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ORIGINAL ARTICLE

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An evaluation of European initiatives established to encourage industry-led development of selective fishing gears

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Abstract

There are numerous examples from across Europe where collaborative science-industry initiatives, which provide a bottom-up approach to trawl gear development, have been successful in developing selective gears. For fishers, the collaborative approach creates a sense of ownership and control over the gears developed and often a greater desire for them to achieve their objectives. Despite the many benefits of collaborative initiatives, a lack of clarity and transparency, incorrect incentives, unclear communication, and distrust or diverging perceptions can inhibit their performance. The present review examines the different collaborative approaches to fishing gear development that have been established within Europe, highlighting their salient features, comparing their objectives, and discussing the types and effectiveness of the incentives offered. Also examined is how the reform of the European Union's (EU) Common Fisheries Policy (CFP), together with the proposed reform of the technical measures framework, can potentially improve the flexibility in the technical regulations and allow for such initiatives to be a central part in improving the state of fish stocks throughout the EU. Finally, a framework is proposed on how initiatives pertaining to industry-led fishing gear development might look like under the reformed CFP.

KEYWORDS

bottom-up, industry-led initiatives, science-industry partnerships, selective gear development

1 | INTRODUCTION

One of the largest concerns with commercial fishing is that unwanted species and sizes of fish are often caught in conjunction with the target species and sizes (Kelleher, 2005), with a considerable amount of the unwanted species/sizes potentially discarded to the sea either dead or dying (Feekings, Bartolino, Madsen, & Catchpole, 2012; Heath, Cook, Cameron, Morris, & Speirs, 2014). Discarding is more pronounced in demersal trawl fisheries, which are usually mixed-species fisheries that target a range of species during each fishing operation. One of the most common ways to reduce discarding is to improve gear selectivity (Broadhurst, Suuronen, & Hulme, 2006; Feekings, Lewy, & Madsen, 2013) by either exploiting the various behavioural and morphological differences between species or sorting the catch mechanically based on size (He, 2010). However, the need to decouple catches of different species and/or sizes is challenging and often results in compromising on some aspects of the selective performance of the gear.

The short-term economic losses often associated with improved selectivity are considered to be the most common reason that discourages fishers from using selective gears (Catchpole, Frid, & Gray, 2005; Hall & Mainprize, 2005; Krag, Herrmann, Feekings, & Karlsen, 2016; Suuronen & Sardà, 2007). Additional factors that reduce the uptake of new selective designs include the costs associated with

new technologies (Catchpole et al., 2005; Hall, Alverson, & Metuzals, 2000; Suuronen & Sardà, 2007) and a perceived increase in economic risk and safety issues when operating more complex gears (Catchpole et al., 2005; Madsen & Valentinsson, 2010; Suuronen & Sardà, 2007). Furthermore, when losses of marketable catch occur, effort may increase to compensate for the loss, thereby negating the benefits of bycatch reduction (Hall & Mainprize, 2005).

Despite the difficulties, improved selectivity not only reduces discards but presents other advantages for the fishers, which could in theory act as additional incentives to fish more selectively. These advantages include: cleaner catches, which in turn reduces sorting time and optimises the value of a quota if operating under a catch quota management system (Bjordal, 1999; Gonçalves et al., 2008); improved catch quality (Bjordal, 1999; Karlsen, Krag, Albertsen, & Frandsen, 2015); increased storage capacity devoted to commercial species if discarding is not allowed (Gonçalves et al., 2008); and, depending on the management regime, the possibility to operate in otherwise closed areas (Valentinsson & Ulmestrand, 2008) or to obtain increased fishing opportunities (O'Neill, Lines, Kynoch, Fryer, & Maguire, 2014). There are also environmental and ecological advantages associated with improving selectivity, such as reduced impacts at the population, species, community and even ecosystem levels (Gonçalves et al., 2008; Heath et al., 2014).

The development of selective fishing gears commonly follows a method where one aspect of the gear is altered in a way that aims to improve either the selectivity between species or the size selectivity of a particular species. Such modifications are then scientifically tested on board either commercial or research vessels and the results are published in reports or scientific literature. This development and testing phase is often carried out in collaboration with industry, that is fishing vessels chartered for the trials or fishers consulted during the design process (e.g. Krag et al., 2016; Melli, Karlsen, Feekings, Herrmann, & Krag, 2018). Despite this collaboration, industry involvement in gear selectivity trials does not in itself ensure that the modifications, when and if adopted, are not negated. There are many examples of technical measures being counteracted by design changes such as using breaking twines (a thin twine typically used to tie off the codend), increasing twine thickness or number, or altering the height of the extension piece where a selective panel is positioned (Krag et al., 2016). Additionally, the high costs associated with carrying out gear selectivity trials can limit the number of designs that can be tested and the extent to which they can be optimised.

