ICES WORKSHOP ON INNOVATIVE FISHING GEAR (WKING)

VOLUME 2 | ISSUE 96

ICES SCIENTIFIC REPORTS

RAPPORTS SCIENTIFIQUES DU CIEM

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ISSN number: 2618-1371 I

ICES Scientific Reports

Volume 2 | Issue 96

ICES WORKSHOP ON INNOVATIVE FISHING GEAR (WKING)

Recommended format for purpose of citation:

ICES. 2020. ICES Workshop on Innovative Fishing Gear (WKING).
ICES Scientific Reports. 2:96. 130 pp. http://doi.org/10.17895/ices.pub.7528

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Contents

i Executive summary

The EU Commission (EU DG-MARE) seeks ICES advice on the progress that has been made, or impact arising from innovative gears within EU waters. This advice should assess the benefits for, or negative effects on, marine ecosystems, sensitive habitats and selectivity.

Specifically, and to the extent possible, the advice sought should provide information on what kind of innovative gears are being used, their objective, their technical specificities and the impact on both target species, non-target species and the environment in which they had been deployed.

In response to the EU DG-MARE request on the progress and impact that has been made in innovative gear use within EU waters, ICES advises that EU adopt the definition of "Innovative gear" as provided in the report for the Workshop on Innovative Fishing Gear (WKING). In addition, through the work in WKING, the international expert group has also identified rigorous approaches and methodologies to assess different levels of innovation and provide insight for possible adoption or approval of use.

According to WKING, an innovation is considered as *"any new ideas, creative thoughts, new imaginations in the form of technology or method"* that breaks into the market or society. It takes place through the provision of more effective products, processes, services, technologies, or business models that are made available to markets, governments and society.

Therefore, an innovation is something original and more effective and, as a consequence, new that "breaks into" the market or society. Thus, an innovative fishing gear is a gear or a significant component of the gear that has not been used commercially and/or that is sufficiently different from the baseline in the current European Regulations, or in the absence of them, different from the commonly used gear in the specific sea basin (area) in EU waters.

For a specific challenge within a fishery, a successful innovation provides a more ideal solution than what previously was available, i.e. the baseline or standard gear. In EU fisheries, baseline standards are derived either from existing technical measures specified in the European Regulations or from unregulated, commonly used commercial practice (e.g. groundgears) and consist of objectives and measurable parameters. Examples of these parameters are mesh sizes for both active gear and passive nets, particular gear specifications, minimum conservation reference sizes for target and bycatch species, closed or restricted areas, as well as conservation measures to mitigate catches of sensitive species.

A framework to objectively assess the performance of an innovative fishing solution in a specific fishery is provided by WKING using catch efficiency, selectivity, and impact on the environment as main "Criteria of Assessment" (CA), as well as other additional, and sometimes indirect or peripheral effects; e.g. energy consumption, greenhouse gas emission, and marine contamination.

Moreover, the "Complexity" and "Technological Readiness Level" (TRL) of each innovative fishing gear are proposed as parameters for evaluating the suitability, readiness, and potential adoption in a specific EU fishery. For each CA, an innovation matrix that allowed identifying the most relevant innovations for the objectives of the European fishery policy was conceived.

Full and objective assessment of the effect based on these criteria helps determine whether a specific innovation is beneficial compared to the baseline gear.

Depending on the expected potential impact on the performance improvement, compared to the baseline (conventional fishing gear), each CA was scored as incremental, transformative, disruptive, or negative, while the technology and/or methods were evaluated by the readiness, assessed by the Technology Readiness Level (TRL) as low, medium, or high. The use of TRLs enables consistent, uniform evaluation of technical maturity across different types of technology.

For each CA, an innovation matrix was conceived to allow identification of the innovations that appear to be most relevant to the objectives of the European policies.

The work carried out includes an innovative fishing gear catalogue with 42 factsheets that describes fishing gear innovations tested in the main EU sea-basins. The CA analysis was conducted within a small group of fisheries scientists. Conclusions drawn within the WKING report must therefore take this narrow focus into account, especially when extrapolating conclusions into industrial or commercial settings.

ii Expert group information

Expert group name	Workshop on Innovative Fishing Gear (WKING)
Expert group cycle	Annual
Year cycle started	2020
Reporting year in cycle	1/1
Chair(s)	Antonello Sala, Italy
	Manu Sistiaga, Norway
Meeting venue(s) and dates	20-22 May 2020, Remote Inception Meeting, WKING I (11 participants)
	10 June 2020, Second Remote Meeting, WKING II (45 participants)
	7 September 2020, Final Remote Meeting, WKING III (22 participants)

1 Official Terms of Reference

2019/WK/EOSG12. The Workshop on Innovative Fishing Gear (WKING), in response to the EU DG-MARE request for ICES advice on the progress and impact that has been made in innovative gears used within EU waters, chaired by Antonello Sala (Italy) and Manu Sistiaga (Norway) will work by correspondence (May to September, 2020) to address the request. The EU DG-MARE seeks ICES advice and prepare the report described in **Article 31.1 of Regulation 2019/1241** on the progress that has been made, or impact arising from innovative gear within European waters.

a) develop a **suite of criteria** to objectively define what an 'innovative gear' is;

b) develop a **catalogue of gears** considered 'innovative', including their:

- objectives,
- technical specificities and
- known impacts/benefits (in terms of selectivity on target and non-target species and environmental impact in terms of benefits for, or negative effects on, marine ecosystems and sensitive habitats).

c) produce a report detailing the process taken and presenting the results;

d) draft a summary advice on the basis of the report produced.

To do so, a Core Group of members from the ICES Working Group on Fishing Technology and Fish Behaviour (WGFTFB) will work by correspondence in advance of the final WKING meeting (**7 September 2020)**. The Core Group will collect preliminary information on the types of innovative gears that have been used in EU fisheries in recent years.

The first meeting of WKING will be held by correspondence during May 20-22, 2020 to discuss criterion and definition of "innovative fishing gear" in EU context and review candidate gears.

The second meeting WKING II, scheduled by June 10th, 2020 will be extended to other experts. The Core-group will facilitate information collection and discuss the Innovative Gears Conceptualization.

At the WKING III (**7 September 2020),** the Core Group will review and deliberate the findings to date, and draft the report and associated advice. WKING will report by the **30th of September 2020** for the attention of EOSG, HAPISG, ACOM and SCICOM.

2 Tasks and EU DG-MARE request

In order to prepare the report described in Article 31.1 of Regulation 2019/1241, the EU Commission seeks ICES advice on the progress that has been made, or impact arising from innovative gear within EU waters. This advice should assess the benefits for, or negative effects on, marine ecosystems, sensitive habitats and selectivity. Specifically, and to the extent possible, the advice sought should provide information on what kind of innovative gears are being used, their objective, their technical specificities and the impact on both target species, non-target species and the environment in which they had been deployed.

In order to respond to this request, the term 'innovative gear' needs to be objectively defined. It is the understanding of ICES that the EU Commission want ICES to define what 'Innovative gear' is.

Gear experts from different regions of EU waters will meet at a workshop hosted by ICES to compile information on:

- ❖ Types of innovative gears being used;
- ❖ Their objectives;
- ❖ Their technical specificities.

Where studies have been conducted and information is available, the impact of these gear innovations will be assessed. This assessment will consider where possible:

- ❖ Selectivity on target and non-target species;
- ❖ Environmental impact of the gears in terms of benefits for, or negative effects on, marine ecosystems and sensitive habitats.

So, the process would entail:

(1) **Developing a suite of criteria to objectively define "Innovative gear"**. The Working Group on Fishing Technology and Fish Behaviour (WGFTFB) could provide many of the candidates for innovative gears, as well as sources such as the H2020 SMARTFISH (http://smartfishh2020.eu) and WWF International Smart Gear Competition (https://www.worldwildlife.org/initiatives/international-smart-gear-competition).

(2) Experts could catalogue gears considered "Innovative" to help identify defining features of 'Innovative gear'. Where relevant, stakeholder (NGO, fishing industry, gear industry) input will be sought during the process (e.g. through contacting Advisory Councils). DG MARE will also be consulted for feedback on the initial suite of criteria.

(3) A workshop (WKING) will be held where experts from different regions of the EU will assess gears being used across EU waters to see which gears meet the developed criteria for 'Innovative gears'.

(4) A **catalogue of 'Innovative gears'** and their characteristics and known impacts/benefits will be produced.

(5) The Working Group on the Ecosystem Effects of Fishing Activities (WGECO) will be consulted.

(6) A report will be published detailing the process taken and presenting the results.

(7) There will be an external (i.e. from outside EU) review of the work done.

(8) ACOM will draft a summary advice on the basis of the report produced and the external review.

2.1 Supporting Information

Priority	High, in response to a specific request from the EU Commission to ICES to prepare the report described in Art. 31.1 of the EC Regulation 2019/1241.
Scientific justification	The EU Commission seeks ICES advice on the progress that has been made, or impact arising from innovative gear within EU waters. This advice should provide the scientific knowledge basis to assess the benefits for, or negative effects on, marine ecosystems, sensitive habitats and selectivity.
Resource requirements	ICES Secretariat support, meeting facilities at ICES HQ, Copenhagen and Advisory process.
Participants	The Core Group is expected to comprise 5-6 members. Other members of WGFTFB will be consulted during their annual meeting. Where relevant, stakeholder (NGO, fishing industry, gear industry) input will be sought during the process. Stakeholders will be invited to the final workshop. DG MARE will also be consulted for feedback on the initial suite of criteria. The requestors should be also engaged in the process through Webexes towards the end of the scoping and final meetings to ensure the product is fit for purpose.
Secretariat facilities	Secretariat support, web conference and meeting rooms
Financial	Covered by DG MARE special requests to ICES
Linkages to advisory committees	ACOM
Linkages to other committees or groups	WGFTFB, WGBYC, WGECO, SCICOM, EOSG, FRSG, HAPISG
Linkages to other organizations	Potentially GFCM, EU DG-MARE, STECF

2.2 Regulation (EU) 2019/1241 of the European Parliament and of the Council of 20 June 2019

Regulation (EU) No 1380/2013 of the European Parliament and of the Council establishes a Common Fisheries Policy (CFP) for the conservation and sustainable exploitation of fisheries resources.

This Regulation establishes **baseline standards for each sea basin**. Those baseline standards are derived from existing technical measures, taking account of STECF advice and the opinions of stakeholders. Those standards should consist of baseline mesh sizes for towed gear and static nets, minimum conservation reference sizes, closed or restricted areas, as well as nature conservation measures to mitigate against catches of sensitive species in certain areas and any other existing regionally specific technical measures.

Member States should have the possibility to develop **joint recommendations** for appropriate **technical measures that differ from these baselines** in accordance with the regionalisation process set out in Regulation (EU) No 1380/2013, based on scientific evidence.

When developing joint recommendations in relation to size and species selective characteristics of gear alternative to the baseline mesh sizes, regional groups of Member States should ensure that such measures result in similar, as a minimum, or improved selectivity characteristics as the baseline gear.

When developing joint recommendations in relation to minimum conservation reference sizes, regional groups of Member States should ensure that the objective of the CFP of ensuring the protection of juveniles of marine species is respected, while ensuring that no distortion is introduced into the market and that no market for fish below minimum conservation reference sizes is created.

On the basis of an assessment of the impacts of **innovative gear**, the use, or extending the use, of such innovative gear could be included as an option in joint recommendations from regional groups of Member States. The use of innovative fishing gear should not be permitted where scientific assessment indicates that their use would lead to significant negative impacts on sensitive habitats and non-target species.

The Commission’s report should also refer to advice from ICES on the progress made or impact of innovative gear. The report should draw conclusions about the **benefits for, or negative effects on, marine ecosystems, sensitive habitats and selectivity**.

Article 20. Innovative fishing gear

A joint recommendation submitted for the purpose of adopting the measures referred to in **Article 15(2)** in relation to the use of innovative fishing gear, **within a specific sea basin**, shall contain an assessment of the likely impacts of using such gear on the **targeted species and on sensitive species and habitats**. The Member States concerned shall collect the appropriate data necessary for such assessment.

The use of innovative fishing gear shall not be permitted where the assessments referred to in paragraph 1 indicate that their use will lead to significant negative impacts on sensitive habitats and non-target species.

Article 31. Review and reporting

By 31 December 2020 and every third year thereafter, and on the basis of information supplied by Member States and the relevant Advisory Councils and following evaluation by STECF,

the Commission shall submit a report to the European Parliament and to the Council on the implementation of this Regulation.

That report shall assess the extent to which technical measures both at regional level and at Union level have contributed to achieving the objectives set out in Article 3 and reaching the targets set out in Article 4. **The report shall also refer to advice from ICES on the progress that has been made, or the impact(s) arising from innovative gear.** The report shall draw conclusions about the benefits for, or negative effects on, marine ecosystems, sensitive habitats and selectivity.

The report referred to in paragraph 1 of this Article shall contain, inter alia, an assessment of the contribution of technical measures to optimize exploitation patterns, as provided for in point (a) of Article 3(2). For that purpose the report may include, inter alia, as a selectivity performance indicator for the key indicator stocks for the species listed in Annex XIV the length of optimal selectivity (L opt) compared to the average length of fish caught for each year covered.

On the basis of that report, where at regional level there is evidence that the objectives and targets have not been met, Member States within that region shall, within 12 months after the submission of the report referred to in paragraph 1, submit a plan setting out the actions to be taken to contribute to achieving those objectives and targets.

3 WKING meetings

3.1 Inception WKING remote meeting information (WKING I)

20 May 2020 Remote meeting starting at 13:00 CEST (07:00 US Eastern)

13:00 - 15:00 CEST (07:00 - 09:00 US Eastern): first session

- *Introduction by ICES (David Miller)*
- *Update and approval the meeting agenda*
- *Appointment of the second WKING Chair/co-chair*

  Role: ensuring the best spread of expertise in the WKING in order to carry out tasks effectively
- *Membership and Core Group responsibilities: it is important to ensure that all Core group members understand their roles and responsibilities. It is essential that this initial meeting establishes clear practical SharePoint arrangements to ensure the effective functioning of the WKING*
- *Executive summary*
- *Official Terms of Reference*
- *Tasks and EU DG-MARE request*
- *Develop a **suite of criteria** to objectively define 'Innovative gear'*
  - ❖ *Definition of sea basins, and*
  - ❖ *Gear baselines*
  - ❖ *Conceptualization*
- *The Core group of experts will work remotely collecting relevant information in preparation for the final remote meeting/Webex/Zoom.*

15:00 - 16:00 CEST (09:00 - 10:00 US Eastern): break *(virtual coffee break)*

16:00 - 18:00 CEST (10:00 - 12:00 US Eastern): second session

- *Information collection of the innovative gears. Factsheet template*

21 May 2020 home working

- *Information collection (e.g. reports, publications): use of SharePoint*

22 May 2020 Remote meeting starting at 13:00 CEST (07:00 US Eastern)

13:00 - 15:00 CEST (07:00 - 09:00 US Eastern): first session

15:00 - 16:00 CEST (09:00 - 10:00 US Eastern): break

16:00 - 18:00 CEST (10:00 - 12:00 US Eastern): second session

List of participants reported in Annex 2.

3.2 Second WKING remote meeting (WKING II)

10 June 2020 Second Remote meeting (WKING II) starting at 13:00 CEST

The second meeting was extended to the whole WGFTFB group, WGBYC (bycatch), and the former WGMEDS (discard survival) members, which confirmed interest to facilitate information collection of selective and innovative gears and devices. The larger group brought knowledge and information into the discussion around the topics of innovative fishing gears:

- Development of a **suite of criteria** to objectively define what an 'innovative gear' is;
- Development of a **catalogue of gears** considered 'innovative'

List of participants reported in Annex 2.

3.3 Final WKING remote meeting (WKING III)

7 September 2020 Final Remote meeting (WKING III) starting at 13:00 CEST

- *Update and approval of the meeting agenda*
- *Appointment of the Strategic Innovations Ltd staff in the WKING Core Group*
- *Core Group tasks and eventually external experts involvement to complete the draft report*
- *Revision of the draft report*
    - ***ToR 1. Suite of criteria to define 'Innovative gear'***
        - *General definition of Innovation*
        - *Interpretation of Innovative gear*
        - *Criteria of assessment (CA)*
        - *Level of innovation (text updated)*
        - *Technology Readiness Level (TRL)*
        - *Performance and technical readiness rating*
        - *Modelling the Innovative gears*
    - ***ToR 2. Catalogue of Innovative gears***
        - *Information collection of the innovative gears. Factsheet template*
        - *New factsheets*
- *The Core group of experts will work remotely to finalize the report (deadline 30 September 2020).*
- *Open session / feedback / questions / suggestions*

An extra WKING Group coordination meeting is scheduled by the 16th of September 2020 to rate the innovations using the Innovation matrixes.

List of participants reported in Annex 2.

3.4 Other WKING remote coordination meetings

Other WKING remote coordination meetings have been convened by the WKING chairs during the period. In particular, the meeting with the British company *Strategic Innovation Ltd* (SI) held the 7th of September 2020 was considered a significant milestone for the WKING ToRs development.

The input from SI provided a valuable perspective from outside the seafood sector that strengthened the WKING approaches and assessment criteria for innovative ideas.

List of participants and meeting notes are reported in Annex 2.

4 Suite of criteria to objectively define an 'Innovative gear'

4.1 General definition of Innovation

There have been considerable efforts in recent years to modify fishing gears and practices to target particular sizes and species of fish and other marine organisms more efficiently, to reduce the catch of non-target and undesirable species, especially sensitive species, as well as to lessen their impacts on bottom habitats. Bycatch considerations is an important motivation in the regulation of many fisheries, and new innovative gear modifications are continuously being proposed and tested to mitigate problems. The evidence that fishing gears may injure marine organisms that are not captured and at least locally reduce habitat complexity and cause reduced biodiversity has appeared in various media with increasing frequency.

In literature, there are many definitions of 'Innovation' [1-6]. In April 2020, Strategic Innovation Ltd (UK), through the Seafood Innovation Fund (SIF), published a report titled "*A global state-of-the-art review of seafood*" [7], presenting technologies and innovations from around the world that are relevant to the fisheries, aquaculture and seafood industries in UK.

According to the SIF report [7], an innovation can be considered as ***"any new ideas, creative thoughts, new imaginations in the form of technology or method"***. Such innovation takes place through the provision of more effective products, processes, services, technologies, or business models that are made available to markets, governments and society. Therefore, an innovation is something original and more effective and, as a consequence, new that "breaks into" the market or society.

A successful innovation gives to customers a more ideal solution than what had previously been available. 'Ideal' in this sense is defined as the (perceived) benefits that the customer receives divided by the costs and harms that are also present. The fact that successful innovations deliver more ideality implies that there is an overall direction of success.

According to Mann [3], the evolution process of innovation takes place through a series of discontinuous evolutionary jumps. Usually these jumps are steps from one way of doing things to another, or, more formally, jumping from one S-curve to another. The overall dynamic of evolution – with systems making discontinuous jumps from one S-curve to another all the time heading in a direction of increasing ideality is summarized in Figure 1. The evolutionary direction towards increasing ideality is driven by a destination, called Ideal Final Result (IFR), where the customer has received all of the benefits they require and none of the additional costs and harms. In most senses, the Ideal Final Result is a theoretical rather than a practical limit.

The y-axis "ideality" concept comes from the TRIZ systematic innovation approach [5, 8, 9]. Ideality could be described as the "main parameter of value" in performing a function. It is the balance between the positive and negative aspects of performing the function from the perspective of the consumer or decision-maker [7]:

$$Ideality = \frac{\sum positive\ effects}{\left(\sum costs\right) + \left(\sum harms\right)}$$

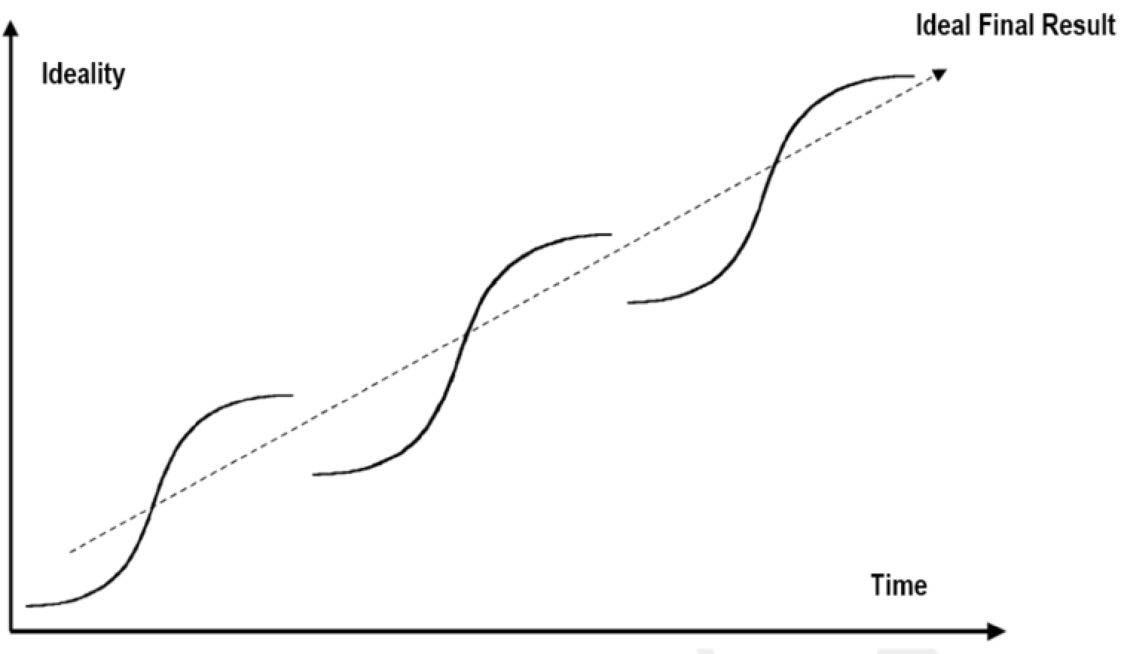


Figure 1. Evolutionary dynamics of innovation. Systems jump from one S-curve to another in the direction of Ideal Final Result (IFR) outcomes. Source: adapted from Mann [3].

The development steps that apply to the core principle / technology of the system can be considered sustaining, or **incremental innovation** (Figure 2). Technologies that make a significant improvement, particularly in the fast-improving middle section of the S-curve, can be considered **transformative innovation** (Figure 2).

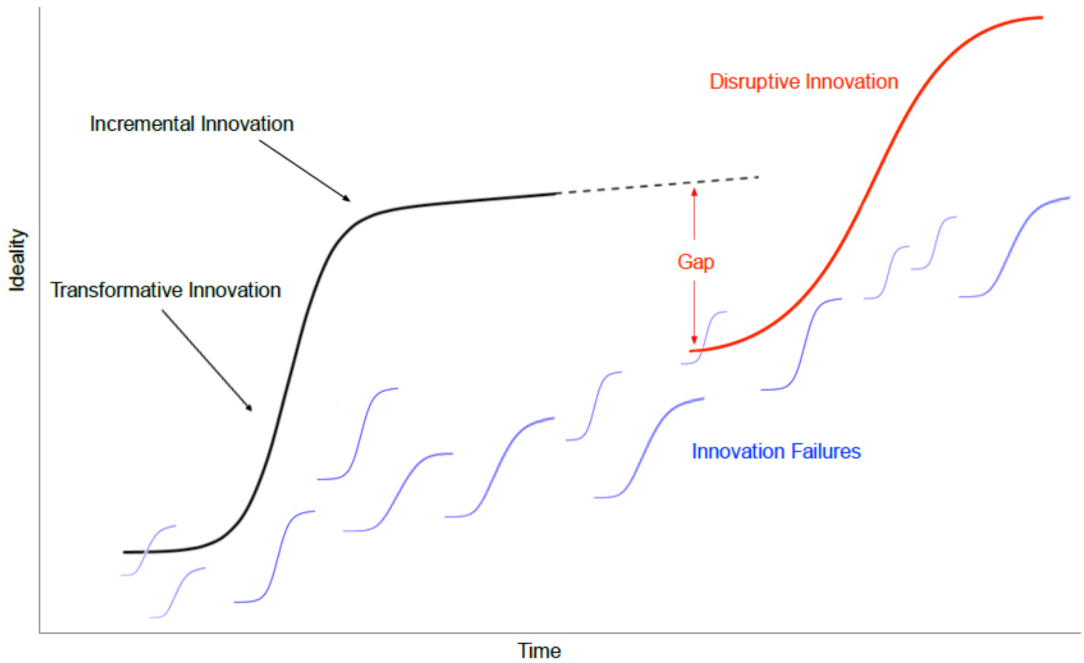


Figure 2. Innovation evolution dynamics. Systems jump from one S-curve to another in the direction of Ideal Final Result (IFR) outcomes [3]. Source: adapted from Techau, et al. [7].

The blue curves in Figure 2 are attempts to fulfil the same function, but using an alternative core approach, technology or principle. These are often the "**innovation failures**" in a sector. They may fail before launch or fail in the market. These can also successfully create a small niche, which is commercially viable and survive, but ultimately not threatening to the incumbent black curve in Figure 2. They are typically introduced by start-ups or niche R&D based initiatives from large organizations. Techau, et al. [7] show that many failures are not due to deficiencies in the technical idea itself but failures in marketing, operations, route to market or being ahead of their time.

At some point, a new technology or approach is introduced, that initially appears to be another blue curve and less ideal than the incumbent, but is fundamentally more capable of achieving higher ideality. Although, initially suffering from a gap through disadvantages (Figure 2), such as lack of scale, limited market presence and under direct threat from the incumbent industry, this new innovation starts to outperform the incumbent technology and eventually dominates the market – becoming the red curve (Figure 2). These are defined as **disruptive innovations**.

An obvious test of success is financial. A successful innovation, by definition, must offer paying customers a value proposition that they will pay sufficiently for that it not only pays all of the direct and indirect costs of providing it, but also allows the provider to obtain a profit.

4.2 Conceptual interpretation of Innovative gear

4.2.1 Baseline standards for each sea basin

As mentioned earlier, a successful innovation provides a more ideal solution than what had previously been available, or the baseline standard. In EU fisheries, baseline standards are derived either from existing technical measures specified in the European Regulations or from unregulated, commonly used commercial practice (e.g. groundgears) and consist of objectives and measurable parameters. Examples of these parameters are mesh sizes for both active gear and passive nets, general gear specifications, minimum conservation reference sizes for target and bycatch species, closed or restricted areas, as well as nature conservation measures to mitigate against catches of sensitive species in certain areas and any other regionally specific technical measures.

4.2.2 European sea basins

As technical measures are established at a regional level (Regionalisation), WKING therefore uses the sea basins identified in the EU Regulation 2019/1241 when establishing region-specific baselines and innovations (Figure 3):

- North Sea (Annex V) .... Area 27.4
- Northwestern Waters (Annex VI)........ Area 27.5, 27.6, 27.7
- Southwestern Waters (Annex VII)....... Area 27.8, 27.9, 27.10, 34.1.1, 34.1.2, 34.2
- Baltic Sea (Annex VIII) .... Area 27.3
- Mediterranean Sea (Annex IX)............. Area 37.1, 37.2, 37.3
- Black Sea (Annex X)............................... Area 37.4

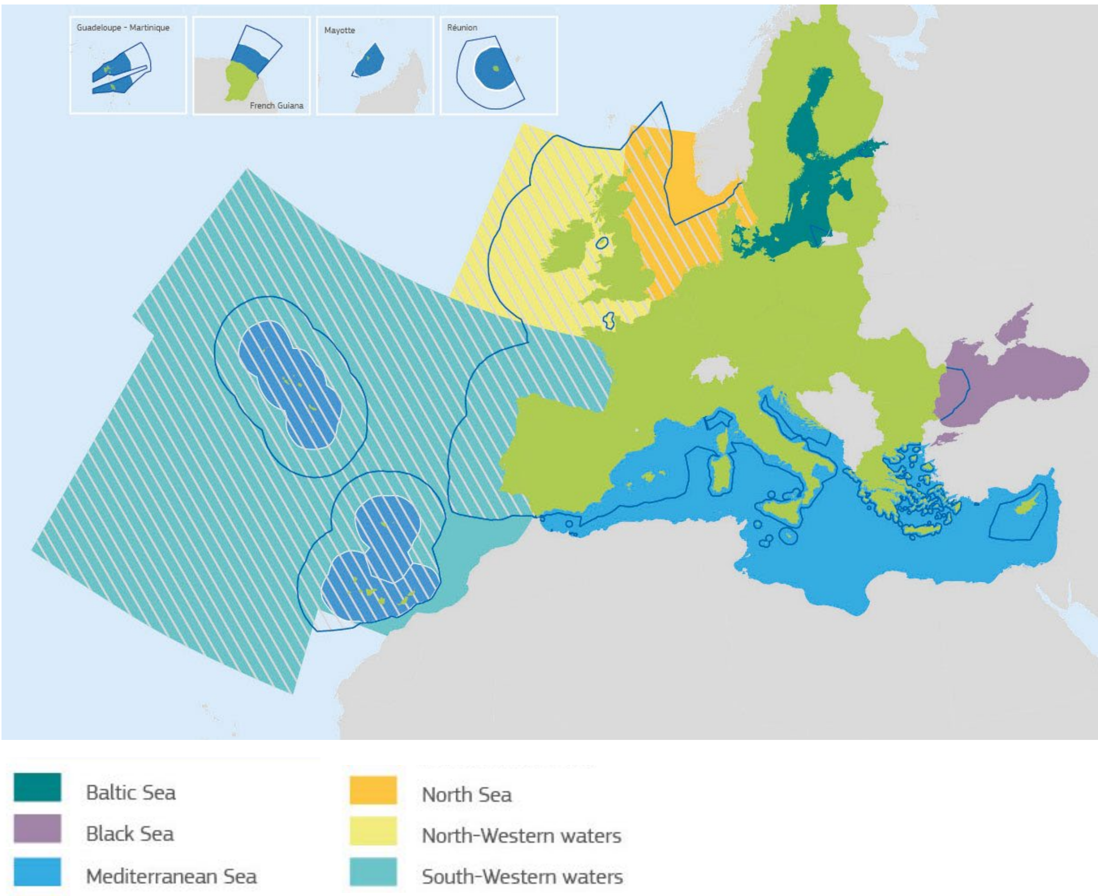


Figure 3. Sea basins identified in the EU Regulation 2019/1241.

4.2.3 Innovative gear

An innovative gear is a gear or a significant component of the gear that has not been used commercially and/or that is sufficiently different from the baseline in the current European Regulations, or in the absence of them, different from the commonly used gear in the specific sea basin (area) in EU waters.

Innovative gears are solutions that differ from the baseline standards in any way and positively contribute to achieve the stated fisheries management or ecosystem objectives e.g. use of a square-mesh codend or insertion of square-mesh panels on an otherwise standard (diamond-mesh) codend.

In general, cutting-edge technologies in fisheries should aim at achieving resource sustainability, improved animal welfare, enhanced food quality and security, and optimize opportunities, whilst supporting economic gains for fishers and coastal communities. Therefore, as described in Section *§2 Tasks and EU DG-MARE request,* three main Criteria of Assessment (CA) are identified for an innovative gear, namely catch efficiency, selectivity and marine ecosystem impact. Each CA is assessed on the potential impact on the **performance improvement,** and scored as incremental, transformative, or disruptive, while the technology and/or methods is evaluated by the **technology readiness**, assessed by the Technology Readiness Level (TRL).

4.3 Criteria of Assessment (CA)

The impact of implementing an innovative fishing solution, whether it is a modification to a design, insertion of additional components, a completely new gear for specific fishery, or a significantly altered operating method, can be evaluated differently depending on the criteria used for the evaluation.

An innovation applied to a particular fishing gear can engender major benefits in certain facets of the gears use but may also be associated with unintended negative consequences. Thus, all benefits and drawbacks need to be considered to provide the overall impact of an innovation introduced to a fishery.

To objectively assess the impact of an innovative fishing solution in a fishery includes an estimation of three main criteria, as well as an evaluation of other additional, and sometimes indirect or peripheral effects. The main Criteria of Assessment (CAs) are: 1) **catch efficiency**, 2) **selective properties** of the gear, and 3) an assessment of the **impact of the gear on the marine ecosystem**, as well as an evaluation of other additional, and sometimes indirect or peripheral effects.

Full and objective assessment of the effect based on these three criteria will help determine whether a specific innovation is beneficial compared to the baseline gear.

Main criteria

Changes in the catch efficiency and selectivity of a fishing gear can imply an impact in the structure of a target and non-target fish stocks. The innovation(s) implemented can lead to the exploitation of larger or smaller quantities of some species and the extraction of new species that were not previously extracted from the ecosystem. Therefore, considering the impact of an innovation on the different stocks and/or the entire ecosystem is of high relevance.

4.3.1 Catch efficiency

The main purpose of a fishing gear is to catch target fish or other species (e.g. crustaceans, molluscs), which are collectively called "fish" in this document. Therefore, the main evaluation criteria for an innovation in a fishing gear will normally imply an assessment of the impact on the target species catch efficiency compared with the existing gear in the fishery (baseline). Catch efficiency is most often evaluated by quantifying the catch per unit of effort (CPUE). Thus, for an innovative fishing solution to be acceptable for a fishery, it would have to result in at least as high CPUE as the baseline gear unless it is highly beneficial in other Criteria of Assessment that a reduction in CPUE can be justified.

4.3.2 Selectivity

Selection of fish by a fishing gear can be considered to be the process which causes the catch to have a different composition to that of the fish population in the geographical area in which the gear is being used. The selectivity of a fishing gear is a measurement of the selection process [10]. Thus, the impact of innovations that aim at changing the selective properties of a specific gear can be evaluated by assessing the change in the size and species composition of the catch with respect to the existing regulated gear used in the fishery (baseline). The selective properties of a fishing gear can be changed in many ways, i.e. the amount and sizes of the **target** and **bycatch** species, and species composition, but this criteria can primarily be evaluated by the ability of the gear to retain the target catch and release of unwanted catch.

4.3.2.1 Catch of target species

A fishery can have one or multiple target species, and the desirable catch is composed by all individuals of these species with sizes above or equal to the Minimum Conservation Reference Size (MCRS) and all marketable individuals for those species without an MCRS.

An efficient fishing gear should retain all targeted species above or equal to the MCRS entering the gear or in contact with the gear while releasing or avoiding all fish below MCRS together with the unwanted component of the bycatch species. Thus, a gear could be considered to have positive or beneficial impact in a specific fishery if it would catch larger quantities of target fish above or equal to the MCRS and/or smaller quantities of fish below the MCRS.

The size selective properties of a fishing gear with respect to the target species are often measured by *population-independent* specific selectivity parameters such as 50 % retention length (L50), the length at which a fish has 50 % chance of being retained by the gear on condition that it enters or interacts with the gear, and the Selection Range (SR), the difference between 75 % retention length (L75) and the 25 % retention length (L25). Size selective property of a fishing gear may also be evaluated by means of *population-dependent* indicators such as the proportion of retained fish above and below the MCRS.

4.3.2.2 Bycatch

It is important in any study about bycatch to define its scope and definition [11]. This is because of the significant difficulty and confusion in settling on a robust and standard definition of 'bycatch'. Depending on one's jurisdiction or personal opinion, bycatch may include general discards, retained, released or discarded vulnerable species, sold ''by-product'' species, juveniles, trash fish, pre-catch losses, slipped fish, mortalities due to ghost fishing, offal, discarded fish heads and frames, and even broader ecosystem and habitat impacts of fishing [12].

Notwithstanding this variety of definitions, the most commonly used definitions tend to settle on ''bycatch'' being the unintended, non-targeted organisms caught while fishing for particular species (or sizes of species). This bycatch is then most commonly divided into those non-target organisms that are kept and eaten/sold ("landed bycatch" or "by-product") and "discards" which are those animals thrown back (alive or dead) into the sea (and can also include "slipped" releases). It is this latter subset of bycatch (discards) which is the usual focus of studies that seek to report, assess or to reduce, because it is this subset that represents a perceived wastage of resources and attracts significant controversy, especially the bycatch and mortality of vulnerable species [11].

This report adopts the definition of bycatch of a fishing gear given in Gray and Kennelly [11], which includes the sum of the following components:

- bycatch of commercial non-target species - retained catch of non-targeted species that are valuable (landed bycatch or by-product);
- unwanted bycatch - non-desired portion of the catch because of economic, legal, or personal considerations; and
- incidental bycatches of vulnerable and endangered, threatened, and protected (ETP) species.

Endangered, Threatened and Protected species are usually defined by state, national and/or regional legislations and international agreements and assessments (e.g. the International Union for Conservation of Nature (IUCN) Red List, the Marine Stewardship Council (MSC) fishery standard, etc.). While innovations that increase the catch of commercial non-target species can be regarded as positive if they can be sold or utilized, an innovation that increases the catch of animals that are later discarded (including threatened and protected species, and individuals of the target species below MCRS) is considered to have a negative impact.

