Roadmap for the Kiwi-codend

Towards introduction of an innovative fishing concept in European fisheries

Wageningen University &
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List of abbreviations

Abbreviation	Explanation
CFP	Common Fisheries Policy
EMFAF	European Maritime, Fisheries and Aquaculture Fund
EMFF	European Maritime and Fisheries Fund
EN-ISO/IEC	European Standard - International Organization for Standardization/International Electrotechnical Commission
EU	European Union
ICES	International Council for the Exploration of the Sea
ISO	International Organization for Standardization
KvK	Dutch Chamber of Commerce (Kamer van Koophandel)
LVVN	Ministry of Agriculture, Fisheries, Food Security, and Nature (NL)
MCRS	Minimum Conservation Reference Size
MHS	Modular Harvesting System
NSAC	North Sea Advisory Council
PSH	Precision Seafood Harvesting
STECF	Scientific, Technical and Economic Committee for Fisheries
TMR	Technical Measures Regulation
WUR	Wageningen University & Research

Management summary

The **Kiwi-codend** is a promising innovative fishing gear component replacing the last part of trawl fishing nets, originally developed in New Zealand, with the potential to improve catch quality and discards survival in trawl fisheries. This codend also offers new selectivity options and makes the use of plastic dolly ropes to protect the net superfluous. The system replaces the last part of a trawl net with three modules: a cone, retention modules, and a lift bag. The cone ensures hydrodynamic stability. Retention modules control water flow, and have holes of specific shapes and sizes allowing unwanted bycatch to escape. The lift bag keeps the catch in non-turbulent water, reducing damage. The Kiwi-codend is buoyant and therefore has less contact with the seabed compared to several conventional demersal codends. Each module of the Kiwi-codend can be customized in size, material, selectivity, and floatation. The design is adaptable to various trawl fisheries.

Currently, the EU Technical Measures Regulation (TMR) does not explicitly ban the Kiwi-codend but mandates mesh size requirements for towed gear. Since the Kiwi-codend does not have netting material and thus no mesh size, this innovative gear component does not comply with the TMR. Therefore, to use the Kiwi-codend in commercial fisheries in the EU the TMR requires **legal amendments**. The pathway towards the amendments include several key steps: selection of the legal approach, recognition of specific innovative gear components, and adaptations for different fisheries all supported by scientific evidence. The Kiwi-codend introduces innovative materials and gear components, which must be formally recognized. Amendments to EU fisheries legislation can be made through the ordinary legislative procedure, involving the amendment of the TMR, or via a Delegated Act under the regionalization process, which allows for regional adaptations. Consultation with the European Commission is essential to determine the best path forward. Flexibility is crucial to ensure fishers can adapt the Kiwi-codend while maintaining regulatory compliance. Scientific evidence is needed for establishing gear parameters, improved selectivity, impact assessment, and guiding policy adjustments. Collaboration between fishers, scientists, and policymakers is essential for establishing the scientific evidence, refining the design and ensuring practical implementation.

In addition to legal considerations, several **technical factors** must be considered. Adapting the Kiwi-codend to different types of fisheries requires clearly defined parameters based on scientific studies and trials. These include:

- <u>Selectivity</u>: The Kiwi-codend must match or exceed the selectivity of conventional codends, with trials necessary for each fishery as the codend will have specific design differences.
- <u>Discards survival</u>: Survival rates are expected to improve, but further research is needed to quantify survival rates. Adjustments to onboard catch processing practices probably further enhance survival rates.
- <u>Catch efficiency</u>: Efficiency depends on hole size, shape and placement in the retention modules, making CPUE (catch per unit effort) comparisons with conventional codends essential.
- <u>Seabed impact & benthic bycatch</u>: No increase in seabed disturbance is expected, compared to conventional trawled codends, but evidence is needed. Benthic species escapement should be measured in selectivity experiments.
- <u>Life Cycle & Gear Loss</u>: The long-term durability and risks of gear loss of the Kiwi-codend must be assessed. As there is no need to use dolly ropes, the use of the Kiwi-codend is expected to significantly reduce plastic pollution, but evidence is needed.
- <u>Fuel Consumption</u>: Differences in fuel use between the Kiwi-codend and conventional codends must be assessed.
- <u>Fish Quality</u>: The codend is designed to reduce fish damage and thereby improve fish product quality (e.g., enhanced shelf life) after landing. Standardized tests can help quantify fish product quality improvements.

Besides legal and technical considerations, there are also some **social and economic** aspects to take into account. The willingness of Dutch fishers to adopt the Kiwi-codend remains uncertain. Initial trials in the Netherlands have yielded positive feedback from those who tested the Kiwi-codend, but fleet-wide acceptance is still unknown. Constructive collaboration between all parties involved in development of the innovation will help to progress more effectively. Uncertain return on investment due to yet unknown upfront costs, operational costs and durability could limit uptake, even though improved fish quality may lead to better prices.

However, if widespread adoption occurs, it could set new market standards, potentially lowering the cost price of this codend over time. To encourage adoption once legalized, financial or regulatory incentives may be necessary.

Implementing new fishing gear components in the EU requires broad stakeholder support, including industry, member states, scientists, and environmental NGOs. The Kiwi-codend shows promise for various EU fisheries – Denmark, for example, is conducting trials as well – but a **Europe-wide stakeholder engagement strategy** is crucial to foster support. Stakeholder involvement should begin directly after the proof-of-concept stage. A structured approach includes forming an independent oversight committee, identifying stakeholders that may be impacted by the gear innovation, and continuously evaluating research. Experimental trials may be limited in scope to refine the technology before wider adoption, for example by setting a limited number of vessels that can experiment with the gear modification or a limited area where the it can be used.

The implementation of the Kiwi-codend follows three key phases. The **first phase** focuses on initial development and legal considerations. It begins with establishing the correct legal pathway, whether through a delegated act or the ordinary legislative procedure. At the same time, the minimum technical and scientific requirements needed for approval must be identified. Stakeholder engagement plays a crucial role in this phase, ensuring that key actors, including fishers and regional groups, are involved from the start. In parallel, studies on selectivity, fuel efficiency, and catch performance must be conducted to demonstrate that the Kiwi-codend is as effective as or better than conventional gear. The **second phase** expands research and involves evaluating the impact of the Kiwi-codend on fish quality, discards survival, seabed disturbance, and gear life cycle. Additionally, economic viability must be determined by analyzing investment and operational costs, as well as market willingness to pay for higher-quality fish. As more data are gathered, gear parameters can be defined for regulatory inclusion, creating an example for other fisheries. This phase also encourages international collaboration among countries with similar fisheries, increasing overall support for the Kiwi-codend. The **final phase** focuses on legal adoption and industry uptake. By this stage, strong stakeholder engagement and sufficient research should provide the necessary foundation for integrating the Kiwi-codend into European fisheries legislation. With legal approval secured, efforts can shift toward encouraging fishers to adopt the Kiwi-codend, potentially through financial incentives. Raising awareness among retailers and consumers about the benefits of the innovation can further drive demand and improve market prices for fish caught with the Kiwi-codend. Lastly, ongoing research on fish behavior and escape devices will ensure continued improvements in gear selectivity, maintaining its effectiveness as a tool for sustainable fisheries.

1. Introduction

Sustainable fisheries and resilient fishing communities are some of the objectives of the Common Fisheries Policy (Regulation (EU) No 1380/2013[1]). Improving the efficiency and sustainability of fisheries is part of these objectives. The European Maritime, Fisheries and Aquaculture Fund (EMFAF[2]) supports fishers in modernizing fleets and adopting low-impact practices to overcome these challenges. Through EMFAF funding, the innovative 'Kiwi-codend', developed in New Zeeland[3], was introduced for experimental piloting by two Dutch beam trawl vessels. The innovative technology replaces the last part of the net material with a gear component of different material and configuration. Initial trials in EU waters showed that the Kiwi-codend concept seems to align with the objectives in the EU and Dutch visions (see Annex 1) for increasing sustainability of fisheries, by improved catch quality; discard survival; and potentially offering novel selectivity options. The higher quality of the fish in the catches could potentially also contribute to the economic resilience of fisheries. The innovation offers fishery entrepreneurs and the sector as a whole options for alternative fishing methods. A full explanation of the Kiwi-codend can be found in chapter 2.

The Kiwi-codend is promising in improving catch quality, discard survival, selectivity and reducing plastic pollution from lost dolly rope compared to conventional codends. The current available research results are presented in chapter 3. However, there are legal, technical, social and economic challenges that need to be dealt with before the Kiwi-codend can be implemented in European fisheries (chapter 4).

To facilitate the successful adoption of the Kiwi-codend by the European Union fisheries sector, this roadmap provides guidance on addressing the challenges associated with its implementation. It also emphasizes the importance of evaluating and effectively communicating the technology, recognizing that specific requirements may vary depending on the region, fishery type, and other factors. Chapter 5 presents a summary of the roadmap to follow towards implementation of the Kiwi-codend.

The roadmap was developed by Wageningen Marine Research using insights gathered through semi-structured interviews with key stakeholders from scientific research institutions (four interviews total, two from the Netherlands, one from France, one from the United Kingdom), fisheries management bodies (two from the Netherlands, one from the United Kingdom), policy authorities (through a brainstorm session attended by ten Dutch representatives from LVVN, the Permanent Representation of the Kingdom of the Netherlands to the European Union in Brussels, and RVO), and industry representatives (two from the Netherlands). These interviews provided essential information on operational challenges, regulatory frameworks, market dynamics, and sustainability concerns.

