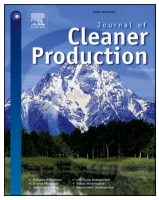
Journal of Cleaner Production 408 (2023) 137045

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro



Resilient or environmentally friendly? Both are possible when seafood businesses prepare for long-term risks

Rebecca St. Clair [a], Dimitrios Pappas [b,e], Carly Fletcher [c], Maria Sharmina [d,*]

[a] Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, United Kingdom
[b] Business School, Liverpool Hope University, Hope Park, Liverpool, L16 9JD, United Kingdom
[c] Department of Natural Sciences, Manchester Metropolitan University, Manchester, M15 6BH, United Kingdom
[d] Tyndall Centre for Climate Change Research, School of Engineering, University of Manchester, M13 9PL, United Kingdom
[e] Tyndall Centre for Climate Change Research, Faculty of Science, University of East Anglia, NR4 7TJ, Norwich, UK

ARTICLE INFO

Handling Editor: Jian Zuo

Keywords:
Resilience
Seafood business
Circular economy
Adaptive capacity

ABSTRACT

To ensure sustainable seafood production for future generations, seafood businesses must be resilient in the face of future shocks and stresses. Recent research suggests that by increasing alignment with principles of circular economy such as eliminating waste and regenerating natural environments, seafood companies may be able to improve their general resilience (i.e. resilience to unforeseen disruptions). Research presented here empirically explores potential links between circular economy, risk mitigation and resilience through a survey and workshops with seafood businesses in the United Kingdom. We found that many of the seafood companies participating in our research are actively implementing a range of circular economy actions such as recycling materials and minimising the use of single-use plastics. When identifying specific risks, businesses tended to adopt short-term mitigation measures that were less likely than longer-term measures to be aligned with circular economy principles. While businesses felt confident about their ability to adapt to and survive future risks, a focus on short-term risk mitigation might reduce their capacity to plan for longer-term risks. An inability to identify and prepare for longer-term risks may also impede businesses' ability to increase their resilience to unforeseen disruptions and lock companies into a reactive, rather than a capacity-building cycle of risk mitigation.

1. Introduction

The UK seafood sector operates within a turbulent global and national context, and is vulnerable to shocks and stresses such as the UK's departure from the European Union (EU) (hereafter referred to as Brexit) (Symes and Phillipson, 2019), climate change (Cheung et al., 2012), and the COVID-19 pandemic (Mangano et al., 2022; Seafish, 2021). While the seafood sector is associated with environmentally damaging impacts such as the depletion of fish stocks and pollution, seafood production is less resource intensive than many alternative animal-based protein sources due to its relatively efficient feed conversion rates (Béné et al., 2016; Farmery et al., 2017) and provides an important source of essential omega-3 fatty acids and micronutrients (FAO, 2022). To improve sustainability and maintain viability, seafood businesses must embrace more environmentally sensitive practices while developing measures that enable them to function in the face of disruptions.

Since the mid-twentieth century, the global seafood system has mirrored the wider agri-food system's trend of increased output and yield (FAO, 2022; Focker et al., 2022). In 2020, when a record 214 million tonnes of seafood was produced, production of aquatic animals was 60% higher than 1990, mainly due to the growth of aquaculture (FAO, 2022). Increased seafood production has positive consequences for food security, employment and the economy; however, the intensification of aquaculture has negative implications for health and the environment such as the emergence of infectious diseases, antimicrobial resistance, and an over-reliance on wild-caught fish for feed (FAO, 2022; Miranda et al., 2013). Furthermore, the efficiency of seafood and aquaculture systems is compromised by waste generated at various points of the supply chain including production, processing and retail (Dauda et al., 2019; Ruiz-Salmón et al., 2020). In order to build a seafood system fit for the future, businesses must seek opportunities for waste products to be reused or valorised (Cooney et al., 2023).

* Corresponding author.
E-mail addresses: R.stclair@leeds.ac.uk (R. St. Clair), pappasd@hope.ac.uk (D. Pappas), carly.fletcher@mmu.ac.uk (C. Fletcher), maria.sharmina@manchester.ac.uk (M. Sharmina).

https://doi.org/10.1016/j.jclepro.2023.137045
Received 3 November 2022; Received in revised form 24 March 2023; Accepted 30 March 2023
Available online 5 April 2023

In this paper, we draw upon the concepts of *circular economy* and *resilience* to explore ways in which businesses in the UK seafood sector can improve their environmental sustainability and their capacity to respond to unforeseen shocks and stresses. This research addresses the need to develop and operationalise the concept of resilience for seafood systems in a way that moves beyond resilience as a means of absorbing shocks (Béné et al., 2016) to one that builds capacity for meaningful adaptation and considers multiple dimensions of sustainability (Love et al., 2021; Mason et al., 2022). In doing so, we build on research that highlighted links between circular economy actions and general resilience mechanisms, and laid foundations for developing a framework combining the two (Fletcher et al., 2021). The Circular Economy Resilience Framework for Business Models (CERF-BM) (see section 2.3), illustrated the need for research to investigate synergies between circular economy and resilience to establish steps for seafood businesses to decrease their impacts on the natural environment while increasing their ability to adapt and survive (Fletcher et al., 2021). In response, our research explores and extends these theoretical links empirically to bridge the conceptual gap the CERF-BM identified. The key contribution of our research, therefore, is its use of circular economy principles to explicate and operationalise resilience for both theory and practice.

Our aims are threefold. First, we assess the extent to which businesses participating in the research engage in (or plan to develop) activities that improve their circularity. Second, we explore whether links can be drawn qualitatively between businesses' adherence to principles of circular economy and resilience mechanisms. Third, we gauge businesses' perceptions of risks and assess whether measures taken to mitigate against specific risks influence companies' adherence to circular economy principles.

The next section reviews literature to provide context for the key concepts used in this paper: circular economy and resilience. This is followed by an explanation of the CERF-BM and its application in the seafood sector. Our methodological approach is described in the subsequent section, followed by results from a survey and workshops with seafood businesses from across the supply chain. The article ends with a discussion of key findings, our contribution to theory and practice, and conclusions.

2. Literature review

2.1. Circular economy

Grand societal challenges and growing environmental emergencies associated with climate change, biodiversity loss and pollution, are symptomatic of our linear 'take-make-waste' model of consumption. To address these challenges, transition to a more sustainable system is needed (Baste and Watson, 2022). A circular economy represents a shift away from a wasteful linear system towards a regenerative closed-loop system. This transition requires reducing resource use, eliminating waste and pollution, designing long-lasting products, and focusing on repair, reuse and recycling rather than disposal (Geissdoerfer et al., 2017).

With origins rooted in Brundtland's definition of sustainable development, the circular economy conceptualises the integration of economic activities and environmental well-being (Murray et al., 2017). While the circular economy concept was coined several decades ago, consensus over its definition is yet to be reached, and a wide variety of definitions exist within academic and practitioner literature (Kirchherr et al., 2017). Most definitions include some application of the '3R' principle (reduce-reuse-recycle) and tend to align with a specific stakeholder group(s). Common limitations of existing definitions include limited acknowledgement of the vast systemic change required and the role of business models and consumers as agents of change. Furthermore, very few definitions link circular economy principles with all three dimensions of sustainable development (Corona et al., 2019). For the context of this study, a circular economy is defined as "*an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes*" (Kirchherr et al., 2017, p. 229).

The lack of a common definition has led to the proliferation of different metrics and indicators which have been developed to measure and evaluate the circularity of businesses and systems (Corona et al., 2019). Circular economy metrics can be distinguished through three clusters covering resource efficiency, material stocks and flows, and product-centric assessments (Parchomenko et al., 2019), with most indicators focusing primarily on material flows and end-of-life strategies (Rossi et al., 2020) and measurements restricted to pre-defined goals (Corona et al., 2019). As such, the narrow scope of circular economy metrics only sheds light on limited aspects of circularity (Rossi et al., 2020), and in doing so, may increase the risk of burden shifting (Corona et al., 2019). To overcome these limitations, Parchomenko et al. (2019) suggests that the future development of circular economy metrics should seek to better integrate policy, economic or business aspects. This recommendation aligns with the idea that circular economy metrics should include all dimensions of sustainability (Rossi et al., 2020).