Discards are regulated in many European fisheries and the extent to which they are allowed can vary between fisheries and species. However, regardless of the limits established, increased discards are considered a negative contribution of an innovation. While discards should be avoided, the protection of endangered and protected species is of high importance and deserves increased focus. Innovative fishing solutions should in every case reduce the risk or otherwise harm to protected species. Further, innovative solutions should minimize alteration to the habitat or other critical environment for the long-term survival of protected species.

Thus, the impact of introducing innovations, especially those that are considered as medium and significant innovations, should be thoroughly assessed with respect to the well-being of protected marine species, and in some cases, plants.

All species encountering a fishing gear suffer from some type impact. However, the level of impact can vary from just being scared or forced to swimming to their death. From the management and ethical points of view, sorting animals out of a fishing gear only makes sense if they survive and recovered to their pre-encounter status. Thus, innovations that can reduce the survival rate of fishing gear escapees or permanently impact their biological and ecological functions should be carefully evaluated and monitored before they are introduced to a fishery.

Another aspect linked to this criterion is fish welfare in the capture process and the welfare or post-release survival of fish that escaped from the gear. Allowing undersized fish to escape the gear, if released in good condition, can have an ecosystem benefit allowing those fish to reach reproductive maturity and achieve commercially viable sizes. Gears allowing escape of target species below minimum size but which reduce the likelihood of survival of the escaped fish would be a less beneficial innovation than what may be operating currently (baseline gear).

4.3.3 Impact on marine ecosystems

All fishing activities have certain negative impacts on the marine ecosystem. These impacts can vary in magnitude and nature, from directly affecting species that are not utilized in the fishery to pollution or damage to benthic ecosystem. When doing an impact assessment of an innovation introduced into a fishery, it is necessary to consider different criteria related to the impact on marine ecosystems and sustainability.

A gear that is positively evaluated with respect to catch efficiency and/or selectivity criteria may have an overall high negative effect in the fishery in the long run due to excessive negative impact in the surrounding marine ecosystems. Although one can list numerous criteria to assess the impact of a gear on marine ecosystems, some of the most widely used criteria are:

- seabed impact;
- risk of gear loss that leading to and potential for ghost fishing and marine plastic pollution; and
- impact on endangered, threatened, and protected (ETP) species.

4.3.3.1 Seabed or benthic impact

While pelagic fishing gear normally have minimal or no benthic impact, demersal fishing gear are operated very close to, in direct contact with, or penetrate the seabed in order to be effective in harvesting certain target species. The degree of benthic impact is especially relevant to demersal towed fishing gears such as trawls and dredges. Thus, innovations altering the configuration of these types of gears that would change its interaction with the seabed should be carefully evaluated with respect to potential changes to their benthic impact.

Parameters such as physical alteration to the seabed, sediment suspensions, as well as the welfare and survival of bottom-dwelling epifauna, or infauna species (e.g. benthic invertebrates) as a result of gear operation may be evaluated in the overall impact assessment.

4.3.3.2 Gear loss, ghost fishing and marine plastic pollution

Abandoned, lost or otherwise discarded fishing gear (ALDFG) is not only a source of marine litter that contributes to marine pollution, it also has the potential for ghost fishing, where ALDFG continues to trap, entangle and kill animals over a period of time.

Ghost fishing is especially relevant to static fishing gear such as gillnets or pots but applies in principle to all fishing gear that continue fishing or entangling animal after they are lost, discarded or abandoned. The potential introduction of innovations that can influence the risk for gear loss and/or the impact the gear on marine ecosystems once they become ALDFG should be carefully addressed with respect to this criterion.

4.3.3.3 Impact on endangered, threatened, and protected (ETP) species

Bycatch of endangered, threatened, and protected (ETP) species in fisheries remains one of the greatest threats to many charismatic marine megafauna, such as sea turtles, marine mammals, seabirds, and sharks and rays. The type and amount of bycatch associated with individual fisheries depends on many factors, including, among others, gear type and design (e.g. hook type), fishing method (e.g. time of day, setting), and the spatial overlap between fishing effort and individual species' distributions [13, 14]. Despite some highly visible efforts to address specific issues in some fisheries (e.g. dolphin-safe tuna), a review of global bycatch patterns suggests that the cumulative impacts of bycatch remain great, and that international and multi-sectoral approaches to improve both bycatch reporting and mitigation efforts are urgently needed [15].

A number of studies have already investigated the impact of fishing gears on long-lived marine species of conservation concern, like sea turtles (for example, see reviews by [16]). However, more investigations are needed to evaluate how mortality due to interactions with fisheries varies by species and gear type.

The adoption of gear innovations that can implement best practices for bycatch mitigation, or innovative traceability systems that trace product back to the catch vessel or fishing area, and precautionary bycatch mitigation practices for gear types, where best practices are well-established (e.g. installing turtle excluder devices (TEDs) on shrimp trawl vessels), should be carefully evaluated, not only against the performance of the baseline gear, but also against the established best practices.

Additional criteria

The evaluation of an innovation may also contain information on its impact with respect to additional parameters such as marine pollution, energy consumption or atmospheric contamination associated with fishing activities. Marine pollution includes all types of pollution in the marine environment related to fishing activities, from plastic pollution (e.g. macro-, micro-, and nano-plastics) due to regular gear use and due to disintegration of ALDFG, to garbage, wastewater discharge, and oil spills from fishing vessels.

Energy consumption and the consequent gas emissions from combustion engines contribute to the release of greenhouse gases (GHG) and atmospheric contamination. There are innovations that directly aim at reducing energy use and environmental impact of fishing gear in general. These may also need to be considered when assessing the overall impact of a potential innovation, although these are not the focus of the innovation that is being assessed in this report.

4.4 Performance improvement

The avenues for the introduction of innovative, environmentally friendly, and smart fishing technologies are often cumbersome and slow. Depending on the expected potential impact on the performance improvement, compared with the conventional fishing gear, a performance indicator corresponding to a four-level grading system was defined:

1. **Incremental performance.** It can be considered an innovation with a minimal or small performance improvement. Typically, they are existing fishing gears or technologies, used in other fisheries in the area or in similar fisheries in other areas, introduced into a specific fishery that has never used these gears/technologies before;
2. **Transformative performance.** This innovation might provide significant performance improvement compared to conventional systems (baseline). It can be any fishing gear or technology used in the given area or in other areas but modified from the regulated operation or commercial practice;
3. **Disruptive performance.** It is a novel solution compared to conventional systems and offers potential for significant step-change performance improvement compared to current baselines in Europe. This is usually a new developed fishing gear or technology that has rarely or never been used in commercial fisheries anywhere in the world;

Negative performance. It is a new fishing gear or technology without much benefits, or having negative effects on, one or more Criteria of Assessment (catch efficiency, selectivity on target and non-target species, and environmental impact) compared to baselines. These innovations are relatively rare or short-lived as the market/consumer rejects them.

4.5 Technology Readiness Level (TRL)

Technology readiness levels (TRLs) are a measure for assessing the maturity of technologies during the acquisition phase of a program. The use of TRLs enables consistent, uniform evaluation of technical maturity across different types of technology [17]. TRLs are based on a scale from 1 to 9 with 9 being the most mature technology [17].

The primary purpose of using TRLs is to help management makes decisions concerning the development and transitioning of technology. Some of the advantages of using TRLs include:

- Providing a common understanding of technology status;
- Aids in Risk assessment and management;
- Helping in making decisions concerning technology funding;
- Supporting decision-making concerning transition of technology.

The usage of TRL in EU policy was proposed in the final report of the first High Level Expert Group on Key Enabling Technologies [18] and it was indeed implemented in the subsequent EU Horizon 2020 framework program [17]. Table 1 shows the TRLs adopted in the European Union.

According to Techau, et al. [7], which provide guidelines for assessing technical readiness of innovations applied to aquaculture and fisheries sector, we classified the TRLs in three categories: Low, Moderate, and High readiness. For the purpose of this report, the assessment of the innovative gear's TRL, and consequently the technical readiness, was based on program concepts, technology requirements, and demonstrated technology capabilities.

Table 1. Technology readiness levels adopted in the European Union [19], and tailored TRL categories for the assessment of the technical readiness of innovative gears.

TRLs category *(technical readiness parameter)*	**European Union TRLs scale**
Low	TRL 1 – Basic principles observed TRL 2 – Technology concept formulated TRL 3 – Experimental proof of concept
Moderate	TRL 4 – Technology validated in lab TRL 5 – Technology validated in relevant environment *(industrially relevant environment in the case of key enabling technologies)* TRL 6 – Technology demonstrated in relevant environment *(industrially relevant environment in the case of key enabling technologies)*
High	TRL 7 – System prototype demonstration in operational environment TRL 8 – System complete and qualified TRL 9 – Actual system proven in operational environment *(competitive manufacturing in the case of key enabling technologies)*

4.6 Performance and technical readiness rating guidelines

Following the work of Techau, et al. [7], which reports an overview of the state-of-the-art technologies and innovations from around the world that are relevant to the UK fisheries, aquaculture and seafood industries, innovative gears can be assessed against two main parameters: the **potential impact on the performance** of the European fisheries sector for each specific targeted Criterion of Assessment (e.g. catch efficiency, selectivity, and impact on marine ecosystems) addressed by the innovation and the **technical readiness level**.

The potential impact on the fisheries sector can be rated using the guidelines provided in section *§4.4 Performance improvement*, that is: Incremental, Transformative, and Disruptive performance. The technical readiness parameter can be evaluated by assessing the TRL, as described in *§4.5 Technology Readiness Level (TRL)*.

For each Criterion of Assessment (CA), a summary table layout, adapted from Techau, et al. [7], was conceived in the form of an Innovation Matrix as shown in Table 2, which allows to visually identify the innovations that appear to be most relevant to the objectives of the European policies. Noteworthy, an innovation can cover more CAs, hence it may occur in more Innovation matrixes. In this case, as the technical readiness is innovation-specific, that innovation will be figured in the same column in every matrix.

Table 2. Innovation matrix layout for the assessment of innovation in each Criterion of Assessment.

Performance		Low	Moderate	High
	Disruptive	Probably worth considering	Highly promising	Unicorn "no brainer"
	Transformative	May be worth considering	Some potential	Very promising
	Incremental	Not worth considering	Probably not worth considering	Commercial R&D
	Negative	Negative outcomes	Negative outcomes	Negative outcomes
		Technology readiness level		

The colour coding of the cells of the matrix provides an indication of the perceived fit to the objectives of the EC Regulation 2019/1241:

Yellow: Innovations that deliver incremental performance gains are of great importance maintaining competitiveness in the context of 'continuous improvement'. These opportunities can often be justified and implemented through commercial research and development activities if technology readiness levels are moderate or high (semi-mature to mature).

Light red: Innovations that offer an incremental performance gain but considered not worth to start the commercial application because of the low level of technology development.

Dark red: Innovation-oriented firms and scientists may become too enamoured with the idea of innovations, creating more innovations for the sake of innovation. Such firms and scientists lose sight of the costs of those innovations, get lost in R&D without realizing environment or other benefits, and fail to adequately consider impact of the gears in terms of effects on marine ecosystems and sensitive habitats.

Green: The best fit between technical readiness and performance gain. Innovations that would not ordinarily be self-funded through commercial R&D due to their technical moderate readiness, but offer potential for transformative or disruptive performance gains. Some other innovations can offer transformative performance gains with a high technical readiness and can be related to e.g. technologies that are commercially implemented in other countries but have not yet been adopted in a certain region.

Sky blue: Innovations that offer potential transformative or disruptive performance gains, hence probably worth to consider or invest despite the low technological readiness.

Blue: Innovations that have shown to have disruptive performance gains and have a high technological readiness. They are very rare ('Unicorns') and are unlikely to be uncovered. If exist, it is "no brainer" for speedy adoption.

4.7 Levels of technological complexity

The understanding and definitions of innovation complexity presented in the existing scientific literature vary greatly from one another, and therefore the use in this report warrants clarification. In the innovation literature, *complexity* is one of many innovation properties that are said to affect the rate of adoption. One of the first attempts to define technological innovation's complexity was by Rogers and Shoemaker [20]: *"the degree to which an innovation is perceived as relatively difficult to understand and use"*.

For the distinction between low and high degree of innovation's technological complexity, there are as many terms in the literature as there are different approaches to the definition of innovations. There are therefore different approaches to measuring the degree of technological complexity. Within the industrial frame, technological complexity is a wide term that includes different levels and approaches. The most recurrent themes are: complexity of product; complexity of the process; complexity of manufacturing system. The third integrates the first two and is also correlated to the complexity of supplies, and in general, of any external entity interacting with the production system. To connect all above three aspects, the following definition can be given: ***technological complexity indicates the needed technological level for the design and manufacture of an industrial product, considering its characteristics and performances*** [21].

The industrial product complexity is meaningfully increased in the past years, in fact to the purpose to satisfy the customers' needs, the variety of components and products has become larger and new materials and technologies have been introduced. To appraise the technological complexity many factors can be considered (technology, production characteristics, quality level, assembly modality, etc.). At the moment, a universal model to represent and to measure technological complexity is still missing, because the variety, the dynamism and the uncertainty on the causes of such complexity and on their relationships make it difficult to establish a unique definition and measurement method. Nevertheless, it is possible to define different types of complexity within an engineering and a manufacturing field. Depending on the technical aspects and specifications, a very widespread division of innovation distinguishes between simple (minimal) and significant (radical) technological complexity. In addition to the illustrated extreme shapes, however, different intermediate shapes are also possible. Therefore, we decided to empirically classify the complexity measurement methods into three main levels:

- **Minimal complexity.** It often represents a low degree of complexity. Innovations belonging to this level usually do not imply new knowledge or new technology. Known technologies, products, services, models or processes are being further developed with a minimal difference compared to the already used fishing gear or technologies (baselines);
- **Medium complexity.** The innovations are predominantly based on the R&D activities, which often have a higher degree of complexity compared to purpose-driven innovations;
- **Significant complexity.** On the other hand, this level represents something fundamentally new, which cause considerable changes in the products, processes or conventional models. They have a very high degree of innovation's complexity, which requires a sharp break with traditional routines and delivered knowledge.

Future researches concerning the most effective way to measure technological complexity and how to connect these measures to fisheries applications are required in order to provide manufacturing enterprises with an effective decision-making support and to provide some indications on the likely rate of adoption of the technology.

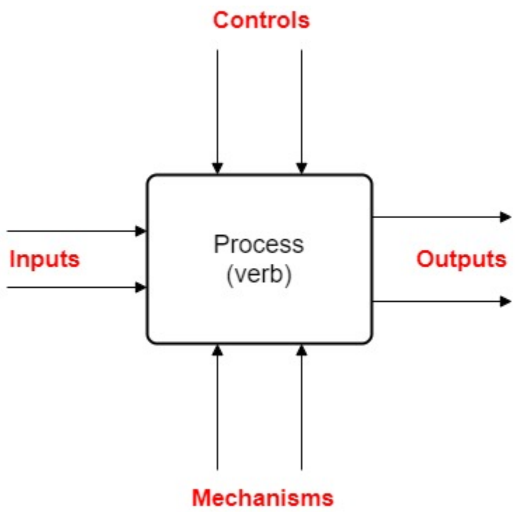
5 Modelling the innovative gears

5.1 General definition of innovation using the IDEFO method

A lot of academic research on innovation [1-9, 22] has focused on describing and developing models of innovation with the aim of supporting organizations to reduce the number of failed innovation attempts and increase the likelihood of developing a disruptive, 'red curve' innovation in Figure 2.

The typical ways of defining innovation as a process, are summarized by Howard, et al. [23]. However, these models of innovation were considered to be merely descriptions of a product development or ideation process rather than giving a clear understanding of the process of innovation itself [24].

A suitable definition and measurement system was therefore required specifically for the current Terms of Reference. The Integration DEFinition (IDEF0) business process mapping system developed in the 1990s is a hierarchical definition tool that uses strict guidelines for analysing processes and presenting them to others [25]. At the heart of this method is the idea that a process or function is a 'verb', and any verb can therefore be mapped as a process. Innovate is a verb and therefore suitable for modelling using the IDEF0 method [24]. According to the IDEF0 method [25], any process must have inputs, controls, mechanisms and outputs (Figure 4).



Inputs are transformed or consumed by the process (the raw material or ingredients).

Controls specify the conditions for the function to produce the correct output.

Outputs are the data or objects resulting from the function.

Mechanisms are the means and resources which support the process.

Figure 4. Generic IDEF0 Function box and data. Source: adapted from Frobisher [24].

The Input to Innovation

The IDEF0 method is very specific in its description of an input as something that is "modified, or consumed by the process" (**investments**, **natural resources**). The input to innovation is knowledge, but because some knowledge will always be hidden to the problem solver, the definition derived in this report is **available knowledge**, including Intellectual Property (IP), the knowledge which is available to the innovator.

Innovation outputs

Economic theory credits innovation as being the underlying mechanism of macro-economic growth, which can be measured in monetary terms [26]. In an industrial context, monetary value comes from either increased revenue, decreased costs or a combination of the two. Two outputs therefore result from Innovation. The first, and most important from a business perspective can be expressed in terms of profitability or **added value**. The second outputs of innovation are **increased knowledge / IP** and **impact**.

Innovation controls

Customer requirements are an arbiter of the benefits of innovation output, and therefore clearly categorized as a control. A second control is the requirement of the new idea to satisfy the laws of science and **technology**. The final generic control is the requirement of the innovation to satisfy the needs of the **business –** in terms of strategic objective and profitability.

Innovation mechanisms

Mechanisms are determined to be the resources required to be supplied by the business to generate innovation. The key resources are **people**, to create, invent and introduce the innovation. The people need to be supported by **infrastructure** with which to work, for instance, a place to work, to design, to manufacture, to test, to validate, to sell and to supply. There are also the **tools and methodologies** that are used to organize and manage the process.

5.2 Defining innovative gear and measurement system using the IDEFO method

This allowed the top-level IDEF0 diagram of innovation to be drawn (Figure 5).

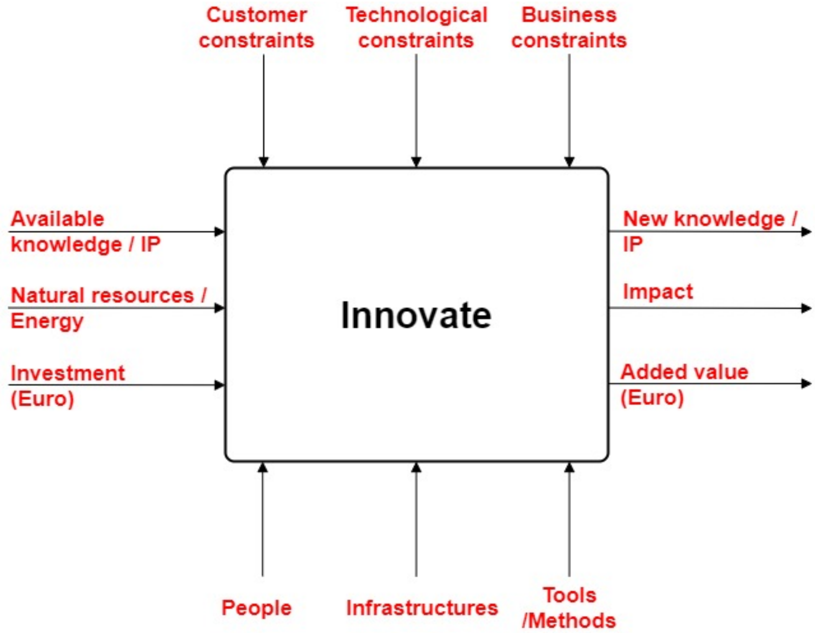


Figure 5. IDEF0 diagram of the innovation process. Source: adapted from Frobisher [24] and Techau, et al. [7].

Successful innovations are those which positively affect the majority of the IDEF0 arrows [7, 24], particularly those that match a trend or solve a contradiction within the control arrows (customer, technology, business). Unsuccessful innovations, that either fail completely or fail to scale, are those that either do not sufficiently address a contradiction in the control arrows or do not possess the means to execute them e.g. due to an insufficiently broad skill base of the people, inadequate infrastructure or insufficient funding [7].

Hence, with the holistic overview provided by the IDEF0 Model of the Innovation process (Figure 5), it is easier to evaluate and compare innovations by identifying the issues that might prevent an innovation from becoming widely adopted ('blue curves' in Figure 2) and recognize the innovations that appear to hold a strong position (potential 'red curves').

Table 3. Parameters used in the IDEF0 model of the Innovation process. Source: adapted from Techau, et al. [7]

Function	Description
Inputs	*Available Knowledge / Intellectual Property (IP)* How quickly is new knowledge being generated in terms of scientific publications and patents? Is there significant "unavailable knowledge" e.g. trade secrets?
	Natural Resources / Energy Primary natural resources consumed by the activity, and if energy consumption is a significant factor.
	Investment Trends in investment in the area where available data exists.
Controls	*Consumer / Customer* To what extent are end consumers involved / affected by the technology, and if so, what are the primary related consumer trends and contradictions?
	Technology What are the core technology approaches used? e.g. biological, chemical, physical fields (i.e. laser, ultrasound etc.). Is the idea solving a technical contradiction?
	Business What are the main influencing factors for business? e.g. legislation, cost reduction, production efficiency / yields and the strategic ambition of the management team.

Means / Mechanisms	*People (key players, academics, companies, experts, suppliers)* Are these people / organizations credible? Demonstrating the required broad range of skills for development and introduction-execution.
	Infrastructures (key processes, plant, equipment required) Can it be multiple types for different approaches?
	Tools / methods What are the techniques required, such as diagnostics, testing methods, production methods?
Outputs	*New Knowledge / IP* Is knowledge in the area likely to increase?
	Impact What impact is the activity in the area already having and likely to have on the tangible or intangible outcomes? Most likely to be addressing the contradictions expressed in the controls.
	Added Value Will it lead to increases in sales volumes, increases in prices, reduction in costs through lower energy use, less labour cost, increased yields?

Example of a recent successful innovation in fisheries

Acoustic alerting devices (ADD). Devices mounted on gillnets/trammel nets to scare marine mammals (e.g. dolphins) from the fishing gear. The next step towards red curve status will occur if smaller, more cost-effective ADDs are developed.	
Inputs	Adequate funding has been available for development. Built on knowledge from research and know-how.
Controls	Aligned with informed consumer and retailer requirements to reduce marine mammal interactions. Solves technical contradictions relating to the core function of capture, increasing efficiency and reducing incidental bycatch, although increasing complexity. Aligned with business objectives and legislation.
Means / Mechanisms	Technical teams are capable, although question marks over abilities to promote adoption. Using existing infrastructure and off-the-shelf core technologies adapted to a new purpose. Manufacturing capacity unknown. Methods appear to have further scope for development.
Outputs	Reduced incidental bycatch of vulnerable species (dolphins), improved catch value per trip. New know-how / knowledge, with potential for considerable further product development. New businesses are profitable. Improved animal welfare with significantly low mortalities.

Example of an innovation with limited implementation, failed to scale up and be brought to market

Pulse trawls. Pulse trawling has been identified as a potential means to improve selectivity. Startle pulses mitigate negative side effects on non-target species. It has been identified as a blue curve that needs a fundamental shift in the ability to control fishing, as it is in effect too good. The analysis suggests that they face one or more significant barriers that are currently preventing them from turning into a 'red curve'. This does not mean that the innovation will not become successful innovations in future if they are able to address the barriers it currently faces. *Analysis adapted from: Techau, et al. [7].*	
Inputs	High efficiency reduces fuel consumption per unit catch and reduces bycatch significantly. Investment appears forthcoming if allowed to proceed.
Controls	Consumer preferences unknown, but theoretically is aligned with low impact fishing. Legislation: pulse trawling was banned in the EU in 1998 due to concerns about the collateral impact (injury) to other benthic species, as well as the very high fishing efficiency. Partial exemptions to the EU ban were introduced in 2009, which has enabled further development of the gear and testing. High efficiency is in line with business objectives.
Means / Mechanisms	Small number of people involved but with high technical skill. Question marks over business skills to manage the downsides of the technology. Gear appears well developed, as well as methods to achieve high efficiency, but lacking in surveillance techniques.
Outputs	New knowledge and Intellectual Property (IP) have been developed. High trawl efficiency = high profitability. Discards reduction proved in several scientific publications. Significantly reduced benthic impact. Negative outputs are primarily due to 'human error' i.e. taking advantage of the exceptionally high technical efficiency. Legislators are likely fearful of reputation due to prior problematic implementations.

Limitations and future works

- The Criteria of Assessment (CA) was conducted within a small group of fisheries scientists. Conclusions drawn within this report must therefore take this narrow focus into account, especially when extrapolating conclusions into industrial or commercial settings.
- A rigorous analysis of the methodologies to assess an innovation was not conducted prior to the commencement of the information collection. Therefore, the IDEF0 modelling and definition of innovative gear presented in section *§5 Modelling the Innovative Gears* have not been implemented in the current report. Nevertheless, the approaches and methodologies reported in that section provide an insight for future work analysis and can guide WKING members to new directions and ideas.

6 Catalogue of innovative gears

At the Inception meeting, the experts agreed to catalogue five/six gears for each European sea basin (Figure 3) that are considered "Innovative" to help identifying and defining features of 'Innovative gear'.

The list of experts designated to catalogue five/six Innovative gears for each region are provided in Table 4. At the subsequent WKING II meeting (10th of June 2020), where relevant, inputs from other fishing technology experts and stakeholder (NGO, fishing industry, and gear industry) were sought. The innovative gears described in the factsheets originated both from scientists and fishing industry.

This report does not contain a global catalogue of Innovative gears of the European fishing industry, but gives examples from different European sea basins to provide an overview of the state-of-the-art technologies and innovations that are relevant to the European fisheries.

The scope of the review covered many topics within the three Criteria of Assessment: catch efficiency, selectivity and reduction of unwanted and incidental species, and impact on marine ecosystems.

Innovations from the European sea basins were captured using a standard factsheet layout, which briefly describe each of the innovation identified. This factsheet-based method reports the **main technical features and the technological complexity of the innovation**, according to the empirical three-level grading system developed in *§4.7 Levels of technological complexity*.

For each innovation, a range of sources of information were reviewed in order to understand recent technological advances and research developments. The use of a broad range of sources was necessary to ensure that the review covered all major types of innovation and research developments.

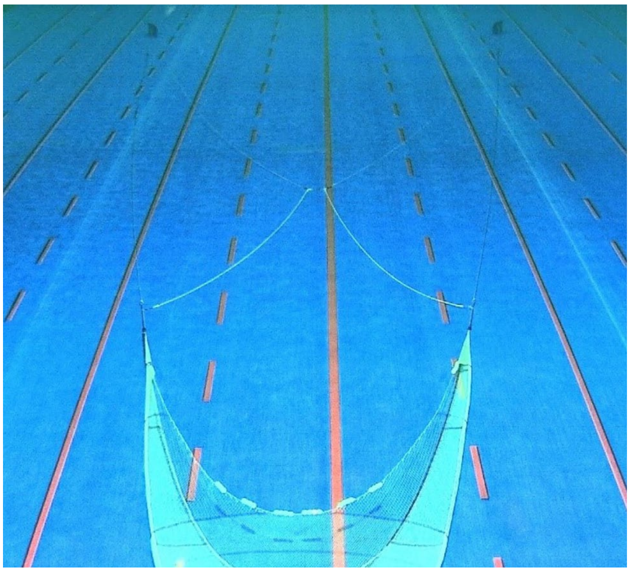
The information collected in the catalogue considered the objectives of the Innovative gears, technical specificities and known impacts/benefits with regards to catch efficiency, selectivity on target and non-target species, and environmental impact in terms of marine ecosystems and sensitive habitats.

Table 4. List of the experts designated to catalogue gears considered 'innovative' for each European sea basin.

Sea basin (Region)	Surname, Name	Annex of the EU Reg. 2019/1241
North Sea	Kynoch, Robert Feekings, Jordan P. Molenaar, Pieke	Annex 5 (page 45)
Northwestern Waters	McHugh, Matthew Catchpole, Tom	Annex 6 (page 55)
Southwestern Waters	McHugh, Matthew	Annex 7 (page 64)
Baltic Sea	Feekings, Jordan P. Stepputtis, Daniel	Annex 8 (page 69)
Mediterranean and Black Sea	Sala, Antonello	Annex 9, 10 (pages 74, 78)

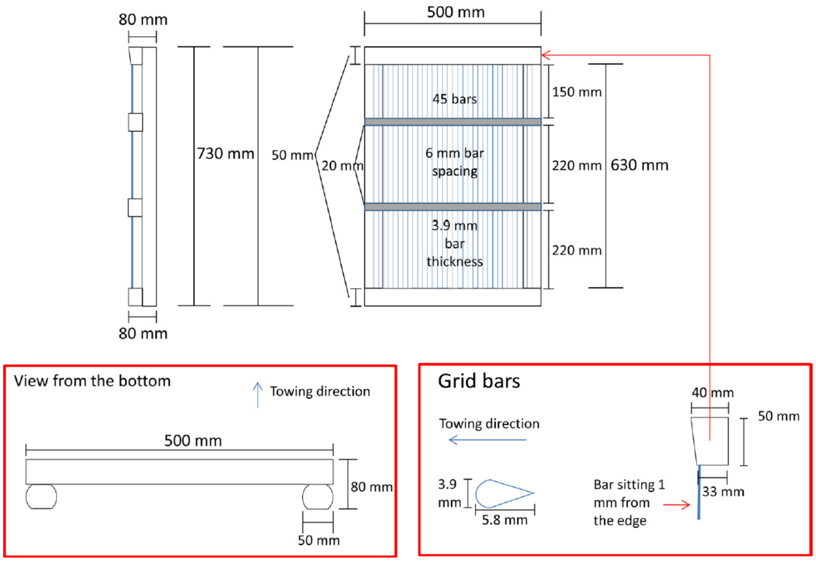
6.1 North Sea

6.1.1 FlexSelect. A counter-herding device

General information			
Date	01/07/2018	**Source supplier name**	DTU Aqua
Region	North Sea	**FAO Area (Division, L2)**	*27.3.a*
Gear sub-category	Bottom trawls	**Gear code**	OTT
Baseline gear	Commercial OTT (SELTRA)	**Baseline Regulation**	EC Reg. 2019/1241
Target species	NEP, PLE, POK	**Bycatch species**	COD
Definition of the Innovative gear	Counter-herding device placed ahead of the trawl	**Technological complexity level**	Minimal / High
		Technology readiness level	High
Main criteria	Improved catchability of main target species (NEP). Improved selectivity for problematic species (COD).	**Additional criteria**	A low-cost innovation that help fishers modify their catch composition on a haul-by-haul basis.
Technical specificities	FlexSelect is a simple and efficient system that can be quickly attached to any existing demersal trawl to reduce the catch of unwanted fish, for example, to improve the species selection in mixed demersal trawl fishery targeting Norway lobster. FLEXSELECT reduces the catch of unwanted fish by scaring or directing unwanted fish away from the path of the trawl so that they do not enter the trawl itself.		
Outcomes expected	FlexSelect were found to significantly reduce the catch of fish, in particular cod (26-50 cm), plaice (27-35 cm), and saithe (48-59; 97-106 cm). With regard to the target species, Nephrops, catches of individuals between 30 and 39 mm (carapace length) were significantly higher in the trawl with FlexSelect compared to the control (SELTRA).		
Drawing / picture of the Innovative gear / Solution	 Scaring lines. An innovative and flexible solution for the Nephrops fishery (FLEXSELECT).		
Relevant information / Reference	Feekings, J. P., Melli, V., Frandsen, R. P., Lund, H., Matias da Veiga Malta, T. A., Nalon, M. & Krag, L. A., 2019, DTU Aqua. 44 p. (DTU Aqua-rapport; No. 352-2019). Melli, V., Karlsen, J. D., Feekings, J. P., Herrmann, B. & Krag, L. A., 2018. FLEXSELECT: counter-herding device to reduce bycatch in crustacean trawl fisheries. Canadian Journal of Fisheries and Aquatic Sciences. 75, 6, p. 850-860.		

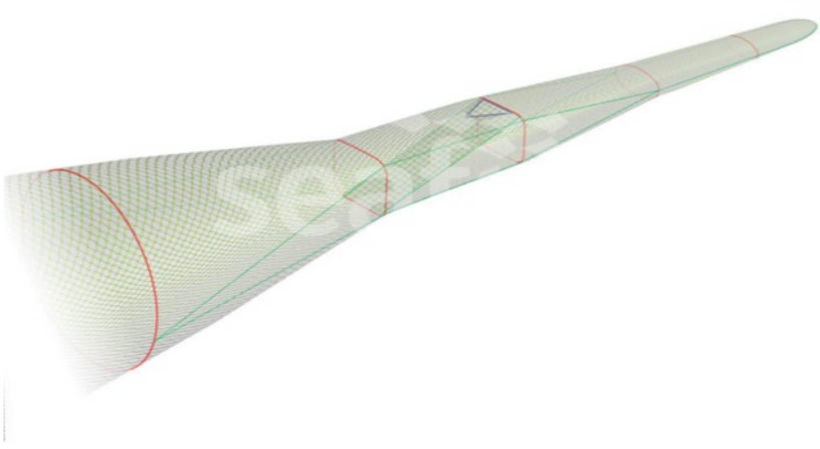
6.1.2 Brown shrimp size sorting grid

General information			
Date	01/02/2019	**Source supplier name**	DTU Aqua
Region	North Sea	**FAO Area (Division, L2)**	27.4.b
Gear sub-category	Beam trawls	**Gear code**	TBB
Baseline gear	Commercial brown shrimp trawl with a sieve net (70 mm) and a 22 mm diamond mesh codend	**Baseline Regulation**	EC Reg. 2019/1241 plus a Marine Stewardship Council (MSC) certification
Target species	CSH	**Bycatch species**	PLE, DAB, SPR, HER,
Definition of the Innovative gear	A size sorting grid with a bar spacing of 6 mm and a 22 mm codend	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Improved selectivity for the target species	**Additional criteria**	
Technical specificities	The North Sea brown shrimp beam trawl fishery became Marine Stewardship Council (MSC) certified in 2017. As part of the certification, the fishers proposed to incrementally increase the mesh size of the codend from 22 mm to 26 mm. As this increase in mesh size could result in a substantial loss of marketable sized brown shrimp (shrimp with total length equal or higher than 50 mm), a combination of a size sorting grid with a bar spacing of 6 mm and a 22 mm codend was proposed by the Danish fishers as a possible alternative to the increase in codend mesh size.		
Outcomes expected	The results showed that the grid reduced catches of shrimp under the marketable size of 50 mm. Moreover, the combination of the grid and a 22 mm diamond mesh codend had an overall selective performance similar to that of a 26 mm diamond mesh codend, both for shrimps under and above the marketable size.		
Drawing / picture of the Innovative gear / Solution	 Size sorting grid for brown shrimp (left panel) with 6 mm bar spacing, mounted in an extension piece (right panel) in front of the codend. Note the opening to the codend in the top (arrow A), the escape panel behind the grid (arrow B) and the guiding panel in the bottom (black netting; arrow C).		

