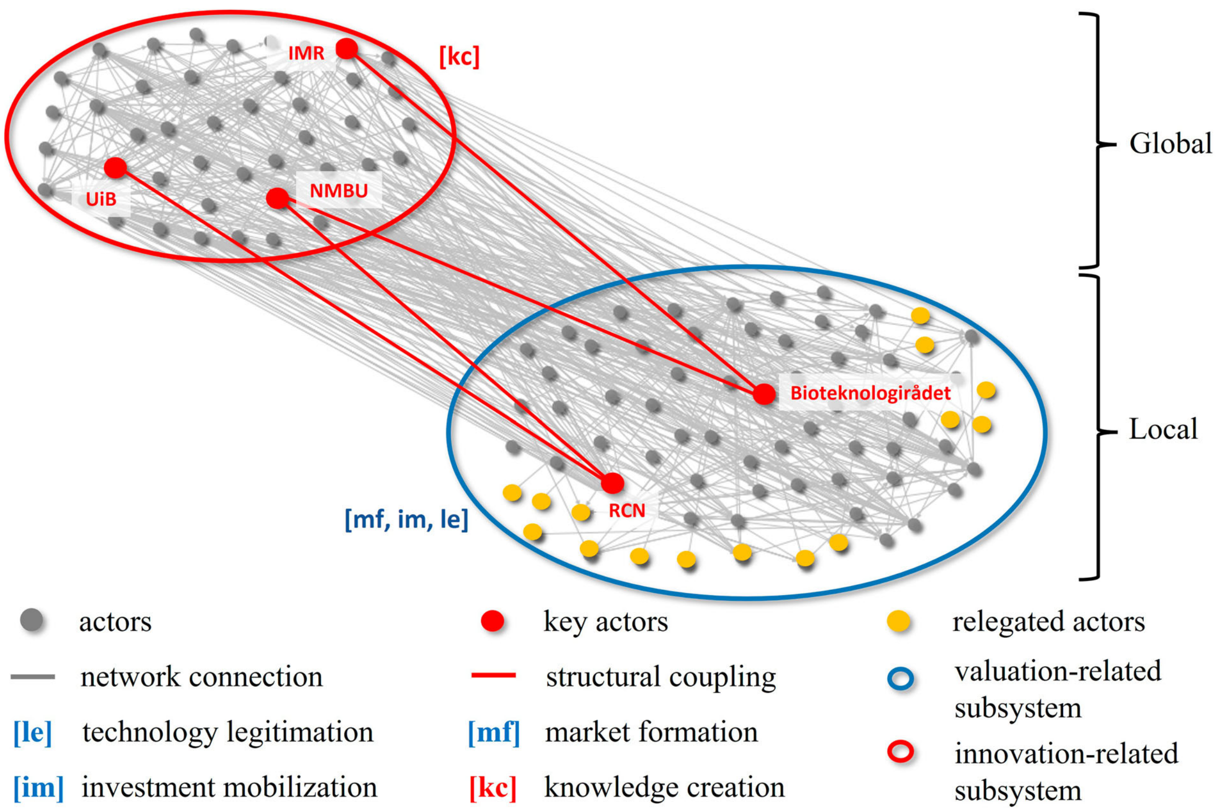

Fig. 1. Market-anchored, global innovation systems (GIS) map of CRISPR innovation in the salmon farming industry in Norway, and the key actors: Institute of Marine Research (IMR), Norwegian University of Life Science (NMBU), University of Bergen (UiB), Norwegian Biotechnology Advisory Board (Bioteknologirådet), Research Council of Norway (RCN)

The map contains two main elements: first, the relations formed by actors participating in innovation projects that focus on the use of CRISPR in the Norwegian salmon farming industry; and second, the formation of subsystems between such actors in accordance with the conceptual premises of GIS. The map (Fig. 1) allows us to distinguish the subsystems formed by actors and the way in which the subsystems are connected. In this way, we can visually understand the rationale that exists in the GIS configuration of CRISPR salmon.