Akin to other models of sustainability, the circular economy requires innovative concepts and actors (Hamam et al., 2021). A key difference between the broad concept of environmental sustainability and the circular economy is their respective levels of operationalisation. Where the concept of sustainability provides overarching objectives and ambitions, circular economy principles provide specific strategies and approaches that allow engagement with companies of all sizes and across a range of stakeholders (Murray et al., 2017). As such, transition towards a circular economy is high on the political agenda, and is being implemented (with varying degrees of success) within numerous sectors, including mining, energy, waste management, construction, and food production (Kalmykova et al., 2018).

With respect to food systems, transition towards a circular economy implies reducing waste generated across the value chain, re-using food where possible, utilising by-products and food waste, and mimicking and supporting natural nutrient recycling cycles, as well as promoting more diversity in diets (Jurgilevich et al., 2016). Circular economy principles are relevant for the seafood sector across the supply chain. At the level of production, wild fisheries must negotiate a balance between providing an essential source of protein and exerting minimal pressure on marine ecosystems (de Carvalho-Souza et al., 2021), while a growing aquaculture industry must adopt a less resource intensive approach to aquafeed production and embrace production methods that support, rather than damage, neighbouring ecosystems (Kusumowardani and Tjahjono, 2020). Processors (primary and secondary) must reduce waste through careful by-product management (Do et al., 2022), and both retailers and processors must consider seafood packaging that is recyclable, makes use of waste products, and extends the life of the product (Almeida et al., 2023, 2023de la Caba et al., 2019). A more circular seafood system would reduce resource use, rely more on renewable resources, and identify and utilise opportunities for the valorisation of by-products across the supply chain (Cooney et al., 2023).

There are several obstacles to the adoption of circular economy measures, and in a study of processors in the seafood industry, Do et al. (2022) categorises barriers into regulatory (e.g. policy/financial support), socio-cognitive (e.g. a reluctance to view by-products as valuable), economic/supply chain (e.g. instability of demand) and technological barriers (e.g. difficulty scaling up operations). To overcome these barriers and to facilitate circular economy actions in the seafood sector more broadly, there is still a need for research that considers circular economy actions from a sector-wide, multi-stakeholder perspective (Do et al., 2022; Govindan and Hasanagic, 2018).

2.2. Resilience

Resilience is a contested term (Brand and Jax, 2007; Sharmina et al., 2016) but can be broadly defined as the ability to maintain functionality

in the face of adversity (Tendall et al., 2015). Resilient systems are robust and flexible enough to withstand short-term shocks and longer-term stresses while maintaining the capacity for continued innovation and development (Folke, 2006). From an organisational perspective, resilient businesses can "anticipate, avoid and adjust to shocks in their environment" (Ortiz-de-Mandojana & Bansal, 2016, p. 1615). While the concept of resilience has been shaped, refined and adjusted for a variety of contexts in recent years, the means by which we can clarify and operationalise resilience remains an important area for investigation (Folke, 2006; Folke et al., 2021; Stoll et al., 2016).

Resilience has been conceptualised in terms of either a system's or an organisation's ability to adapt to specific, identifiable risks (specified resilience) or its capacity to deal with unforeseen risks and to survive in the face of uncertainty (general resilience) (Folke et al., 2010). It has also been characterised as desirable or undesirable (Carpenter et al., 2001) and as helpful or unhelpful (Standish et al., 2014; Stoll et al., 2016), recognising that resilience for one actor in a system may compromise the resilience of the system as a whole and that resilience is fluid, dynamic and context-dependent (Beitnes et al., 2022).

An important component of resilience is *adaptive capacity,* which has been conceptualised in various ways (Gallopín, 2006). Adaptive capacity can refer to a system's ability to cope or respond to disturbances (Smit and Wandel, 2006), but is distinct from *coping capacity*, which is the ability to both respond to harm and avoid the harm that may arise from particular risks (Turner et al., 2003). In relation to human and human-environment systems (including communities, organisation and sectors), Smit and Wandel (2006) note that *coping ability* is a shorter-term faculty than adaptive capacity, which is the ability to make sustainable adjustments over a longer period or for the longer term. A system's or organisation's capacity of response exists before the shock takes place.

The adaptive capacity of a social ecological system comprises both the ability to survive changes in its environment (i.e., to continue to function or even improve in the face of perturbations) *and* the ability to enhance its condition even without changes in the environment or to develop its capacity to adapt to a wider range of environments (Gallopín, 2006). In this article, our understanding of adaptive capacity includes the ways in which systems, sectors and organisations learn and evolve following disturbances (Carpenter et al., 2001) and the ability of people within systems to coordinate and develop resilience (Walker et al., 2004) to be able to adapt and survive in the face of future perturbations. Adaptive capacity may even extend to a system, sector or business being able to take advantage of opportunities emerging from crises or disruptions.

Resilience is a useful conceptual tool through which we can build our understanding of the capacity of seafood systems to prepare for, respond and adapt to disruption. For example, resilience of seafood production means supporting marine ecosystems to ensure the sustainability of fish stocks in the face of climate change impacts (Cheung et al., 2017). Resilience can be strengthened through diversifying products (Fletcher et al., 2021) and diversifying and embracing multiple scales of distribution to help seafood systems function in the face of stress (Stoll et al., 2015, 2021). In the UK's seafood sector, diversity is stifled by the narrow range of seafood products UK consumers are willing to buy (or that supermarkets sell), and by the market domination of a small number of large businesses. For example, of 4150 registered fishing businesses in the UK, 90% have 1–5 employees, while 25 businesses control more than 60% of the total fishing quotas (Uberoi et al., 2022).

Recent disruptions stemming from Brexit and COVID-19 illustrate the interconnected nature of international seafood systems and the ways in which domestic policy decisions can have global implications for resilience. For example, while the decision to leave the EU was made by the UK electorate (including 92% of UK fishers), it affected businesses and trade internationally (Connolly et al., 2022). Given that most of the seafood consumed in the UK is imported, and most UK-produced seafood is exported (Seafish, 2022), resilience in the face of disruptions to international trade is a particularly important consideration.

A challenge for the development of food systems resilience is the tendency to focus on the ability of actors or organisations to cope with, or absorb, shocks and disturbances (Béné et al., 2016) or to view food as primarily an economic commodity rather than a necessity for life that has wide-ranging social and environmental implications (Hodbod and Eakin, 2015). This framing can have a detrimental impact on the potential for meaningful adaptation and systemic transformation without unintended consequences. In order to operationalise desirable resilience for seafood systems, there is a need to further explicate the concept through the exploration of measures that build the capacity for adaptation (Mason et al., 2022) and through the development of frameworks that include social and environmental dimensions as well as economic indicators (Love et al., 2021).

2.3. Circular Economy Resilience Framework for Business Models (CERF-BM)

Previous research proposed theoretical links between resilience mechanisms and circular economy principles to help support the shift towards more sustainable seafood production (Fletcher et al., 2021). The Circular Economy Resilience Framework for Business Models (CERF-BM) was developed with the aim of helping seafood companies to evaluate their own business practices, while acknowledging and connecting with the wider food system (Fletcher et al., 2021).