The implementation of newly developed fishing gears into management plans is typically done in a top-down manner whereby minimum gear specifications are described in legislation. Typical legislation can specify, *inter alia*, the: minimum mesh sizes (traditionally the main legal measure to prevent catching juveniles and small individuals); mesh shape (e.g. diamond mesh, square mesh and T90); mandatory use of selective grids or square mesh panels; square mesh panel size and placement; bar spacing in selective grids; and netting twine number and thickness. A greater understanding of which parameters affect the selectivity of trawls leads to more parameters being included in legislation and consequently to an increasingly micro-managed system.

The top-down management approach can also be slow, inflexible and blunt, taking several years to get legislation on new gears passed, which frequently results in a regulatory regime that makes it legally impossible for fishers to develop and test more selective fishing gears. Top-down management often does not take into account the variation that exists within a fishery, which can comprise different types of vessels, of different sizes and engine power, and with different quota share. As a result, the prescribed gears may not be universally appropriate and may have different levels of success within a given fishery.

One method to encourage the development and uptake of selective gears is to involve stakeholders in a meaningful and comprehensive way; this should occur at all stages in the process, from initial conception, collection and recording of data, through to delivery and uptake of the new fishing gear (Johnson & Van Densen, 2007; Veiga-Malta, Feekings, Herrmann, & Krag, 2018). Herein, this is referred to as a bottom-up approach. The benefits of a bottom-up approach are that it: (a) becomes a more transparent system; (b) creates a higher degree of acceptability and compliance of the rules; (c) utilises the unique practical knowledge within the industry; (d) helps the industry to be seen as taking an active role in improving their activities; (e) creates ownership over their fishery and the tools they choose to employ; (f) increases communication and understanding between the different stakeholders; and (g) reduces the cost of science (Armstrong, Payne, Deas, & Catchpole, 2013; Johnson & Van Densen, 2007; Pomeroy & Rivera-Guieb, 2005; Vedsmand & Nielsen, 1995). Like all management approaches, it may not be suitable for all fisheries, and there are some associated disadvantages and/or potential problems such as: a lack of support from political leaders; a dependence on incentives (where they exist), which may also become expensive in the long run; and the requirement for a high level of participation from all stakeholders (Armstrong et al., 2013; Pomeroy & Rivera-Guieb, 2005; Vedsmand & Nielsen, 1995).

There are many examples from around the world that have attempted to improve collaborations with the fishing industry and make use of their extensive practical knowledge. However, such industry-science partnerships frequently fail due to a lack of clarity and transparency, inadequate incentives, unclear communication, distrust or diverging perceptions of the problem (Kraan, Hendriksen, Van Hoof, Van Leeuwen, & Jouanneau, 2014; Uhlmann, Theunynck, Kinds & Sys, 2015). The aim of the present study was to outline European cooperative research initiatives pertaining to fishing gear development and attempt to understand what leads to their success and/or failure, what types of incentives work and do not work, how much industry involvement is enough, and how fishers' ideas should be developed and tested. The specific objective of the present study is to define the optimal structure of an industry-science partnership under the reformed European Union (EU) Common Fisheries Policy (CFP) (EU, 2013) and in the light of the proposed reform of the technical measures framework (EC, 2016) as part of a discussion on

the importance of a management system that facilitates continual improvement.

2 | METHODS

To evaluate the efficiency of initiatives pertaining to industry-led fishing gear development, a method was outlined in the present study that could be used to evaluate the impact and the effectiveness of the initiatives in relation to economic, social, scientific and management criteria (Table S1). However, the initiatives presented herein could not be rigorously evaluated and compared due to the scarcity of publicly available documentation. Nonetheless, the present study does discuss the different types of initiatives, compare their objectives and assess the types and effectiveness of the incentives offered. Furthermore, it is discussed how the reformed CFP, together with the proposed reform of the technical measures framework, can potentially improve the flexibility in the technical regulations and allow for such initiatives to be a central part in improving the state of fish stocks throughout the EU. Finally, a framework is proposed on how initiatives pertaining to industry-led gear development could look like under the reformed CFP.

To assess industry-led initiatives, bibliographic sources were obtained from participants in the International Council for the Exploration of the Seas (ICES) Working Group on Fishing Technology and Fish Behaviour (WGFTFB), either in the form of project reports, scientific articles or personal communication. Since the objective of the present study, and many of the initiatives described herein, pertain to helping facilitate a more successful implementation of the EU CFP and the landing obligation, the scope was limited to bottom-up initiatives undertaken within Europe. Although the leadership of these initiatives was often shared between industry, science and government, these were considered to be bottom-up because the industry was involved in all stages of the research process, from initial conception, development and testing of the gear-based solutions through to the final documentation and reporting. The compiled information, listed below in chronological order from their date of conception, came from England, Scotland, Denmark, Sweden and the Netherlands.