All data were anonymized as agreed for the interviews. The raw interview data are retained until the publication of this report. A qualitative analysis was conducted to identify key themes relevant to the roadmap's objectives. The process involved iterative consultations, ensuring that the roadmap is informed by scientific research, industry practices, and policy frameworks, and is designed to address current challenges while preparing for future opportunities.

[1] http://data.europa.eu/eli/reg/2013/1380/2023-01-01
[2] https://oceans-and-fisheries.ec.europa.eu/funding/emfaf_en
[3] https://thesolutionsjournal.com/transforming-bulk-seafood-harvesting-producing-authentic-wild-fish/

2. Kiwi concept

2.1 Name of the innovation

The Kiwi-codend is an innovative fishing gear component developed in New Zealand by Precision Seafood Harvesting (PSH). FloMo is the current brand name of the gear component used in New Zealand, but previous names like Tiaki Cod End and Modular Harvest System (MHS), which are no longer in use, indicate that names change over time. For this roadmap, the name Kiwi-codend is used, because it represents the concept, not a brand. Using the name Kiwi-codend avoids tying regulations to a brand name or a specific supplier. Since the concept should be tested and developed independently for European fisheries, keeping terminology generic is essential.

2.2 Function of the Kiwi-codend

The objective of the Kiwi-codend is to significantly improve the quality of fish caught by commercial fishing vessels (PSH, 2020). By improved quality, products can be delivered to the market with longer shelf life (preservation time), which would help in increasing viability of fisheries (Moran et al., 2023).

Fish quality is impacted by what happens in the fishing gear (Veldhuizen et al., 2018; Cook et al., 2019). In conventional codends[4] consisting of netting material, as used in all trawling fisheries in EU waters, a high velocity turbulent water flow is produced during trawling (fishing). This will exhaust and damage the aggregated fish in the codend. Trawling can take up to several hours, increasing the damage to fish caught at the start of the fishing activities. At the end of the trawl, the codend with its catch is hoisted aboard and the catch is compressed. As a result, many of the fish experience damage such as a loss of the slime layer and scales, and bruising. This causes reduced product quality and survival chances of fish that are not landed but put back into the water. The Kiwi-codend offers a solution by herding the fish though a series of modules into a 'lift bag module', where no water flow is present, so the fish are less damaged and exhausted when hauled aboard. The lift bag module practically functions as an aquarium where the fish are able to conduct their natural behaviour (Figure 1). Furthermore, the codend is hoisted aboard in a volume of water preventing compression of the catch (Figure 2). As a result the fish are landed on deck in much better condition compared to fish landed aboard using conventional mesh[5] codends (Figure 3).

[4] The codend is the last part of the fishing net.
[5] Netting

Figure 1. *Flatfish freely swimming in lift bag module of the MHS (Kiwi-codend) during fishing activities. Photo : Pieke Molenaar*

Figure 2. *Kiwi-codend in use on starboard side of a Dutch beam trawler. Note the water retention in the lift bag module shown in the left hand image. Photo: Pieke Molenaar*

Figure 3. *Flatfish caught with the Kiwi-codend on board the trawler. Photo: Pieke Molenaar.*

2.3 Description of the Kiwi-codend modules

2.3.1 Background

In the Kiwi-codend concept, the last part of the trawl net (the tunnel and codend) is replaced by three different modules: a cone, retention modules and a lift bag (Figure 4). Each of these modules is described in the following sub-sections.

Because the Kiwi-codend only replaces the last part of the fishing gear (Figure 5), in theory the concept can be adapted for most trawl and seine fisheries. Technical adaptations will be required for each fishery type. As a starting point, a set of gear parameters has to be defined by fishery type (Annex 2).

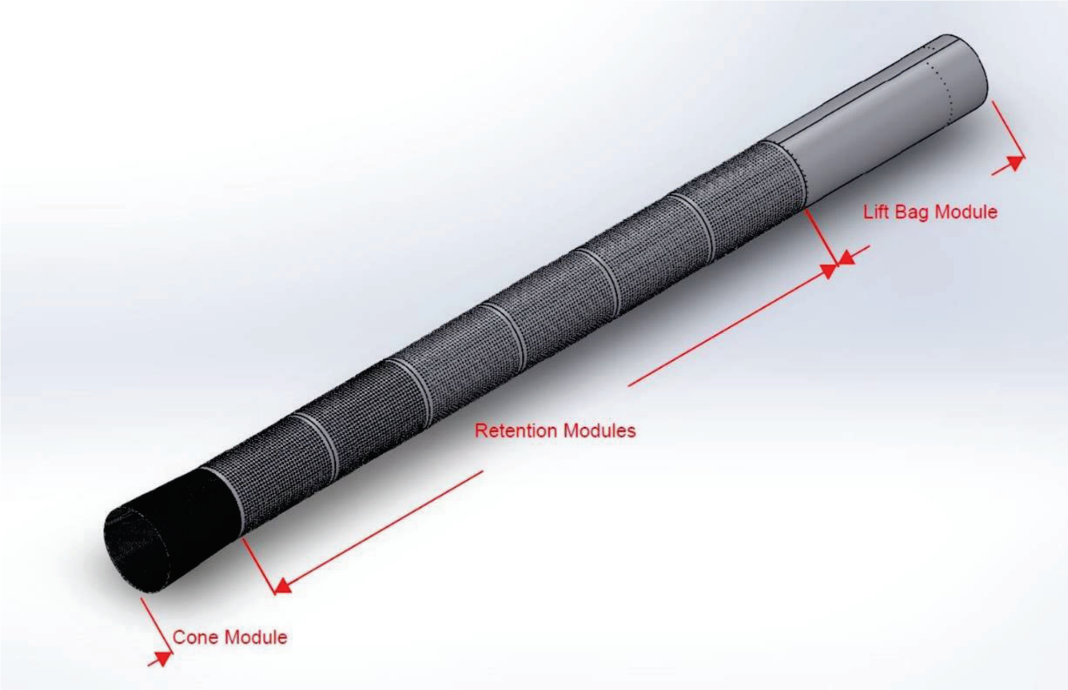


Figure 4. *Conceptual representation of a Kiwi-codend, replacing the codend, tunnel and part of the back net of a conventional gear. The 'cone' is a funnel-shaped module without holes, ensuring that the gear remains open at all times. The 'retention modules' have holes for undersized fish to escape, and for water to exit, avoiding the gear to 'blow'. The 'lift bag' module concerns the codend and has no holes in it so that fish can be hoisted aboard within a volume of water. Source: https://www.flomo.co.nz/*

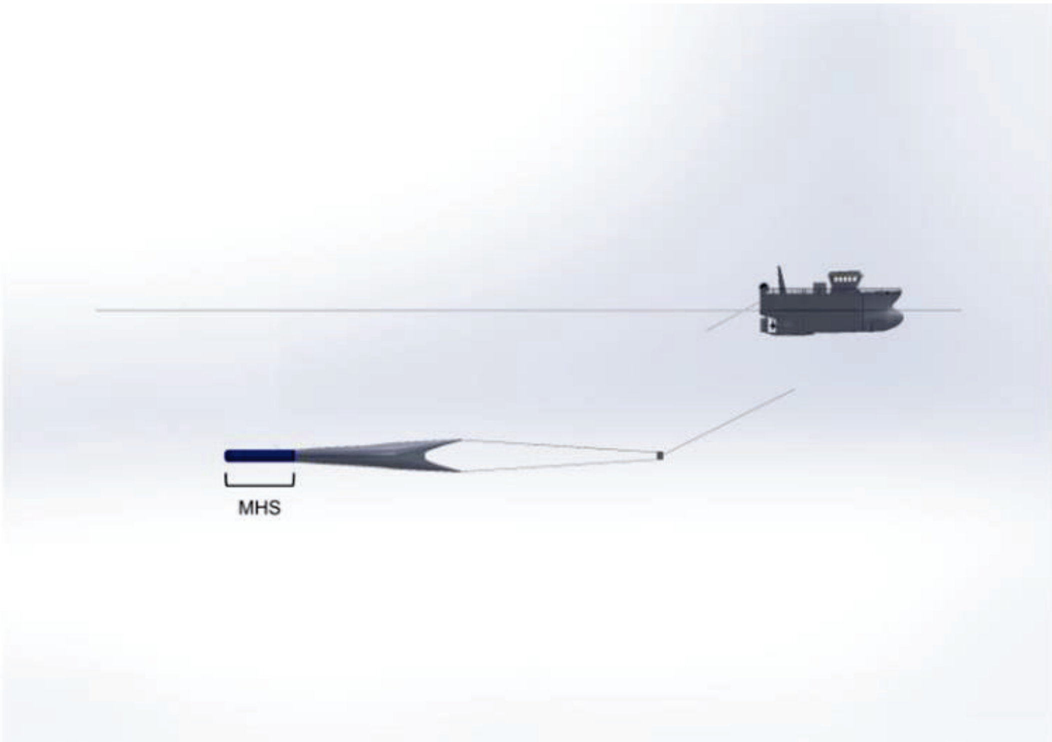


Figure 5. *Part of the classical netting that is replaced by the Kiwi-codend (referred to as MSH in the figure). Source: https://www.flomo.co.nz/*

2.3.2 Transition mesh panel

A transition mesh panel between the trawl body and the cone is needed in some net types to attach the Kiwi-codend. This panel can also be used to compensate for any differences (slack) between length of the top and bottom panel of the trawl. The transition panel can vary in length (number of meshes deep), width (number of meshes wide), mesh in salvage (extra mesh needed for extra strength), mesh size, and twine thickness.