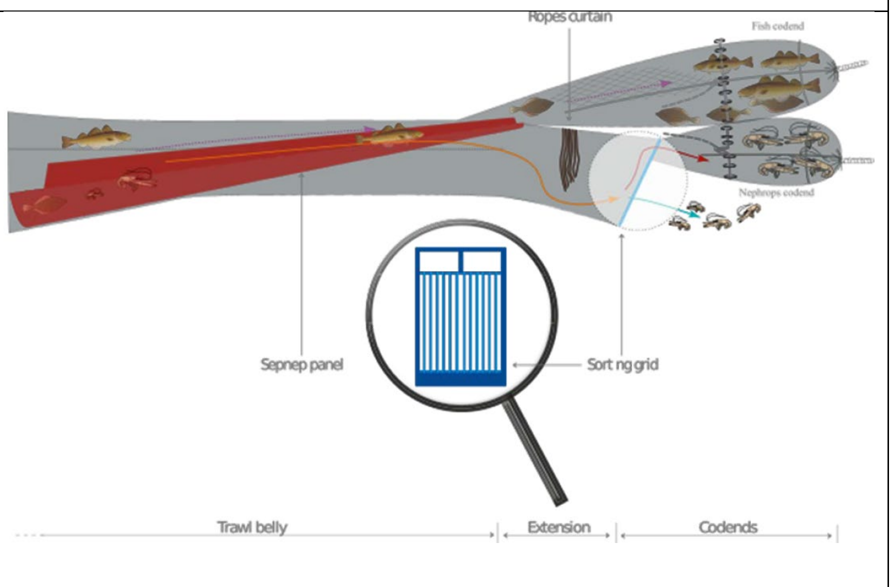
<table>
<tr><td></td><td>

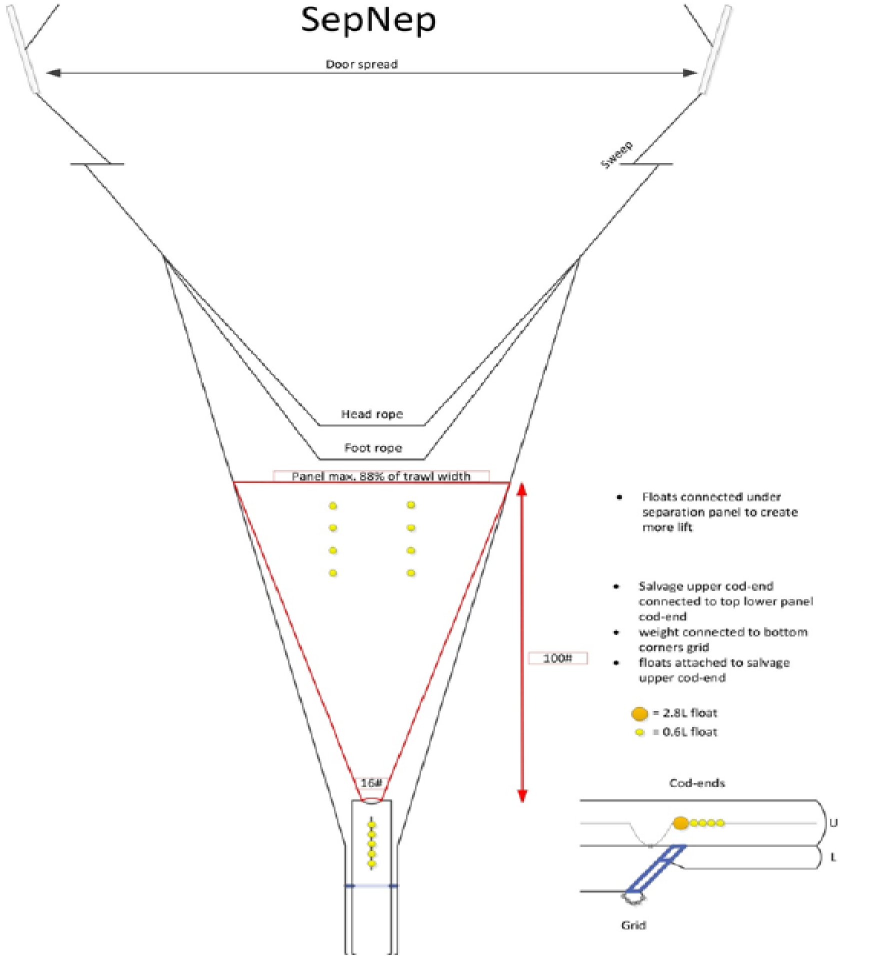
Description of the 6 mm size-sorting grid with drop shaped bars that was used during this study.</td></tr>
<tr><td>Relevant information / Reference</td><td>Veiga-Malta, T., Feekings, J.P., Frandsen, R.P., Herrmann, B., Krag, L.A. 2020. Testing a size sorting grid in the brown shrimp (Crangon Crangon Linnaeus,1758) beam trawl fishery. Fisheries Research, 231.</td></tr>
</table>

6.1.3 Netgrid

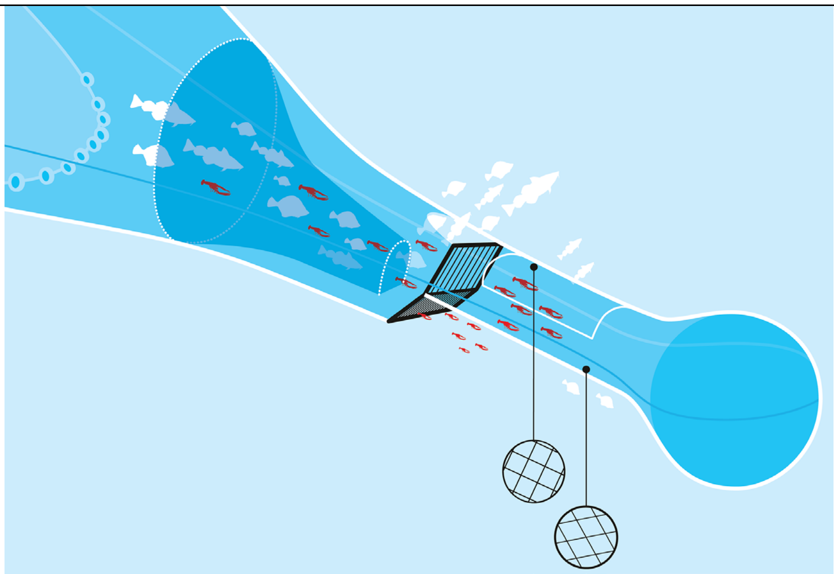
General information			
Date	01/06/2012	**Source supplier name**	Cefas
Region	North Sea	**FAO Area (Division, L2)**	27.4.b
Gear sub-category	Bottom trawls	**Gear code**	OTT
Baseline gear	Commercial OTT (90 mm diamond mesh codend plus 120 mm square mesh panel at end of tapered section 15-18m from codline)	**Baseline Regulation**	EC Reg. 1342/2008
Target species	NEP	**Bycatch species**	COD
Definition of the Innovative gear	Inclined net grid (Netgrid) consisting of 80 mm single braided twine orientated in a square mesh configuration	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Improved selectivity for problematic species	**Additional criteria**	Low cost innovation to existing trawls
Technical specificities	Netgrid is comprised of a four-panel box section inserted into a standard two-panel trawl into which an inclined sheet of 80mm netting is laced. Netgrid is positioned between the codend and the square mesh panel. On the top of the box section in front of netting grid is a fish escape hole. The netting grid acts as a physical barrier and guides fish out of the escape hole while Nephrops pass through the netting to the codend.		
Outcomes expected	Cod catches were reduced by 91% by number with the Netgrid compared to a standard trawl. During Nephrops targeted fishing, cod catches made up 1.5% of the total catch weight with the Netgrid. Catches of haddock, whiting and monkfish across all lengths were significantly less with the Netgrid. Catches of Nephrops were unaffected by the Netgrid. Discards were reduced by 57% by weight with the Netgrid compared with a standard trawl.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Catchpole, et.al. 2012. Trials of a Net Grid for the UK Nephrops trawl fisheries. https://seafish.org/gear-database/wp-content/uploads/2019/12/Avocet-net-grid-Report-1.pdf		

6.1.4 SepNep

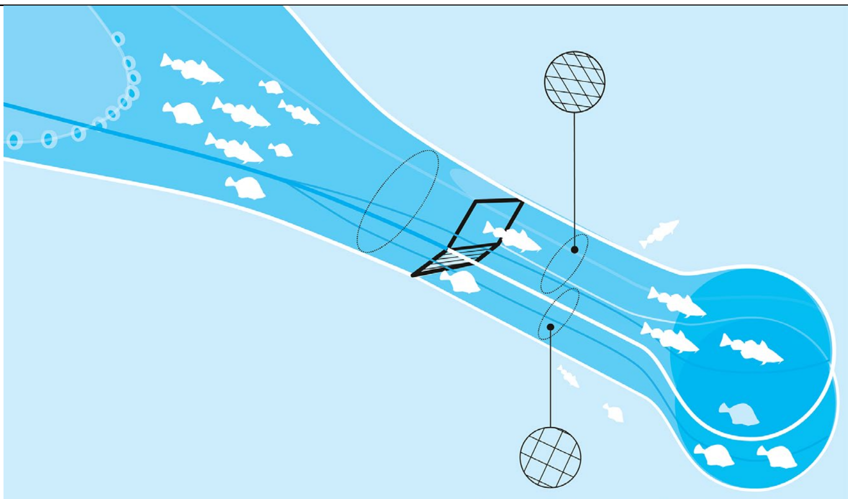
General information			
Date	23/09/2016	**Source supplier name**	WMR
Region	North Sea	**FAO Area (Division, L2)**	27.4.b & 27.4.c
Gear sub-category	Bottom trawls	**Gear code**	TBN
Baseline gear	Commercial OTT (80 mm diamond mesh codend plus 120 mm square mesh panel at the end of tapered section 15-18 m from codline)	**Baseline Regulation**	EC Reg. 1342/2008
Target species	NEP	**Bycatch species**	PLE, TUR, BLL, GUU
Definition of the Innovative gear	Inclined U-shaped tapered net panel, a grid and double codends	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Improved trawl selectivity for Nephrops, plaice, dab and whiting	**Additional criteria**	Innovation to existing trawls
Technical specificities	A regular quad-rig Nephrops trawl is equipped with a 100 meshes long Inclined U-shaped tapered separation panel, the panel consists of 105 mm double knotted Dyneema T0 mesh. The panel should guide the large individuals (fish) towards the entrance of the upper 120 mm codend, Nephrops falls through the panel meshes and enters lower tunnel in the trawl. A Nephrops grid with a 17 mm bar spacing on a 45 degree angle is mounted in the lower tunnel to release undersized Nephrops before entering the lower 80mm Nephrops codend.		
Outcomes expected	The SepNep panel in a commercial trial combined with a 122 mm upper codend reduced overall unwanted bycatch by 65%. In particular bycatch of undersized plaice (69%) and dab (78%) was reduced with this panel and upper codend. The additional grid is able to exclude from 53% to 56% of the biomass of non-marketable Nephrops (<32mm CL) in the tested configurations.		
Drawing / picture of the Innovative gear / Solution			

	
Relevant information / Reference	Santos, J., Molenaar, P., 2016. Bericht über die 725. Reise des FFS Solea vom 07.09 bis 23.09.2016. Thünen Institut Für Ostseefischerei. 44pp. http://library.wur.nl/WebQuery/wurpubs/fulltext/463153. Molenaar, P., Steenbergen, J., Glorius, S., Dammers M., 2016. Vermindering discards door netinnovatie in de Noorse kreeft visserij. IMARES rapport C027/16. 119 pp. https://edepot.wur.nl/376260.

6.1.5 Combination grid for Pandalus and Nephrophs fishery

General information			
Date	01/05/2018	**Source supplier name**	SLU Aqua
Region	North Sea	**FAO Area (Division, L2)**	27.3.a
Gear sub-category	Bottom trawls	**Gear code**	OTB, OTT, TBN
Baseline gear	Pandalus: At least 35 mm with a 19 mm standard Nordmøre grid. Nephrops: at least 70 mm (square mesh) or 90 mm (diamond mesh) with SELTRA 300 mm panel with a 35 mm Nordmøre grid	**Baseline Regulation**	C Reg. 2019/1241
Target species	PRA or NEP	**Bycatch species**	COD, PLE, HAD, WHG, NOP, HKE, PLA, and others
Definition of the Innovative gear	Combination grid system: upper half grid species selective and lower half grid size selective.	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Improve size selectivity for the target species in already species selective Pandalus and Nephrops trawl fisheries	**Additional criteria**	none
Technical specificities	Combination grid: the lower grid section (Pandalus: 9-10 mm, Nephrops: 20-21 mm) size selective, and the upper grid section (Pandalus: 19 mm, Nephrops: 35 mm) - species selective. Only the lower part of the grid is changed compared to the baseline gear. Individuals passing the lower grid are directly released at the sea floor.		
Outcomes expected	About 60 % of undersized Pandalus or Nephrops was sorted out. Loss of larger Pandalus and Nephrops was 5 and 10%, respectively. Further reduction in bycatches of small flatfish and roundfish was observed compared to the standard grid gears in the Nephrops grid system.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	DTU-Aqua reports 2018.3, 2018.4, 2018.13. https://www.slu.se/en/departments/aquatic-resources1/selective-fishing/		

6.1.6 Grid system with double-codend

General information			
Date	01/05/2018	**Source supplier name**	SLU Aqua
Region	North Sea	**FAO Area (Division, L2)**	27.3.a
Gear sub-category	Bottom trawls	**Gear code**	OTB, OTT, PTB
Baseline gear	At least 120 mm	**Baseline Regulation**	C Reg. 2019/1241
Target species	DEM (mixed)	**Bycatch species**	DEM
Definition of the Innovative gear	Grid system with two codends in mixed fisheries for demersal fish	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Separation of flatfish from roundfish to improve species and size selectivity for target species in mixed fisheries	**Additional criteria**	none
Technical specificities	The lower grid section (55 mm horizontal bar spacing) fitted to a square mesh codend (at least 120mm), the upper grid section (an open frame) fitted to a large meshed codend (depending on target species and size). In the experiments 150-200 mm codends were used to retain large cod.		
Outcomes expected	More than 90 % of the flatfish catch was observed in the lower codend compared to only about 18 % of the cod catch. Since flatfish and roundfish (e.g. cod) are separated between the codends a vessel can choose a suitable mesh size in the upper codend given its quota availability for roundfish such as cod, without losing targeted flatfish (or vice versa if the flatfish quotas are limited).		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	SLU Aqua reports 2016.4, 2018.4, 2018.13. https://www.slu.se/en/departments/aquatic-resources1/selective-fishing/		

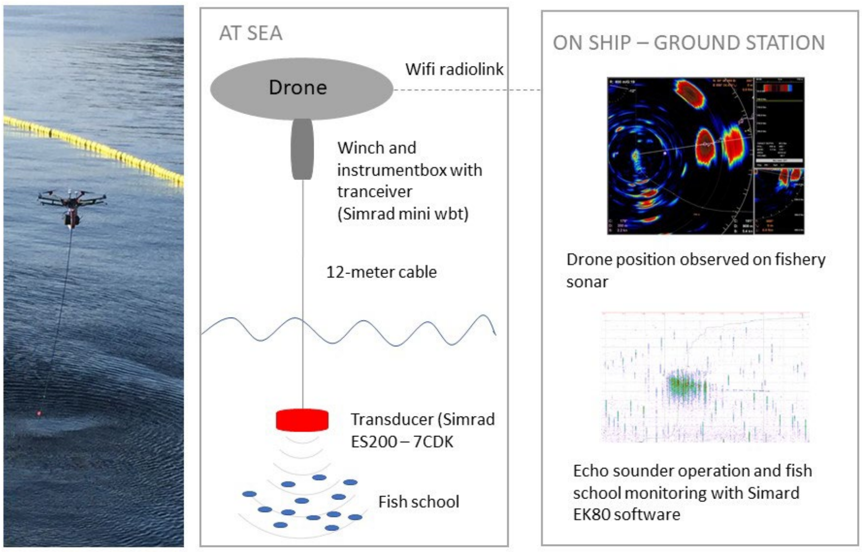
6.1.7 Shrimp pulse

General information			
Date	01/03/2019	**Source supplier name**	ILVO
Region	North Sea	**FAO Area (Division, L2)**	27.4b-c
Gear sub-category	Bottom trawls	**Gear code**	TBS
Baseline gear	TB	**Baseline Regulation**	Regulation (EU) No 1380/2013
Target species	CSH	**Bycatch species**	SOL, PLE
Definition of the Innovative gear	Shrimp pulse trawl	**Technological complexity level**	Significant
		Technology readiness level	High
Main criteria	Selectivity, impact	**Additional criteria**	Reducing bycatch and bottom impact
Technical specificities	The mechanical stimulation to catch shrimp is largely replaced by an electrical stimulus. The shrimp pulse trawl uses a startle pulse (5 Hz) to make brown shrimp jump out of the seabed. The number of bobbins are reduced and set in a straight line perpendicular to the towing direction, making the gear hover over the seabed and reducing the bottom contact.		
Outcomes expected	The innovation reduces the environmental impact in the brown shrimp (*Crangon crangon*) trawl. The results illustrate that pulse stimulation enables a discard reduction of small shrimp of up to 35% and a reduction of benthos and fish discards of up to 76 %, with no or minor loss of commercial size shrimp. In addition, contact of the groundgear with the seabed is reduced by using a straight bobbin rope with less bobbins.		
Drawing / picture of the Innovative gear / Solution	 Front view (top) and details of the bobbin rope (bottom) of a traditional trawl with 36 bobbins in a u-shaped bobbin rope (400 kg, left) and a pulse trawl with 11 bobbins in a straight configuration (150 kg inclusive of electrodes, right) illustrating the difference in mechanical stimulation and the size and orientation of escape opportunities between the bobbins for bycatch species.		
Relevant information / Reference	Verschueren, B., Lenoir, H., Soetaert, M., and Polet, H. 2019. Revealing the bycatch reducing potential of pulse trawls in the brown shrimp (*Crangon crangon*) fishery. Fisheries Research, 211: 191–203		

6.1.8 Flying drone with scientific echosounder

General information			
Date	24/01/2018	**Source supplier name**	IMR, Norway
Region	North Sea	**FAO Area (Division, L2)**	27.2, 27.4
Gear sub-category	Purse seines	**Gear code**	PS, TM
Baseline gear	Commercial pelagic purse-seine and midwater trawl	**Baseline Regulation**	None
Target species	HER, MAC	**Bycatch species**	Undersized target species
Definition of the Innovative gear	Flying drone with scientific echo sounder	**Technological complexity level**	Significant
		Technology readiness level	Moderate
Main criteria	Improved individual and school size selectivity before net is deployed. Improved catch efficiency.	**Additional criteria**	More efficient school searching
Technical specificities	The drone developed by Birdview AS has six propellers, a weight of 14 kg (without instrumentation) and a maximum flight time of 55 minutes. The drone is equipped with a Simrad wideband transceiver (WBT mini) built in a watertight casing and an electric winch with 12-meter cable to the transducer (Simrad ES2000-7CDK). Communication between the ground system on the vessel and the drone (including winch and echo sounder) is over a 5 GHz wifi radiolink. When in desired location the transducer is lowered down and the echosounder is operated with Simrad EK 80 software from a pc on the vessel.		
Outcomes expected	The expected outcome is individual size estimates and biomass estimates of fish schools that are detected on the sonar before capture. Experiments for size estimation using broadband acoustics will be carried out in September 2020. In the longer term the drones are expected to be used for more efficient school search.		

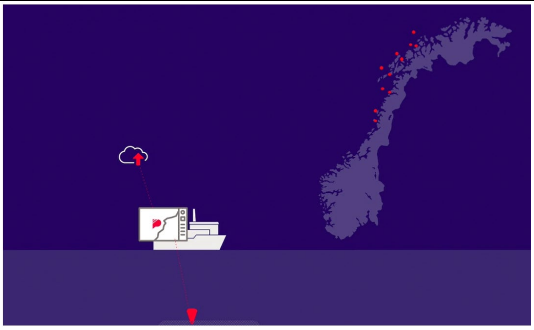
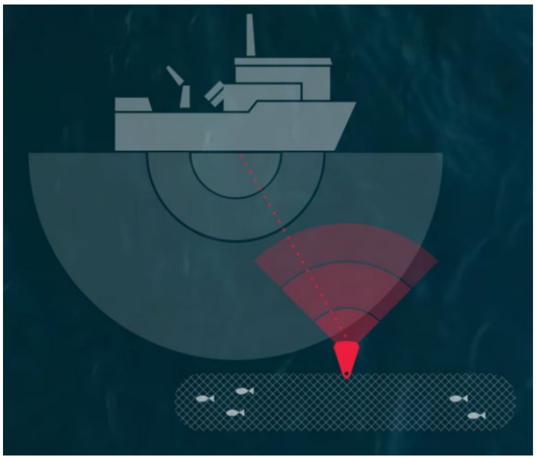
Drawing / picture of the Innovative gear / Solution

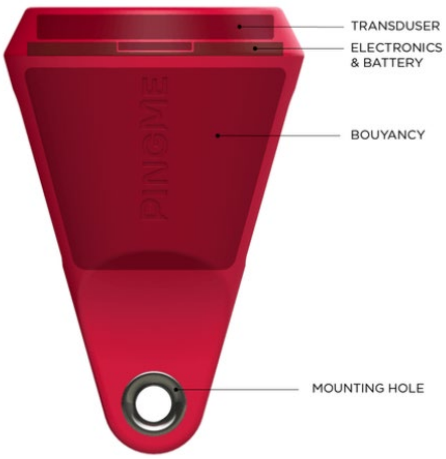


Relevant information / Reference	https://birdview.tech/ Tenningen, M., Øvredal, J. T., Macaulay, G., 2018. Acoustic catch monitoring in Purse Seines. Rapport fra Havforskningen. Nr. 42-2018 *(In Norwegian with English summary).*

6.1.9 Smart acoustic solution for tagging fishing gears and objects underwater (PingMe)

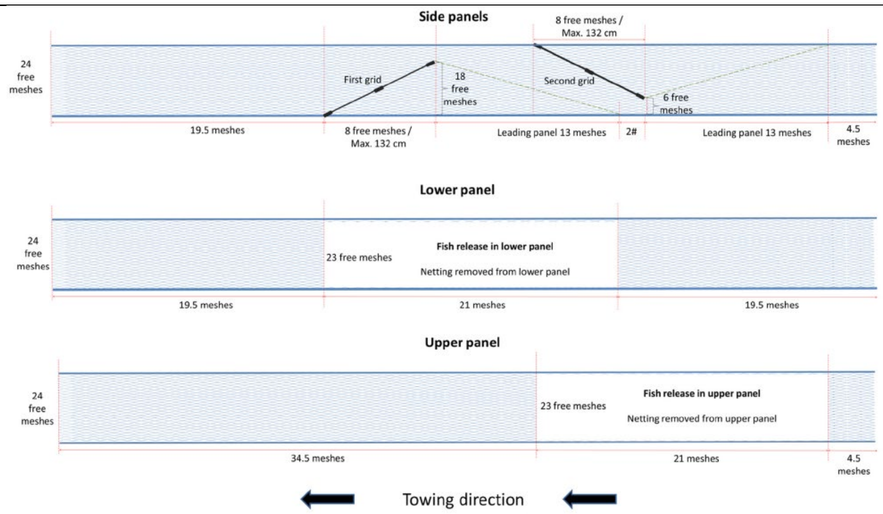
General information			
Date	08/01/2019	**Source supplier name**	OSAC AS, Norway
Region	North Sea	**FAO Area (Division, L2)**	27.2, 27.4
Gear sub-category	Pelagic/ bottom trawl, purse-seine, gillnets and pots/creels	**Gear code**	PS, TM
Baseline gear	None	**Baseline Regulation**	None
Target species	All species, all fishing gear.	**Bycatch species**	-
Definition of the Innovative gear	Three hundred kilometres of ghost-fishing gillnets were retrieved by the authorities from the Barents Sea last year. With PingMe, a lot more of the gear would have been located and identified by the fisher himself, and removed much earlier.	**Technological complexity level**	Significant
		Technology readiness level	Moderate
Main criteria	Find ghost fishing nets (impact) and equipment as well as locate active fishing gear underwater.	**Additional criteria**	Accurately locate and pinpoint the trawl and other fishing gear underwater.
Technical specificities	PingMe is patented and consists of three units: 1) PingMe transponder: A smart, small device attached to gear / objects you want identified and located underwater. 2) PingMe Software: A software module integrated in the boat's existing sonar system or as a stand-alone system. The software allows communication with the transponder to determine location and ID. 3) PingMe Service in the cloud: A management tool for the authorities. Information of lost, detected and retrieved gear is reported to the cloud, some of it automatically. This enables the authorities to keep better control of litter in the ocean, which might come in conflicts with other boats or fisheries. The transponder is passive and reflects the sound waves originating from the sonar. The reflected signal is encoded with a unique identity so that the sonar with PingMe software integrated can identify the transponder and calculate its position. This information might be encrypted if the information is to be transferred to the cloud. With PingMe's scheduled online service, you can: - Register your own lost gear with associated ID, or - Report findings of other lost tools In the long term, such a service can be integrated into the Authorities Public Service (in Norway: The Directorate of Fisheries). PingMe can also be used for better control during active fishing, by attaching transponders at regular intervals to the gear (longline). Better control of where the gear is located can make fishing more efficient and profitable.		
Outcomes expected	The expected outcome is that a lot more of the ghost fishing gear can be located and collected from the sea faster.		

<table>
<tr><td>Drawing / picture of the Innovative gear / Solution</td><td>





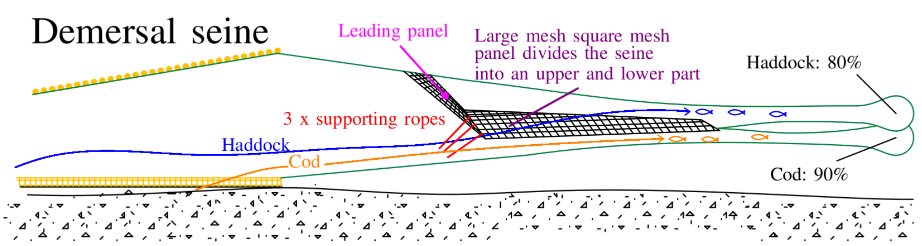
</td></tr>
<tr><td>Relevant information / Reference</td><td>www.osac.no</td></tr>
</table>

6.1.10 Two to four-panel sorting grids

<table>
<tr><th colspan="4">General information</th></tr>
<tr><td>Date</td><td>29/05/2015</td><td>Source supplier name</td><td>IMR, Norway</td></tr>
<tr><td>Region</td><td>Barents Sea, Norwegian Sea</td><td>FAO Area (Division, L2)</td><td>27.1, 27.2</td></tr>
<tr><td>Gear sub-category</td><td>Bottom trawls</td><td>Gear code</td><td>OTB, OTT, OTP</td></tr>
<tr><td>Baseline gear</td><td>The baseline gear is a 2-panel sorting grid section.</td><td>Baseline Regulation</td><td>Norwegian Directorate of Fisheries, J-55-2015</td></tr>
<tr><td>Target species</td><td>COD, HAD</td><td>Bycatch species</td><td>POK, RED, GHL, HAL.</td></tr>
<tr><td rowspan="2">Definition of the Innovative gear</td><td rowspan="2">Compulsory sorting grids installed in 4-panel netting sections.</td><td>Technological complexity level</td><td>Medium</td></tr>
<tr><td>Technology readiness level</td><td>High</td></tr>
<tr><td>Main criteria</td><td>Better selectivity for target species and less clogging risk.</td><td>Additional criteria</td><td>None</td></tr>
<tr><td>Technical specificities</td><td colspan="3">Mounting the sorting grids in 4-panel netting sections instead of 2-panel netting sections. The innovation applies to both the Sort-V and Flexigrid grid designs, which are compulsory in the area. Technical specifications of the baseline and new sections are found in:
www.fiskeridir.no/Yrkesfiske/Regelverk-og-reguleringer/J-meldinger/Utgaatte-J-meldinger/J-55-2015</td></tr>
<tr><td>Outcomes expected</td><td colspan="3">The new 4-panel sections show higher release of undersized fish and the risk for breakage of the section is lowered as the risk for clogging is reduced. In addition, compared with the 2-panel sections, 4-panel sections are easier to mount correctly for the crew.</td></tr>
<tr><td>Drawing / picture of the Innovative gear / Solution</td><td colspan="3">
</td></tr>
<tr><td>Relevant information / Reference</td><td colspan="3">Grimaldo, E., Sistiaga, M., Herrmann, B., Gjøsund, S.H., Jørgensen, T., 2015. Effect of the lifting panel on selectivity of a compulsory grid section (Sort-V) used by the demersal trawler fleet in the Barents Sea cod fishery. Fisheries Research, 170: 158–165.

Sistiaga, M., Brinkhof, J., Herrmann, B., Grimaldo, E., Langård, L., Lilleng, D., 2016. Size selective performance of two flexible sorting grid designs in the Northeast Arctic cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) fishery. Fisheries Research, 183: 340-351.</td></tr>
</table>

6.1.11 Species separation, cod-haddock

<table>
<tr><th colspan="4">General information</th></tr>
<tr><td>Date</td><td>01/04/2017</td><td>Source supplier name</td><td>IMR, Norway</td></tr>
<tr><td>Region</td><td>Norwegian Sea, Barents Sea</td><td>FAO Area (Division, L2)</td><td>27.1, 27.2</td></tr>
<tr><td>Gear sub-category</td><td>Boat seines</td><td>Gear code</td><td>SSC</td></tr>
<tr><td>Baseline gear</td><td>Standard demersal seine with relevant technical conservation measure for specific area.</td><td>Baseline Regulation</td><td>Norwegian Directorate of fisheries J-108-2020</td></tr>
<tr><td>Target species</td><td>COD, HAD</td><td>Bycatch species</td><td>HAD, COD</td></tr>
<tr><td rowspan="2">Definition of the Innovative gear</td><td rowspan="2">Species separation of haddock and cod</td><td>Technological complexity level</td><td>Medium</td></tr>
<tr><td>Technology readiness level</td><td>Moderate</td></tr>
<tr><td>Main criteria</td><td>Avoid catches of cod in the haddock targeted fisheries and haddock in the cod directed fisheries (Catch, selectivity).</td><td>Additional criteria</td><td>None</td></tr>
<tr><td>Technical specificities</td><td colspan="3">In the aft part of the demersal seine, in front of the codend, a species separation device is inserted. A leading panel guides all fish underneath a vertical square mesh panel with large meshes. While the fish passes along the panel towards the codend, mosh haddock exhibit upward escape attempts and penetrate the large meshes. Whether codend is attached on the upper or lower section is determined by which species is targeted. The separation device needs to be positioned well ahead of the codend where the seine is fully expanded</td></tr>
<tr><td>Outcomes expected</td><td colspan="3">About 80-90% separation of cod and haddock has been achieved, depending on size composition of catches. The separation has been shown to be length dependent, with more large fish in the lower compartment.</td></tr>
<tr><td>Drawing / picture of the Innovative gear / Solution</td><td colspan="3">
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<tr><td>Relevant information / Reference</td><td colspan="3">www.youtube.com/watch?v=YLzh1VcaJmw

Norwegian Directorate of Fisheries: www.fiskeridir.no/content/download/28497/407720/version/1/file/J-108-20.pdf

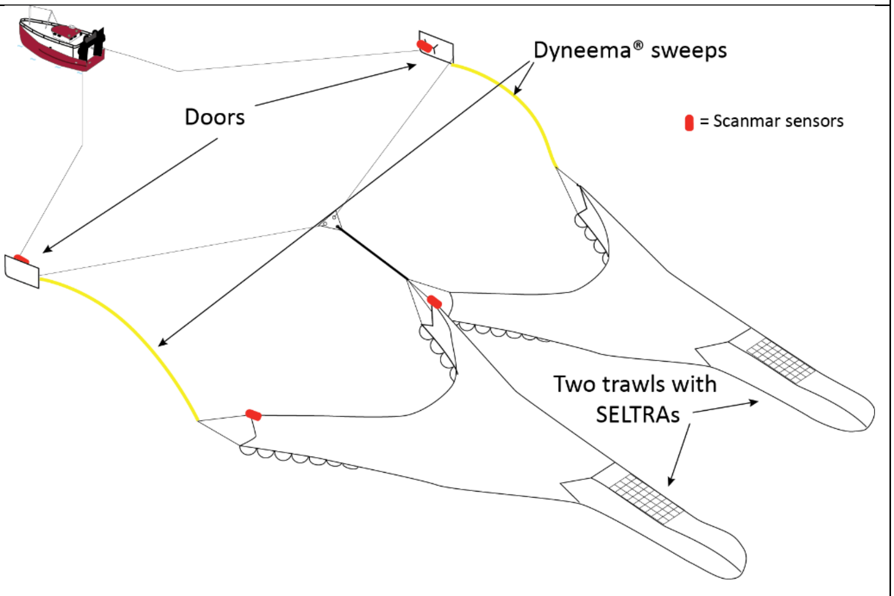
www.fiskeridir.no/content/download/21594/305756/version/1/file/Vedlegg%207-Artseleksjon%20snurrevad.pdf</td></tr>
</table>

6.2 Northwestern Waters

6.2.1 Remotely controllable trawl doors

General information			
Date	19/02/2013	**Source supplier name**	Atli Már Jósafatsson (Polar-doors)
Region	North Western Waters	**FAO Area (Division, L2)**	Worldwide fishing areas.
Gear sub-category	Midwater trawls	**Gear code**	TSP, PTM
Baseline gear	The baseline is any trawl doors for general midwater and semi-pelagic fishing	**Baseline Regulation**	e.g. EC Reg. 1967/2006
Target species	Mixed species	**Bycatch species**	Mixed species
Definition of the Innovative gear	Remote controllable trawl doors made from highly efficient aerodynamic designed wings.	**Technological complexity level**	Significant
		Technology readiness level	Moderate
Main criteria	Controllable trawl doors to be guided in preferable position in the sea to target selected species. Can be controlled to maintain fixed distance from the seabed to avoid direct seabed impact. Catch selected species, reduced bycatch, and protect fragile habitats.	**Additional criteria**	Less resistance compared with existing fishing doors, reduced pollution, reduced fuel emission and substantial energy savings.
Technical specificities	The POSEIDON controllable trawl doors are remotely controlled from the fishing vessel. Highly efficient aerodynamic designed wings that can be rotated to control the flow of water that passes the trawl doors. By controlling the flow of water through the doors, they can be steered to preferable position in the sea and guided to catch the species each boat has allowance to catch. This will reduce bycatch and support sustainable fishing. The POSEIDON trawl doors can also be programmed to keep fixed distance from the seabed to avoid direct impact to the seabed and protect fragile sea habitats. The POSEIDON trawl doors can also be programmed to keep fixed distance between the two trawl doors and fixed distance from the surface.		
Outcomes expected	By controlling the distance between the trawl doors, optimal catch performance can be secured with minimum fuel consumption while towing. The POSEIDON controllable trawl doors are highly environmentally friendly with main aims on selective fishing, reducing bycatch, maintaining biodiversity, reduced fuel emissions, no direct impact to the seabed to support sustainable fishing.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Atli Mar Josafatsson, Polar Fishing Gear, Iceland (atlimarj@polardoors.com) *Similar Trawl steering systems (doors, and trawl) can be found at: http://mld.one*		

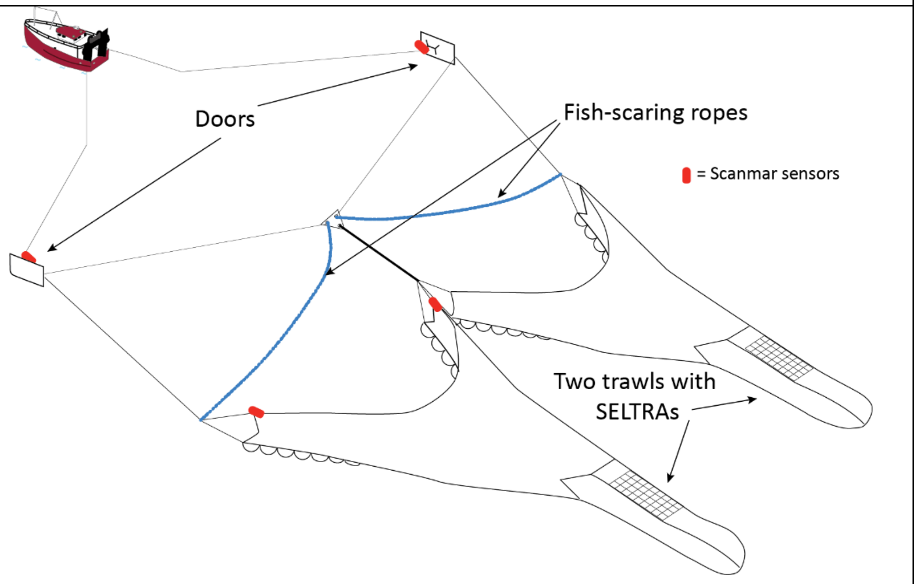
6.2.2 Floating sweeps on *Nephrops* trawl

<table>
<tr><th colspan="4">General information</th></tr>
<tr><td>Date</td><td>30/04/2013</td><td>Source supplier name</td><td>BIM</td></tr>
<tr><td>Region</td><td>Northwestern Waters</td><td>FAO Area (Division, L2)</td><td>27.7.a</td></tr>
<tr><td>Gear sub-category</td><td>Bottom trawls</td><td>Gear code</td><td>TBN</td></tr>
<tr><td>Baseline gear</td><td>Standard demersal trawl with relevant technical conservation measure for specific area</td><td>Baseline Regulation</td><td>EC Reg. 2019/1241</td></tr>
<tr><td>Target species</td><td>NEP</td><td>Bycatch species</td><td>WHI, COD, HAD</td></tr>
<tr><td rowspan="2">Definition of the Innovative gear</td><td rowspan="2">Floating sweeps between the trawl doors and trawl wing ends</td><td>Technological complexity level</td><td>Medium</td></tr>
<tr><td>Technology readiness level</td><td>High</td></tr>
<tr><td>Main criteria</td><td>Bycatch selectivity improved while maintaining target (Nephrops) catches</td><td>Additional criteria</td><td>Likely to have lower habitat impacts with sweeps not in contact with substrate. This is also likely to result in lower fuel consumption.</td></tr>
<tr><td>Technical specificities</td><td colspan="3">Baseline gear is a standard TBN trawl configuration. The innovative component is sweeps (between the trawl doors and trawl wings) that are not in contact with the substrate (i.e. Float)</td></tr>
<tr><td>Outcomes expected</td><td colspan="3">Fish are expected to escape under the floating sweeps. Results of trials (e.g. Catchpole et al., 2013; Browne et al., 2018) were varied but showed potential to reduce fish bycatch while maintaining target (Nephrops) catches.</td></tr>
<tr><td>Drawing / picture of the Innovative gear / Solution</td><td colspan="3">


</td></tr>
<tr><td>Relevant information / Reference</td><td colspan="3">Catchpole, T. L., Doran, S., Graham, R., and Howard, J., 2013. The NW Discard Project: minimising unwanted catches in the NW English Nephrops fishery, Cefas., 43 pp.