2.1 | Fisheries Science Partnership (England)

The Fisheries Science Partnership (FSP) is a government-funded scientific research programme between the UK fishing industry and scientists. It aims to encourage fishers and scientists to work in partnership to collect new data that are vital to the sustainable management of fish stocks. Since it was established in 2003, the programme has sponsored more than 100 projects, including investigations into fishing gear selectivity and spatial patterns and catch compositions as well as the construction of time series of relative abundance of commercial species (Armstrong et al., 2013). In the programme's first ten years, 15 projects focused on improving fishing gear selectivity, including but not limited to (a) the reduction in unwanted haddock catches in demersal otter trawls by inserting large diamond-mesh escape panels into the top sections of the trawl; (b) development of a trawl for the NE English trawl fishery for Norway lobster *Nephrops norvegicus* (L.) that reduces the capture of Atlantic cod *Gadus morhua* L.; (c) the insertion of large diamond mesh panels of variable position and dimension into the sides of the trawl to reduce cod catches without affecting catches of other commercial species; (d) the fitting of square mesh panels to the underside of trawls used to catch Dover sole *Solea solea* (L.) to reduce the catch and hence the discarding of unwanted benthos, for example urchins, crabs and starfish (Catchpole, Elliot, & Mills, 2010); and (e) assessment of a net based on the ideas of the Eliminator trawl (a trawl design developed to reduce the catches of cod in the North-eastern USA groundfish fisheries), which could be used in the North Sea fishery for saithe *Pollachius virens* (L.) (Reeves & Armstrong, 2009).

The uptake of the different designs/modifications into the fisheries is difficult to gauge. For example, despite not all projects showing positive results, a portion of the successful ideas was taken up by the fishers involved (Armstrong et al., 2013). However, some particular cases were described, for example a skipper adopted the design of the square mesh panel near the footrope to reduce the catch of benthos in his Dover sole fishery and continues to use this during commercial fishing in both rigs (Catchpole et al., 2010), whereas the results of the Eliminator trawl trials suggest that the design of net investigated was not suitable for use in the North Sea saithe fishery (Reeves & Armstrong, 2009).

The FSP programme receives ≈ £1 million each year from the UK government, and 2017 was its 15th year. The proposals put forward by the industry for FSP projects are typically developed at a port or regional level, refined and agreed with the Centre for Environment, Fisheries and Aquaculture Science (Cefas), then evaluated and approved by the programme's steering committee. Vessels chartered under the programme are selected through an open tendering procedure and are given dispensations from the relevant quota and effort controls, and to fish in non-UK waters if applicable.

2.2 | The clean fishing competition (England)

This competition was held between August 2006 and May 2007 (Revill, 2007) to encourage south-west beam trawler fishers to develop their own technical solutions to reduce unwanted bycatch and discards in their fisheries. The rules of the competition stipulated that the skipper's designs must be commercially acceptable and effective in reducing discards. Skippers were encouraged to build on the successful work already undertaken in this field by Cefas scientists (i.e. the Benthos Release Panel). The competition was initiated and administered by Cefas and incentivised participation through prize monies totalling £20,000; £12,000 was awarded to the winner and £4,000 to each of the two runners-up.

The three vessels that participated in the competition experimented with different fishing gear modifications and achieved varying degrees of success in terms of discard reduction. The winning design, a standard beam trawl fitted with a square mesh codend in

combination with two strategically placed square mesh exit windows, successfully reduced discard levels by ≈60% while improving catch quality. Importantly, the skipper continued to use the trawl modifications long after the competition had closed, and the modifications were also reported to have attracted interest from other skippers (A. Revill, personal comm.).

2.3 | Scottish conservation credits scheme (Scotland)

The Scottish Conservation Credits Scheme (SCCS) was set up in Scotland in 2008 to support the EU cod recovery plan and uses a range of management measures to reduce the fishing mortality and discarding of cod. The SCCS introduced a series of compulsory measures such as real-time, seasonal and permanent closures, which aimed at reducing fishing effort in areas where the abundance of cod is high (Holmes et al., 2011; Needle & Catarino, 2011). In addition to the compulsory closures, the SCCS encourages the use of fishing gears that are more selective for cod (Kynoch, O'Neill, & Fryer, 2011; Kynoch, O'Neill & Summerbell, 2011; O'Neill et al., 2014).

For the whitefish fleet, the use of more selective gears was optional, and participating vessels were rewarded with additional fishing opportunities (i.e. extra fishing days; O'Neill et al., 2014). Since the schemes introduction in 2008 ≈ 26% of the demersal fleet chose to fish with more selective gears (O'Neill et al., 2014).

In 2011, the SCCS was extended to include Scottish Norway lobster trawlers fishing in the Northern North Sea. These vessels were obliged to fish with "Highly Selective Gears" to support the EU cod recovery plan, that is gears that reduce cod catches by at least 60% (by weight) relative to the standard (EU regulation) gear. The fishing industry was encouraged to develop and test new gears that would meet these requirements, with the understanding that if the new gears demonstrated the potential to achieve this objective, scientific validation trials (catch comparison trials) would then be carried out by Marine Scotland Science. Two gears developed by the industry were accepted and classified as being 'Highly Selective': (a) the Flip Flap netting Grid (FFG) trawl by Michael Watt of Gamrie Bay Trawls; and (b) the Faithlie Cod Avoidance Panel (FCAP) by Willie Hepburn of Faithlie Trawls, Fraserburgh (Drewery et al., 2012; Kynoch, Edridge, & O'Neill, 2012). The intention of these gears was to reduce the need for discarding the cod bycatch, thus ensuring that there is sufficient quota to last the entire year. Hence, the netting barriers in each of these gears were designed to allow passage into the codend of a proportion of cod and other species such as monkfish and megrim, which can form a valuable component of the catch.