The CERF-BM uses the Business Model Canvas (BMC) to describe companies using nine categories: the value proposition, customer segments, customer channels, customer relationships, key activities, key resources, key partners, cost structure, and revenue streams (Osterwalder and Pigneur, 2010). The framework incorporates the IReSOLVE (Implement, Regenerate, Share, Optimise, Loop, Virtualise, Exchange) checklist, first developed by the Ellen MacArthur Foundation and later adapted by Mendoza et al. (2017) and includes four resilience mechanisms derived from Schipanski et al. (2016): 1. diversification across the value chain, 2. utilisation of ecosystem services, 3. promotion of local systems, and 4. knowledge exchange between stakeholders. During framework development, links were made between different circular economy principles (IReSOLVE checklist categories) and resilience mechanisms (Fletcher et al., 2021). Using the CERF-BM, companies can map their current business model and then using the IReSOLVE checklist can determine level of alignment with circularity principles and identify areas for improvement.

Following the development of the CERF-BM, this article contributes to the operationalisation of the concept of resilience by drawing on the circular economy concept to suggest concrete actions by which businesses may improve their general resilience. This paper also develops the theoretical underpinnings of the CERF-BM by considering adaptive capacity as a lens through which resilience may be strengthened.

3. Methods

We took a mixed-methods approach, using a survey and online workshops, to address the aims outlined in the introduction. The triangulation of survey and workshop methods allowed for a thorough exploration of a complex issue (Azorín and Cameron, 2010) and for the elaboration of theory (Turner et al., 2017). The survey and workshops had the shared purpose of exploring theoretical links between resilience and circular economy and developing the CERF-BM. The survey yielded concise answers to a broad range of questions from a larger pool of respondents, while the workshops adopted a participatory approach that allowed for an in-depth exploration of the rationale behind the choices made by a smaller selection of participants.

In both the survey and workshops, existing business models were described using the BMC, the company's adherence to circular economy principles was assessed using the IReSOLVE checklist, and resilience was considered in the context of the four resilience mechanisms described in

the CERF-BM.

3.1. Survey

To understand how well (if at all) current business models align with circular economy principles and to explore businesses' perceptions of risks, we undertook a survey of UK seafood companies. Development of the survey instrument was informed by literature, specifically with respect to circular business models, sustainability and resilience as described in the development of the CERF-BM (Fletcher et al., 2021). The survey instrument used closed (multiple choice and Likert-style responses) and open-ended (text box) questions, structured across five sections.

Section 1 (Company Profile) of the survey collected information about companies such as legal status (sole trader, limited company, or partnership), year of establishment and size (either Micro, Small, Medium, or Large, as categorised by the UK government).
Section 2 (Current Business Model) was based on the BMC (Osterwalder and Pigneur, 2010) and collected information about the company's business model, highlighting unique selling points, choice of production system, customer relationships and experiences of diversification. This section also asked about the company's role in the wider supply chain, and the importance and/or prioritisation of physical, human, intellectual and financial resources.
Section 3 (Sustainability and Circular Economy) asked to what extent the company prioritised different aspects of sustainability linked to the environment, financial viability, and food security. It also asked companies about specific actions towards circular economy and the level/stage of implementation.
Section 4 (Resilience) asked companies about the impact (both in terms of severity and direction) and their ability to adapt (both in the short and long term) to a range of shocks (energy price fluctuation, regulatory changes, automation, critical ingredient shortfall, and election/referenda results) and stresses (climate change, resource degradation, changes to diet, urbanisation, food scares, trade wars, and fall in demand).
Section 5 (Future Ambitions) sought to understand ambitions the company may have for the next five years, with a specific focus on plans to diversify. The companies were also asked to identify potential barriers or threats that may negatively impact their ambitions.

We used purposive sampling to identify respondents, which is a technique often used in qualitative research and exploratory studies (Palinkas et al., 2015; Yin, 2015). While this approach may entail a higher risk of bias than probability sampling (Etikan et al., 2016; Stratton, 2021), our reasons for employing this technique included: the generally acknowledged difficulty in reaching this population (small- and medium-sized enterprises); the COVID-19 lockdowns interfering with planned data collection; and the constraints imposed by the small scale of this research project in terms of its duration and finances. Similarly, the sample size was determined partly by the availability of resources (such as time and funding), and partly by the successful recruitment of a range of businesses across the seafood supply chain, rather than by a specific quantifiable threshold. As the research design did not involve econometric analysis, the sample size was sufficient for this exploratory study.

Companies were approached by email and invited to participate. Individuals of director status or above were targeted where their contact information was publicly available. Surveys were completed online by the respondent or via telephone at the convenience of the participant. Companies were initially contacted by researchers in September 2020, however due to disruptions caused by COVID-19 and an associated low response rate, recruitment of survey participants was put on hold and later outsourced to an external survey company. We recognise that this may have impacted our results, for example by giving the researchers less control over the data collection process. However, this risk had to be balanced against the possibility of cancelling the survey and we suggest that impacts are likely to be minimal as the process was carefully monitored by the research team. A total of 65 responses were collected from survey conducted between September and October 2020 (5 responses) and between February and March 2021 (60 responses).

We used a quantitative descriptive analysis to evaluate 65 responses from sections 2-5 of the survey. We selected results that concern the IReSOLVE circular economy actions and resilience mechanisms and grouped the responses both by the number of companies that selected each option, and by company type.

3.2. Workshops

We designed workshops to explore the alignment of business models with circular economy principles, to investigate perceived resilience in the face of short- and longer-term risks and to explore links between circular economy and resilience. The workshop design was influenced by the Backcasting and Eco-design for the Circular Economy (BECE) framework (Mendoza et al., 2017) and adapted using the conceptual developments from the CERF-BM (Fletcher et al., 2021). Circularity was investigated through the IReSOLVE actions of *Implement, Regenerate, Share, Optimise, Loop, Virtualise and Exchange.* For instance, installing solar panels on a hatchery roof, is categorised as Regenerate or sending fish guts for anaerobic digestion would be categorised as Loop. Resilience was assessed through four mechanisms: *Utilising Ecosystems; Promoting Local Systems; Knowledge Exchange; and Diversification.* The workshops were designed to be participatory and to encourage businesses to consider changes they could make to their business models to increase circularity (Heyes et al., 2018; Mendoza et al., 2017).

We approached individuals of director status and conducted workshops with six businesses from across the UK seafood supply chain: two producers, two processors, an importer/consultant and a retailer. Due to the size of the businesses participating in the workshops (SMEs), directors were well-placed to answer questions about business management and operational matters. The workshops were intended to allow for exploration of companies' current activities and future plans, and to generate ideas to improve the circularity of their business models.

Due to COVID-19 restrictions, we carried out the workshops online over Zoom between November 2019 and February 2020. While this was a change to the original research design, there is evidence to suggest that the quality of data produced using online methods is as high as from in-person events (Shamsuddin et al., 2021; Woodyatt et al., 2016). Each company participated in two workshops of approximately 2 h each with one-two weeks between each session. Workshops were attended by one or two company representatives and one or two researchers. Participants were asked for their permission to record the session to check for accuracy during analysis.

We conducted the workshops collaboratively whereby the researcher led the process but worked with the participants to explore issues and negotiate meanings (Ørngreen and Levinsen, 2017). Following similar steps used by Heyes et al. (2018), during the first workshop, the participant(s) and facilitator(s) began by discussing the company's visions for the company in a sustainable zero-carbon future and barriers related to these goals. Participants also identified company priorities, selecting the three most important. The first workshop ended by the facilitator sharing their screen and mapping the existing business model using the BMC (Osterwalder and Pigneur, 2010). Following the first session, the facilitator drew the company's visions into one cohesive vision statement, which was discussed and agreed upon during the next session.

At the second workshop, companies identified short-term risks (up to 1 year) and longer term risks (up to 10 years) along with mitigating measures they were either already taking or may take in the future. In line with the CERF-BM, the second workshop explored aspects of

business models that aligned with circular economy principles by identifying both existing actions and potential future actions using the IReSOLVE framework. Using the business priorities identified in the first workshop, the two future actions that were considered best aligned with the company priorities and future vision were selected. The workshops concluded by co-designing alternative business models using the two scenarios identified (Fig. 1).