Browne, D., Oliver, M., McHugh, M. and Cosgrove, R. 2018. Assessment of Dyneema® floating sweeps and fish scaring ropes in the Irish Sea Nephrops fishery. BIM, Fisheries Conservation Report, 10 pp.</td></tr>
</table>

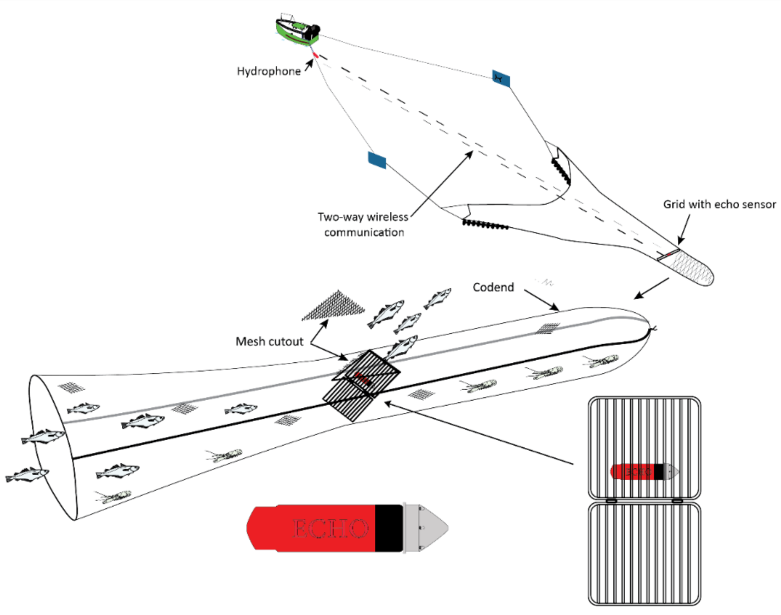
6.2.3 Fish scaring ropes in a *Nephrops* trawl

General information			
Date	05/02/2018	**Source supplier name**	BIM
Region	Northwestern Waters	**FAO Area (Division, L2)**	27.7.a
Gear sub-category	Bottom trawls	**Gear code**	TBN
Baseline gear	Standard demersal trawl with relevant technical conservation measure for specific area	**Baseline Regulation**	EC Reg. 2019/1241
Target species	NEP	**Bycatch species**	WHI, COD, HAD
Definition of the Innovative gear	Fish scaring ropes ahead of a Nephrops trawl’s mouth	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Bycatch (mostly fish) reduced	**Additional criteria**	Limited additional benefits
Technical specificities	Baseline gear is a standard TBN trawl configuration. The innovative component is fish-scaring ropes across the trawl opening.		
Outcomes expected	Fish are expected to encounter the scaring ropes and have time to react (i.e. avoid entering the net) compared to a standard configuration. During assessment (Browne et al. 2018) the length of the scaring rope had an impact on the reduction of fish bycatch and further work is needed to fully understand the process.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Browne, D., Oliver, M., McHugh, M. and Cosgrove, R. 2018. Assessment of Dyneema® floating sweeps and fish scaring ropes in the Irish Sea Nephrops fishery. BIM, Fisheries Conservation Report, 10 pp.		

6.2.4 Electro razor dredge

General information			
Date	01/02/2011	**Source supplier name**	BIM
Region	Northwestern Waters	**FAO Area (Division, L2)**	27.7.a
Gear sub-category	Towed dredges	**Gear code**	DRB/MEL
Baseline gear	The baseline gear is a standard razor clam dredge operated using either a hydraulic fan or water jets	**Baseline Regulation**	EU Reg. 1241/2019
Target species	EQX	**Bycatch species**	Use FAO 3-alpha code
Definition of the Innovative gear	A collecting basket, for razor clams, located behind electrodes	**Technological complexity level**	Medium
		Technology readiness level	Moderate
Main criteria	Better selectivity for razor clams, reduced bycatch and much less habitat impact	**Additional criteria**	Likely lower fuel consumption (and CO_2 emissions) compared to baseline (conventional) gear
Technical specificities	The baseline gear liquefies the sand around the dredge as it is towed forward collecting razor clams; the electro razor dredge is towed across the top of the substrate and picks up razor clams that have been stimulated (with electric current) out of the substrate.		
Outcomes expected	The electro razor dredge is towed slowly across the seabed and the *razor clams* are stimulated to temporarily leave their burrows as an intense electrical field is emitted from electrodes. The *razor clams* are then collected in a basket posterior to the electrodes. This process will reduce seabed impacts significantly, compared with the conventional razor clam dredge.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Breen, M., Howell, T.R.W., Copland, P., 2011. A report on electrical fishing for razor clams (*Ensis* sp.) and its likely effects on the marine environment. Marine. Scotland Scientific Report, 03/11, 120 pp. Fox, C. J., McLay, A., Dickens, S., 2019. Development and application of electrofishing with towed video as a new survey method for razor clams (*Ensis* spp.). Fisheries Research 214: 76-84.		

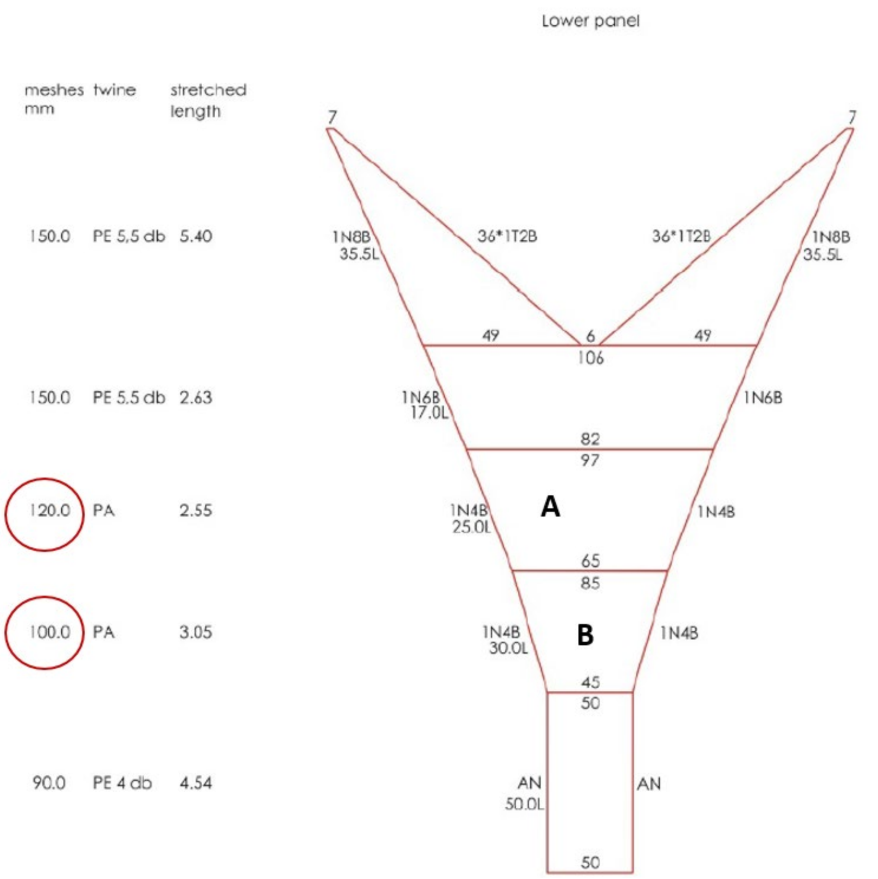
6.2.5 Echo sensor to detect *Nephrops*

General information			
Date	01/10/2019	**Source supplier name**	BIM
Region	Northwestern Waters	**FAO Area (Division, L2)**	27.7.b
Gear sub-category	Bottom trawls	**Gear code**	TBN
Baseline gear	Standard demersal trawl with relevant technical conservation measure for specific area	**Baseline Regulation**	EC Reg. 2019/1241
Target species	NEP	**Bycatch species**	WHI, HAD, COD
Definition of the Innovative gear	Grid sensor to quantify *Nephrops* catches	**Technological complexity level**	Significant
		Technology readiness level	Moderate
Main criteria	Quantify the catch entering the codend	**Additional criteria**	Potential energy savings and lower GHG emissions as quota likely to be filled quicker. Less time fishing will also reduce habitat impacts
Technical specificities	Baseline gear is a sorting grid in the trawl's aft section. The innovative component is a sensor attached to a grid that quantifies the amount of *Nephrops* passing through into the codend. The Echo only works on a sorting grid.		
Outcomes expected	If a fisher knows in real time that a small quantity of Nephrops are entering the codend at the beginning of the tow, the fisher may terminate the two and move to a more abundant area with wasting time for the unproductive tow. In this way, fishers can focus on productive areas to increase fishing efficiency. In Ireland fishers are given a rationed quota each month and if they can fill their quota quicker they will use less fuel (reduced CO_2 emissions), spend less time fishing (potentially lower habitat impacts), and reduce bycatch.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	BIM report available at www.bim.ie/media/bim/content/publications/fisheries/BIM-Assessment-of-the-Notus-Echo-catch-sensor-in-the-Irish-Nephrops-fishery.pdf Notus Echo website: www.notus.ca/echo		

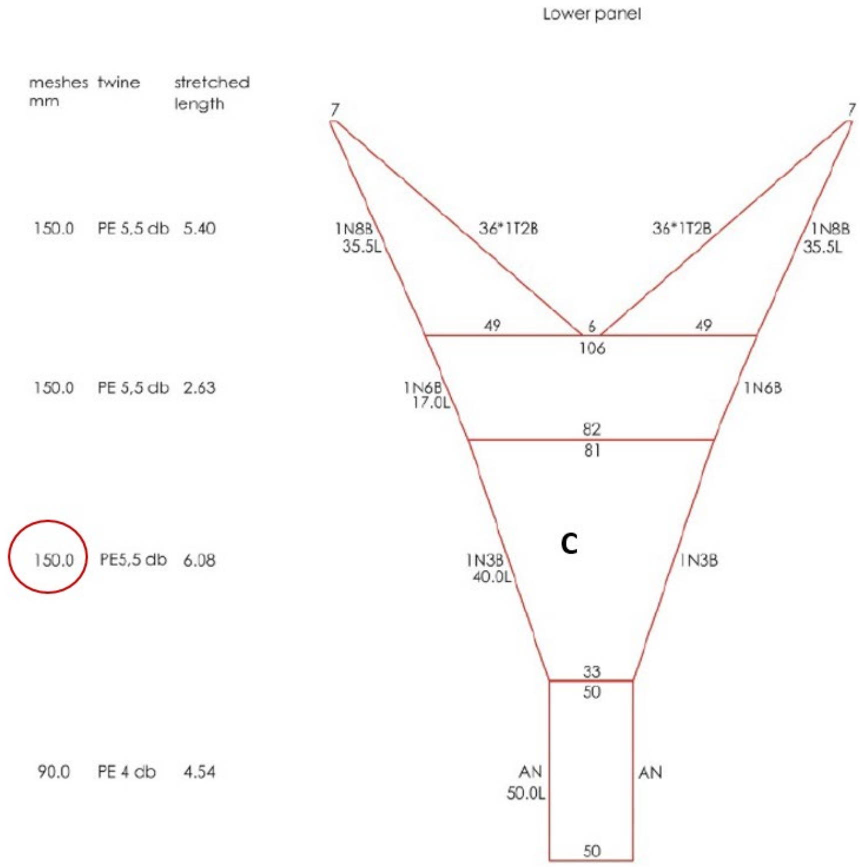
6.2.6 Flemish panel

General information			
Date	01/02/2015	**Source supplier name**	ILVO
Region	North Western Waters	**FAO Area (Division, L2)**	27.4, 27.7
Gear sub-category	Beam trawls	**Gear code**	TBB
Baseline gear	BT	**Baseline Regulation**	Delegated Regulation (EU) 2018/2034
Target species	SOL, PLE	**Bycatch species**	TUR, BLL, DAB, WHG, COD, LEM, MON, GUU, RJH, RJM, RJC, RJE
Definition of the Innovative gear	A flatfish beam trawl with a large mesh panel in the rear part of lower belly.	**Technological complexity level**	Minimal
		Technology readiness level	High
Main criteria	Selectivity	**Additional criteria**	Reducing bycatch and fishing mortality
Technical specificities	The net is attached to a beam and is rigged with a chain matrix in the net mouth. The baseline gear has a net extension nominal mesh size of 80 mm while the innovative gear has a net extension nominal mesh size of 120 mm. All other sections of the trawl are identical.		
Outcomes expected	Increasing the mesh size of the rear part of the lower belly in a beam trawl has shown to be an effective and simple method to reduce the capture of sole, especially sublegal sized fish. The application of the large mesh lower belly in the Belgian beam trawl fishery meets two needs: Reducing fishing mortality of undersized sole, and maintaining the economic viability of the Belgian fishing fleet.		

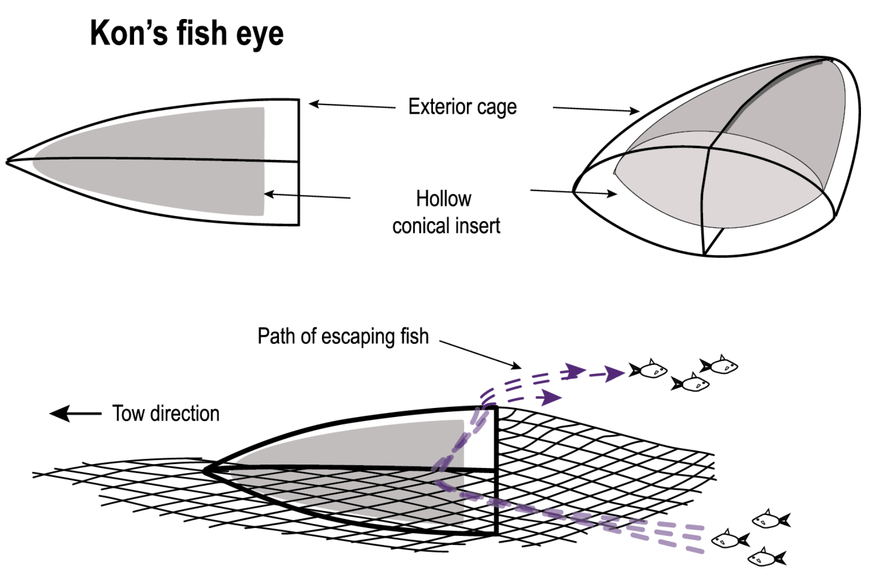
Drawing / picture of the Innovative gear / Solution



Design of lower panel of the standard net.

	 Design lower panel of the experimental net: big mesh extension in the tail.
Relevant information / Reference	Bayse S., Polet H., 2015. Evaluation of a large mesh extension in a Belgian beam trawl to reduce the capture of sole (*Solea solea*). Instituut voor Landbouw- en Visserijonderzoek

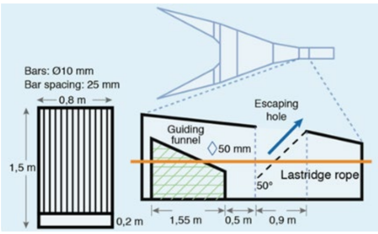
6.2.7 Kon's covered Fisheye

General information			
Date	01/06/2016	**Source supplier name**	NPF Industry Pty Ltd; A. Raptis & Sons Pty Ltd
Region	Northern Australia	**FAO Area (Division, L2)**	71
Gear sub-category	Bottom trawls	**Gear code**	OTB
Baseline gear	Baseline gear is a standard fisheye (cone shaped insert to maintain small opening in a prawn trawl's posterior section)	**Baseline Regulation**	Fisheries Management (Northern Prawn Fishery Gear Requirements) Direction 2020
Target species	PBA; PNI; PRB; TIP; ENS; MPE	**Bycatch species**	Mixed teleost species
Definition of the Innovative gear	Modified fisheye with conical insert to disrupt water flow	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Reduced bycatch of small individuals by 37.6%	**Additional criteria**	Increased target catches by 0.5%, Not assessed for any additional criteria
Technical specificities	The Kon's Covered Fisheyes Bycatch reduction device (BRD) is modelled on the existing Fisheye BRD but encompasses a cone-shaped insert designed to create an area of reduced water flow for small teleost fish to take shelter in and escape. The control gear had a square-mesh panel at 115 meshes from the codend drawstring.		
Outcomes expected	The Kon's Covered Fisheyes BRD is comprised of two modified fisheyes in each net, positioned in line with each other. They are positioned in the 42 mm (diamond-mesh codend) at 55 and 78 meshes from the codend drawstrings. There were large reductions of small teleosts without impacting on target species. The fisheye is unlikely to reduce catches of other larger individuals because of the size of the exit. With less bycatch to sort through, processing times (from hopper to freezer) and potential prawn damage (from larger bycatch volumes) would likely be reduced.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Laird, A., Cahill, J. and Liddell, B.,2016, Kon's Covered Fisheyes BRD Trial Report. Northern Prawn Fishery report, 37 pp		

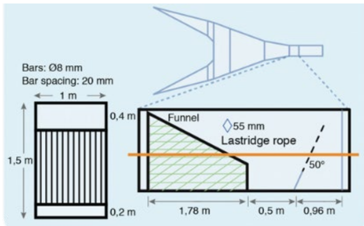
6.3 Southwestern Waters

6.3.1 BRD for bycatch reduction in crustacean fisheries

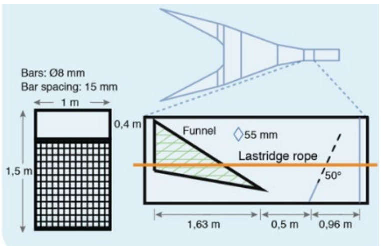
<table>
<tr><th colspan="4">General information</th></tr>
<tr><td>Date</td><td>01/02/2015</td><td>Source supplier name</td><td>Aida Campos, Paulo Fonseca (IPMA, Portugal)</td></tr>
<tr><td>Region</td><td>South Western Waters</td><td>FAO Area (Division, L2)</td><td>27.9.a</td></tr>
<tr><td>Gear sub-category</td><td>Bottom trawls</td><td>Gear code</td><td>TB</td></tr>
<tr><td>Baseline gear</td><td>OTB</td><td>Baseline Regulation</td><td></td></tr>
<tr><td>Target species</td><td>NEP, DPS, ARA</td><td>Bycatch species</td><td>WHB, BOC, HKE, HOM</td></tr>
<tr><td rowspan="2">Definition of the Innovative gear</td><td rowspan="2">GCRUST1. PT crustacean trawl equipped with BRD to sort out blue whiting and boarfish while maintaining the capture of Nephrops and shrimps.
GCRUST2. PT crustacean trawl equipped with BRD to separate crustaceans and bycatch species into an upper and a lower codend.
GCRUST3. PT crustacean trawl equipped with BRD to sort out juvenile Nephrops.</td><td>Technological complexity level</td><td>Medium</td></tr>
<tr><td>Technology readiness level</td><td>Moderate</td></tr>
<tr><td>Main criteria</td><td>Selectivity, catch</td><td>Additional criteria</td><td>None</td></tr>
<tr><td>Technical specificities</td><td colspan="3">GCRUST1: installation in a commercial trawl (baseline gear) of a guiding funnel and a Nordmore-modified rigid grid.
GCRUST2: installation in a commercial trawl (baseline gear) of a guiding funnel and a Nordmore-modified rigid grid.
GCRUST3: installation in a commercial trawl (baseline gear) of guiding funnel and a grid made of square-mesh netting. Trawl has a dual codend.</td></tr>
<tr><td>Outcomes expected</td><td colspan="3">GCRUST1: Loss of 4.3 and 5.9 % above MLS for rose shrimp and Nephrops respectively. Catches of blue whiting and boarfish were reduced by 75 and 48 % respectively.
GCRUST2: Catches of blue whiting equally distributed between the two codends. Thirty percent (30 %) of Nephrops caught in the upper codend.
GCRUST3: 27.1 % of immature and 6.1 % of mature Nephrops were excluded. 12.8 % of hake below MLS were excluded, while all marketable hake were retained. 4.3 % of blue whiting were excluded.</td></tr>
<tr><td>Drawing / picture of the Innovative gear / Solution</td><td colspan="3">
Cruise GCRUST1



Cruise GCRUST2



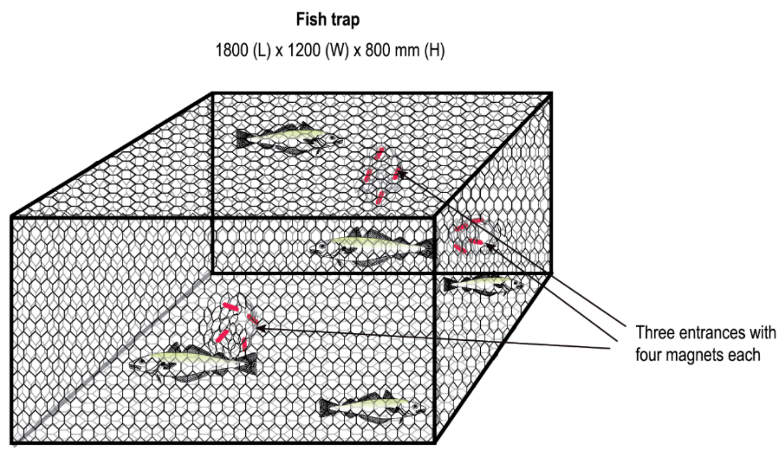
Cruise GCRUST3



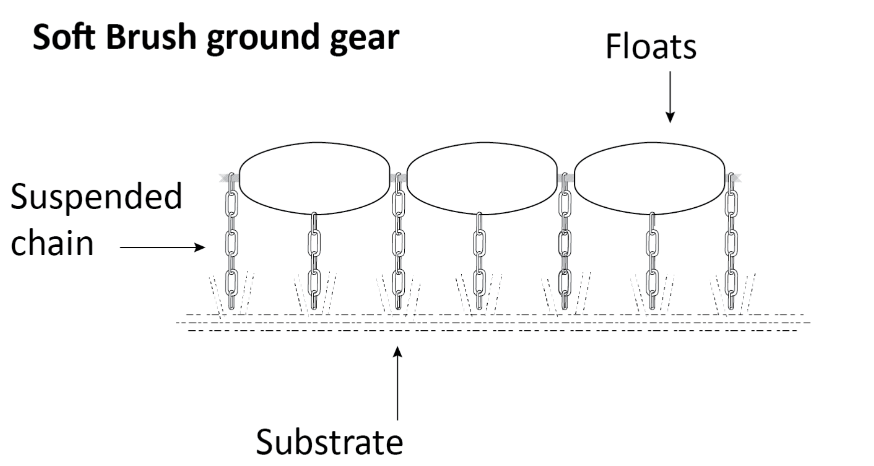
</td></tr>
</table>

Relevant information / Reference	Fonseca, P., Campos, A., Larsen, R.B., Borges, T.C., Erzini, K., 2005. Using a modified Nordmore grid for bycatch reduction in the Portuguese crustacean trawl fishery. Fisheries Research, 71: 223-239. Campos, A., Fonseca, P., Henriques, V., Parente, J., 2014. Reducing by-catch in Portuguese trawl fisheries with a view on a future discard-ban at EU level-a technological approach. Developments in Maritime Transportation and Exploitation of Sea Resources – Guedes Soares & López Peña (eds), Taylor & Francis Group, London, ISBN 978-1-138-00124-4. Millar, R.B, Barros, L., Fonseca, P., Santos, Paulo T., Campos, A., 2019. Further improvements in sorting grids for the crustacean trawl fishery off the Southern coast of Portugal. Fisheries Research, 219: 1-8.

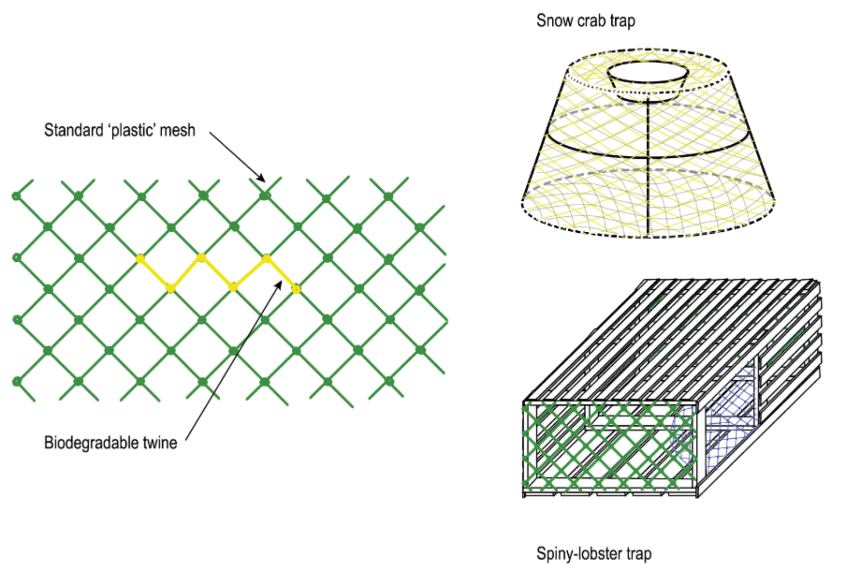
6.3.2 Magnetic deterrents in fish trap

General information			
Date	08/07/2018	**Source supplier name**	University of Newcastle, Australia
Region	Region of origin: Southeastern Australia, potentially viable for SWW fisheries	**FAO Area (Division, L2)**	81
Gear sub-category	Traps	**Gear code**	FPO
Baseline gear	Baseline gear is a fish trap without magnets	**Baseline Regulation**	Fisheries Management (Ocean Trap and Line Share Management Plan) Regulation 2006. Current version for 1 May 2019
Target species	GSU	**Bycatch species**	SKX
Definition of the Innovative gear	Four magnets attached to each funnel entrance	**Technological complexity level**	Medium
		Technology readiness level	Moderate
Main criteria	31% (mean) decrease in elasmobranch (impact), and 34% increase of targeted fish catches (catch) when using magnets	**Additional criteria**	Not assessed for any additional criteria
Technical specificities	A total of four permanent ferrite magnet bars (75 mm long, 12.7 mm high and 16 mm wide) attached to each of the three funnel entrances within the experimental traps.		
Outcomes expected	The study results suggested that elasmobranchs in the fish traps had a negative impact on target catches. The results provide a case for the use of permanent magnets in trap fisheries to reduce bycatch of elasmobranchs, but also to increase the catch of marketable products.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Richards, R.J., Raoult, V., Powter, D.M., & Gaston, T.F. (2018). Permanent magnets reduce bycatch of benthic sharks in an ocean trap fishery. Fisheries Research, 208, 16-21.		

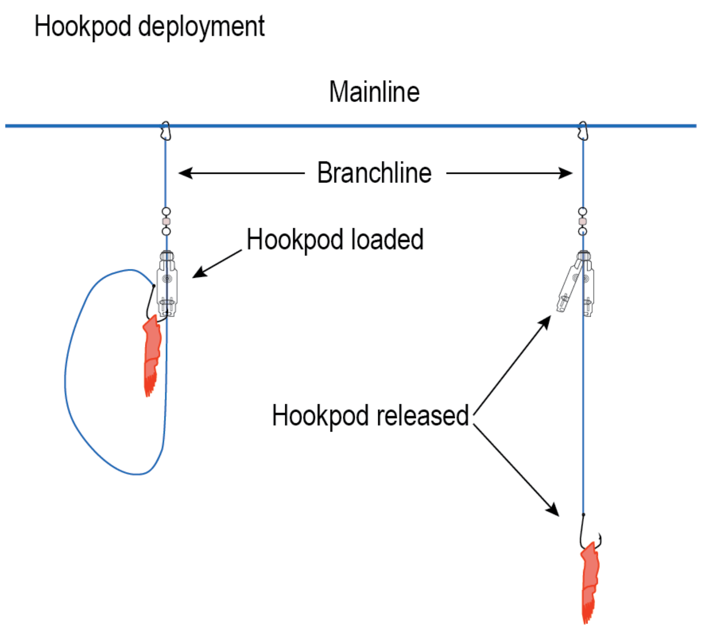
6.3.3 Soft brush groundgear

General information			
Date	01/03/2008	**Source supplier name**	Sterling trawl gear services (NSW DPI)
Region	Region of origin: Australia, potentially viable for SWW fisheries	**FAO Area (Division, L2)**	81
Gear sub-category	Bottom trawls	**Gear code**	OTB
Baseline gear	Groundgears vary depending on the habitat and gear and are typically not regulated	**Baseline Regulation**	Not available
Target species	PNP, WKP, MPM	**Bycatch species**	Mixed fish species and invertebrates
Definition of the Innovative gear	A groundgear that floats above the substrate with chain droppers that contact the substrate	**Technological complexity level**	Minimal
		Technology readiness level	High
Main criteria	The soft brush had 63 % less linear bottom contact than the conventional groundgears (impact). There is likely to be reductions in drag.	**Additional criteria**	Groundgear had no effect on target catches and limited effect on bycatch
Technical specificities	Groundgear in penaeid trawls is typically a length of chain or leaded rope that is in contact with the substrate under the fishing line. The soft brush gear is a floated line that is connected to the fishing line and has short length of chain droppers suspended from it.		
Outcomes expected	The soft brush has less substrate contact and will reduce habitat impacts. To date the soft brush has been tested in two Australian penaeid fisheries (see references) and has shown it maintains target species with limited impact on bycatch. The main benefits are that the soft brush has 63% less linear bottom contact than conventional gears that results in less habitat damage and fewer organisms being displaced. There are additional benefits in this gear is also likely to result in lower fuel consumption due to the likely reductions in drag associated with the lower substrate contact.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Sterling, D., Eayrs, S., 2008. An investigation of two methods to reduce the benthic impact of prawn trawling. Project 2004/060 Final Report. Canberra, Australia: Fisheries Research and Development Corporation, 96 pp. Broadhurst, M.K., Sterling, D.J., Millar, R.B., 2015. Traditional vs novel groundgears: Maximising the environmental performance of penaeid trawls. Fisheries Research, 167: 199-206. McHugh, M.J., Broadhurst, M.K., Sterling, D.J., Millar, R.B., 2020. Relative benthic disturbances of conventional and novel otterboards and groundgears. Fisheries Science, 86(2), 245-254.		

6.3.4 Biodegradable twines in pots

General information			
Date	01/03/2019	**Source supplier name**	PUCV, Chile; MU Canada
Region	Region of origin: Chile, potentially viable for SWW fisheries	**FAO Area (Division, L2)**	87. 2.6; 87.3.3
Gear sub-category	Pots	**Gear code**	FPO
Baseline gear	Gears (pots) used to capture lobster and crab	**Baseline Regulation**	Not applicable
Target species	CRU	**Bycatch species**	CRU
Definition of the Innovative gear	Biodegradable twines to reduce ghost fishing in the pot and trap fisheries of Chile	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Reduces long-tern ghost fishing in crustacean traps (impact)	**Additional criteria**	No additional criteria
Technical specificities	A total of nine twine types manufactured from natural fibers - twisted jute, twisted, and braided, cotton. Three diameters of each twine type were evaluated. Baseline gear has standard 'plastic' mesh and modified gear has section replaced with a biodegradable twine. Assessments were completed under laboratory conditions.		
Outcomes expected	The biodegradable twine degrades over time, creating a hole for individuals to escape. Estimated dates to failure (break) ranged from 68 to 234 days. Cotton twines were considered the best option to assess further a biodegradable escape mechanism in pot and trap fisheries in Chile. Further at sea assessments are required to verify the optimum twine for use in traps.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Araya-Schmidt, T., & Queirolo, D., 2019. Breaking strength evaluation of biodegradable twines to reduce ghost fishing in the pot and trap fisheries of Chile. Latin American journal of aquatic research, 47(1), 201-205.		

6.3.5 Hookpod

<table>
<tr><th colspan="4">General information</th></tr>
<tr><td>Date</td><td>08/11/2017</td><td>Source supplier name</td><td>Fishtek Marine, Hookpod ltd, UK</td></tr>
<tr><td>Region</td><td>Southwestern Waters</td><td>FAO Area (Division, L2)</td><td>27.8; 27.9</td></tr>
<tr><td>Gear sub-category</td><td>Longlines</td><td>Gear code</td><td>LLS</td></tr>
<tr><td>Baseline gear</td><td>Baseline is longline with hook on the end of a branch line (snood)</td><td>Baseline Regulation</td><td>EC Reg. 2019/1241</td></tr>
<tr><td>Target species</td><td>Large pelagic species</td><td>Bycatch species</td><td>Seabirds</td></tr>
<tr><td rowspan="2">Definition of the Innovative gear</td><td rowspan="2">The innovative gear is a hook pod that keeps a hook's barb covered during deployment.</td><td>Technological complexity level</td><td>Medium</td></tr>
<tr><td>Technology readiness level</td><td>High</td></tr>
<tr><td>Main criteria</td><td>Significantly reduction of seabird bycatch without impacting target species.</td><td>Additional criteria</td><td>Potential to reduce turtle bycatch when hooks are released at greater depth (e.g. 20 m).</td></tr>
<tr><td>Technical specificities</td><td colspan="3">Baseline gear is a hook on the end of a branch line (snood). The innovative gear is a pod where the barb and point of a hook is enclosed during deployment and released at a predetermined depth out of reach of diving seabirds.</td></tr>
<tr><td>Outcomes expected</td><td colspan="3">From 59 130 experimental branch lines over 129 sets a bycatch rate of 0.04 birds/1000 hooks for the hookpod deployments and 0.8 birds/1000 hooks during the control (standard) deployments. There was no difference in catch rate of target fish species between Hookpod and control deployments.</td></tr>
<tr><td>Drawing / picture of the Innovative gear / Solution</td><td colspan="3">
</td></tr>
<tr><td>Relevant information / Reference</td><td colspan="3">Sullivan, B.J., Kibel, B., Kibel, P., Yates, O., Potts, J.M., Ingham, B. Domingo, A. Gianuca, D. Jimenez, S. Lebepe, B. Maree, B.A. Neves, T. Peppes, F. Rasehlomi, T. Silva-Costa A. Wanles R.M., 2018. At-sea trialling of the Hookpod: a 'one-stop' mitigation solution for seabird bycatch in pelagic longline fisheries. Animal Conservation, 21(2): 159-167.</td></tr>
</table>

6.4 Baltic Sea

6.4.1 Mini Danish seine

General information			
Date	01/07/2020	**Source supplier name**	DTU Aqua
Region	Baltic Sea	**FAO Area (Division, L2)**	27.3.d.24-25
Gear sub-category	Boat seines	**Gear code**	SDN
Baseline gear	GN	**Baseline Regulation**	EC Reg. 2187/2005
Target species	COD, PLE	**Bycatch species**	BLL, DAB, FLE, GUX, LEM, MER, MXO, PGH, SOL
Definition of the Innovative gear	The principle of the mini Danish seine is the same as for commercially used larger Danish seines, but lengths of seine ropes used is shorter and the rope diameter is smaller so the rope drums can be scaled down in size. In combination with a potentially smaller net, the entire system can be mounted on relatively small vessels.	**Technological complexity level**	Minimal
		Technology readiness level	High
Main criteria	The idea of the gear is to provide gillnet fishers from areas with large numbers of seals an alternative gear from which seals cannot steal/damage the catch (Impact).	**Additional criteria**	none
Technical specificities	As both gears are so different from each other, a detailed comparison of technical specificities is not sensible here. The most important point is that the mini Danish seine has the potential to catch the same species as a gillnet, while seals cannot access the catch.		
Outcomes expected	Initial trials (2018-2019) aiming to catch cod around Bornholm and compare catches to gillnets set in the same area revealed that fishing with the mini Danish seine has the potential to deliver good catches of cod, but also that several technical modifications were needed to the system and further that suitable (preferably sandy) fishing areas need to be identified because muddy as well as stony area can cause the ropes to get stuck on the seabed. Trials conducted in 2020 in the Belt sea aimed to compare catches between seine net types of different sizes, seine ropes of different lengths as well as different diameters, all of which can affect the required deck space for the system. Analyses are still pending. Further trials planned for 2020 shall aim to target specifically flatfish around Bornholm and again to compare catches to gillnets set in the same area. As the main target of conventional Danish seining in other areas is flatfish and catches are known to be of good size and quality, we expect good flatfish catches.		