2.4 | Project 50 Percent (England)

In 2009, Cefas decided to use a social marketing approach to reduce discards and initiated a pilot project in the Devon beam trawl fleet to see what lessons could be learned (French, Merritt, & Reynolds, 2011). Cefas wanted the Devon beam trawl fleet to be the first commercial fishing fleet in Europe to reduce its discards to the most practical minimum level, with up to 50% of the current rate set as the aspirational target.

Project 50 Percent ran from the spring of 2009 through March 2010. Ten crews volunteered to take part in the new experiments with larger mesh sizes. Cefas scientists worked with each of the ten volunteer crews from Plymouth and Brixham, recording details of each fishing trip during the trial period. Many industry experts thought that a 50% reduction in discards was an unrealistically high target. However, the fishers who took part in the trials were proactive, making a number of suggested modifications to the fishing gear, and these resulted in an unprecedented mean reduction of 52%, with one Devon beam trawler, MFV Geeske, reducing discards by 66%. Cefas demonstrated that, by putting effort into understanding the lives, attitudes and concerns of fishers in detail, a constructive and successful partnership could be built to achieve meaningful results (Nelson & Revill, 2011).

The only financial incentive that the fishers were offered was that the new selective gears that each of the fishers designed was paid for by the project. No other financial incentive was offered. With the project being a social marketing exercise, it focused on the fishers as the key players responsible for reducing discarding, rather than the state or scientists. Therefore, project dissemination (a press event and media coverage) aimed to celebrate the fishers' actions and efforts in reducing discards. While not a financial incentive, this increased public recognition and celebration of the fishers' achievements was enough to incentivise the fishers' participation (Nelson & Revill, 2011).

2.5 | MINIDISC (Denmark)

The MINIDISC project was a results-based management project run with the objective of giving fishers free gear choice with the aim of reducing discards within the Danish demersal trawl and seine fisheries. Fourteen vessels participated in the project; five in the Skagerrak, six in the North Sea and three in the Baltic Sea. Participating vessels were required to have cameras installed to be able to fully document catches.

Participation in the project was incentivised through additional quota allocations. For some fishers, the motivation to participate was driven by the opportunity to show that they take the discarding issue seriously, while for others the chance to get extra quota was central (Mortensen et al., 2015). The motivation to obtain extra quota meant that the objectives of the project and some participants were not aligned, which resulted in artificial participation. Despite this, the results showed that fishers, when given free gear choice, were to a large extent able to reduce catches of potential "choke species". For example, vessels active in the North Sea caught fewer cod and saithe in the test gears. Fishers consider these species to be potential "choke species" under the catch quota management. A reduction in catches of cod and saithe in relation to other species can therefore help to keep the fishery open longer as it will take longer to utilise their respective quotas.

While a more flexible choice of gears resulted in an overall reduction of potential "choke species" that might otherwise have a limiting

effect on fishing, its effectiveness also depended on the fishers' quota composition. The possibility to rent quotas in Denmark is something all participants in the project considered to be a good instrument to adjust their individual quota compositions to actual catches.

2.6 | Danish anchor seining project (Denmark)

In the Kattegat and Skagerrak, the technical regulations applicable to demersal trawling require large mesh panels be used when fishing with a codend mesh size of 90–119 mm. The use of large mesh panels has been mandatory in the Kattegat and Skagerrak since 2011 and 2013, respectively (Noack et al., 2017). Their introduction aimed to reduce the catches of juvenile fish, including cod. When the gears were introduced they were prescribed for both the demersal trawl and seine fleets. Shortly after their introduction, the Danish Fishermen's Association raised the concern that the seining vessels were having difficulties catching haddock *Melanogrammus aeglefinus* (L.) and witch flounder *Glyptocephalus cynoglossus* (L.). The fishery for haddock and witch flounder is an important seasonal fishery for the Danish seining fleet.

To encourage the industry to find a solution, three Danish seine vessels were given to opportunity to develop and test gears to retain haddock and witch flounder. During a development year, several potential gears were tested; (a) a 105-mm diamond mesh codend with a 105-mm square mesh panel, (b) a 110-mm diamond mesh codend with a 110-mm square mesh panel and (c) both codends without panels. At the end of the development year, a decision was made to test scientifically the 105-mm diamond mesh codend with a 105-mm square mesh panel. The gear was scientifically tested on board a commercial seine vessel in the Skagerrak in April 2015 using the covered codend method (Wileman, Ferro, Fonteyne, & Millar, 1996).