We summarised data collected on business models, alignment with circular economy actions, risks and resilience into tables and carried out analysis using concepts from the CERF-BM to draw links between circular economy and resilience. Notes and recordings of workshops were used to check for accuracy and to add clarification to workshop outputs where necessary. Companies were anonymised and recordings were not transcribed or used for direct quotes.

4. Results

4.1. Details of participating businesses

To illustrate the range of participating companies, we begin our results with a description of the survey and workshop samples. When classified according to their self-reported primary revenue earning activity, the 65 survey respondents consisted of 22 retailers, 14 primary producers, 17 wholesalers, 12 processors, 6 exporters/importers, 3 suppliers to the service industry, and 1 seller to intermediaries. The 6 companies participating in the workshops comprised 2 primary producers (fish farmers), 2 processors, 1 importer/consultant and 1 retailer.

There are approximately 4150 registered fishing businesses, 344 processing sites, and 950 independent fishmongers in the UK (Holland, 2014; Uberoi et al., 2022), and our sample is not intended to be representative of the distribution of businesses across the sector. Instead, we aimed to gather insights from a range of different types of businesses in a variety of geographical regions across the UK (Fig. 2), acknowledging the need to represent a breadth of views from across the seafood supply chain (Tlusty et al., 2019).

4.2. Current and planned alignment with circular economy

We analysed survey and workshop results using the IReSOLVE circular economy checklist, which details seven categories of actions businesses can implement to increase their circularity (*Implement, Regenerate, Share, Optimise, Loop, Virtualise and Exchange)*. In terms of alignment with circular economy actions from survey responses, the most commonly selected example was "recycling materials/hardware" (Loop, n = 37), with the second most common being "minimising the use of single use plastics" (Loop, n = 30) (Fig. 3 and SI Figs. 1–8). The least commonly selected was "extracting resources from organic waste" (Loop, n = 6) and the second least common was "shifting to renewable energy and materials" (Regenerate/Exchange, n = 9). Four participants aimed to shift to renewable energy immediately, 15 within the next five years, and for 6 companies, it was part of their longer-term strategy. This finding was echoed in the workshops, where participants felt positive about generating renewable energy, (e.g. through installing solar panels), but acknowledged that the large investment made it a more distant priority. In comparison, the actions that companies were most engaged in, such as recycling and minimising plastic use, are easier and cheaper to adopt and more visible from a consumer perspective for some businesses, such as retailers.

All businesses surveyed considered environmental sustainability to be either a high or a moderate priority (Fig. 4) and, when categorised by primary revenue earning activity, processors appear to be the most proactive business type in terms of the number of circular economy actions they were carrying out (Fig. 5). It is important to note that the circular economy actions in the survey and workshops would have different levels of applicability for different business types. For instance, no retailers responded that they were taking actions to improve the health of the immediate ecosystem or extracting resources from organic waste.

During workshops, businesses identified actions they were taking to increase the circularity of their business models (Table 1) and actions that they planned/would like to take in the future. For existing actions, most could be classified under the IReSOLVE categories of Implement (e.g. engaging with research, developing a company vision for sustainability, and engaging with other businesses in the supply chain); Regenerate (e.g. buying wood from renewable sources for smoking, powering operations from renewable sources, and buying certified products); Loop (e.g. cleaning and reusing fish boxes, sending fish heads for fishmeal and recycling); and Virtualise (e.g. online sales of products

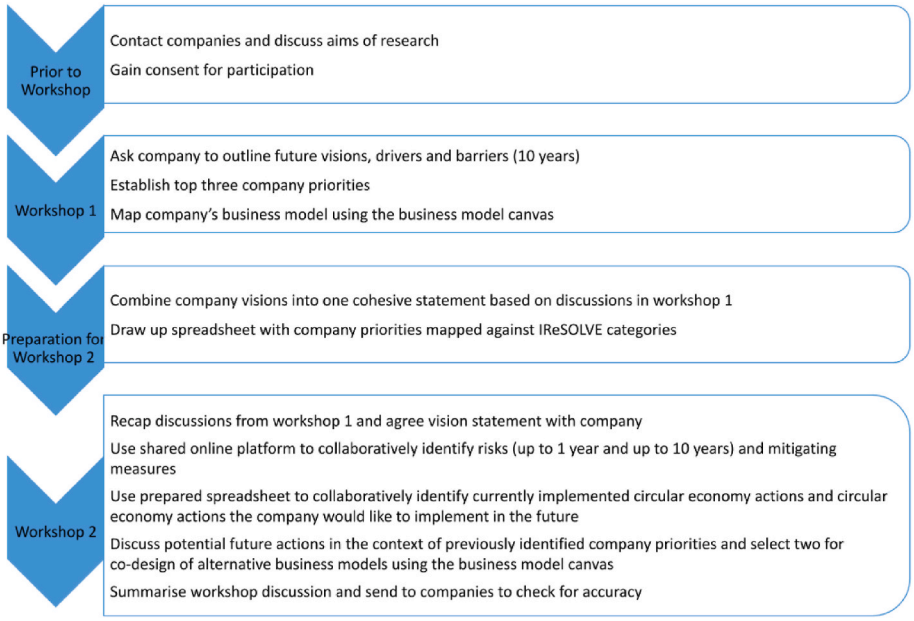


Fig. 1. Description of workshops based on the Circular Economy Resilience Framework for Business Models (CERF-BM) conducted with businesses in the UK seafood sector, with structure adapted from Heyes et al. (2018).

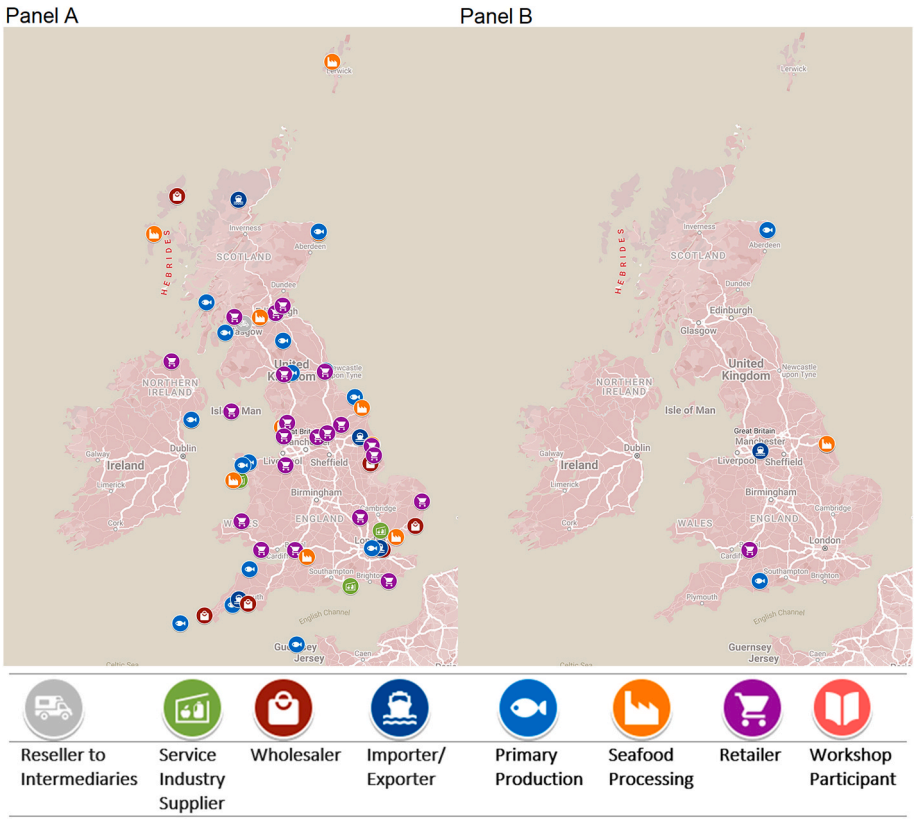


Fig. 2. Geographical distribution of research participants. Survey respondents (Panel A) and workshop participants (Panel B) are colour coded by company type. Note: Two workshop participants (both processors) are located in the same region (North East England). One survey respondent is based outside the UK in Guernsey, a Crown Dependency. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