Drawing / picture of the Innovative gear / Solution	 Rope drums installed onboard fishing vessel
Relevant information / Reference	Report "Nr. 370-2020 Sælsikkert fiskeri. Udvikling og afprøvning af sælsikre redskaber" (*in Danish*) including a section about the initial trials in 2018 can be found at: www.aqua.dtu.dk/Om_DTU_Aqua/Publikationer/Rapporter/Rapporter_siden_2008

6.4.2 Pontoon trap in Baltic fisheries

<table>
<tr><th colspan="4">General information</th></tr>
<tr><td>Date</td><td>23/06/2008</td><td>Source supplier name</td><td>SLU Aqua, Thünen Institute of Baltic Sea Fisheries</td></tr>
<tr><td>Region</td><td>Baltic Sea</td><td>FAO Area (Division, L2)</td><td>27.3.d</td></tr>
<tr><td>Gear sub-category</td><td>Large stationary nets or barrages</td><td>Gear code</td><td>FT</td></tr>
<tr><td>Baseline gear</td><td>Gillnets</td><td>Baseline Regulation</td><td>None</td></tr>
<tr><td>Target species</td><td>SAL, FVE, COD, TUR, FPE, HER</td><td>Bycatch species</td><td>FLE, LUM, FCY</td></tr>
<tr><td rowspan="2">Definition of the Innovative gear</td><td rowspan="2">Development of a trapnet fishery in coastal waters as an alternative to gillnet fisheries.</td><td>Technological complexity level</td><td>Significant</td></tr>
<tr><td>Technology readiness level</td><td>Moderate</td></tr>
<tr><td>Main criteria</td><td>Decreased depredation by seals (Impact) and superior handling for fishers.</td><td>Additional criteria</td><td>Low environmental impact. Fish are alive at collection allowing for release of non-target species.</td></tr>
<tr><td>Technical specificities</td><td colspan="3">Stationary uncovered poundnets (FPN) where the fish holding chamber is equipped with pontoons and are seal safe is referred to as pontoon traps. The design is intended to decrease seal interaction with the catch. Initially, pontoon traps were implemented in salmon fisheries. Hereafter, pontoon traps have also been used in fisheries targeting whitefish and vendace. In these fisheries, current focus in floating chamber pontoon traps is on increasing selectivity on non-target species, mainly using a hose net or other low mortality sorting solutions.
In addition to the use pontoon traps as a floating gear, targeting pelagic species, current development aims to use pontoon traps also as bottom-set gear targeting species associated with the benthic environment, such as cod, pike and perch along with flatfish species. Modifications to increase catch efficiency include using additional entrances between trapnet and fish chamber, and selection panels to increase selectivity. Simultaneously, effort is put into making the gear resistant not only to seal impact but also rough weather conditions, as several potential target species could be caught further away from the coast, in non-protected areas.</td></tr>
<tr><td>Outcomes expected</td><td colspan="3">With traditional gillnet fisheries in the Baltic being subjected to increasing seal depredation, there is a need for alternative fishing gear to allow for a future coastal fisheries in the Baltic. Pontoon traps have shown to be a solution in fisheries fishing for vendace and whitefish. However, there is still a need for further technical development to get the pontoon traps suitable for catching benthic species. Regarding bottom-set pontoon traps, they have shown potential to withstand seal attacks but catch efficiency still has to be increased. Multi-target species fisheries using pontoon traps with release of non-target species and sizes classes could increase catch value. Taking into account the quality of live caught fish is another way, which may increase the catch value. Also, further development on non-stationary traps is needed, where the use of pontoon equipped fish chambers allow for making the gear less labour intense for the fishers. The use of pontoon traps can also reduce the unwanted bycatch of seabirds and marine mammals (harbour porpoises and seals) compared with traditional gillnets.</td></tr>
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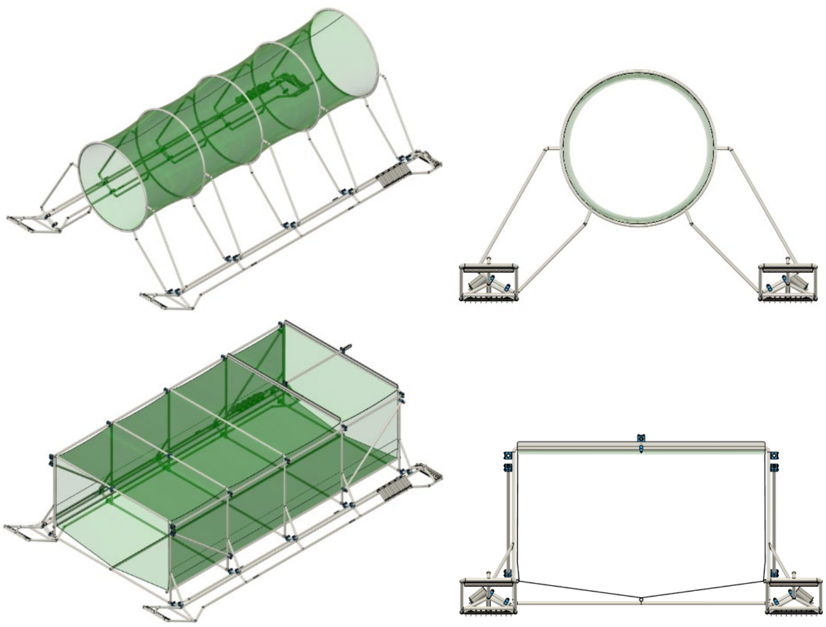
<tr><td>Drawing / picture of the Innovative gear / Solution</td><td>

Stationary poundnet with pontoon trap catch chamber (arial view). a) guiding net; b) trapnet, c) catch chamber, d) pontoons

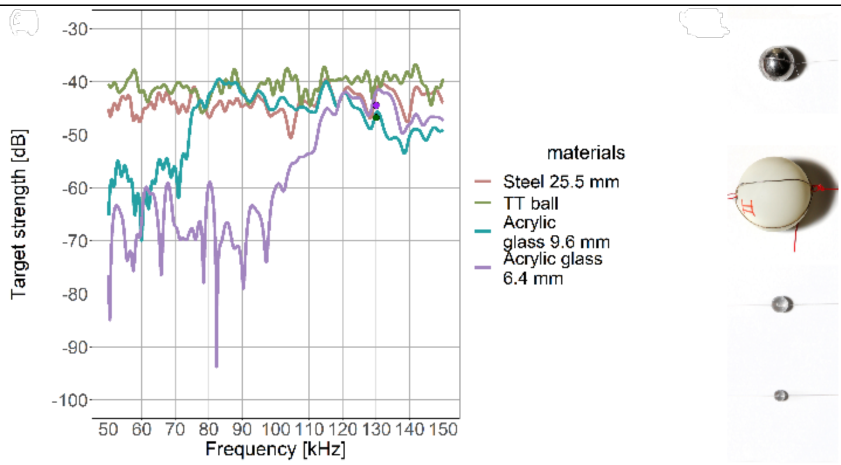
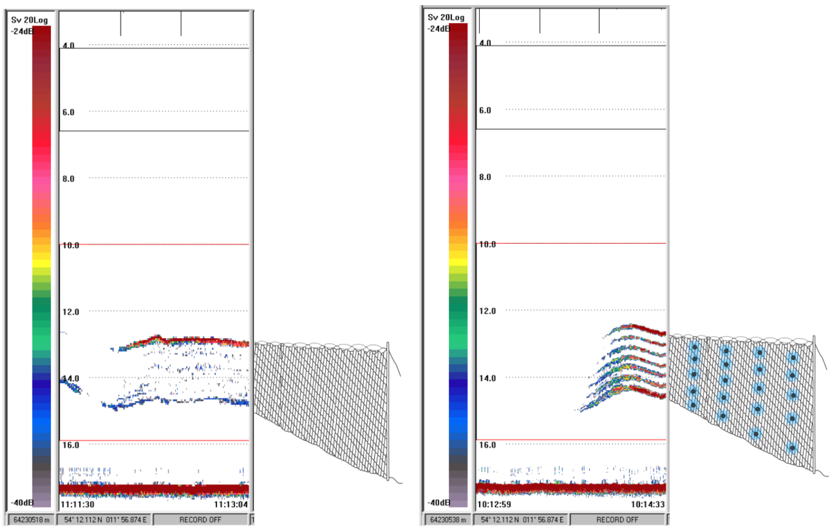

Protection sheet for in pontoon fish chamber, in order to reduce damage between individuals when targeting salmon.


Ring adapter used for bottom-set pontoon traps. This adapter is equipped with additional entrances in order to keep seals from entering the fish chamber but also to lure catch further into the trap.</td></tr>
</table>

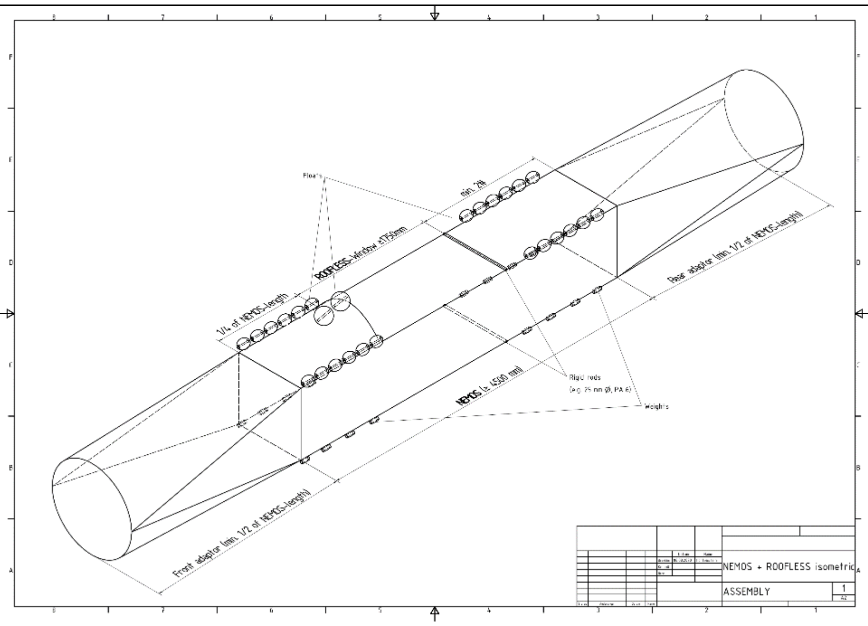
	 Alternative entrance in pontoon trap chamber. Traditionally strings are used in the chamber entrance. Also, the fish chamber is equipped with hose net for catch collection.  Different types of catch chambers for pontoon traps. Above: Swedish design; Below German design for increased stability and catch of flatfish.
Relevant information / Reference	Hemmingsson, M., A. Fjälling, and S.-G. Lunneryd. 2008. The pontoon trap: Description and function of a seal-safe trapnet. Fisheries Research 93:357-359. Sekretariatet för selektivt fiske - rapportering av 2016 och 2017 års verksamhet. (in Swedish). Aqua Reports 2018:4. Sekretariatet för selektivt fiske - rapportering av 2018-års verksamhet. (in Swedish) Aqua Reports 2019:6.

6.4.3 Pearl-nets

General information			
Date	03/07/2020	**Source supplier name**	Thuenen Institute of Baltic Sea Fisheries; DTU Aqua
Region	Baltic Sea	**FAO Area (Division, L2)**	27.3, 37.4 (with potentially for all areas)
Gear sub-category	Gillnets	**Gear code**	TB
Baseline gear	Gillnets	**Baseline Regulation**	-
Target species	COD, TUR, HER	**Bycatch species**	PHR
Definition of the Innovative gear	Modification of standard gillnets to improve the acoustic visibility for small-toothed whales (e.g. harbour porpoises).	**Technological complexity level**	Significant
		Technology readiness level	High
Main criteria	Reduced bycatch of small-toothed whales (Impact).	**Additional criteria**	Desired catch efficiency of standard gillnets without the need of a complete shift to another gear (also resulting in refit of vessels).
Technical specificities	Toothed whales orientate themselves using their sonar, i.e. they send out an acoustic signal and process the echo received from obstacles and prey to perceive their environment. Gillnets have very thin filaments, thus the whales are not able to classify the gillnet netting as an obstacle, swim into the netting and drown. One way to mitigate bycatch in gillnets is to make the gillnets more “acoustically visible”. This way, the animals could perceive the gillnet as an obstacle and swim over or around it. We developed a method to increase the acoustic reflectivity (or echo) of gillnets by attaching small (8 mm diameter) acrylic glass spheres to the netting (“pearl nets”). The spheres resonate at the echolocation frequency of harbour porpoises (130 kHz) and their echo is as strong as the echo of a table tennis ball which has a 5 times greater diameter (Figure 6). Attaching such pearls to a standard gillnet (Figure 7) will increase the echo of the gillnet significantly (Figure 8).		
Outcomes expected	The development and its tests consist of following stages a) identification of optimal objects with high acoustic backscatter b) in situ measurement of acoustic properties of these objects (e.g. Figure 6) c) in situ measurement of acoustic properties of gillnet with this objects (‘pearl net’) (e.g. Figure 8) d) investigation of behaviour response of small whales (i.e. harbour porpoises) to the modified gillnet e) investigation of bycatch reduction in commercial fisheries Investigations a)-c) and e) were conducted successfully and scientific manuscripts (published and under review, see references). The first test in commercial fishery was conducted in Black Sea. The use of ‘pearl nets’ resulted in a reduction of harbour porpoise catches. Nevertheless, due to small numbers of hauls and typically rare bycatch events, the observed bycatch reduction was not statistically significant. Next steps are behavioural observation (d) and a large-scale experiment in commercial fisheries (e). The precondition for the commercial experiment is the industrial production of ‘pearl nets’ – which is currently pending.		

Drawing / picture of the Innovative gear / Solution	 Figure 6. Acoustic reflectivity (Target Strength) of several objects (table tennis ball, steel ball, acrylic glass). The objects have similar echo characteristics between 120 – 150 kHz.  Figure 7. Gillnet with acrylic glass spheres – "pearl net". left: General view, right: detailed view.  Figure 8. echogram (acoustic image) at 120kHz (echo-locating frequency of harbour porpoises) of a standard gillnet (left) and a gillnet modified with acrylic glass spheres ("pearl net", right).
Relevant information / Reference	Kratzer, I.M.F., Schäfer, I., Stoltenberg, A., Chladek, J.C., Kindt-Larsen, L., Larsen, F., Stepputtis, D., 2020. Determination of Optimal Acoustic Passive Reflectors to Reduce Bycatch of Odontocetes in Gillnets. Frontiers in Marine Science 7: Article 539.

6.4.4 Trawl for reduction of cod catches (Nemos+Roofless)´

General information			
Date	01/02/2020	**Source supplier name**	Thuenen Institute of Baltic Sea Fisheries
Region	Baltic Sea	**FAO Area (Division, L2)**	27.3
Gear sub-category	Bottom trawls	**Gear code**	TB
Baseline gear	Commercial trawl Baltic demersal mixed fishery	**Baseline Regulation**	e.g. EC Reg. 2019/1241
Target species	TUR, FLE, PLE	**Bycatch species**	COD
Definition of the Innovative gear	A selectivity device to significantly reduce the bycatch of cod, while maintaining the catch efficiency for flatfish.	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Reduction of cod bycatch.	**Additional criteria**	Catch efficiency for flatfish; easy to convert from available fishing gear; easy to use; affordable.
Technical specificities	Due to the poor status of both Baltic cod stocks, resulting in reduced catch opportunities (Western Baltic cod) or a closure of the directed fishery (Eastern Baltic cod). Consequently, a selectivity device was developed to mitigate cod catch, while keeping the catch efficiency for flatfish species. The selectivity device 'NEMOS+ROOFLESS' consists of a square net section (four-panel extension) mounted between the belly of the trawl and the codend (NEMOS) and an escape window in the top panel of NEMOS (ROOFLESS) (see Figures below)		
Outcomes expected	Cod: catch reduction -75% Flatfish: no statistical significant reduction		
Drawing / picture of the Innovative gear / Solution	 Construction detail and isometric view of NEMOS + ROOFLESS developed as cod-bycatch reduction device for flatfish fisheries. ROOFLESS is an escape window established by removing a section of the top panel of NEMOS, as well as a lifted top panel section in front of the open window.		

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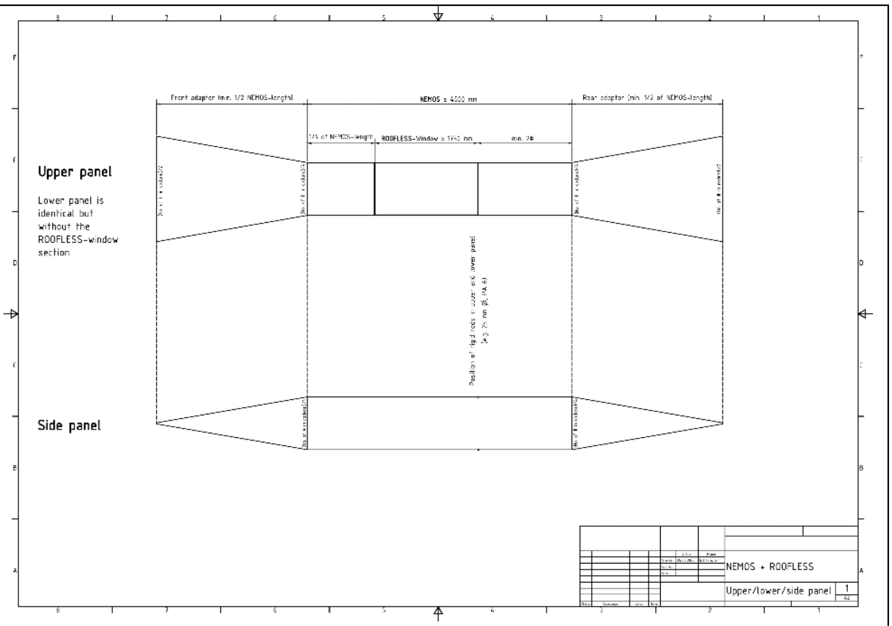
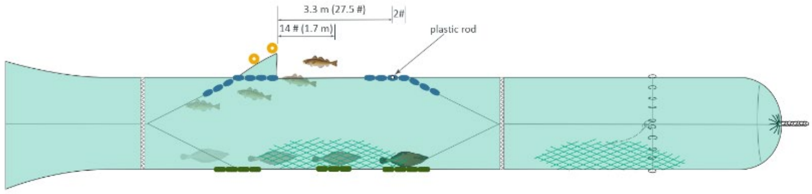


Schematic technical drawing (Top and side view) of NEMOS (NEt Enabling MOdular Selectivity) gear in ROOFLESS configuration (NEMOS+ROOFLESS).



NEMOS+ROOFLESS; Schematic view of species-specific response.
</td>
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<tr>
<td>Relevant information / Reference</td>
<td>Stepputtis et al., 2020, “Technical approaches to avoid cod catches in Baltic Sea Trawl fisheries”. Thünen Institute of Baltic Sea Fisheries, Rostock” (submitted to BALTFISH).</td>
</tr>
</table>

6.4.5 Shifting from gillnet to pots for single or multi target species

General information			
Date	15/01/2011	**Source supplier name**	SLU Aqua
Region	Baltic Sea	**FAO Area (Division, L2)**	27.3a-d
Gear sub-category	Pots	**Gear code**	FPO
Baseline gear	GNS/Pots	**Baseline Regulation**	-
Target species	COD, LBE, CRE	**Bycatch species**	FLE
Definition of the Innovative gear	Developing a new pot fishery for cod in areas where traditionally trawl and net fishery is carried out.	**Technological complexity level**	Minimal
		Technology readiness level	High
Main criteria	Decreased depredation by seals, low environmental impact and increased selectivity with no bycatch of mammals and birds.	**Additional criteria**	Low environmental impact (no sea floor impact) and fuel efficient. The fish is caught alive, which increases its quality.
Technical specificities	All gillnet fisheries are subjected to severe and increasing seal depredation due to the increasing seal populations in the Baltic and the north sea therefore an alternative fishing gear is crucial for keeping future small-scale fisheries in the Baltic. New developed cod pots are effective in catching cod and preventing depredation and gear damage by seals in the Baltic (Division 27.3.d). They are easy to handle, however a large number of pots is needed for a viable fishery. Along Swedish west coast (27.3.a-c) pots has been developed for multispecies targeting lobster and crab in autumn and cod all year-round to replace gillnet fisheries for cod. Also these pots are constructed to prevent depredation and gear damage by seals. The entrance of the pots are designed to decrease the escape rate without affecting the entrance rate of the target species.		
Outcomes expected	The only alternative for a future small-scale gillnet fishery in the Baltic is changing of fishing technique since the seal population are significantly increasing every year intensifying the seal and fisheries conflict. Pots targeting cod in the Baltic have been found to be effective seasonally when compared to traditional gillnet fisheries. A cod pot can be floating with one entrance in line with the direction of the current or bottom standing with several entrances. Bottom standing pots with entrances design to minimize escapes seems to be the most catch efficient.		
Drawing / picture of the Innovative gear / Solution			

	 Cod pots stacked on the docks and on the boat ready to go in the water. Picture below show bottom standing pot with 4 entrances where bait is placed in the centre of the pot.
Relevant information / Reference	Ovegård, M., Könisgon, S., Persson, A., and Lunneryd, S-G., 2010. Effects of escape windows on the capture of cod in floating pots. Fisheries Research 107, 1-3 42 Bryhn, A., Könisgon, S., Lunneryd, S.G., and Bergenius, M., 2013. Visual stimuli affecting the catch efficiency of floating cod (Gadus morhua) pots in the Baltic Sea. Fisheries Research. Königson, S., Lövgren, J., Ovegård, M., Ljunghager, F., and Lunneryd S.G. (2015) Seal Exclusion Devices prevent seal bycatch in cod pot fisheries without necessarily reducing the catchability of the gear. Fisheries Research 167 Königson, S., Fredriksson, R., Bergström, Lunneryd, S.G U., and Strömberg, P., 2015. Cod pots in the Baltic. Are they efficient and what affects their efficiency? ICES journal of marine science Vol 72:5 Ljungberg, P., Lunneryd, S-G., Lövgren, J. and Königson, S., 2017. Including cod (Gadus Morhua) behavioral analysis to evaluate entrance behavioural analysis to evaluate entrance type dependent pot catches in the Baltic Sea. Journal of Ocean Techknowodgy Vol. 11 No 4. Hedgärde, M., Willestofte Berg, C., Kindt-Larsen, L., Lunneryd, S-G., Königson, S., 2017. Explaining the catch efficiency of different cod pots using underwater video to observe cod entry and exit behav-iour. Journal of Ocean Techknowodgy Vol. 11 No 4. Stavenow, J., Ljungberg, P., Kindt-Larsen, L., Lunneryd, S-G., Königson, S., 2017. What attracts Baltic Sea Grey seals to seal-safe cod pots and when do they attempt to attack fish in pots? Journal of Ocean Techknowodgy Vol. 11 No 4.

6.4.6 Acoustic alerting or deterrent devices

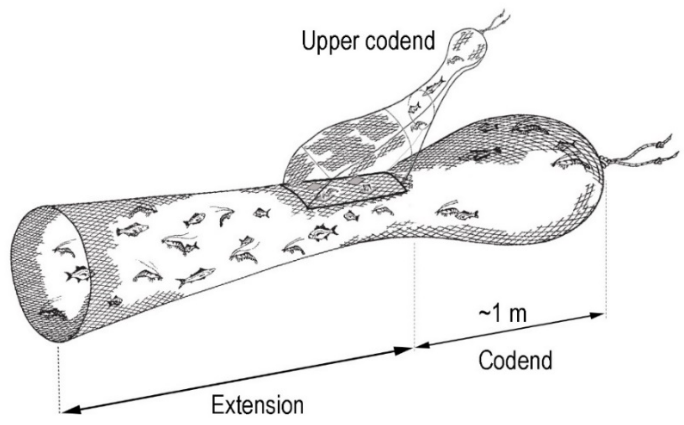
General information			
Date	01/02/2004	**Source supplier name**	e.g. Aquatec
Region	Baltic Sea	**FAO Area (Division, L2)**	27.3 a, b, c and d
Gear sub-category	Gillnets	**Gear code**	GNS
Baseline gear	Commercial gillnet fishery for Cod, haddock or lumpfish.	**Baseline Regulation**	None
Target species	COD, HAD, LUM	**Bycatch species**	PHR, other cetaceans, other marine mammals and birds
Definition of the Innovative gear	Devices added on the gillnet making acoustic sound to scare the animal from the gear	**Technological complexity level**	Medium
		Technology readiness level	Moderate
Main criteria	Catch efficiency, mitigate interaction of cetaceans and gillnets (Impact).	**Additional criteria**	None
Technical specificities	Baseline gillnets are without any devices of any kind. Acoustic alerting or deterrent devices are addition at conventional gillnets. Several versions are in the trial phase.		
Outcomes expected	Acoustic alerting or deterrent devices (pingers, primarily) can serve as an effective bycatch reduction measure in certain situations. Experimental trials and fisheries observer data from monitoring of marine mammal bycatch in some fisheries have shown that pingers can exclude certain species of marine mammal within the range of the sound field.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	https://www.yumpu.com/en/document/read/13770714/acoustic-marine-mammal-deterrents Clay, T. A., Alfaro-Shiqueto, J., Godley, B. J., Tregenza, N., & Mangel, J. C., 2019. Pingers reduce the activity of Burmeister's porpoise around small-scale gillnet vessels. Mar Ecol Prog Ser, 626: 197-208. Cox, T. M., Andrew J, R., Swanner, D., Urian, K., & Waples, D., 2004. Behavioral responses of bottlenose dolphins, Tursiops truncatus, to gillnets and acoustic alarms. Biological Conservation 115(2): 203-212. Culik, B., von Dorrien, C., Müller, V. and Conrad, M., 2015. Synthetic communication signals influence wild harbour porpoise (Phocoena phocoena) behaviour.Bioacoustics,24(3):.201-221. Culik, B., Conrad, M., and Chladek, J., 2017. Acoustic protection for marine mammals: new warning device PAL. DAGA Proceedings, Kiel 2017: 387–390. (also available at: http://www.f3mt.net/uploads/7/5/1/8/75189669/daga-english_jc.pdf). Dawson, S. M., Northridge, S., Waples, D., & Read, A. J., 2013. To ping or not to ping. The use of active acoustic devices in mitigating interactions between small cetaceans and gillnet fisheries. Endangered Species Research, 19: 201-221.		

6.4.7 Boat seine for North Baltic

General information			
Date	01/02/2014	**Source supplier name**	SLU Aqua
Region	Baltic Sea	**FAO Area (Division, L2)**	27.3.d.30 – 31
Gear sub-category	Boat seines	**Gear code**	SSC
Baseline gear	GN	**Baseline Regulation**	EC Reg. 2187/2005
Target species	HER, FVE	**Bycatch species**	FPE, WHF, SME
Definition of the Innovative gear	Adapt bottom seine for smaller inshore fishing vessels	**Technological complexity level**	Minimal
		Technology readiness level	High
Main criteria	An alternative to replace gillnet because an unacceptable level of seal damage (Impact). A necessary development if the coastal fishery should remain in large part of the Baltic	**Additional criteria**	None
Technical specificities	Follow in large parts the technical sheet of Boat seines by DTU Aqua.		
Outcomes expected	Develop technical, ergonomic and economical solutions for smaller vessels (less the 12 m) with a crew of maximal 2 persons. Develop the skills and knowledge of the fishery. Study the bottom effect of the ropes and gear to give a background of effects to authorities in request to allow the gear in areas where trawling is forbidden. Develop selectivity of the gear.		
Drawing / picture of the Innovative gear / Solution	  Development of a small hauling system to a more ergonomic system.		
Relevant information / Reference	Notfiske i Östersjön, Pilotförsök under 2014. Rapport till Program Sälar och Fiske. 2015 Lunneryd S.G and Könignson S. Förebyggande åtgärder för att begränsa sälskador. Utveckling av ett sälsäkert fiske. Notfiske Dnr 622-3527-15. Gotlands länsstyrelse. 2017. Lunneryd S.G.		

6.5 Mediterranean and Black Sea

6.5.1 Dual codend gear

<table>
<tr><th colspan="4">General information</th></tr>
<tr><td>Date</td><td>29/07/2020</td><td>Source supplier name</td><td>Antonello Sala (CNR, Italy)</td></tr>
<tr><td>Region</td><td>Mediterranean Sea</td><td>FAO Area (Division, L2)</td><td>37.2</td></tr>
<tr><td>Gear sub-category</td><td>Bottom trawls</td><td>Gear code</td><td>OTB</td></tr>
<tr><td>Baseline gear</td><td>Commercial Mediterranean OTB with 40 mm square-mesh codend or 50 mm diamond-mesh codend</td><td>Baseline Regulation</td><td>EC Reg. 1967/2006</td></tr>
<tr><td>Target species</td><td>NEP, MTS, HKE, MUT, DPS, MON, WHG</td><td>Bycatch species</td><td>Mixed species bycatch</td></tr>
<tr><td rowspan="2">Definition of the Innovative gear</td><td rowspan="2">Dual codend with the uppermost codend manufactured with at least 54 mm diamond mesh. Fish and shrimps can pass through cuttings on the uppermost netting panel of the lower codend.</td><td>Technological complexity level</td><td>Medium</td></tr>
<tr><td>Technology readiness level</td><td>High</td></tr>
<tr><td>Main criteria</td><td>Potential to significantly improve both the species- and size-selectivity.</td><td>Additional criteria</td><td>Improved fish quality</td></tr>
<tr><td>Technical specificities</td><td colspan="3">This fishing gear modification does not use any separator or guiding, panel or grid to separate catches into two independent (dual) codends, but derive benefit from fish and shrimp swimming ability. Fish and shrimps are able to pass through the cuttings on the netting of the lower codend, leading to the upper codend, while debris ends in the lower codend. The idea might have future development for facilitating species and size-selectivity using a more selective mesh size and/or type in the uppermost codend.</td></tr>
<tr><td>Outcomes expected</td><td colspan="3">Italian fishers in collaboration with local netmakers recently developed a dual codend with the aim of separating commercial fish and shrimp with the debris. Despite the dual codend is currently being used in many fisheries, according to the legislative requirements of the EC Regulation No. 1967/2006 trawlers are limited to using one single codend. The possibility to use larger mesh sizes in the upper codend would make sense to facilitate greater reductions in undersize fish catches when needed, but a change to the current legislations would be required to permit trawl vessels to use the dual codend gear.
Species separation in the dual codends greatly reduced catch sorting times, and likely improved catch quality. Hence, the dual codend gear could be extremely beneficial in that regard. Enhanced fish quality is likely to result in improved prices for the catch, an additional incentive to use the gear.</td></tr>
<tr><td>Drawing / picture of the Innovative gear / Solution</td><td colspan="3">
</td></tr>
<tr><td>Relevant information / Reference</td><td colspan="3">Antonello Sala, CNR Italy (antonello.sala@cnr.it)</td></tr>
</table>

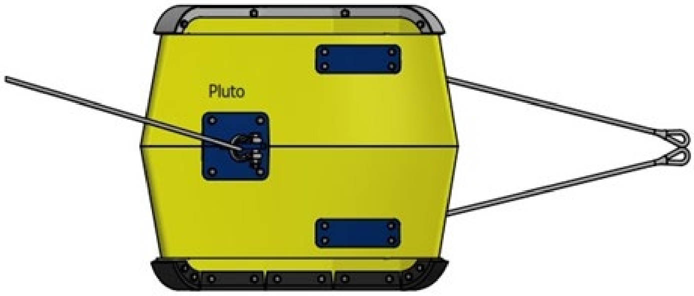
6.5.2 Low-impact and fuel saving semi-pelagic otterboards

General information			
Date	01/10/2008	**Source supplier name**	Antonello Sala, Emilio Notti, Alessandro Lucchetti (CNR, Italy)
Region	Mediterranean Sea	**FAO Area (Division, L2)**	37.2
Gear sub-category	Bottom trawls	**Gear code**	OTB, OTT, OTP, TBN, TBS, PTB
Baseline gear	The baseline is any current otterboards for bottom trawl fisheries	**Baseline Regulation**	None
Target species	Mixed species	**Bycatch species**	Mixed species
Definition of the Innovative gear	High efficient aerodynamic shaped trawl doors with proven higher spreading force in low angle of attack to work off the seabed.	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Semi-pelagic otterboards can eliminate seabed contact by operating 2-5 m off bottom while keeping the trawl on the ground, thus maintaining the same harvesting and catch efficiency. As a result, there is significantly less damage to benthic ecosystems, and decreased bycatch of sedentary benthic animals (Impact).	**Additional criteria**	Lower fuel consumption, pollution and GHG emissions
Technical specificities	New semi-pelagic otterboards have been developed in the last years by different door manufactures (e.g. Thyboron, Denmark; Polardoors, Iceland; Morgére, France). Although they have been widely introduced in other European fisheries and beyond, nowadays in the Mediterranean they can be found only in some Spanish fisheries. Considering the high traditional features of the Central and eastern Mediterranean trawl fisheries, an incentive-driven approach must been adopted to explore the applicability of such innovative technologies. They are semi-pelagic doors with slots and a high aspect ratio of ≥2.5. By lifting the doors off the bottom, it has been demonstrated that the capture efficiency of the gear was guaranteed by two additional chains, which weigh in the Med fisheries around 250-300 kg each, inserted just behind the backstrops. The idea is that the traditional demersal otterboards are replaced with two chains that keep the bridle ends down, while a pair of semi-pelagic otterboards are towed ahead of the chains and clear of the ground to provide spread. This approach to bottom trawling relies entirely on hydrodynamic force to open the gear, eliminating the ground shearing force and seabed impact. Target species, such as hake, shrimp and Nephrops, can therefore be herded by both chains and sweeps/bridles along the bottom.		
Outcomes expected	Substantial environmental improvement to maintaining biodiversity, reduced fuel emissions, no direct impact to the seabed to support sustainable fishing. Higher horizontal openings much greater than baselines, but with less fuel demands (-15-20 % measured in Med fisheries). Monitoring the height of the otterboards above the bottom requires appropriate acoustic instruments which should be used to adjust the door height by altering the towing speed and the trawl warp length. These extra-costs must be considered in eventual economic pay-back analysis.		

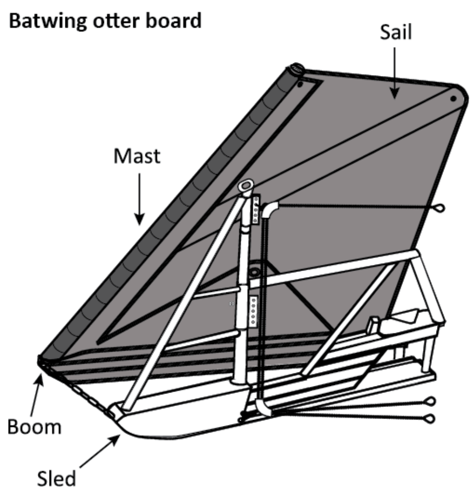
Drawing / picture of the Innovative gear / Solution	 Thyboron (Denmark)  Morgére (France)  Polardoors (Iceland)
Relevant information / Reference	Sala, A., Notti, E., Bonanomi, S., Pulcinella, J., Colombelli, A., 2019. Trawling in the Mediterranean: an exploration of empirical relations connecting fishing gears, otterboards and propulsive characteristics of fishing vessels. Frontiers in Marine Science, 6(534): 1-15. Mellibovsky, F., Prat, J., Notti, E., Sala, A., 2018. Otterboard hydrodynamic performance testing in flume tank and wind tunnel facilities. Ocean Engineering, 149: 238-244. Sala, A., Prat, J., Antonijuan, J., Lucchetti, A., 2009. Performance and impact on the seabed of an existing- and an experimental-otterboard: Comparison between model testing and full-scale sea trials. Fisheries Research, 100: 156-166 (doi:10.1016/j.fishres.2009.07.004). Prat, J., Antonijuan J., Folch A., Sala, A., Lucchetti, A., Sardà F., Manuel A., 2008. A simplified model of the interaction of the trawl warps, the otterboards and netting drag. Fisheries Research, 94: 109-117. Mellibovsky, F., Notti, E., Prat, J., Sala, A., 2014. Assessment of hydrodynamic performance and impact of otterboards in wind tunnel trials. Proceedings of the International ICES Symposium on Effects of fishing on benthic fauna, habitat and ecosystem function (16-19/06/2014, Tromsø, Norway): 82. Sala, A., Buglioni, G., Lucchetti, A., 2010. Fuel saving otterboards. Paper proceedings of the International Symposium on Energy use in Fisheries: Improving Efficiency and Technological Innovations from a Global Perspective, Seattle, USA, November 2010: 4 pp.

6.5.3 Otterboards made from recycled plastic waste (PLUTO©)

General information			
Date	01/08/2020	**Source supplier name**	Atli Már Jósafatsson *(Polar doors)*
Region	Mediterranean Sea	**FAO Area (Division, L2)**	Worldwide fishing areas
Gear sub-category	Bottom trawls	**Gear code**	OTB, OTT, OTP, TBN, TBS, OTM, TMS, TSP
Baseline gear	The baseline is any current otter-boards (bottom, demersal, or midwater fishing).	**Baseline Regulation**	None
Target species	Mixed species	**Bycatch species**	Mixed species
Definition of the Innovative gear	Highly efficient aerodynamic shaped fishing doors made from recycled plastic waster.	**Technological complexity level**	Medium
		Technology readiness level	Low
Main criteria	Catch profile unknown. Catch comparison experiments not yet performed. Lower physical impact on the seabed.	**Additional criteria**	Overall improved economic benefit for boat owners in operational cost. Reduced resistance from highly efficient hydrodynamically designed fishing doors. Fishing doors made from recycled plastic waste. Less resistance compared to current otterboards, consequently promising less pollution, GHG emission, and energy savings. Addressing plastic waste in the world oceans by using recycled plastic waste.
Technical specificities	Polar's Pluto doors are being made from recycled plastic waste, with steel fittings and wear plates. The PLUTO otterboards, low budget fishing doors made from recycled plastic waster will have a revolutionary impact to the fleet of small fishing boats in the size of 8 to 24 metres around the world. The PLUTO will be roto-mould casted in several locations around the world. The PLUTO plastic fishing doors will call for increased environmental awareness in the industry of small fishing boat operation by collecting of used fishing nets and ropes to be recycled. Patent application for the advanced hydrodynamically designed shape of the PLUTO fishing doors have been patented. The innovated idea is it simplicity in mirror design which makes it possible to use only one mould to cast the pair of doors, both the starboard side door and the port side door. Polar has teamed up with their long-time distributors around the world and plan to out-source production to near markets to save cost, reduced transport, call for collecting of used plastic waste for recycling.		
Outcomes expected	Targeted market are small and medium sized fishing boats in the world. According to FAO's statistics more than 3,7 million small and medium sized fishing boats in the length of 8 to 24 metres are in the world. There off, around 30% are trawling, total of 900.000 fishing boats. It is estimated that close to 70% of this fleet is using inefficient poorly designed fishing doors made from wood and steel combination. By using inefficient fishing doors, huge impact to the fishing bed is needed to achieve sufficient opening of the fishing net. The result is too high resistance, too high direct impact to the fishing bed, too high energy consumption, too high operational cost. The outcome is a highly efficient fishing doors that will improve overall operational cost for boat owners in terms of better catch performance and reduced energy consumption.		