The main driver behind the industry finding a solution to the problem was due to the realisation that if a viable solution was not found, the seine fleet would be forced to continue to use the gears that were not viable. The results from the trials pointed towards a reasonably good selectivity for cod while also retaining considerably more marketable haddock and witch flounder (Mortensen et al., 2015). The new gear is expected to be implemented into legislation with the aim of allowing Danish seine vessels who have quota for haddock and witch flounder to use the gear in the season where this fishery is conducted.

2.7 | The selective fisheries secretariat (Sweden)

In 2014, the Swedish Agency for Marine and Water Management (SWAM) and the Swedish University of Agricultural Sciences (SLU) established a scheme (The Selective Fisheries Secretariat) to help fishers formulate ideas and create project proposals that could potentially solve issues they expected to encounter during the implementation of the landing obligation. Fishers were invited to contact the SLU secretariat via telephone, e-mail or via the website (www.slu.se/selektivtfiske), or at a number of physical meetings arranged around the coastline each year. All ideas formulated by the fishers were made into project proposals together with scientists from SLU, with no initial filtering of project ideas being carried out by the scientists. The scheme's steering group then decided which projects to approve and the approved projects were then put out to tender. All approved projects contain four phases. (a) Designing/constructing/buying and mounting of the gear alteration for which the fisher was responsible. (b) Initial testing: Initial testing of the new design was carried out by the fisher himself (under gear dispensation by SLU) during 1–3 months with revenue guarantee (i.e. he still obtained a normal income even if the gear performed poorly). This was an iterative phase with close contact between the fisher and SLU, where changes were encouraged/ needed but all changes and catches were strictly documented by the fisher himself. (c) Scientific testing: When the fisher was satisfied with the gear's performance, SLU-personnel would undertake a more formal scientific evaluation (gear trial). Here, revenue guarantee was also provided. (d) Project evaluation: Scientists at SLU would write a project report describing the selective performance of the new gear and report these results back to the industry and agency.

During the first year of the scheme, five projects were funded. In 2015, twenty-two project proposals were received and out of these, seven were funded. The initial intention of the scheme was to provide a toolbox (i.e. a documented list of gears with different capabilities) for the fishers to use under the reformed CFP/landing obligation. How the future technical baseline regulation will work, and the role of regional plans within Europe, will determine how successful projects are implemented in the fisheries. In light of this uncertainty, the objective was to try and provide tools for the industry's needs that can be fleet-wide solutions or vessel-specific due to different quota access rights. Participation in the scheme was incentivised on a project basis but in general participants had income security, both during testing/iterating and during the scientific evaluation. Participants also got dispensation from gear regulations to have more freedom to test and develop their ideas during the project (under strict documentation of catches).

2.8 | Trawl innovations (Netherlands)

The trawl innovation cutter fishery project was initiated by the Institute for Marine Resources & Ecosystem Studies (IMARES) in 2014 to improve selectivity in the cutter fishery to cope with the landing obligation (Van Marlen et al., 2016). To achieve this, the industry was asked to develop selective trawls for the 80-mm beam trawl, pulse trawl and pulse wing gears for sole and the 100-mm twin-trawl for plaice. A total of fourteen industry ideas were tested on six vessels. Unfortunately, none of the ideas were considered effective enough to cope with the landing obligation. Project participants were compensated with scientific quota for sole during the period they tested and sampled the selective trawls/devices. For some of the project participants, the additional quota was the only incentive to participate.

TABLE 1 The different collaborative science-industry partnerships, which provide a bottom-up approach to trawl gear development, their objectives, the types of initiatives, the incentives offered, as well as the effectiveness of the incentives

Country	Initiative	Objective	Type of initiative	Incentive	Effectiveness of incentive	Information source
Europe						
Sweden	The Selective Fisheries Secretariat	A Programme established to help fishers formulate ideas (mostly gear changes) that can potentially solve issues under the landing obligation.	Programme	Participants are provided income security, both during testing/iterating and during the scientific evaluation. Participants are also granted dispensation from gear regulations.	*Positive*—test some really new ideas without losing money. *Negative*—none.	www.slu.se/sv/institutioner/akvatiska-resurser/selektivt-fiske/
Denmark	MINIDISC	A project run in collaboration with scientist and industry where the fishers were free to choose their gear.	Project	Participating vessels were compensated with additional quota.	*Positive*—provided the possibility for the industry to show that they take issues seriously and work towards resolving them. Demonstrate discards are low. *Negative*—For some, the opportunity to get extra quota was central.	Mortensen et al. (2015)
	Danish seining experiment	Encourage the seine fleet to develop a gear which can retain haddock and witch flounder.	Project	Development and initial testing was paid by the fishers themselves. Scientific testing was compensated in money.	*Positive*—If no solution found, fishers were forced to use ineffective gears. *Negative*—although an effective solution was found it is still illegal to use.	Mortensen et al., (2015); Personal communication: Ludvig Krag
England	Fisheries Science Partnership	To encourage fishers and scientists to work in partnership to collect new data vital to the sustainable management of fish stocks.	Programme	Dispensations from the relevant quota and effort controls and to fish in non-UK waters if applicable.	*Positive*—15 fishing gear selectivity projects by March 2012 were financed with some of the new gears been used by the fishers or added to the legislation.	Armstrong et al., 2013
	The Clean Fishing Competition.	Encourage English beam trawlers to develop their own technical solutions.	Competition	Prize monies totalling £20,000.	*Positive*—the winning design successfully reduced discards and continued to be used by the skipper after the competition had closed.	Personal communication: Andy Revill The Clean Fishing Competition 2007
	Project 50 Percent	Reduce discard levels in the Devon beam trawl fleet by 50% through gear modifications.	Project	Development/modification of the gear was funded.	*Positive*—all 10 vessels reduced their discards, with a mean reduction in discards of 52%.	Personal communication: Andy Revill 50% discards