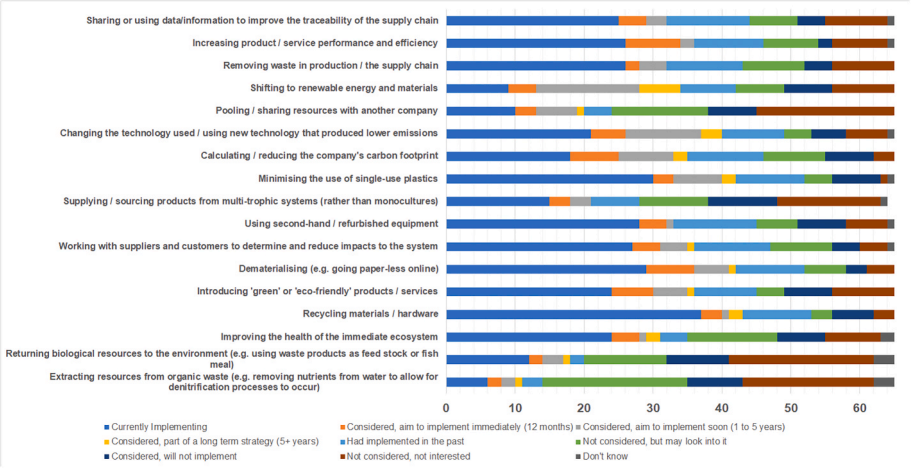


Fig. 3. Stage of implementation of circular economy actions for all company types (see SI Figs. 1–8 for analysis of selected options by business type). Note: one company (a processor) did not provide a response for the option "supplying and/or sourcing products from multi-trophic systems rather than monocultures", generating a discrepancy in the total number of responses.

and conducting meetings and audits remotely). Only one company listed an existing action under Exchange. No companies participating in the workshops reported that they were carrying out actions across all seven of the IReSOLVE categories.

When workshop participants identified future actions, all six reported that they planned to carry out actions under Exchange, such as more automation for processing sites, investing in heat pumps instead of diesel fuel, buying a more efficient ice machine, and utilising more by-products for pet food using an emulsifier.

4.3. Links between circular economy and resilience

In accordance with the CERF-BM, we mapped circular economy actions provided by workshop participants against four resilience mechanisms: Utilising Ecosystems; Promoting Local Systems; Knowledge Exchange; and Diversification (Fig. 6, SI Table 1). This mapping helped us to explore *general* rather than *specified* resilience displayed by the companies. A large proportion of the circular economy actions carried out by both primary producers participating in the workshops could be

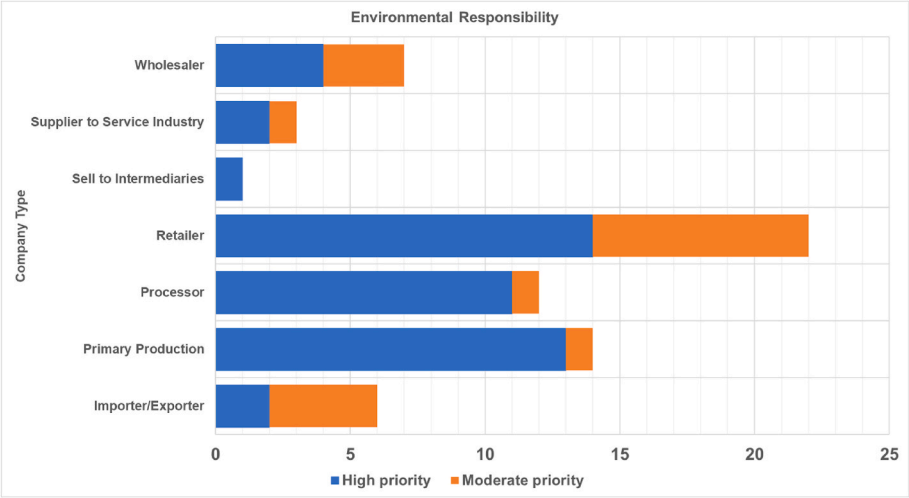


Fig. 4. Level of priority given to environmental responsibility by survey respondents.

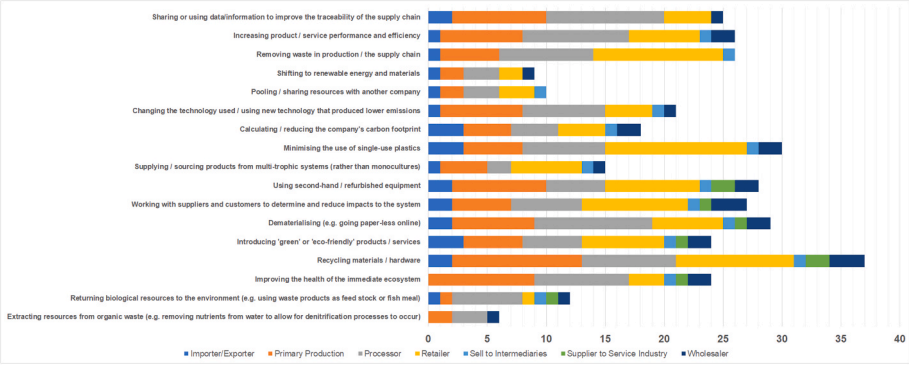


Fig. 5. Current adoption of circular economy actions, by company type.

categorised as Regenerate, and these in turn often linked to the resilience mechanism Utilising Ecosystems. Processor 1, Producer 2 and the Retailer carried out a substantial proportion of circular economy actions under the Share category, which tended to align with the resilience mechanism Promoting Local Systems. The Implement actions were spread more evenly across all business types and tended to align with the resilience mechanisms Knowledge Exchange and Diversification. Circular economy actions categorised as Optimise and Virtualise were the least likely to align with any of the resilience mechanisms.

4.4. *Perception of risk and impact of mitigation on circularity*

Key areas of focus for the survey and workshops were risks that businesses perceived (short- and long-term) and their perceptions of their resilience in the face of risks. For this aspect of the research, we aimed to explore the companies' *specified* rather than *general* resilience. Survey respondents were optimistic about their ability to adapt to a range of risks in the short and long term, with slightly more positive responses for the latter (Fig. 7). Of the risk scenarios provided, most companies felt able to adapt to energy price fluctuations in the short ($n = 51$) and longer term ($n = 53$), with fewer believing they could adapt to natural resource degradation in the short ($n = 31$) and longer term ($n = 36$). Companies were uncertain about their short-term ability to adapt to automation ($n = 33$) and critical ingredient shortfall ($n = 36$); however, confidence in their ability to adapt to both scenarios in the longer term was higher.

Surveyed companies expected the following indicators to impact the sector negatively (in order of decreasing importance): fall in customer demand, food scares, natural resources degradation, regulatory changes, and climate change (SI Fig. 9). Businesses expected changes to dietary preferences, urbanisation, and automation to have a positive impact (SI Fig. 10).

During workshops, we asked participants to identify short-term (up to one year) and longer-term risks (up to ten years) (SI Table 2). Five companies identified COVID-19 as an immediate risk with participants expressing concern around potential site closures, staff shortages, and a struggling hospitality industry following lockdowns. Four companies identified Brexit as a risk in the short term, citing concerns around restricted access to key markets, delays to deliveries, weaker exchange rates, changes to regulations and consumers having less to spend on fish, which is perceived as a luxury item.