Due to the lack of comparable systematic and extensive data, most studies that have applied GIS as a concept have used historical interpretative data obtained through qualitative case studies, and not firsthand empirical data (Hansmeier et al. 2021). However, the Norwegian salmon farming industry has firsthand material available because most innovation related to CRISPR is publicly funded in Norway and thus adheres to strict transparency regulations. This provides an opportunity to establish methodologies that can "move towards more configurational theorizing" in studies of transitions (Heiberg et al. 2022, 2). Following Heiberg & Truffer (2021) and Heiberg et al. (2022), we constructed a sample GIS map by applying socio-technical configuration analysis (STCA), which allowed us to classify actors in subsystems on the basis of the system resources that they generate.

The primary data were taken from descriptive data material relating to innovation projects focusing on CRISPR innovation within the Norwegian salmon farming context. Most of the data comprised project descriptions that explained the motives, background, objectives, and results of a particular innovation, such as projects focusing on the use of CRISPR in salmon to improve the salmon's metabolism (Research Council of Norway n.d.). The information was found in the databases of financial institutions, on innovation network platforms, and in patent registries in Norway, including the Research Council of Norway, the Norwegian Seafood Research Fund (FHF), the Stiim Aqua Cluster, and NCE Seafood Innovation, among other sources. We used these data material to identify the involved actors in each innovation project and thereafter define the type of system resources they generate when making innovations with CRISPR in salmon farming. The identification of system resources was done by coding the texts in an STCA. The process involved the use of the software NVivo, whereby we developed a coding structure that allowed us to distinguish the different types of knowledge and value assessments that actors used within the innovation projects descried in the data material from which our data were collected. The coding structure was determined by using the same terminology as used for GIS (Miörner et al. 2022). As a result, we were able to group actors working with the same system resources (subsystems) and classify them using the same method as Binz & Truffer (2017).

Besides the studied data material describing the research projects, information for our categorizations was also taken from 10 interviews with key stakeholders involved with CRISPR in the Norwegian salmon farming industry. The interviews consisted of asking key open questions about how the salmon innovation system functioned, who the main actors were, and how inclusion practices were performed within the system. The interviewees represented one governmental agency (Mattilsynet), three independent organizations (Bellona, the Norwegian Seafood Federation, and the Norwegian Biotechnology Advisory Board), four research institutions (Institute of Marine Research (Havforskningsinstitutttet), Nofima, University of Bergen, and Western Norway University of Applied Sciences), and three private companies (Skretting, Lerøy Seafood Group, and Grieg Seafood). All interviews were tape-recorded, transcribed, and analyzed separately.

The data used for making the map were manually inserted into the software program NodeXL, which we then combined with the large database obtained from NVivo about each actor that depicting the type of knowledge and value assessments they made. In that way, we were able to identify and visualize all the relations created by actors involved in the projects (Fig. 1). The resulting map includes 28 innovation projects, 86 actors, and 11,358 linkages. Thereafter, by applying algorithms already embedded in NodeXL, we were able to group actors by their system resources and create subsystems. Then, by using the indicator of "betweenness centrality," we identified key actors. This indicator considers nodes (actors) that act as information bridges between other nodes in a network (Hartmann 2014). Based on our interpretation of the GIS framework, we define such bridge-type nodes as the key actors forming structural couplings.

Building a GIS visualization of CRISPR salmon innovation

CRISPR salmon and the related system resources

Although biotechnology innovation in salmon has a long history, recent developments in CRISPR have pushed its potential to a higher level, both technically and in economic terms (Gratacap et al. 2019). CRISPR is a tool for altering DNA sequences in a very precise way so that specific functions can be attained. Its use can correct genetic defects, silence genes, or improve the resilience or growth of organisms. In addition to the potential to "edit in" disease resistance, improve nutrition profiles such as by making omega-3 production and better feed, or helping salmon to adapt to new ecological conditions due to climate change, gene editing is especially useful for rendering farmed salmon sterile. This process has been shown to be technically possible and effective, which means that CRISPR has the potential to provide solutions to the most critical problems that the industry, regulators, and consumers face (Okoli et al. 2021).