(Continues)

TABLE 1 (Continued)

Country	Initiative	Objective	Type of initiative	Incentive	Effectiveness of incentive	Information source
Scotland	Scottish Conservation Credit Scheme (whitefish)	A Programme established to support the EU cod recovery plan by reducing the capture of cod.	Programme	Participants were compensated with additional days at sea.	*Positive*—Up to 26% of the whitefish fleet participated.	Scottish Conservation Credit Scheme
	Scottish Conservation Credit Scheme (*Nephrops*)	A Programme established to support the EU by reducing the capture of cod by the *Nephrops* fleet by 60%.	Programme	Compulsory use of "highly selective" gears. (ie gears that reduced capture of cod by 60%).	100% participation as scheme was compulsory.	Scottish Conservation Credit Scheme
	Gear Innovation and Technology Advisory Group	To develop and trial innovative fishing gears that reduce the amount of discards in preparation of full implementation of the landing obligation.	Project	Financial support is available for gear development and scientific trials.	*Positive*—At least 8 gears have been developed and undergone trials. None have been legislated but some are being used at the skippers own initiative.	www.sff.co.uk/gitag
Netherlands	Trawl innovation cutter fishery	Establish a discard reduction by developing selective trawls for the 80mm beam-, pulse trawl and pulse wing gears for sole and the 100mm + twin-trawl for plaice. This all has been initiated to improve selectivity to cope with the landing obligation.	Project	Participants were compensated with scientific (sole) quota during the weeks they have tested and sampled the selective trawls/devices.	*Positive*—14 industry ideas have been cost-effectively tested on 6 vessels. *Negative*—None of the ideas were effective enough to cope with the landing obligation. For some fishers, the additional quota was the only incentive to participate.	Personal communication: Pieke Molenaar www.vissersbond.nl/wp-content/uploads/2014/04/C110.15-VIP-rapport-Netinnovatie-Kottervisserij-IMARES.pdf
	Discard mitigation by trawl innovation in the *Nephrops* fishery	Develop, test and improve modified *Nephrops* trawls to achieve at least a 50% discard reduction.	Project	Participants were financially compensated for (trawl) material, catch losses and additional working hours.	*Positive*—10 designs were tested on 5 vessels. Most fishers were dedicated to developing innovative gears. One design reduced discards by 65%. *Negative*—Testing on other vessels with same selective device did not result directly in similar results and created dissension between fishers.	Personal communication: Pieke Molenaar http://edepot.wur.nl/376260

In 2014, IMARES initiated a project with the objective of developing, testing and improving modified Norway lobster trawls to achieve at least a 50% discard reduction in the Dutch Norway lobster fishery (Molenaar, Steenbergen, Glorius & Dammers, 2016). Project participants were financially compensated for (trawl) material, catch losses and additional working hours. Ten gear configurations were tested on five vessels. Most fishers who participated were dedicated to seeing their innovative trawls work, with one trawl reducing discards by 65%.

2.9 | GITAG 1 and 2 (Scotland)

The Gear Innovation and Technology Advisory Group (GITAG) is an industry-based body that was established in 2015 by the Scottish Fishermen's Federation's (SFF). The SFF secured funding from the European Maritime and Fisheries Fund (EMFF) to develop and trial innovative fishing gears and to explore practical solutions that reduce the amount of discards in preparation of full implementation of the landing obligation (www.sff.co.uk/gitag/).

The GITAG aims to promote and encourage innovation from the fishing industry as a whole and, in particular, to foster flexible working partnerships between active fishers, industry, public bodies, gear technologists and science. The GITAG has a two-phase approach. The first of which is to encourage individuals or groups of skippers to come forward with innovative proposals and conduct initial gear trials. The second is to bring the industry and gear technologists together to develop and assess further trials with the purpose of assisting skippers to maximise the potential of their ideas and meeting their responsibilities under the landing obligation. Financial support is available to pay for gear development, and it is possible to get derogations to use gears that may not comply with the legislation. If full-scale scientific selectivity or catch comparison trials are deemed necessary, then there is provision to charter a commercial fishing vessel. The group is also responsible for dissemination of project-related results and best practice for recommending a suite of evaluated gear options.