2.3.3 The cone

The cone is the first module that is attached to the tapered section of the trawl net – or to the transition mesh panel - and connects to the retention module aft. The cone is a non-porous flexible membrane module at the front end of the Kiwi-codend that enables the Kiwi-codend to deploy and set correctly, providing hydrodynamic stability during fishing. The cone has to be adjusted for each fishery type by adapting entry diameter, exit diameter, length, floatation devices, material thickness, lifting devices at the start of the top section and weight at the start of the bottom section. Depending on the fishery type, an additional shafting panel (panel protecting the codend, attached outside of the net, used in bottom trawling fisheries) may be applied.

2.3.4 Retention modules

The retention modules are semi-porous modules located between the cone and lift bag modules. They allow for tailoring of the environment within the gear to the physical tolerances of the target species by gradually reducing the water flow. The retention modules have holes that enable water to exit and undersize and incidental bycatch species to escape. These modules must specifically be adapted to retain the target species while allowing unwanted bycatches to escape, by changing hole shapes, size and location, adding or removing modules, adapting material thickness, module length, diameter and flotation devices. The holes also do not shrink, like in conventional nets. Depending on fishery an additional shafting panel may be applied, combined with additional solutions to prevent the panel blocking the escape holes in the bottom panels.

2.3.5 Lift bag (terminal end of the gear) module

The lift bag is a non-porous flexible membrane module at the terminal end of the Kiwi-codend that allows the catch to remain in non-turbulent water during trawling and hauling, preventing further damage to the fish in the catch. It also allows the catch to remain in water while hauled aboard, reducing physical compression of the catch. This module may be adapted in length and diameter per fishery depending on catch volume in the particular fishery. The closing mechanism may be adapted to a specific work flow of the fishery. Depending on fishery an additional shafting panel may be applied.

3. State of the art

3.1 Introduction

The Kiwi-codend was conceptualized in New Zealand in 2012 as part of a research program funded by the New Zealand government. Since then, extensive research has been conducted in the country, leading to partial legislation under a new innovation law for New Zealand fisheries (PSH, 2020). In Europe, research has also been done with the technology in trawl fisheries. Two beam trawlers from the Netherlands experimented with the Kiwi-codend under research derogations.

This section presents the main results of the research that has been conducted, and it summarizes ongoing and planned research for different fishery types. It also gives an overview of the challenges and opportunities specific of the Kiwi-codend per fishery type, with a focus on North Sea fisheries. Most details are available for beam trawl fisheries targeting flatfish, as this is where most knowledge is within EU fisheries.

The MHS (previous FloMo name, see section 2.1) is also included in the catalogue of innovative fishing gears (ICES, 2023b) developed by the International Council of the Exploration of the Sea (ICES), as part of a special advice request by the European Commission (ICES, 2023a).

3.2 Ottertrawl

3.2.1 Past research

Project title	**Precision Seafood Harvesting Primary Growth Partnership Programme**		
Funding country	New Zealand	**Funding source**	Government / PSH (50/50)
Fishery type	New Zealand Inshore & Deepwater	**Start/end**	April 2012 to Sep 2019
Main findings	• Development of FloMo system from concept to commercial prototype. • Regulatory approval for commercial use in NZ for 3 deepwater and 11 inshore species. • Demonstrated gains in fish quality delivering significant increases in catch value. • Improved operational efficiency through capability to hold fish at depth and extend tow time. • Acute juvenile snapper post-harvest survival was vastly superior to mesh trawls.		
Source:	PSH, 2020 - Precision Seafood Harvesting PGP - Final Report		

3.2.2 Planned research

Project title	**'Unrealised Potential' Sustainable Food & Fibre Futures Programmme SFFF21033**		
Funding country	New Zealand	**Funding source**	Government / PSH (50/50)
Fishery type	New Zealand fisheries	**Start - duration**	Oct 2022 to Sep 2026

Research focus and hypothesis	• Further R&D of FloMo systems & commercialization of FloMo technologies.
	• Research into benefits of FloMo systems for:
	  ○ snapper quality
	  ○ hoki selectivity
	  ○ scampi selectivity / by-catch reduction and quality.
	• FloMo development for international fisheries		

Contact person	Martin de Beer, PSH

Project title	**Testing of new selective trawl bag for live catch (GROFISK Project)**		
Funding country	Denmark	**Funding source**	EMFAF / Danish Fisheries Agency (70/30)
Fishery type	Mixed demersal fishery	**Start - duration**	2 May 2024 to 12 Jul 2027
Research focus and hypothesis	• Test FloMo selectivity and fish survivability to support EU rules on selective fishing and discards of unwanted catch, including protected species. • Research into whether FloMo reduces stress in fish and improves quality and value.		
Contact person	Martin de Beer, PSH		

Project title	**Evaluation of the FloMo codend selectivity characteristics in the U.S. West Coast groundfish bottom trawl fishery**		
Funding country	USA	**Funding source**	PSH (precision seafood harvesting)
Fishery type	West coast groundfish bottom trawl fishery	**Start - duration**	21 July 2025, 12 fishing days
Research focus and hypothesis	Comparing the selectivity characteristics between the Kiwi-codend and a conventional codend used in U.S. West Coast groundfish bottom trawl fishery		
Contact person	Mark Lomeli, PSMFC, mlomeli@psmfc.org		

Project title	**Further development of the application of the Kiwi-codend in beam trawl and twin-rig fisheries.**		
Funding country	Netherlands	**Funding source**	EMFAF
Fishery type	Beam trawl and otter trawl	**Start - duration**	2025-2027
Research focus and hypothesis	Practical experience of the Kiwi codend in beam trawl fisheries; selectivity of the Kiwi-codend compared to traditional codends; catch composition (discards & landings); product quality; design, construction and testing Kiwi-codend for twin rig otter trawling targeting flat fish; international network organisation.		
Contact person	Ben Scholten, Nederlandse Vissersbond		

Other research projects are planned but have not yet been disclosed, as funding has not been secured. These studies will focus on the benefits on fish quality and selectivity of the gear component in the Alaskan cod fishery, Norwegian cod fisheries, UK otter trawl fisheries, New England groundfish fisheries, and West Coast groundfish fisheries.

3.2.3 Outlook

The Kiwi-codend was developed as part of the New Zeeland's Precision Seafood Harvesting (PSH) program. It has been designed for and tested in several otter trawl fisheries in New Zeeland ranging from small scale coastal demersal otter trawling to deep sea semi-pelagic trawling with catches up to 50 tons. This New Zealand development already delivered promising results and successful implementation for those métiers. Furthermore UK and Danish research institutes study the use of the technology on a twin-rig otter trawler in mixed demersal fisheries and Nephrops targeting fisheries. More knowledge on challenges and opportunities for EU otter trawl fisheries will become available in a few years' time.

3.3 Beam trawl targeting flatfish

3.3.1 Past research

Project title	**Fishing mortality unwanted bycatch** *"SELOV - OSW Visserijsterfte ongewenste bijvangsten"*		
Funding country	Netherlands	**Funding source**	EMFF
Fishery type	Beam trawl	**Start/end**	February 2019 - October 2023
Main findings	The objectives of this study were to design and test a MHS for beam trawl fisheries targeting sole. The first MHS prototype was successfully tested in combination with small (4m wide gears) and large (12m wide) beam trawls. Landings were quantitatively comparable to traditional trawls while discard amounts were lower. Fish condition was better for fish caught with MHS, suggesting a higher survival probability for discarded bycatches and higher product quality for landings. By trial a 62*1.2mm oval hole was used for this Kiwi-codend, seemingly offering equal selectivity to a 80 mm mesh codend.		
Source:	Molenaar et al., in preparation. Wageningen Marine Research		

Project title	**Survival probabilities of plaice, sole and turbot discarded by beam trawl and flyshoot fisheries**		
Funding country	Netherlands	**Funding source**	EMFF
Fishery type	Beam trawl	**Start/end**	January -September 2023
Main findings	The objectives of this study were: 1. to establish baseline survival probabilities for undersized plaice, sole and turbot discarded by tickler chain beam trawl fisheries with two 12 m wide gears and for plaice discarded by flyshoot fisheries, and 2. to establish the effect of replacing the conventional mesh lengthener and cod-end of a 12 m wide tickler chain beam trawl by a modular harvest system (MHS) on discards survival probabilities of undersized plaice, sole and turbot. To test the MHS, the conventional mesh cod-end of one of the two trawls of a double rigged beam trawler was replaced with a MHS and paired samples of test fish were collected from the catches by both gear types. In total 579 plaice, 294 sole and 128 turbot were sampled from the conventional beam trawl gear. From the beam trawl with MHS a total of 160 plaice, 80 sole and 37 turbot were sampled. Survival probabilities of plaice and turbot were significantly higher for the fish sampled from the beam trawl equipped with a MSH. On average the MHS resulted in an elevenfold increase in survival for plaice and a sixfold increase in turbot. For sole no significant effect was detected. This study confirms and provides the first quantitative insight in the potential increase in survival probability of replacing the conventional mesh cod-end of a beam trawl with a MHS. Further increase in discards survival probability is expected with the refinement of the fishing technique. To fully utilize the potential increase in discards survival that can be achieved by the MHS, research into the refinement of the catch sorting process to maintain the good condition of the fish while on board is recommended.		
Source:	Schram et al. (2023)		

The results of the above-mentioned studies are presented in a summary sheet with an comparison of variables, the current state of the art, challenges and future research required (**Error! Reference source not found.**Annex 3). The main findings can be summarised as follows:

<u>Selectivity:</u> In the first trials, the conventional beam trawl net cod-end (80mm) and the Kiwi-codend (62 x 1.2mm) have similar results for selectivity (Molenaar et al., in prep). Ongoing research so far does not show a substantial better selectivity with the latter. However, improved selectivity is expected and improvements and optimalisation of the Kiwi-codend are desired. The concept allows for species specific escape openings, but these have not been applied in the first trials. More research is needed and is planned for the near future in the Netherlands.