Using CRISPR to sterilize salmon is achieved by inactivating a particular gene to prevent farmed salmon from developing germ cells (Wargelius 2019). One of the innovation projects descried in the data material from which our data were collected has used CRISPR to make salmon resistant to sea lice, which is the most serious problem currently faced by the salmon farming industry. CRISPR is also being used to control time of maturity and disease resistance in salmon, and to develop genomic sequence data to provide more effective daily breeding operations. Additionally, various efforts are being made to help fish adapt to climate change by altering fish metabolism. Nevertheless, the most striking innovation using CRISPR in salmon is its application in gene inactivation to control light-sensitive hormones so that daily routines can be influenced.

The type of knowledge that serves as a basis for innovations using CRISPR is mainly guided by scientific principles and is technology-driven innovation at its core (Zyontz 2019). This mainly due to the nature of biotechnology, namely that knowledge generated by biotechnology is the result of experimentation from in-lab techniques that can be synthesized in models, patents, and reports. It is a type of knowledge that has no geographical identity and can be developed and integrated in any place in labs with the right equipment and know-how (Jensen et al. 2007). Given that such knowledge can easily be disembodied and exchanged in space, thereby generating knowledge spillovers beyond local boundaries, it is referred to as footloose knowledge (Martin & Moodysson 2013). By contrast, the value assessments carried out on CRISPR innovation are geographically "sticky" (Okoli et al. 2021) because manufacturing, mobilizing investment, and legitimizing CRISPR innovation are activities mainly based on criteria defined by local actors and institutions (Zyontz 2019). Although several aspects of value assessments based on the outcome of the use of CRISPR depend on internationally agreed guidelines, such as the Cartagena Protocol on Biosafety (Rosado & Eriksson 2022), the specific ways in which innovations are socially addressed depend on national jurisdictions and market dynamics. The way in which value assessments of CRISPR innovations are conducted in one country differ from those in another country, thus making it clear that they are a local-dependent process regarding how they are perceived by both consumers and regulators (Shew et al. 2018).

The rationale of the GIS configuration of CRISPR salmon

Given that innovations using CRISPR in the Norwegian salmon farming industry are based on footloose knowledge and local value assessments, the resulting GIS configuration is defined as "market anchored." This is depicted in Fig. 1, where relationships between two subsystems are identified: the main innovation-related subsystem, which comprises actors involved in knowledge creation (shown in red), is global; the valuation-related subsystem (shown in blue) is local. In Fig. 1, the red lines linking the key actors are the structural couplings, which are defined as the most important relations connecting the subsystems. These structural couplings connect the five most important actors, upon which the other actors are dependent for inclusion in the innovation system.

The actors developing footloose knowledge (circled in red in Fig. 1), are not only research institutions but also involve salmon-producing companies and service providers. They build knowledge through networks of science, where the priorities are set by technical terms and the argumentation is based on technological vocabulary. These actors' recompilation of information occurs mainly through the diffusion of papers published in international journals. Thus, their strategy for influencing society is through formal information channels and is conducted in a top-down manner. The same actors focus on technological issues for which the goal is to determine clear-cut solutions, and they tend to present their initiatives as apolitical. These characteristics may due not only to the nature of CRISPR technology per se, but also due to gene technology only being legal in Norway for research purposes.

The actors involved in making value assessments of CRISPR salmon (shown circled in blue in Fig. 1), comprise actors that make different types of value assessments. The current controversy concerning CRISPR centers on the issue of legitimization, hence most actors focus on this controversy. In Norway, various civil society organizations, union platforms, government agencies, and even private firms are active in this regard and as their main source for information is the Norwegian Biotechnology Advisory Board (Bioteknologirådet). Moreover, these same actors are active in market formation as either future producers or consumers, given that CRISPR-based products have not yet been commercialized. The relegated actors within the network (i.e., those with the lowest number of connections) (see Fig. 1) are mainly civil society organizations and network platforms. The actors active in mobilizing investment are government institutions that provide funds and are mainly involved in research-based innovation projects (e.g., the Research Council of Norway).