Companies participating in the workshops identified longer-term risks such as the supply and cost of fish and fish feed, consumer perceptions of the seafood sector and a shift away from meat towards plant-based diets. This finding contrasts with the 30 survey respondents who perceived changes to dietary habits positively (SI Fig. 10). As the nature of dietary changes was not specified in the survey question, it is possible that some survey respondents expected higher levels of seafood consumption in the future.

Short-term risk mitigation measures discussed during workshops generally did not align with IReSOLVE actions. This finding suggests that the most immediate risks to businesses are not seen as having solutions that would increase the environmental sustainability or circularity of the business. In the longer term, suggested measures were often more in line with circular economy actions. For instance, in response to a lack of a particular type of fish, a processor could use a different species

Table 1
Examples of circular economy aligned actions from workshops categorised according to the IReSOLVE checklist.

IReSOLVE Categories	Actions Included in each IReSOLVE Category	Examples from Workshops
Implement	**Have a vision or target to achieve** **Engage with stakeholders** **Employ systems thinking**	- Vision to have fully electric company car fleet (Company 4) -Actively engaging with relevant research (Company 3) -Collaboration between supplier and company to contribute to fund for local community (Company 2)
Regenerate	**Use renewable resources** **Ensure a healthy ecosystem** **Return biological resources**	-Solar panels on hatchery roof and semi-circulated production system (Company 1) -Extended fallow period allowing for ecosystem recovery and regeneration (Company 2) -Try to source from small boats fishing for shorter periods (Company 6)
Share	**Share assets** **Reuse items or use second hand**	-Harvesting vessel sometimes loaned out to other fish farming companies (Company 2) -Shared use of forklift (Company 3) -Shared use of polystyrene recycling machine (Company 6)
Optimise	**Prolong the lifespan of products** **Increase product efficiency** **Remove waste in the value chain** **Leverage big data**	-Genetic selection for stronger, leaner fish that convert food to muscle efficiently (Company 1) -Curing, smoking, and freezing fish extends shelf life from fresh (Companies 3 and 4) -Utilising every part of the fish and ensuring none goes to waste, including giving fish bones to customers for stock and sending fish to pet food and fish meal manufacturers (Companies 3, 4 and 6)
Loop	**Remanufacture** **Recycle** **Anaerobic digestion** **Extract nutrients**	-Fish faeces collected and used by local farmer as fertiliser (Company 1) -Cleaning and reusing fish boxes (Companies 3 and 4) -Fish guts sent to anaerobic digester (Company 6) -Recycling materials wherever possible (e.g. plastic packaging, nets, feed bags) (Companies 2 and 6)
Virtualise	**Direct dematerialisation** **Indirect dematerialisation**	-Meetings, audits or staff training online where possible (Companies 2, 4 and 5) -Sell product online (Companies 3 and 6)
Exchange	**Use new efficient technology** **Design new products and services** **Utilise advanced materials**	-Old pumps replaced with newer, more efficient pumps on fish farm (Company 1)

from a more sustainable stock or farmed fish (Exchange). To overcome the limitations of their current processing site, a processor planned to move to a larger site with more up-to-date facilities, where they could power more of their operations through renewables (Regenerate). To respond to changing eating habits, a retailer suggested exploring options around non-animal alternatives such as seaweed (Exchange), and increasing their online offering to widen their customer base (Virtualise), which may have the effect of reducing emissions generated through personal car journeys.

4.5. Future plans: barriers and drivers for circularity

Our survey asked companies to detail future plans and to suggest what might negatively impact those plans. Over half of respondents had plans for expansion (n = 34) and approximately one quarter (n = 16) aimed to maintain their market position, to survive the COVID-19 pandemic, or to regain the market position they had prior to the pandemic and Brexit. Other plans included diversifying the customer base or product (n = 16) and retracting the business and/or ceasing trading (n = 4). Only four companies mentioned plans to improve their environmental sustainability over the next five years. As this was an open question, the low number does not signify that these were the only companies with plans to improve their environmental sustainability. Barriers to future plans included policy/regulations (n = 16), Brexit and related bureaucracy (n = 16), access to finance (n = 10), COVID-19 (n = 9), availability of suitable sites and facilities (n = 5), staffing (n = 5), climate change (n = 4), supply of raw material (n = 4), competition (n = 4), quotas (n = 3) and supermarkets (n = 2). The last point refers to competing with supermarkets, and struggling to meet growing demand in order to supply supermarkets.

Workshop participants were generally positive about making future changes to improve their circularity, however a common theme when discussing barriers to adopting new practices or acquiring new equipment was the lack of suitable alternatives. This barrier was discussed in relation to the technological availability of alternatives, or a lack of financial incentives (e.g. solar panels being too large an investment). Companies felt they would benefit from more research into low carbon and zero waste targets and a greater pace of innovation. A particular concern was the lack of environmentally sustainable alternatives to plastic packaging, specifically for perishable foods.

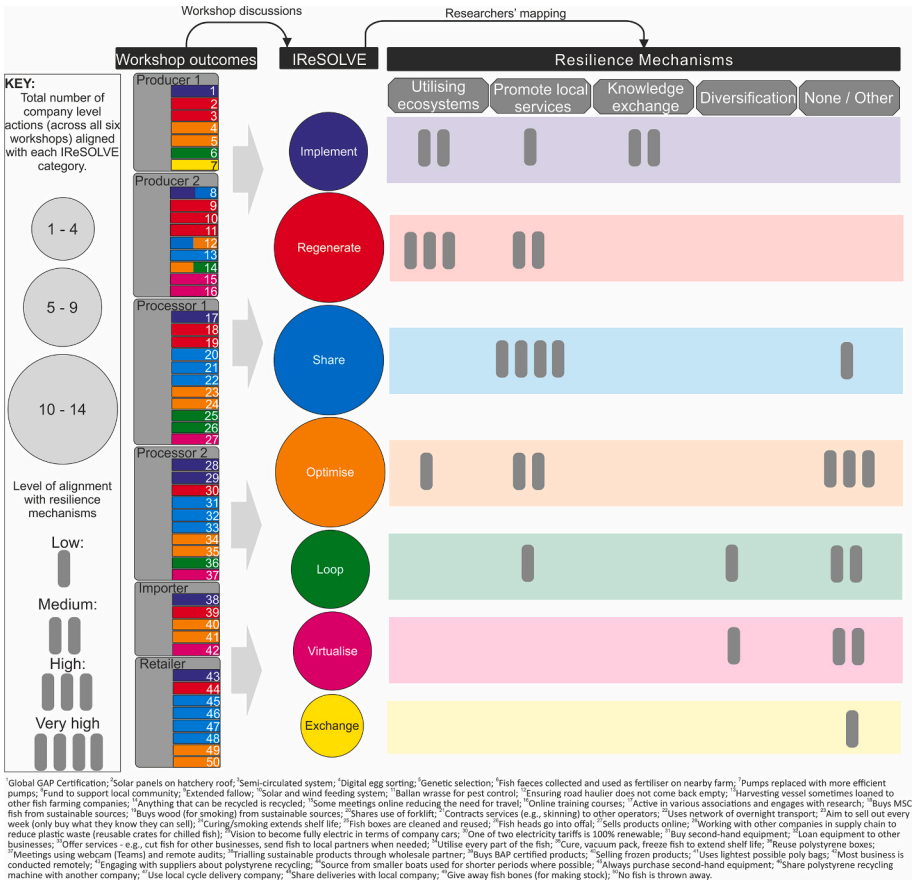
Several businesses lamented the lack of consumer awareness of the seafood sector. The limited consumer awareness included inadequate knowledge regarding dietary benefits of seafood consumption, a lack of preparation skills, a preference for convenience over quality, fresh over frozen, low cost over sustainability, and a lack of curiosity about the water and energy footprint of frozen shellfish. Most companies advocated for better information sharing to shape a more informed consumer base. When discussing drivers of change or factors that could help to facilitate change, businesses suggested that the UK seafood sector would benefit from a more positive media environment that shared positive aspects of the sector as well as health benefits of seafood in diets.