During its first year, four applications from skippers and net makers were trialled. These were considered options to reduce unwanted bycatches of round and flatfish by modifying the ground gear and installing 200-mm square mesh panels, and to improve sorting time and catch quality by directing fish and Norway lobster to different codends (Kinghorn, Dooley, Edridge, Kynoch & O'Neill, 2017). In the follow-on project (GITAG 2), more applications have been considered and, at present, four gears are under development or being trialled.

3 | OVERVIEW OF CASE STUDIES

The eleven initiatives presented here, which involved industry-led gear development (Table 1), were carried out across five countries and comprised projects, programmes and competitions. A commonality of these initiatives is the scarcity of publicly available documentation. The purpose and processes of the partnerships were often presented on dedicated websites or in reports, but the results and outcomes often went unreported or were difficult to access. This suggests that a lot of the communication during the partnerships themselves was undocumented or at least unpublished and that little was done after completion of the initiatives to wrap up and synthesise the results in a readily accessible form. This absence of long-lasting documentation can hinder the dissemination and uptake of good ideas beyond the group of fishers and scientists directly involved in the initiatives, while also making it difficult to evaluate which aspects of the initiatives actually worked.

The incentives offered to the industry to encourage participation in collaborative research initiatives relating to fishing gear technology can be financial, such as additional fishing effort or quotas, revenue guarantees, funding gear construction, chartering of vessels and prize money. There can also be non-monetary incentives such as publicising and celebrating the industries efforts in reducing discards, as well as the possibility of having the developed gear included in the legislation. Incentives were available at the development stage in most initiatives examined in the present study and generally took the form of financial assistance to cover expenses and/or additional quota to mitigate for lost fishing opportunities. These initiatives were successful at ensuring stakeholder participation and, in general, led to the development of more selective gears. In addition, there was one initiative that was set up as a competition where prize money was offered to the fishers that reduced discards most effectively. In this scheme, there was no guarantee that development costs would be recouped, however, the non-monetary incentives offered were found to be very effective, and gave fishers recognition and credit as being the key players responsible for reducing discards, rather than the managers or scientists.

In the present study, two other issues are also highlighted which can affect the uptake of selective gears. Firstly, In a few of the initiatives presented here, gears were developed that increased selectivity and achieved the aims of the initiative, but that, for legal reasons, were not allowed to be used in the fishery. Secondly, the finite lifespan of some of the initiatives resulted in the positive gear developments not actually transcending into the fishery, despite otherwise successful collaborations.

4 | DISCUSSION

While incentives that ensure fishers do not have any income loss provide strong encouragement for the industry to develop and trial new gears, they can also lead to artificial participation where some individuals only participate for the immediate reward that an incentive may offer and not the longer term objective of improving their fishery. The different types of incentives offered highlight the need to distinguish between those that aim to encourage participation at the gear development stage and those that support the uptake of more selective fishing gears. While many of the initiatives did not consider incentivising uptake, it was addressed by managers in one fishery by offering additional fishing effort (days at sea) to those that fished with more selective gears. In another,

the new gears were made compulsory and access to the fishery was not permitted unless these gears were employed. Although it is not obvious what the best approach is, an effective incentive appears to be one that promotes participation, minimises economic loss and encourages stakeholders whose objectives are aligned with those of the initiative. Moreover, the incorporation of managers into such projects could help to understand the data requirements needed to get the gears passed into legislation. Additionally, prescribing the right kind of incentives and advocating for continued use after the life of the initiative, assuming that the objectives are met, can help ensure that such initiatives and their results actually filter into "real" benefits for the fishery (Armstrong et al., 2013).

The initiatives presented here typically fall between truly 'bottom-up', as leadership is often shared between industry and collaborating scientists, and 'top-down' implementation of government or academically developed strategies. However, it is most often closer to the former, as the motivation comes from industry, while ideas, research efforts and leadership are shared. It is important to highlight the fact that each stakeholder group contributes with their own unique expertise in such initiatives, and these should be emphasised. A proposed best way to involve stakeholders was to view all stakeholders as experts, where each contributes with their own experiences, perspectives and expertise (Kraan et al., 2014). The same can be considered for industry-led initiatives focusing on gear development, where fishers have the expertise around the problems encountered in their fisheries and potential tools which can be employed to alleviate these; scientists have a general overview of gears tested and the expertise on how to rigorously test and document a gear's performance in relation to those gears currently legislated; and managers understand the political and legal realms, and are able to outline what is required and how to legally implement a new or modified gear into the fishery.

Despite considerable work that focused on promoting and facilitating greater industry involvement in gear development, it has remained unclear whether such initiatives may truly lead to improvements in the fisheries. To help understand this, and potentially help facilitate change within the fishing industry, a topic group on Change Management in Fisheries (ICES, 2015; 2016; 2017) was established in 2015 as part of the ICES Working Group on Fishing Technology and Fish Behaviour (WGFTFB). The objective of the topic group was to evaluate the application of organisational change management concepts, and models in a fisheries context and recommend new approaches to overcome resistance to change in the fishing industry (ICES, 2015). The topic group looked at the question of what approaches are most successful in adoption of fishing gears and practices. Based on the initial results of a survey that was open to all WGFTFB members, and discussions at the first meeting, it was not clear whether the top-down or bottom-up approach was more successful—both methods have in the past been met with mixed success.