Drawing / picture of the Innovative gear / Solution	 
Relevant information / Reference	Atli Már Jósafatsson (Polar), atlimarj@polardoors.com

6.5.4 Batwing otterboards

General information			
Date	01/03/2008	**Source supplier name**	Sterling trawl gear services (NSW DPI)
Region	Place of origin: Australia	**FAO Area (Division, L2)**	81
Gear sub-category	Bottom trawls	**Gear code**	OTB
Baseline gear	Otterboards vary depending on the habitat and personal preference and are typically not regulated	**Baseline Regulation**	NA
Target species	PNP, WKP, MPM	**Bycatch species**	Mixed fish species and invertebrates
Definition of the Innovative gear	Low angle of attack otterboard-Batwing	**Technological complexity level**	Medium
		Technology readiness level	Low
Main criteria	The batwing had up to 86 % less bottom contact and 18 % less drag, compared to conventional otterboards	**Additional criteria**	The trawl with batwings caught up to 90 and 12 % fewer sedentary bycatch and target species, respectively
Technical specificities	Demersal otterboards operate at an acute angle to the direction of travel (angle of attack, AOA), typically between 30 and 40^{o}. The batwing uses a sled orientated to the direction of travel with an offset sail set at a 20^{o} AOA that lightly touches the substrate.		
Outcomes expected	The Batwing otterboard has been tested in Australian penaeid fisheries and has up to 86 % less substrate contact, due to its unique design. The lower substrate contact means that the Batwing disturbs less flora and fauna than conventional boards. The lower drag associated with the Batwing will also mean that CO_2 emissions will be much lower for vessels using them.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Sterling, D., Eayrs, S., 2008. An investigation of two methods to reduce the benthic impact of prawn trawling. Project 2004/060 Final Report. Canberra, Australia: Fisheries Research and Development Corporation, 96 pp. McHugh, M.J., Broadhurst, M.K., Sterling, D.J., Millar, R.B., 2015. Engineering and catching efficiencies of three conventional penaeid-trawl otterboards and the new batwing design. Fisheries Research 167: 180-189. McHugh, M.J., Broadhurst, M.K., Sterling, D.J., Millar, R.B., 2020. Relative benthic disturbances of conventional and novel otterboards and groundgears. Fisheries Science, 86(2): 245-254.		

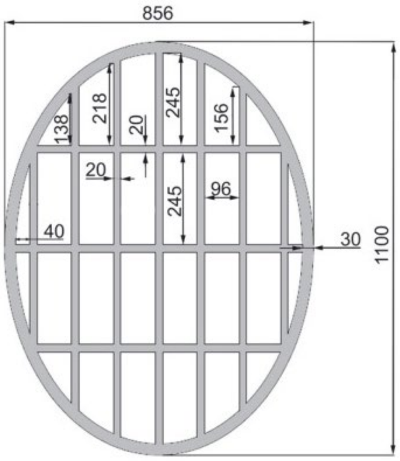
6.5.5 Introduction of high strength materials to bottom otter trawl

General information			
Date	01/08/2008	**Source supplier name**	Dr. Alexis Conides (Hellenic Centre for Marine Research)
Region	Mediterranean Sea	**FAO Area (Division, L2)**	37.2, 37.3
Gear sub-category	Bottom trawls	**Gear code**	OTB
Baseline gear	Commercial Mediterranean OTB	**Baseline Regulation**	EC Reg. 1967/2006
Target species	HKE, MUR, MUT, LEZ, BLL, SOL, PAX, DPS, HOM, SQM	**Bycatch species**	MSF, DPS, SBA, SYC, ANK, OUM, EJE, WHB
Definition of the Innovative gear	New material used to make the twine from Dyneema/Dnet	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Improve catchability, operability, and handling of the trawlnet onboard. Improved selectivity due to thinner twines.	**Additional criteria**	Reduction of fuel consumption by 17-20 %
Technical specificities	Improve operational characteristics of the net such as avoid overall shrinking during operation, prevent mesh closure, increase strength (tension by a factor of 2 and friction by a factor of 3), improve operation during manoeuvres, improve catch through the reduction of the "bucket" effect, enable operation at higher than typical speeds (common fishing speed in region 2-3 knots), reduce volume of the net onboard and reduction of weight of the net overall onboard (factor of 2.5-3; hence better management by workers), reduce oil consumption by 17-20 %, improve the use of vessel horsepower.		
Outcomes expected	Tested: improve operational characteristics, improve onboard manageability of the net and storage, measured the reduction in oil consumption due to better operation in the water by 17-20 %. Two new research projects followed-up this one: one with the testing of a hybrid trawlnet with a bottom net and pelagic doors to decrease the width of effects on the sea bottom and decrease further oil consumption (2019-2022, ongoing and (b) the design of 2 devices (i) for the reduction of ghost fishing by enabling the finding and retrieval of lost gears and (ii) the reduction of undersized bycatch using simple grid systems in the codend (just submitted for funding; expected 2021-2023).		
Drawing / picture of the Innovative gear / Solution	 Full sized trawl designed for a 1100 hp trawl OTB.		

Relevant information / Reference	Conides, A., 2018. Technical improvement of the fishing gear 'trawl' in order to improve its use and reduce energy consumption. Final Report, Project 185368/086-8, Hellenic Centre for Marine Research, 83 pp (*in Greek*). Similar experiences have been developed in other Mediterranean fisheries. Relevant outcomes can be found in the following references: Sala, A., Lucchetti, A., Palumbo, V., Hansen, K., 2008. Energy saving trawl in Mediterranean demersal fisheries. In Guedes Soares & Kolev (eds) Maritime Industry, Ocean Engineering and Coastal Resources. Taylor & Francis Group, London, ISBN 978-0-415-45523-7: 961-964. van Marlen, B., Thøgersen, T., Frost, H., Vincent, B., Planchot, M., Brigaudeau, C., Priour, D., Daurès, F., Le Floch, P., Rihan, D., Costello, L., Sala, A., Messina, G., Lucchetti, A., Notti, E., De Carlo, F., Palumbo, V., Malvarosa, L., Accadia, P., Salz, P., Powell, J., van Vugt, J., de Vries, L., van Craeynest, K., Arkley, K., Metz, S., 2009. Energy Saving in Fisheries (ESIF), Final Project Report FISH/2006/17 LOT3, 425 pp.

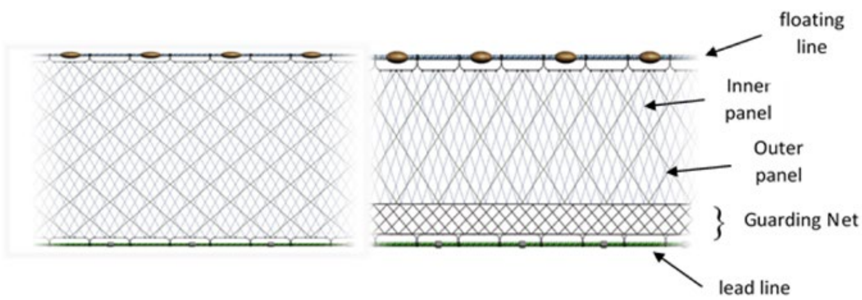
6.5.6 Flexible turtle excluder device (FLEX-TED)

General information			
Date	03/07/2019	**Source supplier name**	Ocean Marine & Fishing Gears A/S (Denmark) modified by Tecnopesca srl (Italy) Source: Lucchetti, A., Petetta, A., Virgili, M. (CNR, Italy)
Region	Mediterranean Sea	**FAO Area (Division, L2)**	37.2.1
Gear sub-category	Bottom trawls	**Gear code**	OTB, OTT
Baseline gear	Baseline standards are derived from either existing European Regulations or commonly used unregulated. No existing EU Regulations concern the use of TEDs in Mediterranean waters.	**Baseline Regulation**	EC Reg. 1967/2006 Reg. EU 2019/1241
Target species	MTS, HKE, MUT, DPS, MON, WHG	**Bycatch species**	TTL, MYL, MPO
Definition of the Innovative gear	TEDs are not used in the Mediterranean. FLEX-TED is made of an alloy of plastic material, which ensures a lightness of the grid (compared to rigid TEDs made of aluminium), rigid configuration during the tow and the capacity of withstanding considerable bends and resuming its natural shape when the mechanical stresses are finished. As a consequence, this grid can be safely winded around a standard net winch, allowing to carry out the normal fishing operations without additional time.	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	The bycatch of loggerhead sea turtles (*Caretta caretta*) is reduced by 100 %. The amount of debris is reduced, while the commercial catch is maintained. Similar catch performance of TED and a baseline. No differences were found in the species composition. The quality of the target species is improved, and a reduction of sorting time is observed.	**Additional criteria**	None
Technical specificities	The FLEX-TED dimensions are: height: 1130 mm; width: 845 mm; circumference: 3110 mm; bar diameter: 20 mm; spacing between bars: 96 mm. This grid is mounted on a tubular netting section (6 m in length) and placed immediately in front of the codend. An escape opening is cut on the lower or upper portion of the net just before the TED and covered by a netting panel with three sides sewn to the net to prevent loss of commercial species. The fourth side is free and function as a valve, as it opens only when it is hit by large and heavy objects, and thus allowing sea turtles and other bycatch species to out the net. TED angle is usually set to 45-48°.		

Outcomes expected	FLEX-TED device does not affect neither bottom trawl technical performances (horizontal and vertical net opening and door spread) nor increase the required towing force, hence fuel consumption remain constant. Comparison of commercial catches for the major species showed that the use of this TED did not affect catching efficiency, while it reduced the amount of debris. Underwater video camera recordings documented that fish caught in the net swam through the grid and easily reached the codend, missing the TED escape opening. FLEX-TED is a very light grid made of an alloy of high-strength plastic material. These features allow the grid maintaining a stiff configuration during trawling, and safely winding around a standard net winch as the net is hauled onboard. The effectiveness of the FLEX-TED has been already proved under the TartaLife Project (LIFE12 NAT/IT/000937), and allowed overcoming some problems connected with other rigid TEDs tested during the hauling phase (i.e. net and TED breaking and loss of time with handling). The easy storage and handling make the flexible TED a practical and valuable solution to reduce turtle bycatch in coastal Mediterranean de-mersal multispecies fisheries. In support of the efficacy of the FLEX-TED, some vessels, after having tested this device during the experimentation trials of the TartaLife project, voluntarily adopted the use of the device. Positive results have led to the adoption of a "Turtle safe" label by Friends of the sea.
Drawing / picture of the Innovative gear / Solution	  
Relevant information / Reference	Lucchetti, A., Bargione, G., Petetta, A., Vasapollo, C., Virgili, M., 2019. Reducing sea turtle bycatch in the Mediterranean mixed demersal fisheries. Frontiers in Marine Science, 6, 387. Vasapollo, C., Virgili, M., Petetta, A., Bargione, G., Sala, A., Lucchetti, A., 2019. Bottom trawl catch comparison in the Mediterranean Sea: Flexible Turtle Excluder Device (TED) vs traditional gear. PLoS ONE 14(12): e0216023. https://doi.org/10.1371/journal.pone.0216023.

6.5.7 Trammel net provided with “guarding net” in the caramote prawn and other coastal fisheries in western Mediterranean

<table>
<tr><th colspan="4">General information</th></tr>
<tr><td>Date</td><td>01/12/2018</td><td>Source supplier name</td><td>Paolo Sartor (CIBM, Italy)</td></tr>
<tr><td>Region</td><td>Mediterranean Sea</td><td>FAO Area (Division, L2)</td><td>37.1.3</td></tr>
<tr><td>Gear sub-category</td><td>Entangling nets</td><td>Gear code</td><td>GTR</td></tr>
<tr><td>Baseline gear</td><td>Trammel net (GTR)</td><td>Baseline Regulation</td><td>EC Reg. 1967/2006</td></tr>
<tr><td>Target species</td><td>TGS</td><td>Bycatch species</td><td>Retained by catch
PAC, JRS, MTS

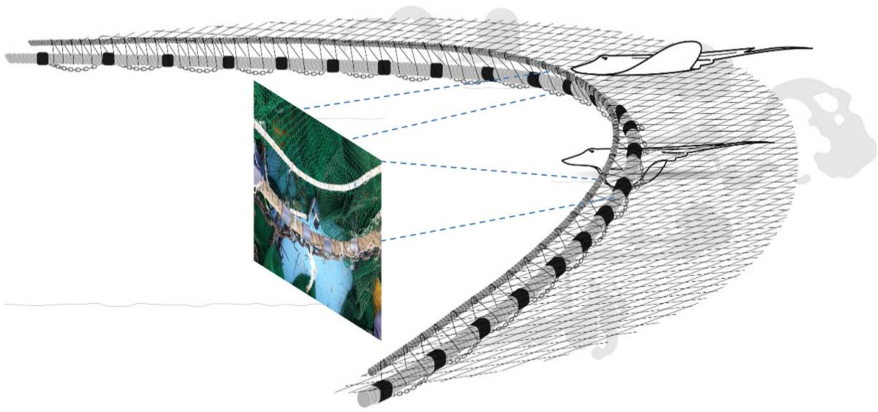
Discarded by catch
LQV, BOY, OHQ</td></tr>
<tr><td rowspan="2">Definition of the Innovative gear</td><td rowspan="2">Trammel net provided with “guarding net” in the Mediterranean coastal fisheries.</td><td>Technological complexity level</td><td>Minimal</td></tr>
<tr><td>Technology readiness level</td><td>High</td></tr>
<tr><td>Main criteria</td><td>Selectivity, Bycatch, Benthic impact</td><td>Additional criteria</td><td><u>Economy</u>. This guarding net is a low-cost device. The economic loss due to the reduction of catches of target species and retained by catch is compensated by the reduction of costs of sorting, labour and net maintenance.</td></tr>
<tr><td>Technical specificities</td><td colspan="3">The innovative gear consists in a strip of gillnet (“Guarding Net”), placed at the bottom, above the lead line of a professional trammel net used for the caramote prawn fishery (se figure below). The professional trammel net has an inner panel of Polyammide (PA) with stretched meshes of 40 mm and two outer panels in multifilament, with stretched mesh size of 300 mm. The hanging ratio of the inner panel was 0.45, which of the outer panels was 0.7. The total height of the net, due to that of the outer panels, was 1.20 m (4 meshes of 300 mm each). The guarding net is a monofilament strip with stretched mesh size of 54 mm. It is placed at the bottom of the two nets, just above the lead line. The height of the guarding net is 20 - 25 cm. The STN was built with an inner panel of Polyammide (PA) with stretched meshes of 40 mm and two outer panels in multifilament, with stretched mesh size of 300 mm. The hanging ratio of the inner panel was 0.45, that of the outer panels was 0.7. The total height of the net, due to that of the outer panels, was 1.20 m (4 meshes of 300 mm each).


Scheme of a standard trammel net (left) and of a trammel net provided with guarding net (right).</td></tr>
<tr><td>Outcomes expected</td><td colspan="3">It was scientifically proved (Sartor et al., 2018) that that the guarding applied to the trammel nets in the caramote prawn fishery of Viareggio is effective in reducing the problems due to unwanted catches (mostly benthic species). When a guarding net is applied to a standard trammel net, a decrease up to about 60-70% of the discarded biomass can be obtained. The use of trammel nets provided with guarding net could be expanded also to other fisheries, e.g. also in areas where the unwanted catches of benthic species constitute a problem, as well as in areas where fishing activity is regulated, e.g. marine protected or sensitive areas.</td></tr>
<tr><td>Relevant information / Reference</td><td colspan="3">Sartor, P., Li Veli, D., De Carlo, F., Ligas, A., Massaro, A., Musumeci, C., Sartini, M., Rossetti, I., Sbrana, M., Viva, C., 2018. Reducing unwanted catches of trammel nets: experimental results of the “guarding net” in the caramote prawn, Penaeus kerathurus, small-scale fishery of the Ligurian Sea (western Mediterranean). Sci. Mar., 82S1: 131-140. https://doi.org/10.3989/scimar.04765.15B.</td></tr>
</table>

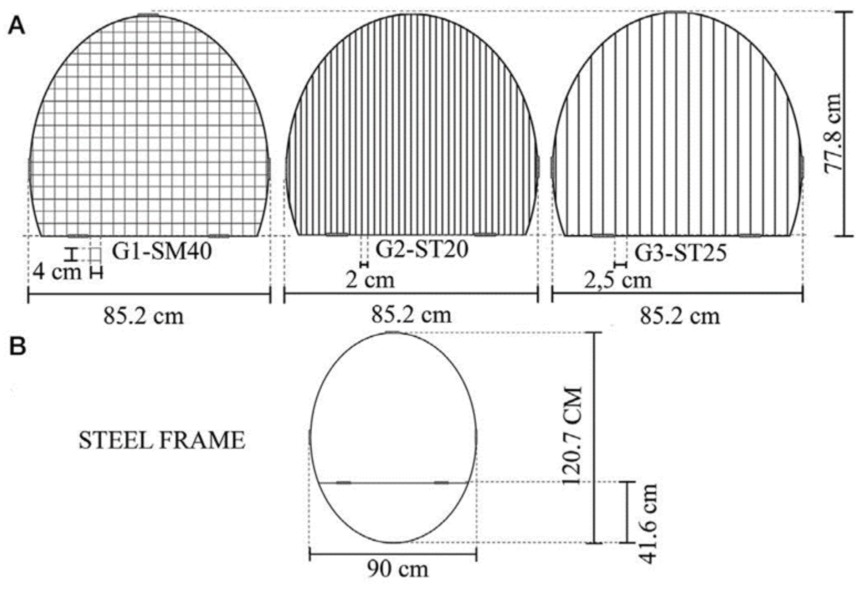
6.5.8 Double-detached groundgear

General information			
Date	08/06/2018	**Source supplier name**	Emre Fakioglu (WWF Turkey)
Region	Mediterranean Sea	**FAO Area (Division, L2)**	37.2.2
Gear sub-category	Bottom trawls	**Gear code**	OTB
Baseline gear	Commercial Mediterranean OTB.	**Baseline Regulation**	No specific regulation
Target species	MUT, TIP, LIB, SOL, PAC	**Bycatch species**	RBC, RBX, JDP
Definition of the Innovative gear	This innovation is named “Double Detached (DD)”. The main objective of this modification is to design a groundgear that gives elasmobranchs, e.g. incidental bycatches of endangered, threatened, and protected (ETP) species, a chance to escape without compromising the retention of target species. The conventional groundgear was modified by cutting the rigging between fishing line and footrope in the central part. The new groundgear is simple, efficient, cost free and not having handling problems which can make it easily accepted by fishers. There is no commercial-scale assessment of the gear but we can say that modification is beneficial compared to conventional gear.	**Technological complexity level** **Technology readiness level**	Minimal High
Main criteria	Species selectivity	**Additional criteria**	None
Technical specificities	The standard gear is one of the most commonly used conventional groundgear (hereafter referred to DA; Double Attached) which consists of two ropes attached to each other with a 3.5 mm diameter polypropylene (PP) rigging twine. The overall groundgear was 20.8 m long. The fishing line was 22 mm diameter made of polyamide material and the footrope was 28 mm diameter made up of combination of lead and nylon with extra chain and lead on it. Both of groundgears were rigged with 60 pieces of lead (1.15 kg/m) and 8 mm diameter mid-link chain (2.9 kg/m). The gap between fishing line and the footrope was average 7 cm in the air. DA groundgear was modified by cutting this rigging twine between these two ropes in the central part 2.7 m or 13 % of the overall groundgear (DD; Double Detached).		
Outcomes expected	By modifying the groundgear, two out of three elasmobranchs have been released successfully under the fishing line without loss of commercially valuable species. Video recordings showing that stingray (*Dasyatis pastinaca*) and guitarfish (*Rhinobatos sp.*) species excluded from the trawl mouth also have supported this reduction. The length-based catch ratio between the standard and the modified groundgears did not show any significant reduction in target species except for Common sole (*Solea solea*).		

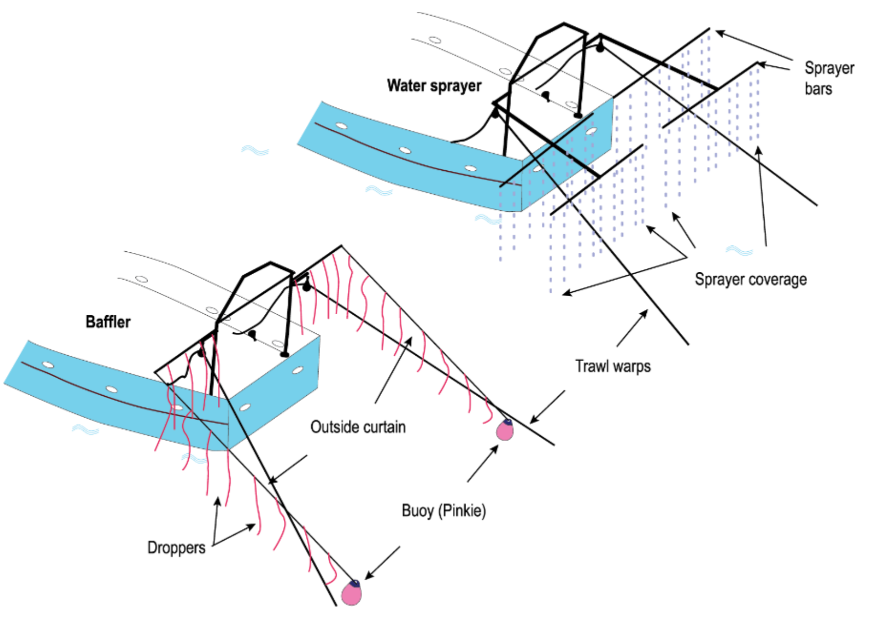
Drawing / picture of the Innovative gear / Solution	  Central part of standard groundgear (above) and modified groundgear (below).   Underwater footages of central part of the modified groundgear-

	 The gap that was created in the modified gear.
Relevant information / Reference	Fakıoğlu, Y. E., Özbilgin, H., Gökçe, G., Kalecik, E., Demir, O., Özbilgin, Y., Yalçın, E., Herrmann, B., 2018. A Simple Groundgear Modification to Reduce Bycatch of Elasmobranchs in the Mediterranean Trawl Fishery. ICES/FAO WGFTFB (Working Group On Fishing Technology and Fish Behaviour), Hirtshals, Denmark, 4-8 June 2018.

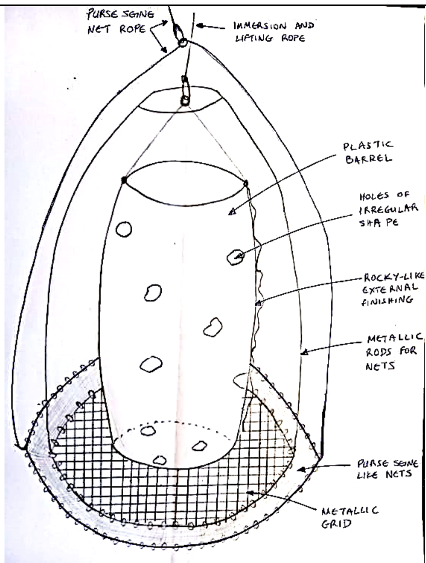
6.5.9 Juvenile and Trash Excluder Device

General information			
Date	01/12/2018	**Source supplier name**	Michele Geraci, Sergio Vitale (CNR, Italy)
Region	Mediterranean Sea	**FAO Area (Division, L2)**	37.2.2
Gear sub-category	Bottom trawls	**Gear code**	OTB
Baseline gear	Commercial Mediterranean OTB with 40 mm square-mesh codend or 50 mm diamond-mesh codend	**Baseline Regulation**	EC Reg. 1967/2006
Target species	DPS	**Bycatch species**	HKE, mixed fisheries
Definition of the Innovative gear	Sorting grids with different bar spacing and widths	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	Catch efficiency, improved selectivity (catch of target species and unwanted bycatch)	**Additional criteria**	None
Technical specificities	Test was equal to baseline trawlnet except for a sorting grid mounted in the extension section. In particular, three different sorting grids were tested: the first grid type (G1-SM40) was built with a net of 40 mm square mesh while the second (G2-ST20) and third (G3-ST25) were made from vertical steel bars spaced 20 and 25 mm apart, respectively.		
Outcomes expected	G1-SM40, the reduction of undersized individuals in the codend was about 60% and 44% for DPS and HKE, respectively. With G2-ST20, a 34% catch decrease of HKE individuals smaller than 20 cm total length was observed. Finally, G3-ST25 was efficient at reducing the catch of undersized specimens of DPS and HKE, but showed a higher loss of marketable fractions than the other grids.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Vitale, S., Milisenda, G., Gristina, M., Baiata, P., Bonanomi, S., Colloca, F., … Sala, A. (2018). Towards more selective Mediterranean trawl fisheries: are juveniles and trash excluder devices effective tools for reducing undersized catches? Scientia Marina, 82(S1), 215. doi:10.3989/scimar.04751.28°. Vitale, S., Enea, M., Milisenda, G., Gancitano, V., Geraci, M.L., Falsone, F., … Colloca, F. (2018). Modelling the effects of more selective trawlnets on the productivity of European hake (*Merluccius merluccius*) and deep-water rose shrimp (*Parapenaeus longirostris*) stocks in the Strait of Sicily. Scientia Marina, 82(S1), 199. doi:10.3989/scimar.04752.03a.		

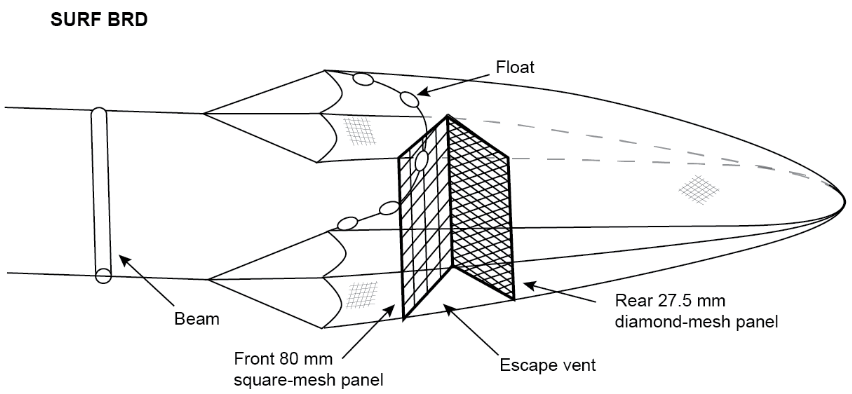
6.5.10 Seabird mitigation devices

General information			
Date	01/08/2018	**Source supplier name**	SETIFA
Region	Place of origin: Southern Australia	**FAO Area (Division, L2)**	57.6
Gear sub-category	Bottom trawls	**Gear code**	OTB
Baseline gear	Baseline gear is a Pinkie (a large diameter float attached to the warps)	**Baseline Regulation**	Fisheries Management (Ocean Trawl Share Management Plan) Regulation 2006. Current version for 1 May 2019
Target species	GRN; BEH	**Bycatch species**	ALZ
Definition of the Innovative gear	Either a baffler (streamers) or water jets deployed over trawl warps	**Technological complexity level**	Minimal
		Technology readiness level	High
Main criteria	Baffler and water jets reduced bird strikes to the trawl warps (impact)	**Additional criteria**	Not assessed for any additional criteria
Technical specificities	Two bird mitigation devices (a baffler and a water sprayer) were compared against the pinkie. The 'baffler' is essentially a curtain of droppers that shrouds the warps and the 'water sprayer' is a water curtain that covers the warps. The pinkie was a buoy that was slid down the warp to act as a bird deterrent.		
Outcomes expected	The 'baffler' and the 'water sprayer' showed significant reductions in bird interactions with the warps compared with the 'pinkie' 83.7 and 58.9%, respectively. Both mitigation devices were considered easier and safer to use than the previously approved pinkies, From the results of this work the Australian Fisheries Management Authority (AFMA) now allows vessels to meet seabird bycatch mitigation requirements using either the 'baffler' or the 'water sprayer'.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Koopman, M., Boag, S., Tuck, G.N., Hudson, R., Knuckey, I., and Alderman, R., 2018. Industry-based development of effective new seabird mitigation devices in the southern Australian trawl fisheries. Endangered Species Research, 36: 197–211.		

6.5.11 Trap for lionfish

General information			
Date	01/08/2020	**Source supplier name**	Gerasimos Kondylatos (Hellenic Centre for Marine Research)
Region	Mediterranean Sea	**FAO Area (Division, L2)**	37.2, 37.3
Gear sub-category	Pots	**Gear code**	FPO
Baseline gear	FPO	**Baseline Regulation**	EC Reg. 1967/2006
Target species	UHQ	**Bycatch species**	URC, STF, MMH, SCO
Definition of the Innovative gear	A bottom fish trap for long term immersion	**Technological complexity level**	Minimal
		Technology readiness level	High
Main criteria	Target to an invasive species (lionfish) as a means to successfully remove or control its populations from rocky fishing grounds (Impact)	**Additional criteria**	-
Technical specificities	This long term immersion trap for lionfish (PAMEAL) is a customized construction based on a cylindrical or pitcher-like plastic barrel of a 1.2 m diameter (range 1-1.5 m) and about 1.5 m high, incorporating lightweight material so that it can be sunk and lifted by a net winch, i.e. existing equipment of fishing vessels. Both base and sides are perforated with large hole through which the fish can move in and out, and the water can be drained. This construction is mounted on a round metal grid (base) that will not bend under its weight. The mess eye of the grid is smaller (e.g. 1-5 cm), than the desired size of the fish. The confinement of the lionfish that will colonize the construction will be made by net which will frame the perimeter of the round base and will form a bag as it is picked up from the boat (as in the boat-seining fishing method). In general, the construction will have to match and resemble to a rocky background.		
Outcomes expected	The trap is expected to be able to gather 5-20 lionfish and remove them efficiently every 2-3 months of operation. If this should be accomplished then a series of such traps in areas dominated by lionfish will contribute in its removal through periodical fishing or scientific operations.		
Drawing / picture of the Innovative gear / Solution	 Rough sketch of the trap for lionfish.		
Relevant information / Reference	Project in progress: “Design and piloting methods of commercial exploitation of invasive alien species with a view to contributing to their population control” funded by the Greek Ministry of Agriculture; 2020-2022. Project coordinator for the Hellenic Centre for Marine Research, Gerasimos Kondylatos, Hydrobiological Station of Rhodos.		

6.5.12 SURF-BRD Panel

General information			
Date	04/07/2008	**Source supplier name**	Tokyo University of Fisheries, Japan
Region	Place of origin: Japan	**FAO Area (Division, L2)**	61
Gear sub-category	Bottom trawls / Beam trawl	**Gear code**	TBB
Baseline gear	Standard gear is a beam trawl used in the small-scale penaeid fishery.	**Baseline Regulation**	Not available
Target species	MJB	**Bycatch species**	SZX, CIF
Definition of the Innovative gear	Two inclined mesh panels near the groundgear that reduces unwanted catches entering the codend.	**Technological complexity level**	Medium
		Technology readiness level	High
Main criteria	The SURF-BRD effectively excluded bycatch species while maintaining target species (catch and selectivity).	**Additional criteria**	Other criteria not assessed
Technical specificities	A beam trawl modified with a groundgear panel (termed 'SURF (System of Unwants Ramp-way Filter)-BRD') designed to direct unwanted catches to a lateral escape exit. The SURF BRD comprises two inclined panels, a front (with 80 mm square mesh) and a rear (with 27.5 mm diamond mesh).		
Outcomes expected	The SURF BRD works by reducing the amount of unwanted catch entering the codend. It allows organisms to pass through the front panel (80 mm square mesh) but not the rear (27.5 mm diamond mesh) one. The organisms not passing through the rear panel can escape through side vents.		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference	Kajikawa, Y., Tokai, T., Hu, F. 2009. Improvement of species- and size-separation in SURF-BRD with high encounter probability of marine organisms. Nippon Suisan Gakkaishi 75:219–229 *(in Japanese with English abstract)*. Kajikawa,Y., Tokai, T. Hu, F., 2013. Modeling of available size selectivity of the SURF-BRD for shrimp beam trawl**.** Fisheries Science. 79(6): 879-894.		

7 Innovation evaluation

7.1 Summary statistics

A total of 42 factsheets were developed by WKING experts and reviewed during the remote meetings as part of the catalogue of the innovative gears. The review generated an overview of the state-of-the-art technologies and innovations that are relevant to the European fisheries and beyond. This led to the identification of different innovations across the three target Criteria of Assessment (CA): selectivity, catch efficiency, and environmental impact.

Assessing the technological readiness level of new innovations can be very subjective without an understanding of the level of development/testing its undergone i.e. still a concept, validated by science/industry or system complete and qualified (being extensively used).

This could lead to a situation where a simple innovation could achieve a low TRL and be discarded but an untested concept being considered an (artificially) high TRL. Furthermore, it is particularly relevant when evaluating innovations from fisheries in other sea areas.

Figure 9 and Figure 10 present the distribution of the innovations across the three CAs and includes a breakdown by performance impact rating and level of technical complexity, respectively. Automation, reduced bycatch, species selectivity, mitigation of the environmental impact, and reduced energy consumption, are often largely addressed simultaneously by the innovations collected.

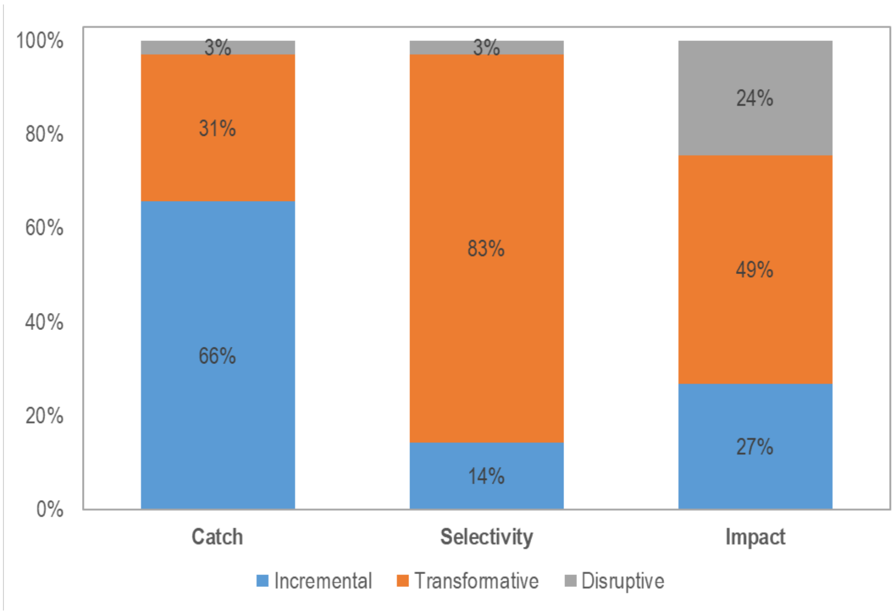


Figure 9. Breakdown of innovations captured by Criteria of Assessment (CA) and performance level (Incremental, Transformative, and Disruptive).