5. Discussion

In this paper, we assessed the alignment of seafood businesses' activities (current and future) with circular economy actions and explored businesses' perceptions of risk. We also sought to understand links between the adherence to circular economy principles, the implementation of specific risk-mitigation measures, and alignment with general resilience mechanisms.

We found that survey participants were implementing a variety of circular economy actions and felt positive about their ability to adapt to several identified future risks, i.e. their specified resilience. Interestingly, slightly more businesses were confident about their ability to survive risks in the longer term than in the shorter term, perhaps indicating a greater focus on short-term risks. In line with existing research, this finding may reflect a short-sighted approach to the level of change required to respond to future challenges (Corona et al., 2019).

Survey responses showed that impediments to future plans ranged from policy and a lack of access to finance, to staffing and availability of suitable facilities, confirming that engagement from a range of actors is vital (Baste and Watson, 2022). During workshops, businesses expressed a desire to adopt more sustainable and circular practices, but lamented the lack of available alternatives, for example to the current widespread use of polystyrene boxes. While progress is being made in terms of developing novel food packaging (de la Caba et al., 2019), this is still an



[1]Global GAP Certification; [2]Solar panels on hatchery roof; [3]Semi-circulated system; [4]Digital egg sorting; [5]Genetic selection; [6]Fish faeces collected and used as fertiliser on nearby farm; [7]Pumps replaced with more efficient pumps; [8]Fund to support local community; [9]Extended fallow; [10]Solar and wind feeding system; [11]Ballan wrasse for pest control; [12]Ensuring road haulier does not come back empty; [13]Harvesting vessel sometimes loaned to other fish farming companies; [14]Anything that can be recycled is recycled; [15]Some meetings online reducing the need for travel; [16]Online training courses; [17]Active in various associations and engages with research; [18]Buys MSC fish from sustainable sources; [19]Buys wood (for smoking) from sustainable sources; [20]Shares use of forklift; [21]Contracts services (e.g., skinning) to other operators; [22]Uses network of overnight transport; [23]Aim to sell out every week (only buy what they know they can sell); [24]Curing/smoking extends shelf life; [25]Fish boxes are cleaned and reused; [26]Fish heads go into offal; [27]Sells products online; [28]Working with other companies in supply chain to reduce plastic waste (reusable crates for chilled fish); [29]Vision to become fully electric in terms of company cars; [30]One of two electricity tariffs is 100% renewable; [31]Buy second-hand equipment; [32]Loan equipment to other businesses; [33]Offer services - e.g., cut fish for other businesses, send fish to local partners when needed; [34]Utilise every part of the fish; [35]Cure, vacuum pack, freeze fish to extend shelf life; [36]Reuse polystyrene boxes; [37]Meetings using webcam (Teams) and remote audits; [38]Trialling sustainable products through wholesale partner; [39]Buys BAP certified products; [40]Selling frozen products; [41]Uses lightest possible poly bags; [42]Most business is conducted remotely; [43]Engaging with suppliers about polystyrene recycling; [44]Source from smaller boats used for shorter periods where possible; [45]Always purchase second-hand equipment; [46]Share polystyrene recycling machine with another company; [47]Use local cycle delivery company; [48]Share deliveries with local company; [49]Give away fish bones (for making stock); [50]No fish is thrown away.

Fig. 6. Potential links between circular economy actions carried out by UK seafood businesses and resilience mechanisms.

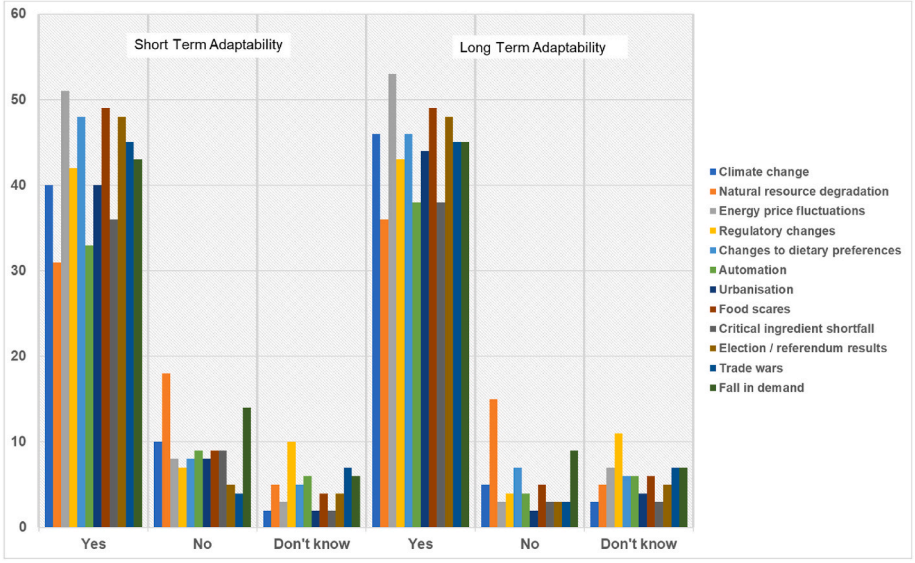


Fig. 7. Short- and long-term ability to adapt for a variety of risk factors.

area where some participating seafood businesses would like to see more development. This finding is in line with Do et al. (2022), who identifies technological barriers as potential challenges for seafood businesses in adopting more circular practices.

Workshop results revealed a temporal dimension to the consideration of links between circular economy and resilience. When discussing existing circular economy actions, very few companies were investing in significant changes that would fall under Exchange, whereas all six companies were implementing Regenerate actions, and five were carrying out Implement, Optimise, Loop and Virtualise actions. When discussing potential future circular economy actions, four participants had plans for future actions that could be classified as Exchange. In other words, companies appear to be aware of the significant changes needed to improve environmental sustainability, but these changes require

investment and time, which are often in short supply. As a result, the more challenging circular economy actions are put on hold for extended periods, which supports existing research that observes that the scale of transformation required is not yet being realised by businesses (Corona et al., 2019).

Perhaps unsurprisingly, we found that the primary producers who participated in workshops were engaged in activities categorised as Regenerate (circular economy) and Utilising Ecosystems (resilience). The circular economy actions reported in the workshops that could be categorised as Optimise and Virtualise were the least likely to align with resilience mechanisms. In line with existing research on circular economy actions in the seafood sector (Fletcher et al., 2021), companies evidently seek efficiency measures that allow for increased profit margins in the short term but may not enhance their resilience in the longer term. This finding also demonstrates the importance of alignment with the full spectrum of circular economy actions and the need to assess the circularity of businesses with multidimensional indicators inclusive of all pillars of sustainability, including the social dimensions of the circular economy (Mies and Gold, 2021; Rossi et al., 2020).

When considering whether risk mitigation measures align with circular economy actions, we found that measures that addressed short-term risks (e.g. Brexit or food scares) generally did not increase circularity, but longer-term risk mitigation often did. This finding perhaps reflects a sector constantly adapting to short-term risks and lacking capacity for longer-term planning. As increased adherence to circular economy principles may improve businesses' general resilience (i.e. their ability to adapt and survive in the face of unforeseen shocks and stresses), we suggest that the identification of longer-term risks and mitigation measures that are in line with circular economy principles may be an important capacity-building activity.