<u>Discards survival:</u> The Dutch Kiwi-codend tests showed that the use of the Kiwi-codend resulted in an elevenfold increase in survival of discarded plaice compared to a conventional codend (Schram et al, 2023). Another study found less catch fatigue and physical damage to the fish due to the flow reduction and open geometry of the Kiwi-codend (Moran et al., 2023).

<u>Catch efficiency</u>: In preliminary studies (Molenaar et al., in prep), catch levels of marketable sole in the Kiwi-codend were higher than in the 80mm codend. No significant differences for other species were identified. Nonetheless, additional data collection concerning catch efficiency is required.

<u>Seabed disturbance:</u> The Kiwi-codend is buoyant and therefore it will have less seabed disturbance than a conventional cod-end for some fisheries. Do note that in beam trawl fisheries the bottom disturbance of a codend is marginal compared to the rest of the gear (i.e. tickler chains). Moran et al. (2023) stated in their study that the Kiwi-codend remained in a more steady position while movement was minimized compared to the conventional codend. This may provide implications regarding seabed disturbance, however more trials are required.

<u>Fuel consumption</u>: From preliminary studies, the drag force of a regular mesh codend showed to be the same (when full) compared to the Kiwi-codend (Molenaar et al., in prep). Additional data collection concerning fuel consumption is desired to strengthen first observations and provide additional data.

<u>Fish quality</u>: Since there is stagnant water in the final section of the Kiwi-codend, fish can swim freely (Figure 1). This contrasts sharply with regular codends, where fish are typically damaged by the combination of turbulent water flow and contact with other catch and codend netting during the fishing process, and compressed together when hauling (Veldhuizen et al., 2018; Cook et al., 2019). Beam trawl fishers involved in the Kiwi-codend trials highlighted the significant improvements in fish quality (Molenaar et al., in prep). Additionally, fishers reported strong interest from fish traders in this net innovation due to its proven success in enhancing fish quality (see Annex 4). Fish captured with the Kiwi-codend are in a more viable and lively state and exhibit better overall condition.

<u>Life cycle:</u> During ongoing research with the Kiwi-codend, so far, the material proves to be at least, if not more durable compared to the conventional beam trawl nets (interviews and personal observations). Furthermore, trials in New Zeeland shows minimal gear loss, damage or plastic pollution (interview PSH). For the Dutch case, the situation appears comparable, although final conclusions can only be drawn over time. To address the issues of durability, plastic emissions and effectiveness of the system extended research is scheduled for 2026-2027.

3.3.2 Planned research

Project title	**Further development of the application of the Kiwi-codend in beam trawl and twin-rig fisheries.**		
Funding country	Netherlands	**Funding source**	EMFAF
Fishery type	Beam trawl and otter trawl	**Start - duration**	2025-2027
Research focus and hypothesis	Practical experience of the Kiwi codend in beam trawl fisheries; selectivity of the Kiwi-codend compared to traditional codends; catch composition (discards & landings); product quality; design, construction and testing Kiwi-codend for twin rig otter trawling targeting flat fish; international network organisation.		
Contact person	Ben Scholten, Nederlandse Vissersbond		

Further research is planned in the Dutch beam trawl fisheries but has not yet been disclosed, as funding has not been secured. The intention is to continue studying: 1. Selectivity, 2. Discards survival, 3. Catch efficiency, 4. Seabed impact & bentic bycatch, 5. Life cycle & gear loss, 6. Fuel consumption & emissions and 7. Fish quality.

3.3.3 Outlook

For beam trawl fisheries it is suggested to conduct further experiments with the Kiwi-codend on British, and other, fishing grounds, particularly during the peak fishing season as the fishery at that time and in that area generates an important income for fishermen. Fishing in different areas will also be essential in understanding how the kiwi-codend performs and impacts different grounds. This will provide a more realistic assessment of the marketable catches and the economic viability of the Kiwi-codend.

Initial steps include conducting video recordings to better analyse fish behaviour in the low turbulent water of the Kiwi-codend environment. Additionally, gaining hands-on experience in repairing the Kiwi-codend is recommended to ensure effective maintenance and functionality onboard. Also, Kiwi-codend trials are necessary on different fishing grounds and under demanding weather conditions to assess its performance in harsher environments.

3.4 Beam trawl fishery targeting brown shrimp

3.4.1 Planned research

Project title	**Kiwi-codend brown shrimp fisheries (Kiwikuil garnalenvisserij)**		
Funding country	Netherlands	**Funding source**	Waddenfund / LVVN
Fishery type	Brown shrimp beam trawl	**Start - duration**	2025-2028
Research focus and hypothesis	Focus on improved selectivity for both small shrimp and very small flatfish. This unwanted bycatch in this fishery cannot be reduced by conventional diamond mesh without a significant loss of marketable catches. This project focuses on the development of a different shaped codend opening to enhance selectivity and reduce unwanted bycatch of small shrimp (≤5cm) and flatfish (3-10cm).		
Contact person	Pieke Molenaar, Wageningen Marine Research		

3.4.2 Outlook

Beam trawl vessels in brown shrimp fisheries differ substantially in engine power and size from beam trawl vessels targeting flatfish. Vessels are usually ranging between 19 to 24 meters while fishing with engines of 150 to 300 hp. The beam has a length of 6 to 9 meters. The codend mesh size is significantly smaller (24-26 mm) compared to tickler chain beam trawls targeting flatfish. Application of Kiwi-codend technology in this fishery may enhance selectivity by reducing bycatches of non-marketable brown shrimp and small undersized flatfish. Optimal slit size opening for this fishery needs to be assessed.

3.5 Outlook for EU Flyshoot fisheries

Flyshooting (Scottish or Danish seine) demands expertise in hydrographic conditions, such as currents and seabed types, along with precise control of seine rope tension. A major challenge is the quick stretching of the seine ropes. Research is needed to assess the suitability of the Kiwi-codend for this métier, particular as it is a mixed fishery with several target species without minimum landing size, the design of escape holes may be challenging. Flyshoot fisheries captures and brings fish onboard very quickly, resulting in relatively few damaged fish. Consequently, the fish quality improvement of a flyshoot Kiwi-codend may be less pronounced as the fish quality of the conventional gear is already good, also reflected by higher discard survival probabilities of flatfish and skates compared to beam trawling (Schram et al., 2023; Schram et al., 2024). However, damage of fish while lifting the codend on board is most likely reduced. The reduced water flow in the Kiwi-codend may enable improved selectivity in this fishery.

3.6 Outlook for EU pelagic fisheries

In pelagic fisheries initial trials have been done in the New Zealand deep sea hoki fisheries. However, in the European pelagic fisheries targeting small-pelagic species, the catch volumes are considerably larger. Consequently, there are concerns about the material strength. Application of a modified Kiwi-codend might have a positive implications on fish welfare and it may also enhance fish quality. First steps for a pelagic design and its application will be done in the Netherlands by the end of 2025.

4. Challenges

4.1 Introduction

Based on interviews conducted, there are several challenges to overcome in adopting the innovative Kiwi-codend technology in EU fisheries. This chapter outlines some of the key issues that need to be addressed, including legal, technical, social and economic and stakeholder engagement aspects. The relevant stakeholders differ based on the challenge, and the main stakeholders are also identified below.

4.2 Legal factors

A legal challenge is that the Kiwi-codend does not currently fit in the Technical Measures Regulation (TMR) of the EU (Regulation (EU) 2019/1241[6]). One significant issue is the lack of mesh configurations, which requires regulatory amendments. To make the Kiwi-codend legal for use in the EU fishing sector, its design, materials, and specifications must be formally incorporated into European fisheries policy.

The existing Technical Measures Regulation (TMR) describes legal fishing gear by its parameters such as mesh sizes, selectivity devices (e.g. square mesh panels, escape holes) codend circumference, and length. The regulation is based on decades of scientific selectivity studies and extensive field data.

While the TMR does not explicitly prohibit the use of the Kiwi-codend, it does include requirements regarding mesh sizes for towed fishing gear. Since the Kiwi-codend is classified as towed gear but is a codend without netting material, it does not comply with the TMR. Therefore, an amendment of the TMR is required, allowing for the use of the Kiwi-codend in commercial fisheries.

The overall process of securing an amendment is expected to take one to several years. The key actions under this legal challenge are listed below and further detailed in this section:

1. To clarify how to regulate the Kiwi-codend concept;
2. To decide on the correct legal approach to secure amendment of the TMR;
3. To adapt the Kiwi-codend concept for every métier (fishery type), and leave room for fishers to further innovate;
4. To provide the scientific evidence-base for decision-making.

4.2.1 Action 1: To clarify how to regulate the Kiwi-codend ‘concept’

As explained above, the Kiwi-codend challenges the current TMR by the use of a codend **without meshes** (hence, no mesh size), unlike the codends made from netting material. It introduces **new gear components**, including a cone and retention modules. Finally, it uses **innovative sturdy material**, which replaces traditional netting materials.

The **selectivity** of the Kiwi-codend does not occur in the final part of the net, as with traditional designs, but in the area that is best compared to the tunnel of a conventional net. In the Kiwi-codend, this area is referred to as the **retention module**.