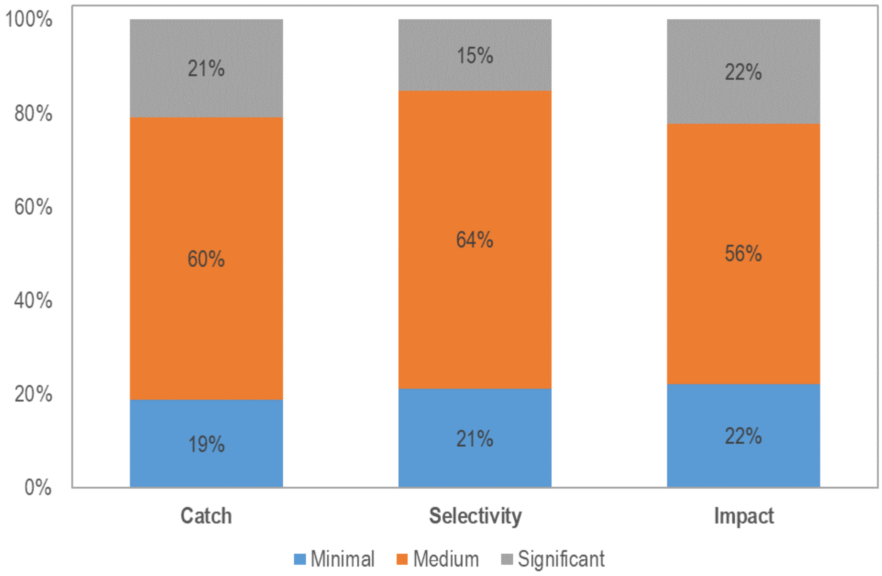


Figure 10. Breakdown of innovations captured by Criteria of Assessment (CA) and Level of technical complexity (Minimal, Medium, and Significant).

7.2 Innovation matrix by Criteria of Assessment

The information collection and methodology applied in this report has generated numerous examples of innovations across the three criteria of assessment (CA). The examples highlighted the main areas where innovation is currently happening. It is recognized that there are existing innovations and research areas that are not included here, and new areas where future innovations may occur. Therefore, the inclusion or exclusion of a specific innovation in this report does not determine the outcome of applications to allow identification of the innovations that appear to be most relevant to the objectives of the European policies.

In the following chapters, we present an overview of the potential performance improvement for each CA, resulting from the information collection using the standard factsheet layout and the Innovation matrix analysis. The evaluation of innovations in terms of their potential impact, Technical Readiness Level and technological complexity was performed using the guidelines described from section *§4.4 to 4.7* but was limited by the availability of information in the public domain concerning these innovations and so should not be seen as a definitive evaluation. During the scoring exercise, it was noted that there were conflicting opinions and different 'schools of thought' for some of the Criteria. Wherever possible, WKING has kept an objective approach and presented findings to include diverging views.

7.2.1 Catch efficiency

Performance		Low	Moderate	High
	Disruptive	-	Flying drone	-
	Transformative	-	Species separation, Controllable door, Echo-sensor detector, Magnetic deterrent	FlexSelect, Netgrid, SepNet, Flemish panel, Nemos+Roofless, Dual codend, Semi-pelagic doors
	Incremental	Batwing doors	Electro-razor, Crustacean BRDs, ADD	Brown shrimp sorting grid, Combination grid, Grid and double codend, Shrimp pulse, Floating sweeps, Scaring ropes, Kon's covered fisheye, Soft brush groundgear, Hokpod, Mini Danish seine, Pontoon trap, Pearl-nets, Alternative pots, Boat seine, High-strength materials, Flex-TED, Guardian-nets, JTED, Surf-BRD panel
	Negative	-	-	-
		Technological readiness level		

7.2.2 Selectivity

Performance		Low	Moderate	High
	Disruptive	-	Flying drone	-
	Transformative	-	Species separation, Electro-razor, Controllable door, Echo-sensor detector, Magnetic deterrent, Crustacean BRDs,	FlexSelect, Brown shrimp sorting grid, Combination grid, Grid and double codend, Netgrid, Shrimp pulse, Four-panel grid, Scaring ropes, Kon's covered fisheye, Alternative pots, High-strength materials, SepNet, Flemish panel, Floating sweeps, Nemos+Roofless, Dual codend, Hokpod, Flex-TED, Seabirds mitigation device, Guardian-nets, JTED, Surf-BRD panel
	Incremental	Batwing doors	-	Soft brush groundgear, Pontoon trap, Semi-pelagic doors, Lionfish trap
	Negative	-	-	-
		Low	**Moderate**	**High**
		Technological readiness level		

7.2.3 Impact on marine ecosystems

Performance	Technological readiness level: Low	Technological readiness level: Moderate	Technological readiness level: High
Disruptive	Batwing doors, Recycled plastic doors	PingMe, Controllable door, Electro-razor	Shrimp pulse, Biodegradable twines, Pearl-nets, Semi-pelagic doors, Flex-TED
Transformative	-	Flying drone Echo-sensor detector, Magnetic deterrent, ADD	Grid and double codend, Boat seine, Scaring ropes, Lionfish trap, JTED, Alternative pots, Floating sweeps, Hokpod, High-strength materials, Nemos+Roofless, Dual codend, Seabirds mitigation device, Guardian-nets, Pontoon trap, Soft brush groundgear, Mini Danish seine
Incremental	-	Species separation, Crustacean BRDs	FlexSelect, Brown shrimp sorting grid, Netgrid, Combination grid, Four-panel grid, SepNet, Flemish panel, Kon's covered fisheye, Surf-BRD panel
Negative	-	-	-
	Low	**Moderate**	**High**

Technological readiness level

8 References

[1] C.M. Christensen, The innovator's dilemma: when new technologies cause great firms to fail, Harvard Business School Press, Boston, Mass., 1997.
[2] K. Dorst, The core of 'design thinking' and its application, Design Studies 32(6) (2011) 521-532.
[3] D. Mann, Hands-On Systematic Innovation, 2002.
[4] J. Tidd, K. Pavitt, Managing Innovation: Integrating Technological, Market And Organizational Change, (2011).
[5] J. Tidd, J. Bessant, Strategic Innovation Management, 2014.
[6] J. Tidd, J. Bessant, Managing Innovation Integrating Technological, Market and Organizational Change Sixth Edition, 2018.
[7] M. Techau, M. Forrest, B. Kleinsorge, J. O'Hare, P. Frobisher, A Global State-of-the-Art Review of Seafood Industry Innovation, Strategic Innovation Ltd report, SIF Baseline Review (2020) 648 pp.
[8] D. Mann, Using S-Curves and Trends of Evolution in R&D Strategy Planning, I Mech. Eng. seminar on Future Heat Pump and Refrigeration Technologies, London, 1999.
[9] M.S. Slocum, Technology Maturity Using S-curve Descriptors, TRIZ Journal (1999).
[10] D.A. Wileman, R.S.T. Ferro, R. Fonteyne, R.B. Millar, Manual of methods of measuring the selectivity of towed fishing gears, ICES Cooperative Research Report:RAPPORT DES RECHERCHES COLLECTIVES 215 (1996) 126 pp.
[11] C.A. Gray, S.J. Kennelly, Bycatches of endangered, threatened and protected species in marine fisheries, Reviews in Fish Biology and Fisheries 28(3) (2018) 521-541.
[12] FAO, Report of the Expert workshop on the methodology to assess and quantify the extent and impact of fisheries bycatch and discards, FAO Rome, Casablanca (2015) 71.
[13] B.P. Wallace, A.D. DiMatteo, A.B. Bolten, M.Y. Chaloupka, B.J. Hutchinson, F.A. Abreu-Grobois, J.A. Mortimer, J.A. Seminoff, D. Amorocho, K.A. Bjorndal, J. Bourjea, B.W. Bowen, R. Briseño Dueñas, P. Casale, B.C. Choudhury, A. Costa, P.H. Dutton, A. Fallabrino, E.M. Finkbeiner, A. Girard, M. Girondot, M. Hamann, B.J. Hurley, M. López-Mendilaharsu, M.A. Marcovaldi, J.A. Musick, R. Nel, N.J. Pilcher, S. Troëng, B. Witherington, R.B. Mast, Global Conservation Priorities for Marine Turtles, PLoS One 6(9) (2011) e24510.
[14] R.L. Lewison, J. Soykan Cu Fau - Franklin, J. Franklin, Mapping the bycatch seascape: multispecies and multi-scale spatial patterns of fisheries bycatch, (1051-0761 (Print)) (2009).
[15] R.L. Lewison, L.B. Crowder, B.P. Wallace, J.E. Moore, T. Cox, R. Zydelis, S. McDonald, A. DiMatteo, D.C. Dunn, C.Y. Kot, R. Bjorkland, S. Kelez, C. Soykan, K.R. Stewart, M. Sims, A. Boustany, A.J. Read, P. Halpin, W.J. Nichols, C. Safina, Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots, Proc. Natl. Acad. Sci. 111(14) (2014) 5271.
[16] A. Lucchetti, A. Sala, An overview of loggerhead sea turtle (Caretta caretta) bycatch and technical mitigation measures in the Mediterranean Sea, Reviews in Fish Biology and Fisheries 20(2) (2010) 141-161.
[17] M. Héder, From NASA to EU: the evolution of the TRL scale in Public Sector Innovation, The Innovation Journal 22 (2017) 1-23.
[18] European Commission, High-Level Expert Group on Key Enabling Technologies – Final Report, (2011) 56 pp.
[19] European Commission Decision C (2015)8621 of 4 December 2015, Horizon 2020 Work Programme 2014 – 2015, General Annexes Revised (Part 19), (2015) 36.
[20] E.M. Rogers, F.F. Shoemaker, Communication of innovations: a cross-cultural approach, 2nd ed. / (by) Everett M. Rogers with F. Floyd Shoemaker. ed., Free Press, New York, 1971.

[21] G. Tani, B. Cimatti, Technological complexity: A support to management decisions for product engineering and manufacturing, 2008 IEEE International Conference on Industrial Engineering and Engineering Management, 2008, pp. 6-11.
[22] D. Mann, Hands-On Systematic Innovation for Business and Management, 2nd Edition (2014).
[23] T. Howard, S.J. Culley, E. Dekoninck, Describing the Creative Design Process by the Integration of Engineering Design and Cognitive Psychology Literature, Design Studies 29 (2008) 160-180.
[24] P. Frobisher, Improving innovation using TRIZ, Department of Mechanical Engineering, University of Bath, Bath, 2010.
[25] IDEF0, Integrated DEFinition Methods (IDEF). IDEF0 Overview, 2005. http://www.idef.com/IDEF0.html.
[26] D. Sahal, Patterns of Technological Innovation, Addison-Wesley, Reading, MA (1981).
[27] FAO, Report of the twenty-third session of the Coordinating Working Party on Fishery Statistics. Hobart, Australia, 22–26 February 2010, (2010) 87 pp.
[28] FAO, Report of the twenty-fifth session of the Coordinating Working Party on Fishery Statistics. Rome, Italy, 23-26 February 2016, (2016) 54 pp.
[29] C. Nédelec, J. Prado, Definition and Classification of Fishing gear categories, (1990) 92 pp.

Annex 1: Information collection of the innovative gears. Factsheet template

"Title of the Innovative gear"

General information			
Date	[Select a date]	**Source supplier name**	
Region	Select a Region	**FAO Area (Division, L2)**	*See Annex 3*
Gear sub-category	Select a gear sub-category	**Gear code**	*See Annex 4*
Baseline gear	*Baseline standards are derived from either existing European Regulations or commonly used unregulated*	**Baseline Regulation**	e.g. EC Reg. 1967/2006
Target species	Use FAO 3-alpha code	**Bycatch species**	Select a Levels of innovation
Definition of the Innovative gear	*Define the innovative gear / Innovation*	**Technological complexity level**	Minimal / Medium / Significant
		Technology readiness level	Low / Moderate / High
Main criteria	*List the main criteria affected (e.g. selectivity, catch, impact)*	**Additional criteria**	*List the additional criteria affected (e.g. pollution, GHG emission, energy saving)*
Technical specificities	*Compare the technical specificities between the baseline gear and the Innovative gear*		
Outcomes expected	*Outlines the main outcomes expected and/or tested*		
Drawing / picture of the Innovative gear / Solution			
Relevant information / Reference			

Annex 2: List of participants

WKING I, Inception Remote meeting (May 20-22, 2020) *(in alphabetic order)*

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WKING coordination meeting, Remote meeting with the *Strategic Innovation Ltd* (UK) company (4 September 2020)

A coordination meeting was held on the 4th of September 2020 to discuss the involvement of *Strategic Innovation Ltd* (UK) in WKING. A list of participants is reported below.

The approaches and outcomes shown by the Strategic Innovation team throughout the research report [7] resulted in a thorough and fit-for-purpose output that will be critical in benchmarking the level of innovation achieved in WKING, and for evaluating the impact across the European seafood industries.

The input from *Strategic Innovation* (SI) provided a valuable perspective from outside the seafood sector that strengthened the WKING assessment criteria for innovative ideas. The WKING chairs found the team at SI to be extremely professional and knowledgeable, therefore it was decided to involve Dr. Techau Michala and Mr. Frobisher Paul in the WKING Core Group.

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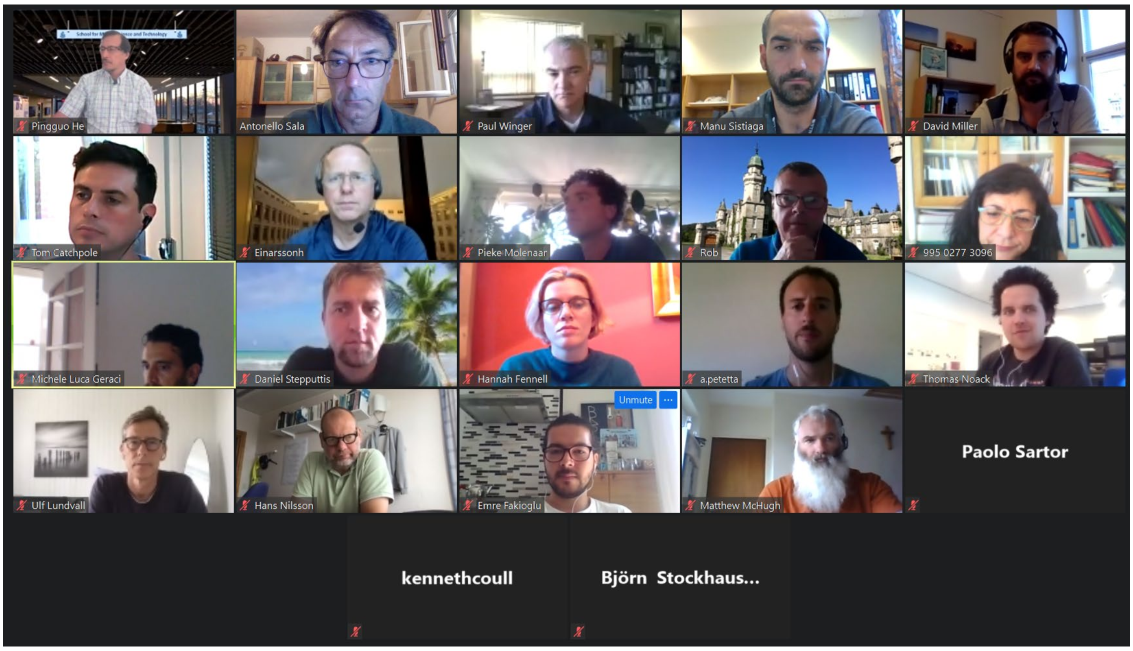
WKING III, Final Remote meeting (7 September 2020) *(in alphabetic order)*



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Annex 3: FAO Area Codes

Relevant Areas according to the FAO Area classification as provided in the Master Data Register repository. Note that only those areas of interest for the current workshop are included. Areas are specified from Level 1 (L1) to Level 4 (L4).

- North Sea (Annex V) .... Area 27.4
- Northwestern Waters (Annex VI)........ Area 27.5, 27.6, 27.7
- Southwestern Waters (Annex VII)....... Area 27.8, 27.9, 27.10, 34.1.1, 34.1.2, 34.2
- Baltic Sea (Annex VIII) .... Area 27.3
- Mediterranean Sea (Annex IX)............ Area 37.1, 37.2, 37.3
- Black Sea (Annex X)............................... Area 37.4

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
27					**Atlantic, Northeast**
	27.1				Barents Sea (Subarea I)
		27.1.a			Barents Sea - NEAFC Regulatory Area
		27.1.b			Barents Sea - non-NEAFC Regulatory Area
	27.2				Norwegian Sea, Spitsbergen, and Bear Island (Subarea II)
		27.2.a			Norwegian Sea (Division IIa)
			27.2.a.1		Norwegian Sea - NEAFC Regulatory Area
			27.2.a.2		Norwegian Sea - non-NEAFC Regulatory Area
		27.2.b			Spitsbergen and Bear Island (Division IIb)
			27.2.b.1		Spitsbergen and Bear Island - NEAFC Regulatory Area
			27.2.b.2		Spitzbergen and Bear Island - non-NEAFC Regulatory Area
	27.3				Skagerrak, Kattegat, Sound, Belt Sea, and Baltic Sea, the Sound and Belt together also known as the Transition Area (Subarea III)
		27.3.a			Skagerrak and Kattegat (Division IIIa)
			27.3.a.n		Skagerrak
			27.3.a.s		Kattegat
		27.3.b			Sound and Belt Sea or the Transition Area (Divisions IIIb)
			27.3.b.23		Sound
		27.3.c			Sound and Belt Sea or the Transition Area (Divisions IIIb)
			27.3.c.22		Belt Sea
		27.3.d			Baltic Sea (Division IIId)

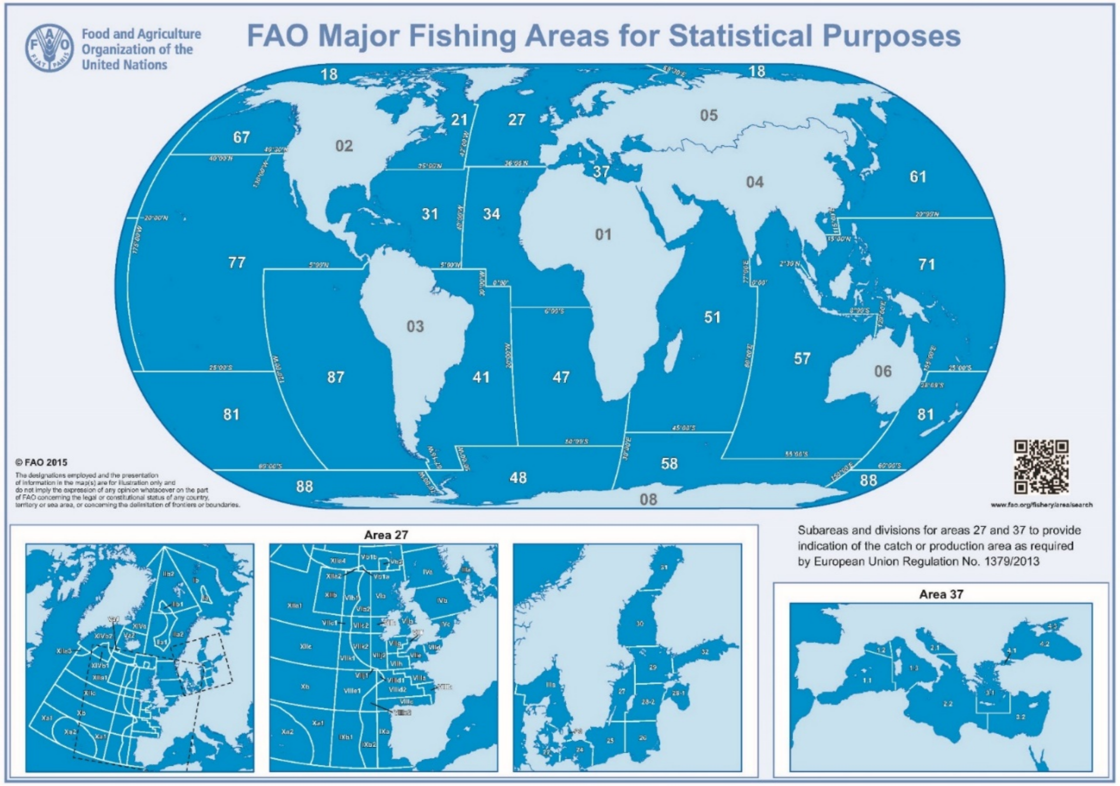
Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
			27.3.d.24		Baltic West of Bornholm (Subdivision 24)
			27.3.d.25		Southern Central Baltic – West (Subdivision 25)
			27.3.d.26		Southern Central Baltic - East (Subdivision 26)
			27.3.d.27		West of Gotland (Subdivision 27)
			27.3.d.28		East of Gotland or Gulf of Riga (Subdivision 28)
				27.3.d.28.1	Gulf of Riga
				27.3.d.28.2	East of Gotland
			27.3.d.29		Archipelago Sea (Subdivision 29)
			27.3.d.30		Bothnian Sea (Subdivision 30)
			27.3.d.31		Bothnian Bay (Subdivision 31)
			27.3.d.32		Gulf of Finland (Subdivision 32)
	27.4				North Sea (Subarea IV)
		27.4.a			Northern North Sea (Division IVa)
		27.4.b			Central North Sea (Division IVb)
		27.4.c			Southern North Sea (Division IVc)
	27.5				Iceland and Faroes Grounds (Subarea V)
		27.5.a			Iceland Grounds (Division Va)
			27.5.a.1		Northern Reykjanes Ridge
			27.5.a.2		Icelandic Shelf
		27.5.b			Faroes Grounds (Division Vb)
			27.5.b.1		Faroe Plateau (Subdivision Vb1)
				27.5.b.1.a	Faroe Plateau - Part of NEAFC Regulatory Area
				27.5.b.1.b	Faroe Plateau Non-NEAFC Regulatory Area
			27.5.b.2		Faroe Bank (Subdivision Vb2)
	27.6				Rockall, Northwest Coast of Scotland and North Ireland, (the Northwest Coast of Scotland and North Ireland also known as the West of Scotland) (Subarea VI)
		27.6.a			Northwest Coast of Scotland and North Ireland or as the West of Scotland (Division VIa)
		27.6.b			Rockall (Division VIb)
			27.6.b.1		Rockall - Part of NEAFC Regulatory Area
			27.6.b.2		Rockall Non-NEAFC Regulatory Area

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
	27.7				Irish Sea, West of Ireland, Porcupine Bank, Eastern and Western English Channel, Bristol Channel, Celtic Sea North and South, and Southwest of Ireland - East and West (Subarea VII)
		27.7.a			Irish Sea (Division VIIa)
		27.7.b			West of Ireland (Division VIIb)
		27.7.c			Porcupine Bank (Division VIIc)
			27.7.c.1		Porcupine Bank - Part of NEAFC Regulatory Area
			27.7.c.2		Porcupine Bank - Non-NEAFC Regulatory Area
		27.7.d			Eastern English Channel (Division VIId)
		27.7.e			Western English Channel (Division VIIe)
		27.7.f			Bristol Channel (Division VIIf)
		27.7.g			Celtic Sea North (Division VIIg)
		27.7.h			Celtic Sea South (Division VIIh)
		27.7.j			Southwest of Ireland / East (Division VIIj)
			27.7.j.1		Southwest of Ireland - East - Part of NEAFC Regulatory Area
			27.7.j.2		Southwest of Ireland - East - Non-NEAFC Regulatory Area
		27.7.k			Southwest of Ireland - West (Division VIIk)
			27.7.k.1		Southwest of Ireland - West - Part of NEAFC Regulatory Area
			27.7.k.2		Southwest of Ireland - West - Non-NEAFC Regulatory Area
	27.8				Bay of Biscay (Subarea VIII)
		27.8.a			Bay of Biscay / North (Division VIIIa)
		27.8.b			Bay of Biscay / Central (Division VIIIb)
		27.8.c			Bay of Biscay / South (Division VIIIc)
		27.8.d			Bay of Biscay / Offshore (Division VIIId)
			27.8.d.1		Bay of Biscay - Offshore - Parts in NEAFC Regulatory Area
			27.8.d.2		Bay of Biscay - Offshore - Non-NEAFC Regulatory Area
		27.8.e			West of Bay of Biscay (Division VIIIe)
			27.8.e.1		West of Bay of Biscay - Parts in NEAFC Regulatory Area
			27.8.e.2		West of Bay of Biscay - Non-NEAFC Regulatory Area

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
	27.9				Portuguese Waters (Subarea IX)
		27.9.a			Portuguese Waters / East (Division IXa)
		27.9.b			Portuguese Waters / West (Division IXb)
			27.9.b.1		Portuguese Waters - West Parts in NEAFC Regulatory Area
			27.9.b.2		Portuguese Waters - West Non-NEAFC Regulatory Area
	27.10				Azores Grounds (Subarea X)
		27.10.a			Azores Grounds (Division Xa)
			27.10.a.1		Azores Grounds - Parts in NEAFC Regulatory Area
			27.10.a.2		Azores Grounds - Non-NEAFC Regulatory Area
		27.10.b			Northeast Atlantic South (Division Xb)
	27.12				North of Azores (Subarea XII)
		27.12.a			Southern mid-Atlantic Ridge (Southern Reykjanes Ridge south to Charlie-Gibbs Fracture Zone) (Division XIIa)
			27.12.a.1		Subdivision XIIa1 - NEAFC Regulatory Area
			27.12.a.2		Subdivision XIIa2 - NEAFC Regulatory Area
			27.12.a.3		Subdivision XIIa3 - Non-NEAFC Regulatory Area
			27.12.a.4		Subdivision XIIa4 - Non-NEAFC Regulatory Area
		27.12.b			Western Hatton Bank (Division XIIb)
		27.12.c			Central Northeast Atlantic - South (Division XIIc)
	27.14				East Greenland (Subarea XIV)
		27.14.a			Northeast Greenland (Division XIVa)
		27.14.b			Southeast Greenland (Division XIVb)
			27.14.b.1		Southeast Greenland - Parts of NEAFC Regulatory Area (Division XIVb1)
			27.14.b.2		Southeast Greenland - Non-NEAFC Regulatory Area (Division XIVb1)
34					**Atlantic, Eastern Central**
	34.1				Northern Coastal
		34.1.1			Morocco Coastal
			34.1.1.1		El Jadida
			34.1.1.2		Morocco Coastal

Area	Subarea *(L1)*	Division *(L2)*	Subdivision *(L3)*	Unit *(L4)*	Description
			34.1.1.3		Cabo Bojador
		34.1.2			Canaries/Madeira Insular
		34.1.3			Sahara Coastal
			34.1.3.1		Cape Barbas
			34.1.3.2		Cape Timiris
	34.2				Northern Oceanic
	34.3				Southern Coastal
		34.3.1			Cape Verde Coastal
			34.3.1.1		Senegal River (estuary)
			34.3.1.2		Cape Roxo
			34.3.1.3		Subdivision 34.3.1.3
		34.3.2			Cape Verde Insular
		34.3.3			Sherbro
		34.3.4			Western Gulf of Guinea
		34.3.5			Central Gulf of Guinea
		34.3.6			Southern Gulf of Guinea
	34.4				Southern Oceanic
		34.4.1			Southwest Gulf of Guinea
		34.4.2			Southwest Oceanic
37					**Mediterranean and Black Sea**
	37.1				Western Mediterranean
		37.1.1			Balearic
		37.1.2			Gulf of Lions
		37.1.3			Sardinia
	37.2				Central Mediterranean
		37.2.1			Adriatic
		37.2.2			Ionian
	37.3				Eastern Mediterranean
		37.3.1			Aegean
		37.3.2			Levant
	37.4				Black Sea
		37.4.1			Marmara Sea
		37.4.2			Black Sea
		37.4.3			Azov Sea

FAO Major Areas



Annex 4: Fishing gear classification

Master Data Register (MDR) contains data structures and lists of fisheries codes to be used in electronic information recording and exchanges among Member States and for Member States' communications with Norway with the purpose to record and report fishing activities. The MDR website with data structure and all code lists are publicly accessible at the following link: https://ec.europa.eu/fisheries/cfp/control/codes/.

The current fishing gear classification system is based on the FAO International Standard Statistical Classification of Fishing Gear (ISSCFG) [27-29]. The ISSCFG classification has been readapted to respect the logics and formalisms of database structures. The three levels of classifications, Type, Sub-type, and Gear; are conceived to respect the FAO ISSCFG criteria.

Table 5 is designed to improve the compilation and collection of harmonized information, as well as to provide data correspondence with the FAO ISSCFG.

Table 5. Gear classification system used in the current WKING information collection. The classification is based on the FAO International Standard Statistical Classification of Fishing Gear (ISSCFG) and the classification in the Master Data Register repository (*Version 2.0, updated the 01/01/2019*).

Type	Sub-type	Gear	Description
P			**Surrounding nets**
	PS		**Purse-seines**
		PS1	One boat operated purse-seines
		PS2	Two boats operated purse-seines
	LA		**Surrounding nets without purse lines**
		LA1	Surrounding nets without purse lines *(Lampara)*
S			**Seine nets**
	SB		**Beach-seines**
		SB1	Beach-seines operated from the shore
	SV		**Boat seines**
		SDN	Danish seines
		SSC	Scottish seines
		SPR	Pair seines
T			**Trawls**
	BT		**Beam trawls**
		TBB	Beam trawls *(Tickler chain and Chain matrix beam trawls)*
		PUK	Electric beam trawls *(Pulse Beam)*
		PUL	Electric sumwing trawls *(Pulse Wing)*
	TB		**Bottom trawls**
		OTB	Single boat bottom otter trawls
		OTT	Twin bottom otter trawls
		OTP	Multiple bottom otter trawls
		TBN	Nephrops bottom otter trawls
		TBS	Shrimp bottom otter trawls
		PTB	Bottom pair trawls
	TM		**Midwater trawls**
		OTM	Single boat midwater otter trawls
		TMS	Midwater shrimp trawls

Type	Sub-type	Gear	Description
		TSP	Semipelagic trawls
		PTM	Midwater pair trawls
D		**Dredges**	
	DR		**Towed dredges**
		DRB	Boat dredges
		DRH	Hand dredges
		DRM	Mechanised dredges *(Hydraulic jet dredges)*
L		**Lift nets**	
	LN		**Lift nets**
		LNP	Portable lift nets
		LNB	Boat-operated lift nets
		LNS	Shore-operated stationary lift nets
F		**Falling gears**	
	FG		**Falling gears**
		FCN	Castnets
		FCO	Cover pots / lantern nets
G		**Gillnets and entangling nets**	
	GN		**Gillnets**
		GNS	Set gillnets (anchored)
		GND	Drift gillnets *(driftnets)*
		GNC	Encircling gillnets
		GNF	Fixed gillnets (on stakes)
	GT		**Entangling nets**
		GTR	Trammel nets
	GC		**Combined nets**
		GTN	Combined gillnets-trammel nets
R		**Traps**	
	FT		**Large stationary nets or barrages**
		FPN	Stationary uncovered poundnets
		FWR	Barriers, fences, weirs, etc.
		FAR	Aerial traps
		FYK	Fykenets
		FSN	Stow nets
O		**Pots**	
	FP		**Pots**
		FPO	Pots *(single or in strings)*
H		**Hooks and lines**	
	LH		**Pole and lines**
		LHP	Handlines and hand-operated pole-and-lines
		LHM	Mechanized lines and pole-and-lines
		LTL	Trolling lines
	LL		**Longlines**
		LLS	Set longlines
		LLD	Drifting longlines
	LV		**Vertical lines**
		LVT	Vertical lines

Type	Sub-type	Gear	Description
M			**Miscellaneous gears**
	MH		**Hand operated gears**
		HAR	Harpoons
		MHI	Hand implements *(Wrenching gear, Clamps, Tongs, Rakes, Spears)*
		MPN	Pushnets
		MSP	Scoopnets
		MDV	Diving
		MDR	Drive-in nets
	MM		**Mechanized gears**
		MPM	Pumps
		MEL	Electric fishing
		HMX	Harvesting machines
	RG		**Recreational fishing gears**
		RG1	Recreational fishing gears
N			**Gears unknown or not specified**
	NK		**Gears unknown or not specified**
		NKK	Gears unknown
		NKS	Gears not specified

Annex 5: Review of the ICES Workshop on Innovative Fishing Gears (WKING) 2020 Report

Consensus Summary

The three external reviewers met to discuss the draft WKING report on October 8, 2020. We recognized that the report as presented is a remarkable achievement under the difficult circumstances of a global pandemic and a short time frame. A unanimous consensus was reached finding that the report, as currently constituted, did not fully meet the Terms of Reference or Task as described and needs improving before serving as the basis for advice from ICES.

We unanimously agreed that the definition of innovation was not part of the task of the group and did not substantially contribute to the report, and that the reported definition of innovative gear did not adequately capture the intent of the task by not being restricted to gears *in use*. We recommend that the definition be revised to more closely meet the Terms of Reference and Task. To meet the Terms of Reference and Task, the definition should be simplified to assess the variation in gear characteristics within each European basin and to determine which gears in use are different enough to be defined as innovative.

We unanimously agreed that the suite of criteria developed for objective assessment of innovative gear was not objective in nature and were broader than the scope of the Terms of Reference. We recommend the criteria should be revised and be made more objective, with more quantitative criteria consistent with performance metrics mentioned in the report capturing differences in target catch, bycatch, and ecosystem impact between innovative and baseline gears.

The reviewers differed in their opinions of the Technical Readiness Levels, but unanimously felt that it was not objectively applied or transparent. We recommend either a more objective approach fully employing the technique, or applying a strictly quantitative approach using performance metrics and standards.

We unanimously agreed that the IDEFO modelling approach provided unclear utility to the process of defining innovative gears and for assessing innovative gears and should be reconsidered and perhaps deleted from the report.

We unanimously agreed that the Catalogue of Innovative Gears was a substantial achievement but was both insufficiently comprehensive as a global catalogue, and also inappropriately broad by including gears outside the area of interest (e.g. Australia, Japan, Chile), which biased the summary statistics in section 7. Further, it did not appear to meet the intent of the Terms of Reference or Task, which requested a Catalogue of Innovative Gears *in use* in European waters. We recommend that the Catalogue should be revised to meet the Terms of Reference of gears in use in European waters.

In sum, it was our opinion that, based on our understanding of the Terms of Reference and the Task, that insufficient appropriate information was provided in the report to form the basis of advice by ICES. We recommend that ICES and WKING confirm mutual agreement of the tasks to be accomplished and the Terms of Reference and that WKING reconvene with additional time for the purposes of revisiting and meeting the Terms of Reference.

Individual reviews are provided below. They were developed independently prior to group discussion and consequently reiterate the unanimous conclusions as well as providing individual concerns and observations.

Reviewer: Dr. Noëlle Yochum, NOAA Alaska Fisheries Science Center, United States

In the ICES Scientific Report ICES Workshop on Innovative Fishing Gears the collaborative group of authors were tasked with providing advice on the "progress that has been made, or impact arising from innovative gears within EU waters". They provided an in-depth definition of "innovation" and how it can be measured. Also provided were examples of innovative fishing gear at various stages of development and an assessment of those innovations based on the evaluation criteria described in the report.

I commend the group for attempting to put objective terms and assessment metrics on such a broad and subjective concept. I also acknowledge that the amassed list of innovative gears is useful, and the authors provide an assessment of the benefits and potential negative impacts of those innovations. While technically correct, the scope and depth of the report could more fully address the request based on my interpretation of the stated objectives. In the following review, I suggest ways that the report (and future iterations of this report) could be improved for increased utility, noting that the views and opinions expressed herein do not necessarily reflect those of NOAA or the US Department of Commerce.

In general, I inferred that the focus of the report was to establish a baseline inventory and assessment of innovative gears being used in EU waters from which to track progress and impact over time and relative to changes in the fisheries. The report, however, seemed to focus largely on defining "innovation" and describing innovative gear being developed. Building on what was accomplished in the Catalogue of Innovative Gear (hereafter "Catalogue"; Section 6), I think it would improve the reach of the report to put more focus on collecting additional information on innovative gear being developed or used in EU waters (e.g., from Discardless, http://www.discardless.eu/selectivity_manual; Seafish, https://www.seafish.org; and Gearing Up Project, https://gearingup.eu), then categorizing and evaluating the innovative gear based on the fishery type, the aim of the innovation (e.g., separating flat from round fish), the mechanism (e.g., sorting grid), whether the innovation was previously used in a different region or fishery type (e.g., the biodegradable twine described in the Catalogue) or builds on an older design, what phase those innovative gears are in (inception to adoption in the fishery), and what impact it has or could make in the fishery (both positive and negative). These metrics are objective and can be tracked over time (e.g., evaluating changes in the proportion of innovative gears that are newly imagined compared to newly adopted). They could be used to identify from where innovation is primarily originating (e.g., building off old ideas), where and to what extent progress is being made, and impact relative to uptake and use in fisheries. This organization of data could also provide a database from which to seek out ideas that could be extrapolated to fisheries facing similar challenges, and the analyses would be less subjective than the evaluation criteria provided in the report.

I also suggest that the report would benefit from more context in regard to the objective of the assessment of innovative gear and from more clearly defining terminology. Foremost, the term "innovative gear" needs to be further defined. Based on the evaluation criteria, I infer that the focus of this assessment was gear innovations to affect selectivity. However, in the examples provided in the report, "innovative gear" includes that which removes invasive species, addresses derelict gear, mitigates depredation, or increases fuel efficiency. Without putting bounds on how "gear" is defined, it affects the applicability of the evaluation criteria (e.g., it is difficult to evaluate a gear based on selectivity if its aim is to increase fuel efficiency). The geographic bounds of the study similarly could be clearer. With a focus on EU fisheries, examples from outside that geographic area (e.g., Australia, Chile, Japan) that do not directly link with European fisheries confused the focus of and analyses in the report. Moreover, the aim of evaluating the innovative gear was not clear, which made it challenging to understand the meaning of the evaluation criteria. Specifically, more explanation is needed about the end goal in order to translate the "scores". For example, what does it mean practically to have a "low" score? Is the implication that the innovator should stop, that funders should not invest, or that it should not be used? Along those lines, is the pinnacle of the innovation process voluntary uptake by the fishing industry, or are the metrics used to inform regulatory changes? The aim is not clearly explained. For example, the authors state that the "TRLs help management mak[e] decisions concerning the development and transitioning of technology" and that a "high" score indicates candidacy for "speedy adoption", and gear "readiness" is discussed. However, the relationship between the evaluation criteria and next steps is unclear. It would be helpful to further define these objectives and terms to have an understanding for the overarching objective of innovating. Along those lines, it should be mentioned that even if an innovative gear is attempted, but fails to be implemented, that innovation can serve a purpose by catalyzing other, more effective ideas.