The fact that the analyzed case forms a market-anchored GIS gives a clear idea about the type of rationale that is behind the GIS for CRISPR salmon. This can be seen by the relations formed through the structural couplings, which connect the subsystem defined as generating global knowledge with a subsystem generating local value assessments. This in turn indicates that the rationale in the innovation system centers on how footloose knowledge is communicated and/or influenced by the value assessments made by local actors. In other words, the rationale is all about *capturing footloose knowledge and applying it in strategies that target value assessments made at a national level.* Based on this rationale, in the next section we discuss how inclusion should be addressed within the innovation system for CRISPR salmon in Norway.

The rationale for systemic inclusion in a CRISPR salmon market-anchored GIS

Systemic inclusion and footloose knowledge in CRISPR salmon innovation

Throughout the analyzed documents in data material, we found clear common suggestions as to why footloose knowledge must be taken seriously to make the innovation system for CRISPR salmon more inclusive (Brossard et al. 2019). This implies that inclusivity should focus on facilitating actors of all types and that are operating at all levels to access footloose knowledge. Highlighting footloose knowledge does not mean that other types of knowledge should be neglected; rather, it simply crystallizes the logic behind the nature of the technology that is being addressed. Seemingly, taking other types of knowledge as equal would to be more logical when aiming for inclusion, but this is a would be as misunderstanding because it would not follow the rationale of the innovation system.

One interesting observation made when coding the data material that described the type of knowledge concerns gene technology being proposed as a scientific-based solution to problems within the industry for which other technologies have not been able to give satisfactory results. This shows the importance of prioritizing footloose knowledge when acknowledging the relevance of CRISPR innovation for salmon production, as it is a type of innovation that arises from the need to find new scientific solutions to scientific problems. For example, initiatives for tackling salmon lice have focused on mechanical options such as the use of warm water, physically brushing the fish's skin, or using medical or chemical alternatives (Overton et al. 2019). One of the most commonly applied methods is the use of other fish that eat the lice on the salmon, which would seem an acceptable solution but has been criticized for the lice-eating fish to be killed before harvesting the salmon (Garcia de Leaniz et al. 2022). Similar criticisms have been made about projects that aim to sterilize salmon or change hormonal behavior.

Furthermore, a common thread identified when coding the data material relating to the need to prioritize footloose knowledge when aiming for inclusion was their reference to how risk should be understood. In all cases, the focus on risks is on their potential to occur, not on the negative consequences that have actually occurred (Archibald 2018). Most attention is given to the fact that little is known about gene technology (Okoli et al. 2021). Thus, the argumentation for handling risk is usually framed as the need to be preventive, and follows the precautionary principle, which is required by law in Norway. Although assessing an "acceptable" level of risk is important, it does not mean that gene technology per se is risky or at least riskier than other technologies that are already in use. The aim should therefore be to reflect on real risks by prioritizing scientific knowledge to avoid unjustified speculation. It is documented that the potential risk of gene technology is equal to or lower than the technologies already being used for the same objective, such as triplodization for sterilization or the use of antibiotics (Dankel 2018). Therefore, the inclusion of more ideas in the global innovation system should prioritize those relating to the acquisition of knowledge that would minimize unscientific risk assumptions.

Systemic inclusion and the importance of local value assessments in CRISPR salmon innovation

When aiming for systemic inclusion, the need for local actors to make value assessments should be prioritized within the innovation system because it is where key value assessments are made. Hence, inclusion in the global innovation system (GIS) for CRISPR salmon in Norway should be based on recognizing the influence that local actors have in shaping the local political structure. It is important to consider local actors in order to understand who and how to include new voices, as it is in this context that constructive criticisms of sociocultural and socio-economic terms can be found.