A first step towards the regulation of the Kiwi-codend across different métiers would be to formalize and incorporate its core components: **the cone, retention module(s), and lift bag** - into the TMR. Once formally recognized, the concept could be adapted to address the specific needs in dimensions of the gear components

[6] Technical measures are a broad set of rules that govern how, where and when fishers may fish in EU waters. They are established for all European sea basins. http://data.europa.eu/eli/reg/2019/1241/oj

(i.e. gear parameters) to fit different métiers and regions. It is recommended to involve fishers in the description of these dimensions, as they can assess the practical feasibility of regulations (Steins et al. 2022).

Further exploration and collaboration between the Dutch ministry of LVVN, other Member States that are potentially interested in the innovation, and the European Commission to clarify the steps to be taken.

4.2.2 Action 2: To decide on the correct legal approach to secure amendment of the TMR

There are two general approaches for amending the EU TMR and getting the Kiwi-codend legalized:

1. Amending the TMR via the ordinary legislative procedure
2. Amending Annex(es) of the TMR through a Delegated Act[7]

The correct legal approach should best be clarified in an early stage in consultation with the European Commission. This asks for maintaining ongoing communication with the European Commission, making sure that the case for the Kiwi-codend is clear and compelling.

- *Amending the TMR via the ordinary legislative procedure*

Article 8 of the TMR (about general restrictions on the use of towed gear) appears to assume that towed fishing gear must have mesh. This may result in the conclusion that for the Kiwi-codend to be allowed an amendment of Article 8 is required. The latest revision of the TMR was agreed in 2019 and took many years to achieve, and no new revision is to be expected soon. The expected evaluation of the Common Fisheries Policy in 2025 may, however, open an opportunity.

Changing the TMR via this route asks for a co-decision process between the European Council and the European Parliament. The benefit of this is that the Kiwi-codend can also be regulated in the main body of the TMR, and for example in the definitions and general restrictions on the use of towed gear. The Kiwi-codend may also be regulated in the Annexes of the TMR, per region. This creates the possibility to amend these rules with a delegated act (see below).

- *Amending Annex(es) through a Delegated Act*

The TMR establishes in Article 15 and corresponding annexes technical measures at regional level. Furthermore, it empowers the Commission to adopt Delegated Acts in order to amend, supplement, repeal or derogate from those technical measures. These Delegated Acts shall be adopted based on Joint Recommendations submitted by Member States concerned, in accordance with Article 18 of the Basic Regulation. These Delegated Acts allow the Commission to adjust or update certain technical, detailed aspects of EU laws through amendments of Annexes without needing to go through the full legislative process (Regulation (EU) No 1380/2013[8] - Article 18).

Member States having a direct management interest may submit joint recommendations in the regional Member States groups. Based on these joint recommendations, the Commission may adopt a Delegated Act. Once a Delegated Act is drafted, the European Parliament and the Council (of Ministers) have two months to scrutinize it. There is some flexibility around this timeframe, as the co-legislators may request an extension of this period. If one of them objects, the Delegated act cannot be implemented. When the Delegated Act is adopted by the European Commission, it will amend the Annex(es) of the TMR. The process of adopting a Delegated Act can be done in six months.

4.2.3 Action 3: To adapt the ‘concept’ for every metier, and leave room for fishers to further innovate

When the general concept of the Kiwi-codend is regulated, it must still be adapted for each métier specifically. A decision that needs to be made is whether amendments of the (Annexes of the) TMR are needed on a métier-by-métier basis or to propose a broader amendment that addresses multiple métiers and regions simultaneously.

For a successful continuation of the development of the innovation, it is crucial not to obstruct fishers with overly rigid and precise regulations. Too precise regulations prevent fisher from being able to tailor the

[7] Delegated acts are non-legislative acts adopted by the European Commission that serve to amend or supplement the non-essential elements of the legislation. The Commission’s powers to adopt delegated acts are subject to strict conditions.

[8] http://data.europa.eu/eli/reg/2013/1380/2023-01-01

innovation to their needs. Flexibility must be preserved to ensure practical application and to encourage adoption. This means that there should be room for modification of gear parameters and for additional future selectivity options. Again, as in Action 1, it is recommended to involve the fishing industry in the formulation of regulations, ensuring practical feasibility (Steins et al. 2022).

The Kiwi-codend provides multiple opportunities to enhance baseline selectivity through its modular design. Each section of the system can, in theory, be customized to achieve specific selectivity goals. For instance, a theoretical whiting escape module could easily be integrated. The development of such modules takes some time and the modules improve with increased fishing experience. When possible, the proposed case should allow for future module adaptations within the legal framework. Additionally, the commercial use of the Kiwi-codend will generate valuable practical insights, further refining and optimizing its design.

4.2.4 Action 4: To provide the scientific evidence-base for decision-making

Scientific studies play an essential role in generating preliminary knowledge about the gear and in identifying ranges of parameters for the various components of the gear. These studies provide a broad overview of the specific features that are likely to be important.

To support the process of future continued innovating, ranges of parameters for the Kiwi-codend's components should be established through a collaboration between scientists and fishers (Table 1). Those ranges should be included in the Annexes to the TMR or in a Delegated Act under the TMR.

The parameter ranges vary for each type of fishery and are likely to differ regionally, depending on the target species and the fishing season. Flexibility and additional selectivity options, such as extra or adapted modules, should also be taken into account.

The regulatory challenges will benefit from strong scientific data and at sea tests with the technical challenges presented in the section below as a guideline. Additionally, for overcoming regulatory challenges it is important to have a wider stakeholder support, which is further discussed in section 4.5.

Table 1. *Parameters of Kiwi-codend gear components for which ranges need to be established.*

Gear component	Parameters to establish
Cone	• diameter front (cm) • diameter back (cm) • length (cm)
Retention Modules	• quantity (#) • diameter (cm) • length (cm) • general escape holes: 1. shape (round, oval, ...) 2. size (mm) 3. position(s) 4. quantity (#) • alternative escape holes: same parameters as above
Lift Bag	• diameter (cm) • length (cm)
Transition panel *(relevant only in some specific fisheries)*	• length (#mesh deep) • width (#mesh wide) • mesh in salvage (#mesh) • mesh size (mm) • twine thickness (mm)

4.3 Technical factors

A technical challenge is that the Kiwi-codend must be adapted to suit various European fisheries, while it was originally designed for pelagic fisheries in New Zealand. This requires scientific testing and validation to ensure it meets EU standards for efficiency and sustainability.

The Kiwi-codend can be adapted for various types of fisheries. One the one hand, a set of parameters for the gear components need to be defined for each fishery (Table 1). This needs to be based on scientific studies and practical trials by fishers. On the other hand, there are several questions that have to be answered for each fishery about how the Kiwi-codend compares to a conventional codend regarding selectivity, discards survival, catch efficiency, seabed disturbance, gear life cycle, fuel consumption and fish quality.

4.3.1 Selectivity

Selectivity in fishing nets refers to the ability of the gear to target and retain specific sizes and species of fish or other marine organisms while allowing non-targeted species or undersized individuals to escape. High selectivity minimizes undersized bycatch and helps promote sustainable fishing practices by reducing the capture of non marketable or protected species, as well as undersized individuals, allowing them to contribute to the population's growth and reproduction.

- *Baseline selectivity*

The selectivity of the Kiwi-codend probably varies by fishery. For the technology to be widely accepted, it needs to demonstrate equal or improved selectivity compared to conventional methods. A positive effect is anticipated from the holes in the retention modules – these holes remain open at all times, allowing fish that fit through to escape continuously throughout the trawl period (Moran et al., 2023). Because species composition varies between fishery types, for each fishery substantial amounts of selectivity experiments are needed to collect reliable selectivity data for the Kiwi-codend. This will also create the opportunity to adapt the Kiwi-codend to fit the specific fishery type, e.g. by changing hole sizes and shapes. At present, the selectivity of the Kiwi-codend remains largely untested for most fisheries and fish species in EU waters, with only an exploratory campaign conducted on a Dutch demersal mixed fishery beam trawler (see chapter 3).

Selectivity experiments should be conducted by specialized research institutes in collaboration with fishers. Selectivity should be compared to regular commercial codends. All parameters need to be carefully recorded to help with the development of the technical description of the Kiwi-codend.

- *Advanced selectivity and behaviour*

The Kiwi-codend offers multiple options for improving baseline selectivity due to its modular design. Each section of the system can, in theory, be tailored to target specific selectivity goals. For example, specific escape modules could easily be integrated for species that need to be avoided. The development of these modules might take some time; increased practical experience will help improve such innovations in time.

Additionally, future research into fish behaviour within the codend may lead to the development of improved innovative selectivity devices. Since the lift bag module lacks a water flow, fish can swim more freely and exhibit natural escape behaviour, which opens new possibilities for improving baseline selectivity or species-specific selectivity.

4.3.2 Discards survival

The survival probability of fish caught with Kiwi-codend and then returned to sea (discarded) is likely to increase across all fishery types (Molenaar et al., in prep.; Schram et al., 2023), although further research is required to confirm and quantify this under variable fishing conditions (e.g. seasonal effects). Additionally, improvements to onboard catch handling is probably needed to prevent a reduction in discards survival chances and fish quality due to deterioration of fish condition during catch processing. This will require changes of the onboard catch processing which could be considered as a future improvement. This type research might not be necessary for each fishery type.

4.3.3 Catch efficiency

Catch efficiency (expressed as catch per unit of effort, CPUE) of target species above the Minimum Conservation Reference Size (MCRS) would ideally be higher in the Kiwi-codend. It is linked to selectivity and depends mainly on the placement, shape and size of the holes in the retention modules.