For the evaluation criteria, while the authors present a thorough and compelling description of how "innovation" is measured in other fields, rather than to describe those other applications, it would have been beneficial to borrow those concepts to create a novel assessment process specific to fishing gear. As described in the report, the evaluation process is not clear and it is not immediately evident how the various assessment metrics fit together or are prioritized. Along those lines, the way the criteria are presented in the Technology Readiness x Performance matrix implies that technological readiness is a fixed category rather than a dynamic continuum.

My final general remark is to highlight a noticeably absent discussion point: the role of the fishing industry. It is my assumption that the majority of the innovative gear described and considered originated from scientists. I think the report would benefit from a discussion about innovation stemming from the fishing industry and how that has or has not changed over time and in response to changes in the fishery. Along those lines, two evaluation criteria that seemed to be missing were the ability to integrate new innovative gear into fishing operations and buy in from the fishing industry. For example, a highly selective and efficient gear would not likely get traction with the fishing industry if it was cost prohibitive or impeded fishing operations. Using the terminology of the report, perhaps "TRL10" could be included as a final "uptake" stage with respect to logistic feasibility and validation from industry.

I acknowledge that the WKING report was compiled over a short time frame and that the aim is for the Workshop to continue the discussion of innovative gear over time. The aim of my comments are therefore to highlight areas that need more clarity and to suggest ways to more fully address the objective of assessing the progress that has been made and the impact arising from innovative gears used in EU fisheries. I conclude with a list, below, of minor editing suggestions.

- I suggest increasing the font size for Figure 3.
- From section 4.3.2.2 (*Bycatch*), it would be beneficial to have a separate section to discuss bycatch mortality discretely.
- Increased fuel usage when using a new gear type (e.g., due to heavier gear, increased tension, etc.) could be included in section 4.3.3 (*Impact on marine ecosystems*).
- In section 4.3.3.2 (*Gear loss, ghost fishing and marine plastic pollution*), there is no specific detail provided for marine plastic pollution. Moreover, this section could be

combined with "Additional Criteria", changing the heading to *Gear loss, ghost fishing, marine plastic pollution, and energy consumption.*

- Seabirds could be included in section 4.3.3.3 (*Impact on endangered, threatened, and protected species*).
- For terms related to the evaluation criteria (e.g., minimal, medium, significant complexity), it would be useful to provide examples to demonstrate differences.
- The assessment information provided in Figures 9 and 10 should be included for the individual gears described in the Catalogue.
- It is not clear to me what is being captured in Figures 9 and 10, nor how 7.2.1, 7.2.2, and 7.2.3 differ in practice.
- More clarity is needed in the definition of the following terms: "technology" (from TRL; is this meant to be synonymous with "gear"?); "smart fishing technology (section 4.4); "failures" (section 4.1); "adoption" (section 4.7); and "system complete and qualified" (section 7.1).
- For sentence "The evidence that fishing gears may injure marine organisms that are not captured and at least locally reduce habitat complexity and cause reduced biodiversity has appeared in various media with increasing frequency" (section 4.1), I suggest replacing the final "and" with "and/or" or "may".
- For sentence "All species encountering a fishing gear suffer from some type impact. However, the level of impact can vary from just being scared or forced to swimming to their death" (from 4.3.2.2), I suggest replacing anthropomorphized and more charged language.
- I suggest removing the generalization that "All fishing activities have certain negative impacts on the marine ecosystem" (section 4.3.3).

Reviewer: Dr. Paul Winger, Fisheries and Marine Institute, Canada

Is it technically correct?

The authors are commended for tackling a difficult task. They have prepared a document that is well written and easy to read. It wrestles with difficult concepts like 'innovation' and 'bycatch', both of which have varying and competing definitions within the literature. The list of authors is exhaustive. The resulting document cites numerous scientific studies across multiple disciplines. They develop a framework to assess innovation based on three criteria of assessment, namely catch efficiency, selectivity, and ecosystem impact. They then proceed to score fishing gears based on their technological complexity and technological readiness.

Is the scope and depth of the science appropriate to the request?

It appears the authors have decided not to produce a catalogue of all known fishing gear innovations, but have instead elected to provide examples across different EU basins. Somewhat curiously, there are several examples from Australia and Japan included in the catalogue. These non-EU fishing gears are then included in the summary statistics (section 7), which produces a bias in the results and would make it difficult to measure progress over time.

Does it answer the request?

Yes, the authors have developed a scoring system (TRL, complexity, and performance) for each gear for each CA. However, the scoring system is rather coarse (e.g., low, medium and high) and the process by which the scoring was conducted is not transparent. It appears to have fallen to the subjective opinions of a few "core group" fisheries scientists. How they assessed complexity and readiness is currently missing and could have been more objectively described in the report.

Yes, they developed a catalogue of fishing gears (section 6). The factsheets are well laid-out and easy to interpret. However, it is not clear why only examples are used, and why these particular 42 examples were chosen? If a more complete database of EU fishing gears does exist, where is it? The authors do not provide citations or url's for the reader. On this metric, it appears the authors have not adequately completed the terms of reference. A robust catalogue of innovative fishing gears used in the EU has not been provided.

Yes, the authors provide a report and document their process for defining innovation and scoring various example fishing gears. The scoring however appears to be coarse (low, medium, high) and the process for determining these grades appears to have fallen to the subjective discretion of a few people. How a fishing gear was determined to be "transformative" with "significant" complexity and "moderate" readiness is not clear.

The section on modelling innovative fishing gears (section 5) is rather curious. It appears to jump-out in a disjointed manner, not fitting with the rest of the document. It appears the authors want to highlight the potential to conduct a desktop modelling exercise. They do not actually implement the modelling approach. It is not mentioned in the Executive summary, and is not mentioned in the request from EU-DGMARE - for these reasons it seems a little unclear why it is included in the report.

Minor issues:

- Where are figures 6-8? They appear to be missing.

Reviewer: Dr. Mike Pol, Principal, katpol consulting, United States

Reviewers were tasked with technical review of the scientific findings and results presented in the Report of the Workshop on Innovative Fishing Gears (WKING). Specifically,

1. Is it technically correct;
2. Is the scope and depth of the science appropriate to the request, and;
3. Does it answer the request;

Question 3 will be dealt with first, as it seems to be of the highest priority.

The Official Terms of Reference (p.4) of WKING recognizes that the DG-MARE request for ICES advice should describe "progress and impact that has been made in innovative gears used within EU waters". The information requested is further defined in the first paragraph of Tasks and EU DG-MARE request (p.5) as "what kind of innovative gears are being used, their objective, their technical specificities, and the impact on both target species, non-target species and the environment". The task is further detailed in subsequent paragraphs, and includes bullet points of tasks for the workshop, the first of which is "Types of innovative gears being used."

It is further noted that the mandated report by the European Commission to the European Parliament (p.7-8) appears intended to capture progress and impacts of innovative gear as used. It is appreciated that the task of identifying "criterion and definition of "innovative fishing gear""

(Tasks and EU DG-MARE request, p. 5) is a difficult one. However, it appears an important context has not been recognized by WKING. That is, definitions of innovation and innovative fishing gear aside, the challenge of identifying "innovative gears…being used" within EU waters has been unmet (emphasis added).

Employing a plain reading of "in use" or "used" that means "deployed by fishermen in a commercial fishery", the task as outlined and the information provided in the WKING report are not matched. It is not questioned that the report identifies a substantial number of remarkable and innovative gear and ideas. However, it appears that nearly all of them have not been taken up to any degree by fishing fleets. Therefore, they are not "being used" and therefore have not had impact of interest to managers capturing progress towards the defined objectives, or inferior performance when compared to the "baseline standards" (p. 7).

Indeed, the second step of the process (p. 5) implies the need for the gear to be in use by fishermen by identifying industry stakeholders including the Advisory Councils as relevant sources of information.

In that light, the definition of "innovative gear" provided at 4.2.3 (p.15) appears unsuitable for the Task, as it includes gears that have "not been used". With the redaction of that phrase, the definition appears consistent with the ToRs and Task.

Criteria to define innovative gear were identified, but I did not find how they might be applied objectively. The technical readiness levels described and offered in this regard, while intriguing and potentially useful in other arenas, appear inherently subjective and difficult to apply in a consistent and even manner for the purpose of defining innovative gears. The utility of the IDEFO method was not clearly justified.

Aside from concerns over meeting the task, I find that the sections on Criteria of Assessment (4.3, p.16) and the Catalogue of Innovative gears are technically correct, and provide scope and depth appropriate to the science. The section on Impact on marine ecosystems could be more developed in terms of recognizing resilience as a potential criterion for assessment of impact.

The report includes acknowledgement that the catalogue of innovative gears is limited in scope. Nevertheless, the Catalogue provides an impressive set of creative gears under varying stages of development, and illustrates a broad diversity of invention.

I would like to recognize that the report as presented is a remarkable achievement under the difficult circumstances of a global pandemic and a short time frame.

Response from Advice Drafting Group

The Advice Drafting Group prepared responses to a number of the reviewer comments when drafting the advice. These comments and decisions can be found in Annex 6.

Annex 6: Explanation on how the ADGING has addressed the main comments by the reviewers. All decisions are based on consensus of all ADGING members.

Comment: The definition of innovative gear should be simplified to assess the variation in gear characteristics within each European basin and to determine which gears in use are different enough to be defined as innovative.

Decision: modify the definition of innovative gear proposed by WKING by removing the phrase 'that has not been used commercially'.

Comment: The suite of criteria developed for objective assessment of innovative gear was not objective in nature. The criteria should be revised and made more objective, with more quantitative criteria consistent with performance metrics mentioned in the report capturing differences in target catch, bycatch, and ecosystem impact between innovative and baseline gears.

Decision: the advice should be based on the work done by WKING and proposed suggestions be considered in future work of ICES. It was also agreed that the methodology can always be improved by making the evaluation criteria more objective.

Comment: Develop either a more objective approach fully employing the technique for Technical Readiness Level, or applying a strictly quantitative approach using performance metrics and standards.

Decision: WKING did not have the time and resources to include a more rigorous assessment approach. It was agreed to keep the analysis/results as done by WKING, but add an explanatory statement with a suggestion for further improving the methodology.

Comment: The catalogue of innovative gears is insufficiently comprehensive as a global catalogue and inappropriately broad. Catalogue to be revised to meet the Terms of Reference of gears in use in European waters.

Decision: Doing a full and comprehensive review of all gear innovations in the EU requires substantial resources and this was not feasible under the present circumstances. It is stated in the advice, that the catalogue is preliminary and indicative on gear innovations in the EU. It was agreed the advice to include information for the EU waters only.

Comment: IDEF0 modelling approach should be reconsidered and perhaps deleted.

Decision: Not to include IDEF0 modeling results into the advice, given they are preliminary.

Annex 7: Innovation evaluation. Scoring matrixes, and reviewed statistics

A basic evaluation of each identified innovative gear was performed to estimate for each Criterion of Assessment (e.g., selectivity, catch efficiency, and environmental impact) the potential performance gain and the technology complexity.

After the factsheets collection and final catalogue compilation, all the WKING experts were requested to score all the factsheets according to the grading systems below reported Table 6. With levels of Complexity varying from Significant, Medium, to Minimal; and Performance improvement from Disruptive, Transformative, to Incremental. For the Performance scoring, the level “No effect or negative effect” was not found in any factsheet collected.

A total of 13 scoring matrixes were received from the experts. A new revised summary of the result statistics are presented in Table 7-Table 10. Figure 11 and Figure 12 show the distribution of the innovations across the three CAs and includes a breakdown by performance impact rating and level of technical complexity, respectively.

This analysis replaces the Summary statistics and the Innovation matrixes reported in section 7. Innovation evaluation.

Table 6. Scoring assigned to the three categorical levels of technical Complexity and performance improvement.

Complexity	Value
Significant	3
Medium	2
Minimal	1
Performance	**Value**
Disruptive	3
Transformative	2
Incremental	1
No effect or negative	0 / -1

Table 7. Number of scoring evaluations for each factsheet collected by the WKING experts. Complexity: levels of technological complexity; Catch: catch efficiency; Selectivity: size- and species-selectivity; Impact: impact on marine ecosystems). The Ref. column refers to the factsheet number reported in the report. NS: North Sea; NWW: North Western Waters; SWW: South Western Waters; BS: Baltic Sea; Med: Mediterranean Sea. For the 9 gear innovations beyond EU, which are potentially relevant for EU fisheries, the area of origin is reported in parenthesis (Nor: Norwegian and Barents Sea; Aus: Australia; Chi: Chile; Jap: Japan).

					Performance improvement Criteria of Assessment		
No.	**Ref.**	**Area**	**Innovation**	**Complexity**	**Catch**	**Selectivity**	**Impact**
1	6.1.1	NS	FlexSelect	13	13	13	2
2	6.1.2	NS	Brown shrimp sorting grid	13	4	13	2
3	6.1.3	NS	Netgrid	13	4	13	3
4	6.1.4	NS	SepNep	13	3	13	2
5	6.1.5	NS	Combination grid	13	4	13	3
6	6.1.6	NS	Grid and double-codend	13	4	13	2
7	6.1.7	NS	Shrimp pulse	13	3	13	11
8	6.1.8	NS	Flying drone	13	10	11	1
9	6.1.9	NS	PingMe	13	-	-	13
10	6.1.10	NS(Nor)	Four-panel grid	13	-	11	1
11	6.1.11	NS(Nor)	Species separation	13	9	11	1
12	6.2.1	NWW	Controllable doors	13	7	2	12
13	6.2.2	NWW	Floating sweeps	13	1	12	6
14	6.2.3	NWW	Scaring ropes	13	1	11	-
15	6.2.4	NWW	Electro-razor	13	2	11	13
16	6.2.5	NWW	Echo-sensor detector	13	9	5	6
17	6.2.6	NWW	Flemish panel	13	2	11	1
18	6.2.7	NWW(Aus)	Kon's covered fisheye	13	3	12	2
19	6.3.1	SWW	Crustacean BRDs	13	7	13	1
20	6.3.2	SWW(Aus)	Magnetic deterrent	13	10	6	8
21	6.3.3	SWW(Aus)	Soft brush groundgear	13	1	2	13
22	6.3.4	SWW(Chi)	Biodegradable twines	13	-	-	12
23	6.3.5	SWW	Hookpod	13	2	2	11
24	6.4.1	BS	Mini Danish seine	13	9	-	5
25	6.4.2	BS	Pontoon trap	13	4	3	12
26	6.4.3	BS	Pearl-nets	13	1	-	13
27	6.4.4	BS	Nemos+Roofless	13	2	13	2
28	6.4.5	BS	Alternative pots	13	1	10	12
29	6.4.6	BS	ADD	13	5	-	13
30	6.4.7	BS	Boat seine	13	1	-	10
31	6.5.1	Med	Dual codend	13	9	12	2
32	6.5.2	Med	Semi-pelagic doors	13	5	1	13
33	6.5.3	Med	Recycled plastic doors	13	-	-	11
34	6.5.4	Med(Aus)	Batwing doors	13	2	1	11
35	6.5.5	Med	High-strength materials	13	3	8	7
36	6.5.6	Med	Flex-TED	13	2	2	12
37	6.5.7	Med	Guardian-net	13	1	12	9
38	6.5.8	Med	Detached groundgear	13	1	6	8
39	6.5.9	Med	JTED	13	2	12	2
40	6.5.10	Med(Aus)	Seabird mitigation device	13	-	2	12
41	6.5.11	Med	Lionfish trap	13	-	2	12
42	6.5.12	Med(Jap)	Surf-BRD panel	13	1	10	2

Table 8. Sum of scorings for each Innovative gear received from the WKING experts. Complexity: levels of technological complexity; Catch: catch efficiency; Selectivity: size- and species-selectivity; Impact: impact on marine ecosystems). The Ref. column refers to the factsheet number reported in the report. NS: North Sea; NWW: North Western Waters; SWW: South Western Waters; BS: Baltic Sea; Med: Mediterranean Sea. For the 9 gear innovations beyond

EU, which are potentially relevant for EU fisheries, the area of origin is reported in parenthesis (Nor: Norwegian and Barents Sea; Aus: Australia; Chi: Chile; Jap: Japan).

					Performance improvement Criteria of Assessment		
No.	**ID**	**Area**	**Innovation**	**Complexity**	**Catch**	**Selectivity**	**Impact**
1	6.1.1	NS	FlexSelect	19	24	28	3
2	6.1.2	NS	Brown shrimp sorting grid	23	6	26	2
3	6.1.3	NS	Netgrid	25	9	30	4
4	6.1.4	NS	SepNep	27	6	26	3
5	6.1.5	NS	Combination grid	25	8	25	4
6	6.1.6	NS	Grid and double-codend	26	7	26	4
7	6.1.7	NS	Shrimp pulse	37	5	31	28
8	6.1.8	NS	Flying drone	39	27	28	3
9	6.1.9	NS	PingMe	35	-	-	35
10	6.1.10	NS(Nor)	Four-panel grid	24	-	20	2
11	6.1.11	NS(Nor)	Species separation	24	19	24	2
12	6.2.1	NWW	Controllable doors	35	15	6	32
13	6.2.2	NWW	Floating sweeps	21	2	22	9
14	6.2.3	NWW	Scaring ropes	20	2	21	-
15	6.2.4	NWW	Electro-razor	32	4	26	34
16	6.2.5	NWW	Echo-sensor detector	34	25	10	12
17	6.2.6	NWW	Flemish panel	13	5	20	2
18	6.2.7	NWW(Aus)	Kon's covered fisheye	25	4	25	4
19	6.3.1	SWW	Crustacean BRDs	24	14	27	2
20	6.3.2	SWW(Aus)	Magnetic deterrent	24	18	11	17
21	6.3.3	SWW(Aus)	Soft brush groundgear	16	2	4	29
22	6.3.4	SWW(Chi)	Biodegradable twines	20	-	-	33
23	6.3.5	SWW	Hookpod	21	3	5	25
24	6.4.1	BS	Mini Danish seine	13	10	-	9
25	6.4.2	BS	Pontoon trap	33	4	3	25
26	6.4.3	BS	Pearl-nets	34	1	-	35
27	6.4.4	BS	Nemos+Roofless	26	5	26	5
28	6.4.5	BS	Alternative pots	14	1	18	25
29	6.4.6	BS	ADD	32	9	-	32
30	6.4.7	BS	Boat seine	14	1	-	19
31	6.5.1	Med	Dual codend	25	18	23	5
32	6.5.2	Med	Semi-pelagic doors	32	10	2	35
33	6.5.3	Med	Recycled plastic doors	30	-	-	29
34	6.5.4	Med(Aus)	Batwing doors	32	3	2	29
35	6.5.5	Med	High-strength materials	21	5	15	13
36	6.5.6	Med	Flex-TED	24	4	5	34
37	6.5.7	Med	Guardian-net	13	3	20	18
38	6.5.8	Med	Detached groundgear	13	2	12	16
39	6.5.9	Med	JTED	23	3	23	5
40	6.5.10	Med(Aus)	Seabird mitigation device	17	-	5	26
41	6.5.11	Med	Lionfish trap	18	-	3	23
42	6.5.12	Med(Jap)	Surf-BRD panel	24	2	19	4

Table 9. Average and standard deviation (in parenthesis) of scorings for each Innovative gear received from the WKING experts. Complexity: levels of technological complexity; Catch: catch efficiency; Selectivity: size- and species-selectivity; Impact: impact on marine ecosystems). The Ref. column refers to the factsheet number reported in the report. NS: North Sea; NWW: North Western Waters; SWW: South Western Waters; BS: Baltic Sea; Med: Mediterra-nean Sea. For the 9 gear innovations beyond EU, which are potentially relevant for EU fisheries, the area of origin is reported in parenthesis (Nor: Norwegian and Barents Sea; Aus: Australia; Chi: Chile; Jap: Japan).

					Performance improvement Criteria of Assessment		
No.	ID	Area	Innovation	Complexity	Catch	Selectivity	Impact
1	6.1.1	NS	FlexSelect	1.5 (0.7)	1.8 (0.4)	2.2 (0.4)	1.5 (1.0)
2	6.1.2	NS	Brown shrimp sorting grid	1.8 (0.4)	1.5 (0.8)	2.0 (0.4)	1.0 (0.6)
3	6.1.3	NS	Netgrid	1.9 (0.3)	2.3 (1.3)	2.3 (0.5)	1.3 (0.8)
4	6.1.4	NS	SepNep	2.1 (0.5)	2.0 (1.0)	2.0 (0.0)	1.5 (1.0)
5	6.1.5	NS	Combination grid	1.9 (0.5)	2.0 (0.9)	1.9 (0.3)	1.3 (0.8)
6	6.1.6	NS	Grid and double-codend	2.0 (0.4)	1.8 (0.9)	2.0 (0.6)	2.0 (1.5)
7	6.1.7	NS	Shrimp pulse	2.8 (0.4)	1.7 (1.0)	2.4 (0.7)	2.5 (0.5)
8	6.1.8	NS	Flying drone	3.0 (0.0)	2.7 (0.5)	2.5 (0.7)	3.0 (2.1)
9	6.1.9	NS	PingMe	2.7 (0.5)	- (-)	- (-)	2.7 (0.5)
10	6.1.10	NS(Nor)	Four-panel grid	1.8 (0.6)	- (-)	1.8 (0.4)	2.0 (1.4)
11	6.1.11	NS(Nor)	Species separation	1.8 (0.6)	2.1 (0.3)	2.2 (0.4)	2.0 (1.4)
12	6.2.1	NWW	Controllable doors	2.7 (0.6)	2.1 (0.4)	3.0 (1.7)	2.7 (0.7)
13	6.2.2	NWW	Floating sweeps	1.6 (0.5)	2.0 (1.4)	1.8 (0.4)	1.5 (1.0)
14	6.2.3	NWW	Scaring ropes	1.5 (0.7)	2.0 (1.4)	1.9 (0.3)	- (-)
15	6.2.4	NWW	Electro-razor	2.5 (0.7)	2.0 (1.2)	2.4 (0.7)	2.6 (0.7)
16	6.2.5	NWW	Echo-sensor detector	2.6 (0.7)	2.8 (0.4)	2.0 (1.2)	2.0 (1.0)
17	6.2.6	NWW	Flemish panel	1.0 (0.0)	2.5 (1.5)	1.8 (0.4)	2.0 (1.4)
18	6.2.7	NWW(Aus)	Kon's covered fisheye	1.9 (0.5)	1.3 (0.8)	2.1 (0.3)	2.0 (1.2)
19	6.3.1	SWW	Crustacean BRDs	1.8 (0.4)	2.0 (0.0)	2.1 (0.5)	2.0 (1.4)
20	6.3.2	SWW(Aus)	Magnetic deterrent	1.8 (0.6)	1.8 (0.4)	1.8 (0.8)	2.1 (0.4)
21	6.3.3	SWW(Aus)	Soft brush groundgear	1.2 (0.4)	2.0 (1.4)	2.0 (1.2)	2.2 (0.6)
22	6.3.4	SWW(Chi)	Biodegradable twines	1.5 (0.7)	- (-)	- (-)	2.8 (0.6)
23	6.3.5	SWW	Hookpod	1.6 (0.7)	1.5 (1.0)	2.5 (1.5)	2.3 (0.5)
24	6.4.1	BS	Mini Danish seine	1.0 (0.0)	1.1 (0.3)	- (-)	1.8 (0.8)
25	6.4.2	BS	Pontoon trap	2.5 (0.8)	1.0 (0.4)	1.0 (0.5)	2.1 (0.3)
26	6.4.3	BS	Pearl-nets	2.6 (0.8)	1.0 (0.7)	- (-)	2.7 (0.5)
27	6.4.4	BS	Nemos+Roofless	2.0 (0.4)	2.5 (1.5)	2.0 (0.0)	2.5 (1.5)
28	6.4.5	BS	Alternative pots	1.1 (0.3)	1.0 (0.7)	1.8 (0.4)	2.1 (0.7)
29	6.4.6	BS	ADD	2.5 (0.8)	1.8 (0.4)	- (-)	2.5 (0.7)
30	6.4.7	BS	Boat seine	1.1 (0.3)	1.0 (0.7)	- (-)	1.9 (0.3)
31	6.5.1	Med	Dual codend	1.9 (0.3)	2.0 (0.0)	1.9 (0.3)	2.5 (1.5)
32	6.5.2	Med	Semi-pelagic doors	2.5 (0.8)	2.0 (0.0)	2.0 (1.4)	2.7 (0.5)
33	6.5.3	Med	Recycled plastic doors	2.3 (0.9)	- (-)	- (-)	2.6 (0.5)
34	6.5.4	Med(Aus)	Batwing doors	2.5 (0.7)	1.5 (1.0)	2.0 (1.4)	2.6 (0.5)
35	6.5.5	Med	High-strength materials	1.6 (0.5)	1.7 (1.0)	1.9 (0.4)	1.9 (1.2)
36	6.5.6	Med	Flex-TED	1.8 (0.6)	2.0 (1.2)	2.5 (1.5)	2.8 (0.4)
37	6.5.7	Med	Guardian-net	1.0 (0.0)	3.0 (2.1)	1.7 (0.8)	2.0 (0.0)
38	6.5.8	Med	Detached groundgear	1.0 (0.0)	2.0 (1.4)	2.0 (1.0)	2.0 (0.0)
39	6.5.9	Med	JTED	1.8 (0.4)	1.5 (1.0)	1.9 (0.3)	2.5 (1.5)
40	6.5.10	Med(Aus)	Seabird mitigation device	1.3 (0.6)	- (-)	2.5 (1.5)	2.2 (0.4)
41	6.5.11	Med	Lionfish trap	1.4 (0.8)	- (-)	1.5 (1.0)	1.9 (0.5)
42	6.5.12	Med(Jap)	Surf-BRD panel	1.8 (0.4)	2.0 (1.4)	1.9 (0.3)	2.0 (1.2)

Table 10. Final mean scorings for each Innovative gear received from the WKING experts. Complexity: levels of technological complexity; Catch: catch efficiency; Selectivity: size- and species-selectivity; Impact: impact on marine ecosystems). The Ref. column refers to the factsheet number reported in the report. NS: North Sea; NWW: North Western Waters; SWW: South Western Waters; BS: Baltic Sea; Med: Mediterranean Sea. For the 9 gear innovations beyond EU, which are potentially relevant for EU fisheries, the area of origin is reported in parenthesis (Nor: Norwegian and Barents Sea; Aus: Australia; Chi: Chile; Jap: Japan).

					Performance improvement Criteria of Assessment		
No.	**ID**	**Area**	**Innovation**	**Complexity**	**Catch**	**Selectivity**	**Impact**
1	6.1.1	NS	FlexSelect	1	2	2	2
2	6.1.2	NS	Brown shrimp sorting grid	2	2	2	1
3	6.1.3	NS	Netgrid	2	2	2	1
4	6.1.4	NS	SepNep	2	2	2	2
5	6.1.5	NS	Combination grid	2	2	2	1
6	6.1.6	NS	Grid and double-codend	2	2	2	2
7	6.1.7	NS	Shrimp pulse	3	2	2	3
8	6.1.8	NS	Flying drone	3	3	3	3
9	6.1.9	NS	PingMe	3	-	-	3
10	6.1.10	NS(Nor)	Four-panel grid	2	-	2	2
11	6.1.11	NS(Nor)	Species separation	2	2	2	2
12	6.2.1	NWW	Controllable doors	3	2	3	3
13	6.2.2	NWW	Floating sweeps	2	2	2	2
14	6.2.3	NWW	Scaring ropes	2	2	2	-
15	6.2.4	NWW	Electro-razor	2	2	2	3
16	6.2.5	NWW	Echo-sensor detector	3	3	2	2
17	6.2.6	NWW	Flemish panel	1	3	2	2
18	6.2.7	NWW(Aus)	Kon's covered fisheye	2	1	2	2
19	6.3.1	SWW	Crustacean BRDs	2	2	2	2
20	6.3.2	SWW(Aus)	Magnetic deterrent	2	2	2	2
21	6.3.3	SWW(Aus)	Soft brush groundgear	1	2	2	2
22	6.3.4	SWW(Chi)	Biodegradable twines	2	-	-	3
23	6.3.5	SWW	Hookpod	2	2	3	2
24	6.4.1	BS	Mini Danish seine	1	1	-	2
25	6.4.2	BS	Pontoon trap	3	1	1	2
26	6.4.3	BS	Pearl-nets	3	1	-	3
27	6.4.4	BS	Nemos+Roofless	2	3	2	3
28	6.4.5	BS	Alternative pots	1	1	2	2
29	6.4.6	BS	ADD	2	2	-	2
30	6.4.7	BS	Boat seine	1	1	-	2
31	6.5.1	Med	Dual codend	2	2	2	3
32	6.5.2	Med	Semi-pelagic doors	2	2	2	3
33	6.5.3	Med	Recycled plastic doors	2	-	-	3
34	6.5.4	Med(Aus)	Batwing doors	2	2	2	3
35	6.5.5	Med	High-strength materials	2	2	2	2
36	6.5.6	Med	Flex-TED	2	2	3	3
37	6.5.7	Med	Guardian-net	1	3	2	2
38	6.5.8	Med	Detached groundgear	1	2	2	2
39	6.5.9	Med	JTED	2	2	2	3
40	6.5.10	Med(Aus)	Seabird mitigation device	1	-	3	2
41	6.5.11	Med	Lionfish trap	1	-	2	2
42	6.5.12	Med(Jap)	Surf-BRD panel	2	2	2	2

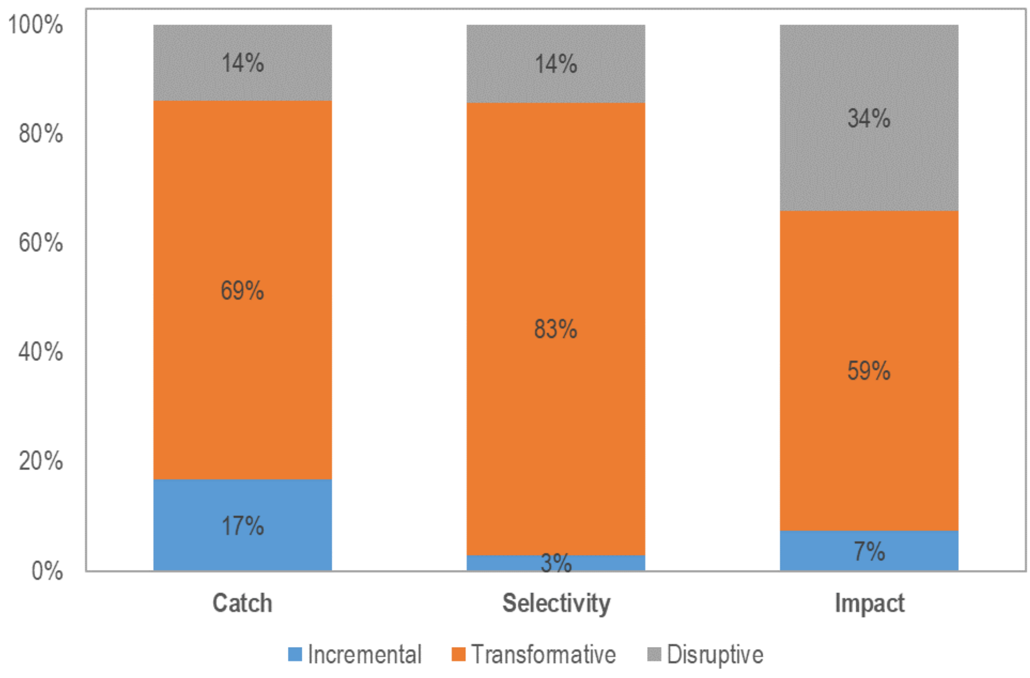


Figure 11. Breakdown of innovations captured by Criteria of Assessment (CA) and performance level (Incremental, Transformative, and Disruptive).

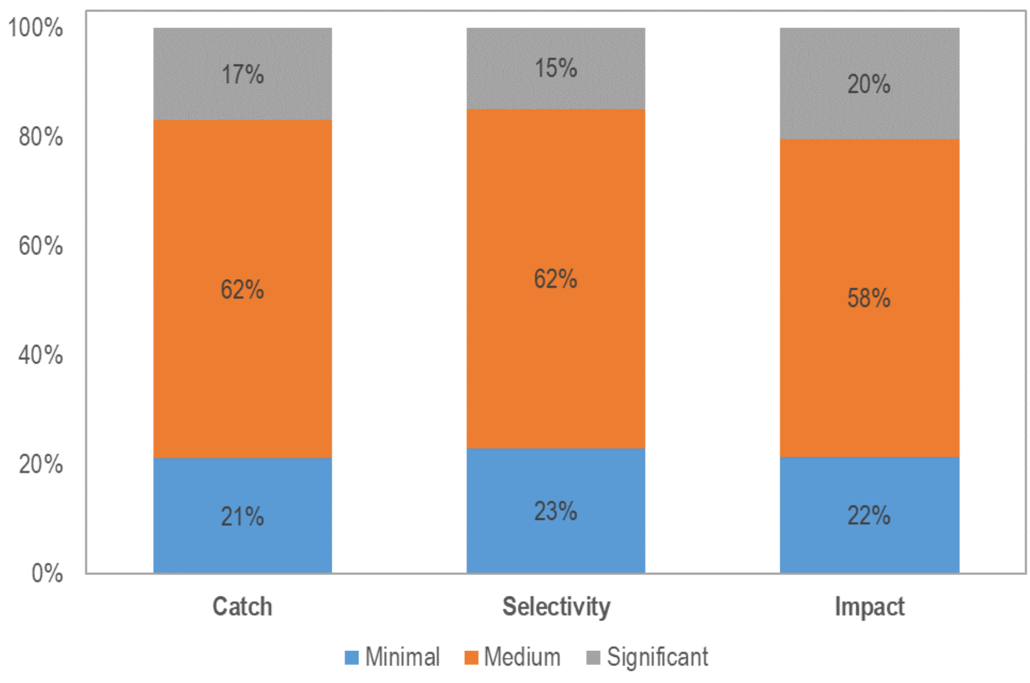


Figure 12. Breakdown of innovations captured by Criteria of Assessment (CA) and Level of technical complexity (Minimal, Medium, and Significant).

Catch efficiency

Performance		Low	Moderate	High
	Disruptive	-	Flying drone, Echo-sensor detector	Flemish panel, Nemos+Roofless, Guardian-nets
	Transformative	-	Controllable doors, Electro-razor, Crustacean BRDs, ADD	Floating sweeps, Scaring ropes, Hookpod, FlexSelect, Brown shrimp sorting grid, Netgrid, SepNet, Combination grid, Grid and double codend, Shrimp pulse, Dual codend, Semi-pelagic doors, High-strength materials, Flex-TED, Detached groundgear, JTED
	Incremental	-	Pontoon trap	Mini Danish seine, Pearl-nets, Alternative pots, Boat seine
	No effect or Negative	-	-	-
		Technological readiness level		

Selectivity

Performance				
Performance	**Disruptive**	-	Flying drone, Controllable door	Hookpod, Flex-TED
	Transformative	-	Electro-razor, Echo-sensor detector, Crustacean BRDs	FlexSelect, Brown shrimp sorting grid, Netgrid, SepNet, Combination grid, Grid and double codend, Shrimp pulse, Floating sweeps, Scaring ropes, Flemish panel, Nemos+Roofless, Alternative pots, Dual codend, Semi-pelagic doors, High-strength materials, Guardian-nets, Detached groundgear, JTED, Lionfish trap
	Incremental	-	Pontoon trap	-
	No effect or Negative	-	-	-
		Low	**Moderate**	**High**
		Technological readiness level		

Impact on marine ecosystems

Performance				
	Disruptive	Recycled plastic doors	Flying drone, PingMe, Controllable door, Electro-razor	Shrimp pulse, Pearl-nets, Nemos+Roofless, Dual codend, Semi-pelagic doors, Flex-TED, JTED
	Transformative	-	Echo-sensor detector, Crustacean BRDs, Pontoon trap, ADD	FlexSelect, SepNet, Grid and double codend, Floating sweeps, Flemish panel, Hookpod, Mini Danish seine, Alternative pots, Boat seine, High-strength materials, Guardian-nets, Detached groundgear, Lionfish trap
	Incremental	-	-	Brown shrimp sorting grid, Netgrid, Combination grid
	No effect or Negative	-	-	-
		Low	**Moderate**	**High**
		Technological readiness level		