We suggest that while the identification and mitigation of short-term risks may increase a company's *coping ability* (Smit and Wandel, 2006) and *specified resilience* (Folke et al., 2010), it is unlikely to increase the circularity of activities and will not necessarily build *desirable resilience* for the system as a whole (Carpenter et al., 2001). Focusing predominantly on short-term risk mitigation could result in businesses falling into a 'reactive cycle', which might negatively impact their *general resilience* as they are unable to effectively learn from disruptions (Carpenter et al., 2001), manage and coordinate their future resilience (Walker et al., 2004), and improve their condition in relation to their environment (Gallopín, 2006) (Fig. 8). Companies with the ability to identify long-term risks to their business are more likely to implement measures that increase their circularity. The adoption of more circular activities may in turn improve adaptive capacity and general resilience. We suggest that the potential to increase general resilience through a capacity building cycle presents a convincing argument both from the perspective of company self-interest, and of collective need, for businesses to engage in longer-term circular actions.

An illustrative example from the survey was companies' confidence in their ability to survive fluctuations in energy prices. While companies might expect energy prices to fluctuate, it seems unlikely that many would anticipate extreme volatility in energy markets, such as the recent sharp increases in the cost of energy in the UK (Office for National Statistics, 2022). Companies that had planned for the longer term and engaged in more circular activities, such as reducing energy use and investing in renewable energy, would be better placed to survive the unanticipated scale and abruptness of this risk. The integration of circular economy measures and resilience thinking may therefore be a way of operationalising the concept of resilience to support the capacity for adaptation rather than coping.

5.1. Implications for theory and practice

This research has empirically explored theoretical links that bridge resilience and circular economy principles. Informed by the development of the CERF-BM (Fletcher et al., 2021), we utilised primary data collected via online surveys and workshops to operationalise the concept of resilience and provide concrete actions by which businesses may improve their general resilience. In doing so, this research has also explored the notions of capacity building vs. reactive cycles and employed them as a theoretical link between short-term specific risk mitigation, long-term specific risk mitigation, circular economy alignment and general resilience.

The continued development of this theoretical framework presents a valuable contribution when operationalising resilience and making resilience-building activities practicable for businesses in the seafood sector (and beyond). This research notes that an inability to identify and prepare for longer-term risks may impede a company's ability to increase its resilience to unforeseen disruptions and may lock a company into reactive, rather than capacity-building cycles of risk mitigation.

Our descriptive results contribute value with respect to collecting in-depth data from a difficult-to-reach group of participants (SMEs). Using this information, we have drawn upon the concepts of circular economy and resilience to explore ways in which SMEs in the UK seafood sector can improve their environmental sustainability and their capacity to respond to unforeseen shocks and stresses. The participatory nature of the workshops can also act as a template for future collaboration between businesses and researchers to identify ways in which business models can be developed to increase circularity.

Although shocks such as COVID-19 and Brexit present challenges for seafood businesses, they may also provide opportunities for interventions to improve the sustainability of the UK seafood sector. For

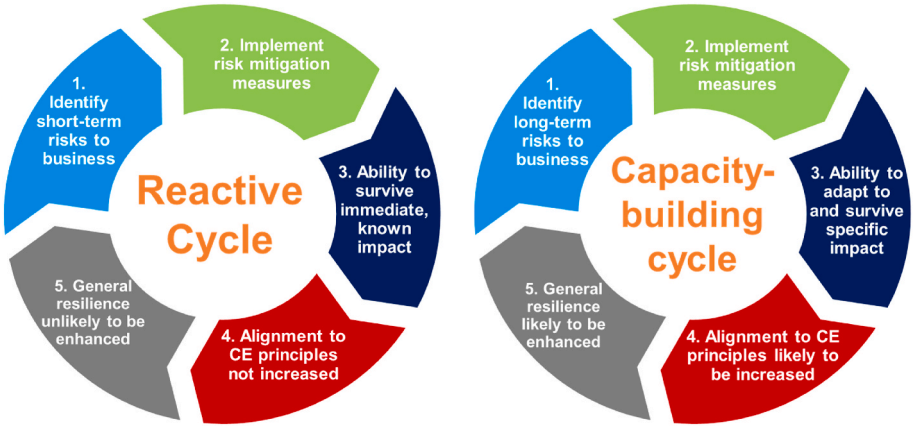


Fig. 8. 'Reactive cycle' and 'Capacity-building cycle' theorising link between short-term specific risk mitigation, long-term specific risk mitigation, circular economy alignment and general resilience.

example, prior to COVID-19, the UK government took a 'business as usual' approach to the future of UK fisheries policy. However, the combination of Brexit and the effects of COVID-19 (for example, the partial recovery of some overfished populations, facilitated by the global slowdown of activities) may provide a chance to embrace joined-up thinking, where fisheries management and the wider seafood sector are coordinated with policies for non-food sectors (Kemp et al., 2020). Furthermore, the FAO (2022) has recently called for efforts to integrate seafood production into wider food system strategies and to accelerate efforts towards a sustainable and efficient seafood sector at the global, regional and national levels. To this end, while our research has focused on the seafood system in the UK, this paper contributes to a global understanding of the ways in which seafood businesses can build resilience through enacting circular economy principles.

To build a seafood system that is resilient to trade disruptions and can respond to global climate and ecological crises, international collaboration is paramount, as are policies that support businesses to improve their practices and restore nature (Connolly et al., 2022; Hooper et al., 2021; Van Der Zwet et al., 2022). This research provides a mechanism whereby the intertwined concepts of circularity and resilience can be considered, with specific focus on the seafood sector. By using a circular economy lens, differences between short- and long-term priorities can be bridged, enabling seafood companies to employ capacity-building measures to overcome shocks and stresses, rather than relying on reactive cycles of adaptation.

6. Conclusion

We have investigated links between the circular economy and resilience and explored the potential for circular economy actions to further explicate the concept of resilience. We have identified ways in which businesses are carrying out circular economy actions and to what extent they plan to adopt circular economy actions in the future. We found that short-term risk mitigation measures tended not to increase businesses' circularity whereas longer-term risk mitigation measures more often did. This finding suggests that where businesses are able to be forward-thinking in their identification and mitigation of risks, they may also improve their alignment with the circular economy, and in turn, their general resilience.

Regulation, investment and government actions at all levels are key in transforming systems in a way that is just and informed, and will ultimately contribute to a more sustainable society (Baste and Watson, 2022). The UK seafood sector inhabits a complex policy area that must balance territorial sovereignty, economic concerns and environmental necessities (Van Der Zwet et al., 2022). This complexity requires policies that address long-standing cross-sectoral challenges such as environmental sustainability and resilience. We argue that a circular economy lens can help policymakers and businesses bridge short- and long-term priorities, adopt capacity-building and establish concrete steps to lower resource use and waste in seafood systems.

Limitations of the study include possible selection bias, particularly regarding workshop participants. Participation involved a substantial time commitment from companies, and we have found that the participants were generally interested in issues of environmental sustainability, which may have been a motivation for involvement in the research. Additionally, the survey and workshops were conducted during a time of stress (COVID-19 and Brexit negotiations), which might have impacted businesses' perception of risk.

While we have attempted to link specific to general resilience, our research has focused on circular economy and resilience from the perspective of individual businesses, and further insights could be gained from research that takes a broader systems approach.

Funding sources

The Diverseafood project was funded through the Global Food Security's 'Resilience of the UK Food System Programme' with support from the BBSRC, ESRC, NERC and Scottish Government (grant number BB/S014144/1).

CRediT authorship contribution statement

Rebecca St Clair: Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **Dimitrios Pappas:** Formal analysis, Writing – original draft, Visualization. **Carly Fletcher:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Visualization. **Maria Sharmina:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

We would like to thank the Diverseafood project partners at the Scottish Association for Marine Science (Dr Sofia Franco and Dr Alan MacDonald), Newcastle University (Dr Luca Panzone, Dr Lucia Rehackova and Naomi Kang) and the University of Greenwich (Dr Pamela Katic and Dr Andrea Gatto) for their support and guidance throughout the project.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2023.137045.

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