The missing flexibility in the EU's CFP is something that has potentially led to the limited uptake of successful gears developed, not only under such industry-led initiatives, but also in general. The previous management system in the EU was one where managers were interested in having one or two gears that worked best, on average, in each management area, and nothing more. Furthermore, the industry's focus was not on optimising selectivity, as discarding was legal and resulted in no economic loss, but on preventing loss of wanted catch. The 2013 CFP, and the proposal for a new technical measures framework within the EU, aims to address this issue by introducing the flexibility needed in the legislation to be able to introduce new highly selective gears relatively quickly and at a regional level. This change in the legal framework means that it may be possible for multiple gear solutions to be introduced within each management area to address the specific issues each fisher faces. This flexibility is something that is crucial for the success of the new CFP and the landing obligation. This is because the previously discarded portion of the catch now has a value to the fishers, as, although it is unmarketable, it is to be counted against the quotas. This, together with the growing number of countries having some form of Individual Transferable Quota system, means that the gears employed in a fishery will need to be tailored to each vessel segment or fishery and time of year, as each fisher's quota mix will be different and the availability of each quota will differ throughout the year as it is fished up.

Initiatives that put the responsibility on the industry to develop and test the tools they see applicable to their fishery can be very advantageous, not only in improving the selectivity of the gears used and reducing discards, but also increase compliance with the regulations, trust among stakeholders, and ownership over the gears used. Ongoing work on the value of industry-led initiatives will hopefully identify circumstances and approaches that will result in smoother, more effective and cost-efficient initiatives for the fishing industry in the future. The framework and proposed evaluation methodology for industry-led initiatives proposed below can potentially help facilitate this process. Furthermore, such initiatives need to demonstrate that it is possible for industry to develop more selective gears than those implemented. Only then will it be possible for the managers to be able to account for this by increasing the flexibility in the legislative framework.

In conclusion, a framework for industry-led initiatives for fishing gear development is proposed here that considers incentive structures, involvement of stakeholders, as well as the documentation of a gear's performance. The proposed framework aims to increase the flexibility and ownership over the gears used while ensuring an effective introduction of the new EU Common Fisheries Policy and the landing obligation. The proposed framework will achieve this by facilitating a more bottom-up approach to gear development where the industry is responsible for identifying gear-related problems, and where possible coming up with the ideas they feel applicable for their fishery. Additionally, the framework transfers the responsibility of testing the gear and collecting the data to the fishers, thus speeding up the testing process and increasing the diversity of gears being tested.

The proposed framework comprises two phases: industry-led testing and development; and scientific documentation. The

industry-led testing phase affords fishers the opportunity to test an idea they find applicable to their fishery as well as a development period during which issues relating to the gear's performance can be resolved iteratively. This iterative development phase is something that is often missing in scientific trials due to its cost and limited duration. Finally, solutions that show potential under the industry-led testing phase are required to undergo a phase of scientific documentation to evaluate their effects. The purpose of this latter phase, that is describing a gear's overall effect, is to ensure a certain quality that will be acceptable to, for example, the EU's Scientific, Technical and Economic Committee for Fisheries (STECF) or similar bodies in relation to the inclusion of the gear in technical regulations.

The involvement of fishing industry representatives (e.g. fishers' associations) and fisheries managers is integral in such collaborative initiatives. The participation of fishers' associations focuses on identifying the best ideas (an initial selection process) before the more promising ideas can be put forward to a scientific appraisal. The involvement of fisheries managers focuses on providing advice concerning the potential avenues and obstacles when trying to "fast-track" gear modifications through the legislative framework, such as the case in Denmark (Fast-Track; www.fast-track.dk).

Participation by the industry should be incentivised in several ways. Firstly, costs associated with the development of new gears (e.g. the purchase of new equipment/material) should be covered by the initiative. Secondly, the gears that proceed to the scientific documentation phase should be tested on commercial vessels, where the vessels are chartered and the subsequent landings are counted against scientific quota. Thirdly, while not directly compensated through monetary incentives, these initiatives provide the possibility for fishers to develop and test gears that would otherwise be considered illegal. Allowing fishers the possibility to develop, test and, where successful, implement the use of a gear that suits their fishery better than those currently prescribed in legislation.

The expected effects of the proposed framework are that: (a) the collaboration among stakeholders (fishers, net makers, industry representatives, managers and scientists) facilitates the development of ideas and solutions originating from the industry; (b) the industry becomes more proactive in the development and testing of solutions for the effective implementation of the landing obligation; (c) the close cooperation between industry and researchers leads to greater ownership of the solutions developed; and (d) the speed with which innovative solutions are developed, tested and approved is reduced, thus allowing multiple gears to be developed in parallel.

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SUPPORTING INFORMATION

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

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