When we coded the data material described by actors who had made value assessments about gene technology, we found that they focused on issues at a national level. This might have been because it has proven important to consider local actors when determining legal challenges relating to genetically modified organisms (Tagliabue 2016). Taking local value assessments seriously is vital in order to understand the potential legal obstacles that gene technology innovators might have, either due to direct bans or severe regulation procedures (Callegari & Mikhailova 2021). Interestingly, and consequent to the GIS rationale, such argumentation does not need to be grounded on footloose knowledge but is political and/or ethical in nature. This is clearly seen in how actors representing consumers or final users articulated their arguments, wherein their main idea was to highlight the potential risks by framing their speculations on ethical grounds rather than on scientific arguments.

Independently of these legal and market reasons, it is important to stress that acknowledging local value assessments when aiming for systemic inclusion is critical because it is the most effective way to capture the collective wisdom of potential sociopolitical risks (Zhang et al. 2016). This in turn can lead to critical ideas about perceptions that are difficult for innovators to realize, and much more so for actors who produce footloose knowledge but are not directly involved in local matters, conflicts, and dilemmas. Such ideas could be related to future visions, lifestyles, social priorities, and economic and political models that need to be questioned in order to create the basis on which innovation systems operate (Scheufele et al. 2021). Such social imaginary is an important element in order to understand not only how an innovation will be accepted but also how it could be used and how it might evolve over time.

Conclusions

Acknowledging systemic inclusion in a market-anchored GIS on theoretical terms implies generating channels for democratic participation (Arocena et al. 2018) between footloose knowledge and value assessments made at a national level. This notion, which we refer to as the rationale of the innovation system, is expressed by Binz & Truffer (2020, 407) as follows: "rather than supporting basic R&D or breakthrough innovation locally, a smart governance design [as inclusion in a market-anchored GIS] would encourage the local industry to access globally available innovative ideas and optimize their (economic/social/environmental) performance in demanding local applications." Therefore, inclusion in a CRISPR salmon market-anchored GIS should strengthen and expand the relations between the subsystems with respect to the type of system resources being generated in the innovation system.

Explicitly, inclusion of knowledge production concerning CRISPR salmon innovation in a market-anchored GIS is about facilitating the access of footloose knowledge to local actors and is a process of strengthening a top-down approach to communication. From our analysis of our GIS map (Fig. 1), we see that this means channeling scientific fact-based information to the local actors making the decisions. The underlying logic is to create interactive spaces in which footloose-knowledge producers (not only researchers but also actors within companies and civil society organizations) are given the opportunity to explain their work and their technical reasoning. This is critical because such opportunities are not always the case, as several gene technology approaches tend to minimize the importance of scientific language with the intention of incorporating other voices. Such approaches can be misleading because they may cause negative effects in the innovation process if the importance of footloose knowledge is not established. The incorporation of actors making value assessments should focus on the local criteria for developing guidelines in legal, social, and cultural terms, and/or ethical bottlenecks, and not on blocking the production of scientific knowledge. This approach gives rise to a process wherein all actors are conscious of their co-responsibility within the system and their need to be responsive toward it (Blok et al. 2015).

Our analysis provides a theoretical contribution to the literature on global innovations systems (GIS) by extending the concept of value assessments as they relate to the RRI literature. This is important because to date the concept of value assessments in GIS has mainly emphasized the economic side of innovation (Heiberg & Truffer 2022). Considering value assessments through the concepts portrayed by RRI opens up for the opportunity to address ethical perceptions that should be seen as vital for any GIS analysis, such as the issue of inclusion we have described in this paper. Furthermore, acknowledging inclusion from a systemic point of view is relevant for the RRI literature because it suggests how inclusion can adopt analytical elements from the innovation systems literature for a more pragmatic RRI analysis, as suggested by van Mierlo et al. (2020).

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