4.3.4 Seabed disturbance and bycatch of benthic species

The current assumption of scientists is that the Kiwi-codend does not disturb the seabed more than conventional codends. A possible advantage for bottom trawling is that the Kiwi-codend is buoyant and therefore there will be less contact with the seabad compared to conventional codends for some fisheries. Note that in demersal fisheries with tickler chains, the bottom contact of the codend is negligible compared to that of the tickler chains. Providing evidence is of importance, mainly for fishery types where there is significant contact between the fishing gear and the seabed.

In demersal fisheries, part of the bycatch consists of benthic species. Their escapement probabilities should be quantified in the selectivity experiments that need to be conducted for the various demersal fishery types.

4.3.5 Gear life cycle

In the light of the EU Directive on the reduction of the impact of certain plastic products on the environment (Directive (EU) 2019/904[9]), it is of high imortance to reduce plastic pollution due to abrasion of gear components or gear loss. This has to be one of the focus points in the development and implementation of the Kiwi-codend.

Some interviewed parties have expressed concerns about potential gear loss. Currently, there have been two instances of gear loss in New Zealand where the gear has been in use for ten years. In one of these instances, the gear was recovered. The materials used are designed to be exceptionally strong and durable. However, long-term trials in demersal fisheries, where abrasion and loss are more likely, have not yet been conducted.

Options like releasing buoys or pingers could be explored if instances of the Kiwi-codend loss arise. Fishers are also likely to search for their lost gear as it is expensive (they also have been seen doing this when losing large parts of conventional nets).

Researching the life cycle of the gear will also be important, if the codend needs to be replaced too frequently due to e.g. abrasion. As the Kiwi-codend has natural buoyancy while fishing, it probably needs little to no protection against abraision due to contact with the seabed nor does it need to be replaced often. If much abrasion does take place, it may deter fishers due to high costs and it would result in unwanted emissions of (micro)plastics. Another aspect regarding life cycle is whether the material of a used Kiwi-codend can be recycled.

Plastic pollution is expected to be reduced with the Kiwi-codend, as there is no need for dolly ropes – those codend-protective plastic strands that deteriorate over time due to bottom contact used in beam trawling. However, this effect remains to be studied.

4.3.6 Fuel consumption

Differences in fuel consumption are likely to be caused by differences in the required towing power needed for trawling the gear and the fishing speed. Tracking towing power and fishing speed using conventional gear and using the Kiwi-codend will give insight into fuel use (for trawling the gear). In case fuel consumption differs, it should be recorded to assess the fuel-efficiency of the gear (fuel use per mass of caught fish, l/kg).

4.3.7 Fish quality

The Kiwi-codend was originally designed to enhance fish quality. Less damage to the fish, less impact on scales and slime layer leads to better fish quality, reduced amount of fish waste, and longer shelf life of the products. Another result of reduced damage to fish is a potentially higher survival rate of discarded undersized and

[9] https://eur-lex.europa.eu/eli/dir/2019/904/oj/eng

bycatch species (Schram et al., 2023). The quantification of the improvement in quality can be obtained through standardized tests.

On the longer term, fish quality could be further maximized by e.g. changing the onboard handling procedures. Note that investments in fish quality may be incentivized if the market is willing to pay higher prices for higher quality fish.

4.4 Social and economic factors

The availability of new fishing technologies does not guarantee their uptake by the fishing industry. There are several social and economic challenges that lie ahead. Previous innovative devices, even after legalisation, were rejected by the fishing industry due to increased workload, economic concerns, or resistance to change (Steins et a., 2022). In other cases, gear innovations under derogation, did not make it into legislation due to lack of wider stakeholder support – despite proven ecological, environmental and socio-economic benefits (Delaney et al., 2022; Rijnsdorp et al., 2024). Additionally, while higher-quality fish may improve market value, this does not always offset the costs of implementation. Industry stakeholders may perceive the required investments in new gear and training as a barrier to adoption. Addressing these issues will be critical to ensuring the successful long-term uptake of the Kiwi-codend.

Social factors that need addressing are the willingness and ability of fishers to adopt the Kiwi-codend and collaboration between the involved parties. The main economic factor is profitability. These three factors are described in more detail below.

Willingness and ability: Behavioural factors such as willingness and ability are critical elements in the successful implementation of gear innovations (Figure 6) (Steins et al., 2022). Current policy focus is often too much on enabling fishers to take up gear innovations. More attention should be paid to addressing factors underlying willingness, which are closely tied to intrinsic motivation, beliefs about sustainable fishing, perceptions of others' behavior, policy legitimacy, and shared norms on fairness, equal rules, and trust in enforcement (*ibid.*).

Willingness to adopt this technology will to an important extent depend on the early involvement of fishers in testing and refining the Kiwi-codend system. The small group of beam trawl fishers who were involved in preliminary experiments in the beam trawl fishery (interviews) expressed their willingness to adopt the Kiwi-codend. Other fishers in the Netherlands (and outside of), who are not currently engaged in the Kiwi-codend research and have no prior experience with the Kiwi-codend, have expressed interest in testing it. However so far, the willingness of the broader Dutch fleet, or indeed from other Member States, to implement the Kiwi-codend remains unknown. To learn more about the willingness, meetings with EU fishers could be organized to systematically assess what they know about the innovation, why they would be reluctant to use it and what would be needed for them to adopt the innovation.

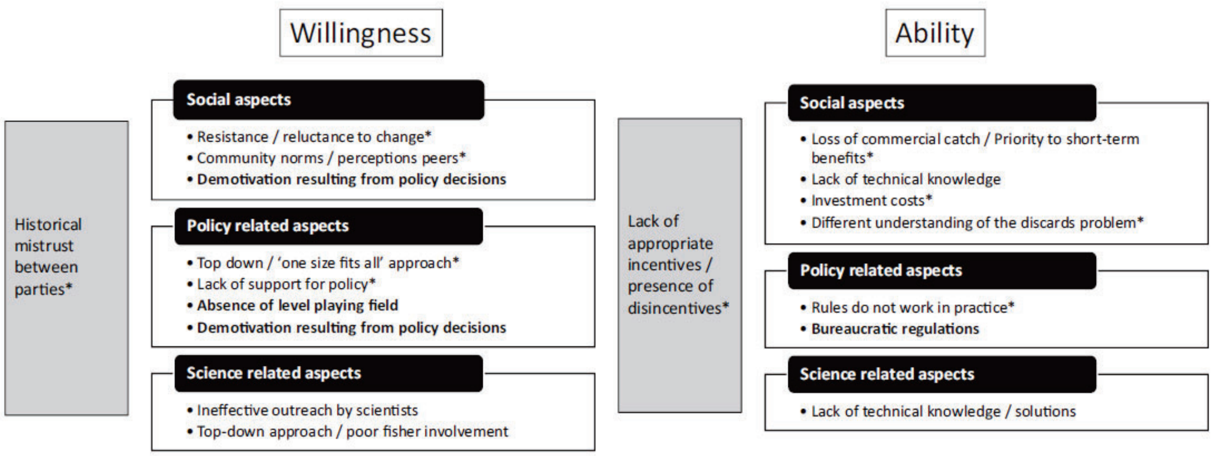


***Figure 6**. Schematic overview of factors associated with low uptake of proven fishing gear. Organised by aspects linked to Willingness and Ability. The two grey boxes indicate factors that span over social, policy- and science-related aspects. (from: Steins et al., 2022; * From literature sources, and also found for Dutch fishers in the Steins et al. (2022) study. Bold: Found in the Steins et al. (2022) study)*

Collaboration: good collaboration between fisheries, governments and science can help the development and adoption of the Kiwi-codend. Coordinated trials and tests within different métiers are needed. Intertwined with this, co-production of knowledge, data and best practice sharing ought to be focused upon for a wider social awareness and adoption. Engaging with fishers in the development process of the Kiwi-codend is crucial, and it is recommended to collaborate with producer organisations in order to create a strengthened uptake and ownership of this innovation.

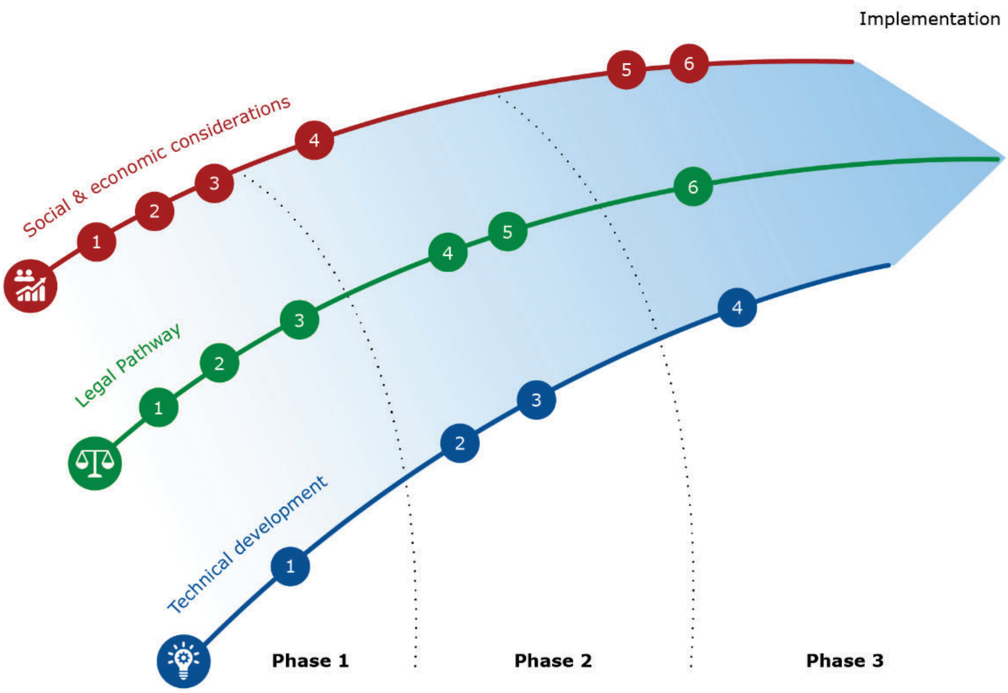
Profitability: The implementation of the Kiwi-codend in the fishing industry is highly dependent on the economic hurdles fishers face when they are willing to use it. While the Kiwi-codend proves to improve fish quality substantially while reducing mortality of undersized fish, a key driver if fishers favor this gear component depends on its economic efficiency. High upfront costs for producing or importing the codend within Europe may discourage widespread use. Once the Kiwi-codend is regulated in the EU legislation, it may not immediately provide significant economic or operational advantages compared to conventional mesh codends. Higher quality fish resulting in a better market price is likely to benefit a few stakeholders only and not necessarily fishers themselves. If all fishers deliver higher-quality fish, this will set a new standard, and prices might eventually decrease. Achieving eco-labeling (e.g. Marine Stewardship Council) has the potential to benefit early adopters. However, limited public awareness of fish caught with the Kiwi-codend may constrain market demand, hindering the economic profitability of Kiwi-codend caught products. Without targeted outreach, the use of alternative gear types could be slowed down due to insufficient financial incentives for fisheries. Therefore, a sound business model is needed for the acceptance and use of the Kiwi-codend.

4.5 Stakeholder engagement

To implement a new gear (component) in European fisheries, it is essential to have the support of a wide group of actors, including industry, member states, scientists and environmental NGOs (Haasnoot et al. 2016). It is expected that the Kiwi-codend may be an innovation interesting for various EU fisheries. Therefore, an EU wide approach to stakeholder engagement is recommended. Such an EU-wide approach is also important in case the Kiwi-codend innovation would only concern Dutch vessels, as past experiences with the development of the pulse trawl have shown (Delaney et al., 2022). Simply pushing forward any new technology without really engaging stakeholders, potentially results in a pushback from those stakeholders (Haasnoot et al. 2016, Rijnsdorp et al. 2024). An additional consideration is that even when all ecological, technological, social, and economical challenges have been overcome, the political decision making process is also influenced by lobby, political interests and (potentially) court cases (Rijnsdorp et al., 2024).

Engagement of stakeholders should be set-up as soon as the Kiwi-codend is past the stage of “proof of concept”. Delaney et al. (2022) developed an approach to ensure that the innovation is co-owned between stakeholders, giving them a meaningful role to provide input and to help shape the research program. In this approach, the first step is to set up an independent oversight committee to provide objective quality assurance and suggestions for the science program designed to evaluate the consequences of the Kiwi-codend. A second step is a social impact assessment to identify the groups that will potentially be impacted by the innovation. Representatives of all groups should be engaged to scrutinize the possible impacts the Kiwi-codend may have on fishing effectiveness or profitability of other fisheries; on the ecosystem; and on other stakeholder communities. As a result, the research areas that need to be addressed can be identified and priorities can be set. Then follows a continuous process of evaluation and feedback, and adaptive research, with room for modification of the research program as new information becomes available. A consideration could be to limit any experimental fleet in the number of vessels involved or the area where experiments take place.

5. Roadmap for implementation of the Kiwi-codend



Phase 1

- 1 Identify path towards legislation.
- 2 Overview of required minimum knowledge for amendment of the TMR.
- 1 Comparison of selectivity, fuel consumption, and catch efficiency in a testcase (e.g. flatfish targeting beam trawl test case).
- 1 Social Impact Assessment and stakeholder engagement.
- 2 Test willingness of industry to participate in the development.
- 3 Set up collaborations between relevant parties that can help advancing the technical development.
- 3 Involving other countries that may be interested in the Kiwi-codend or that may be impacted by this innovation. Decision on the pathway to legalisation to follow.

Phase 2

- 2 Comparison of fish quality and bycatch survival in a test case.
- 4 Study on profitability.
- 3 Studies on of seabed disturbance and life cycle of the Kiwi-codend (abrasion, gear loss).
- 4 Filling in the table with gear parameters to be included in the TMR for a test case.
- 5 Explore other possible test cases (i.e. other fisheries) for which the development of the Kiwi-codend and the definition of its parameters can start.

Phase 3

- 6 Inclusion of Kiwi-codend as an accepted gear component in EU fisheries.
- 5 Incentivise fishers to use the Kiwi-codend.
- 6 Making information about the Kiwi-codend available for the wider public.
- 4 Advanced selectivity studies on fish behaviour and escape devices.

Figure 7. *Roadmap for implementing the Kiwi-codend. Explanation of the codes below. A Europe-wide stakeholder engagement strategy is an integral part of this roadmap.*

The process of implementing the Kiwi-codend consists of three phases, in which the various actions discussed in the previous sections should be addressed. In each phase, a well-defined stakeholder engagement strategy is crucial to building the necessary support for successfully implementing the Kiwi-codend in EU fisheries.

Phase 1: Initial development and legal considerations

The first step is to start incorporating the Kiwi-codend into European fisheries legislation. The correct legal path towards regulation (ordinary legislative procedure or Delegated Act) needs to be established in agreement with the European Commission (Figure 7, L1). The minimum technical and scientific requirements needed by the European Commission (and STECF) to approve its legalization should be identified (Figure 7, L2). This will ensure that subsequent technical development and experiments can be planned accordingly.

At the same time, it is essential to start involving the appropriate stakeholders early in the process of the development and implementation of the Kiwi-codend. A stakeholder mapping exercise helps to identify who are the stakeholders and how the impact is distributed between the stakeholders (Figure 7, S1 – Social Impact Analysis). Simultaneously, efforts should begin to engage other implicated countries, for example, by sharing information through the regional groups. For North Sea fisheries this is the Scheveningen Group (Figure 7, L3). Similarly, the relevant Advisory Councils should be involved. This step is closely tied to deciding the regulatory pathway for legalizing the Kiwi-codend - either through the ordinary legislative process or a Delegated Act.

A critical aspect of this phase is demonstrating that the selectivity of the Kiwi-codend is equal to or better than the conventional gear. Studies reporting on this are a priority and must be well-documented (Figure 7, T1). The beam trawl fishery targeting flatfish is a suitable test case, as research on the Kiwi-codend is most advanced in this EU fishery. In parallel with selectivity studies, assessments should also be conducted on fuel consumption and catch efficiency (Figure 7, T1). Positive outcomes in these areas are crucial for gaining support from fishers and industry stakeholders and for evaluating their willingness to invest in this innovation (Figure 7, S2). This phase also presents an opportunity to establish collaborations with technical partners to advance development (Figure 7, S3).

Phase 2: Expanding research and investigating economic viability

Once the initial developments are underway and key stakeholders are engaged, Phase 2 will focus on quantifying the broader effects of the Kiwi-codend, including its impact on fish quality and the survival of discards species (Figure 7, T2). This phase should also explore seabed disturbance and the gear’s lifecycle, including abrasion and potential gear loss (Figure 7, T3).

Additionally, economic feasibility must be assessed (Figure 7, S4). This includes evaluating:

- Required investments and operational costs;
- The market’s willingness to pay for higher-quality fish;
- Whether these factors make the Kiwi-codend financially viable for fishers.

By this stage, there should be sufficient data to define a range of gear parameters for inclusion in the TMR for the test case (Figure 7, L4). This case will serve as a precedent and example how to adapt legislation for the inclusion of the kiwi-codend specific for a fishery type. Other fisheries may also express interest in adopting the Kiwi-codend, prompting the development of additional specifications of the gear component (Figure 7, L5). This would create an opportunity for countries with similar fishery types to collaborate. Increased collaboration between and involvement of more member states is likely to increase the level of support for the implementation of the Kiwi-codend in EU fisheries.

Phase 3: Legal adoption and industry uptake

With broad stakeholder support, that is developed since the start of the first phase, and a finalized list of gear parameters, Phase 3 can end in the final legislative adoption (Figure 7, L6). Phase 1 and phase 2, both including a strong stakeholder engagement process, should provide sufficient basis for introducing the kiwi-codend in European fisheries legislation.

At this stage, further actions can be taken to encourage fishers to adopt the Kiwi-codend (Figure 7, S5), including potential incentives. Retailers and the wider public should also be informed about the innovation and its benefits (Figure 7, S6), which could enhance demand and market prices for products caught with the Kiwi-codend.

Finally, continued improvements in gear selectivity should be pursued through further studies on fish behavior and escape devices (Figure 7, T4), ensuring the Kiwi-codend remains an evolving, effective innovation for sustainable fisheries.

5.1 A living document

To ensure this roadmap remains relevant and operational, it must be regularly updated with the latest insights, data, and regulatory changes affecting the Kiwi-codend's adoption and legal landscape. Effective implementation requires embedding the roadmap within key decision-making processes, ensuring it shapes strategic choices and fosters alignment across all involved stakeholders. Given the evolving nature of fisheries policies, adapting the roadmap to new conditions is essential. Its greatest strength lies in its role as a communication tool to stakeholders, serving as a unified reference point for coordinating efforts, sharing critical updates, and facilitating alignment across regulatory bodies, industry players, and research institutions.

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7. Participants

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- **Wageningen Economic Research** – for help in designing the feedback on interview design and insights into communication strategies.
- **Wageningen Marine Research** – for providing information on fisheries, research possibilities and effects of fishing gear.
- **Scientific, Technical and Economic Committee for Fisheries (STECF)** – for their insights in the legalisation process and backed scientific needed information.
- **Centre for Environment, Fisheries and Aquaculture Science (CEFAS)** – for their information on the UK legalisation process, insightful conversations and outlook on the future of fisheries.
- **PROSEA** – for their focus on the transfer of knowledge and future of fisheries.
- **VISFEDERATIE** – for representing industry perspectives and practical applications.
- **Vissersbond** – for their information of effects within the fisheries sector.
- **Ministry of Agriculture, Fisheries, Nature and Food Quality (LVVN)** – for taking the time responding to questions and helping gain information on internal processes and knowledge gaps.
- **Netherlands Enterprise Agency (RVO)** – for taking the time responding to questions and helping gain information on internal processes and knowledge gaps.
- **Precision Seafood Harvesting** – for their time to explain the history of the technology and future visions.

8. Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

Justification

Report: C012/25

Project Number: 4318300188

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Dr. ir. N.A. Steins

Project Manager

Signature: Signed by: [redacted]

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Date: 19 February 2025

Approved: Dr. ir. T.P. Bult

Director

Signature: Signed by: [redacted]

Date: 19 February 2025

Annex 1 Visions for the future of sustainable and resilient fisheries

The EU Oceans Pact and the vision of the Dutch ministry of LVVN are closely aligned, both promoting innovative entrepreneurship, development of sustainable fishing practices and a greater resilience across the entire fisheries sector.

The European Oceans Pact

The European Union is working on a new European Oceans Pact[10] with three main objectives:

1. **Healthy and Productive Oceans**: Promote sustainable management and restoration of marine ecosystems in line with the EU's international ocean governance agenda.
2. **Boost the Blue Economy:** Enhance competitiveness, resilience, and sustainability across maritime sectors, including fisheries.
3. **Consolidate Marine Knowledge:** Simplify and extend the EU's framework for marine data.

These objectives will be supported by, among other things, innovation and competitiveness by encouraging investments in blue technologies supporting sustainability, innovation and economic opportunity for the marine (fisheries) sector. The development of innovations to support more sustainable and competitive fishing gear and practices fits well in the proposed vision.

Adding to the vision of the EU as a whole, every member state produces their own vision and goals for its waters. These are often in line with the general vision of the EU, but can emphasize certain aspects more than others.

The Dutch vision on food production at sea towards 2050

The vision on food production at sea towards 2050[11] from the Dutch ministry of Agriculture, Fisheries, Food security and Nature focuses on long-term seafood sustainability and the required actions to achieve this goal by 2050. The Dutch government envisions a future with robust fisheries delivering regional, healthy, and sustainable products that are valued by consumers. The fishing sector should be able to earn a good livelihood within the ecological carrying capacity of the sea and lead in sustainable entrepreneurship on a multifunctional sea. Entrepreneurs must be adaptable and embrace **innovations** to maintain healthy businesses.

Central to this vision are two main principles:

1. **Marine Food is Important:** Sustainable food production and consumption are crucial for mitigating climate change and restoring nature. Marine food provides a valuable contribution with a relatively small CO_2 footprint compared to other animal proteins and supports a healthy diet. To reduce dependence on foreign countries, food should be sourced from local waters whenever possible.
2. **Sustainable Marine Food Production:** Both existing and new food producers must operate sustainably within the ecological limits of the ecosystem to ensure long-term viability and profitability. The government will support this transition through policies and collaborations with stakeholders.

By focusing on these principles and collaborating with fishery and aquaculture sectors, stakeholders, and European partners, the Dutch government aims to balance the energy, nature, and food transitions on the North Sea and other waters. The vision also outlines plans to support innovative entrepreneurship as a requirement for achieving the objectives of the vision

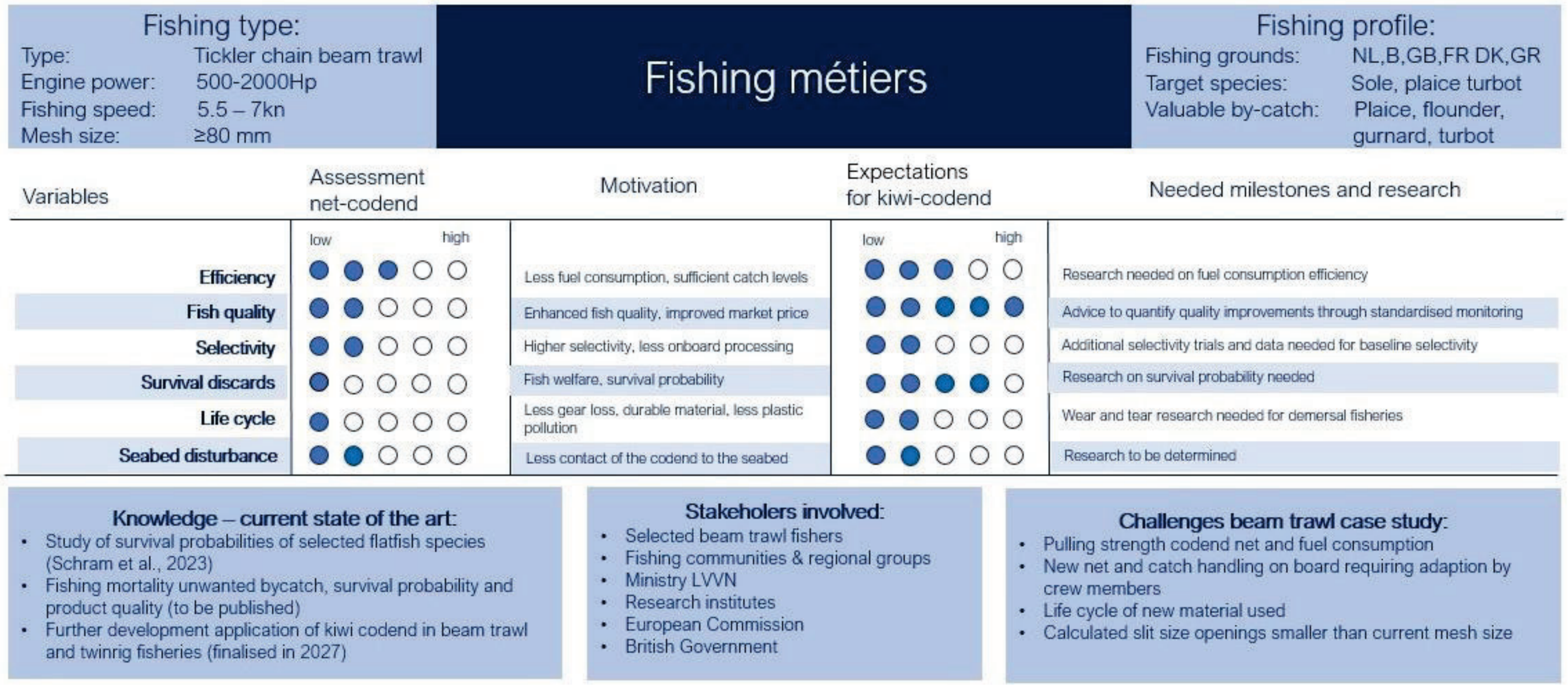
[10] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/14474-The-European-Oceans-Pact_en
[11] Dutch food vision 2050

Annex 2 Gear parameters to be defined by fishery type

Fishing type:		Fishing métiers technical description	Fishing profile:	
Type:	Tickler chain beam trawl		Fishing grounds:	NL,B,GB,FR DK,GR
Engine power:	500-2000Hp		Target species:	Sole, plaice turbot
Fishing speed:	5.5 – 7kn		Valuable by-catch:	Plaice, flounder, gurnard, turbot
Mesh size:	≥80 mm			

Component	Parameter	Unit	Value	Source
Cone	Diameter (front)	cm		
	Diameter (back)	cm		
	Length	cm		
Retention Modules	Quantity	#		
	Length	cm		
	Diameter	cm		
General Escape Holes	Form	Round, oval, etc.		
	Size	mm		
	Position(s)	-		
	Quantity	#		
Alternative Escape Holes	Same parameters as above	-		
Lift Bag	Diameter	cm		
	Length	cm		
Transition Panel (if applicable)	Length	# mesh deep		
	Width	# mesh wide		
	Mesh in salvage	# mesh		
	Mesh size	mm		
	Twine thickness	mm		

Annex 3 Assessment sheet Kiwi-codend vs. conventional beam trawl codend



Results obtained from studies on the Kiwi-codend, along with onboard observations on selected vessels, can be presented in an assessment sheet. This sheet offers an overview and considerations that may aid the development of similar research on the possibility of the Kiwi-codend implementation in other fisheries. The sheet includes a variable comparison, the current state of the art, challenges and future research required.

Annex 4 Fish Quality

Quality difference of sole and red mullet between a Kiwi-codend (MHS) and conventional mesh codend (top: sole; bottom: mullet). Note the difference between the two top pictures of sole: on the left sole still has all its scales, and slime layer, this is not the case on the right hand side. The two pictures of mullet clearly show colour differences indicating higher quality of fish on the right hand side (more vibrant red).

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With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.

The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,700 employees (7,000 fte), 2,500 PhD and EngD candidates, 13,100 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.