Dsolve

Centre for Research-based innovation

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Biodegradable plastics for marine applications

Annual Report 2020

Photo: Erling Svensen

Contact
Centre Director
Roger B. Larsen
roger.larsen@uit.no
UiT The Arctic University of Norway

Administrator
Hanne Risan Johnsen
hanne.r.johnsen@uit.no
UiT The Arctic University of Norway

Content

Summary

Marine litter from non-degradable plastics end up as macro- and micro-plastic while lost and abandoned fishing gears can cause "ghost fishing", resulting in unaccounted mortality. The main working hypothesis of the SFI Dsolve is that the problems associated with marine plastic litter caused by the fishery and aquaculture sectors can be significantly reduced if traditional plastics in these sectors are replaced with new biodegradable materials.

The goal of this centre is to develop technologies and new products, improve the governance framework, and foster innovations that enable the plastic value chains to become more circular and resource efficient. This will reduce the carbon and greenhouse gas footprints to be more in line with the UN climate, energy, and sustainable development goals. The centre is designed to address the challenges described above.

The expected impact of this centre is to reduce plastic pollution in the marine environment, thereby reducing the effects of macro-, microplastics and ghost fishing caused by the fishing and aquaculture industries. The centre will lead to development of profitable and socially accepted circular business models to enhance market uptake and large-scale utilization of biodegradable plastics to replace materials derived from fossil fuels (oil). Moreover, the centre will optimise and/or validate waste sorting technologies and circular waste processing options (reuse, mechanical, chemical and organic recycling) for biodegradable materials.

Norwegian fisheries as of 2020

Our Centre focuses on marine litter and associated problems caused by marine fisheries. It is, however, important to place our SFI in the correct context. Harvesting living marine resources is a traditional way of living and an important and major industry today. Despite that less than 30.000 people are directly involved in the production in marine fisheries and aquaculture, fisheries are the second largest export industry. Fish produced in Norway meet the highest standards regarding product safety and protection of human resources.

The value creation in the Norwegian marine fish sector reached NOK 127 billion by 2020, whereof NOK 106 billion in export value. The marine fisheries and aquaculture production in Norway is regarded sustainable. Further expected growth in the Norwegian fisheries sector depends on continuation of a successful management inside a clean and healthy physical environment. SFI Dsolve - Centre for development of biodegradable plastic for marine applications in fisheries and aquaculture, will contribute to this national vision with international impact.

Globally, fishery and aquaculture industries represent a major source of plastics and marine litter at sea. Research and industrial development during the last decade have revealed the potential to develop special biodegradable materials to replace the conventional plastics commonly used in the marine sector, in particular those used by the fishing and aquaculture industries.

Vision and objectives

Vision:

Reduce plastic litter and associated problems (macro-, microplastics and ghost fishing) caused by the fishery and aquaculture industries.

Ambition:

Place Norway at the forefront of research, development, and use of smart biodegradable materials to reduce the global problem of marine litter from fisheries and aquaculture.

Photo: Fjellfrosk Media

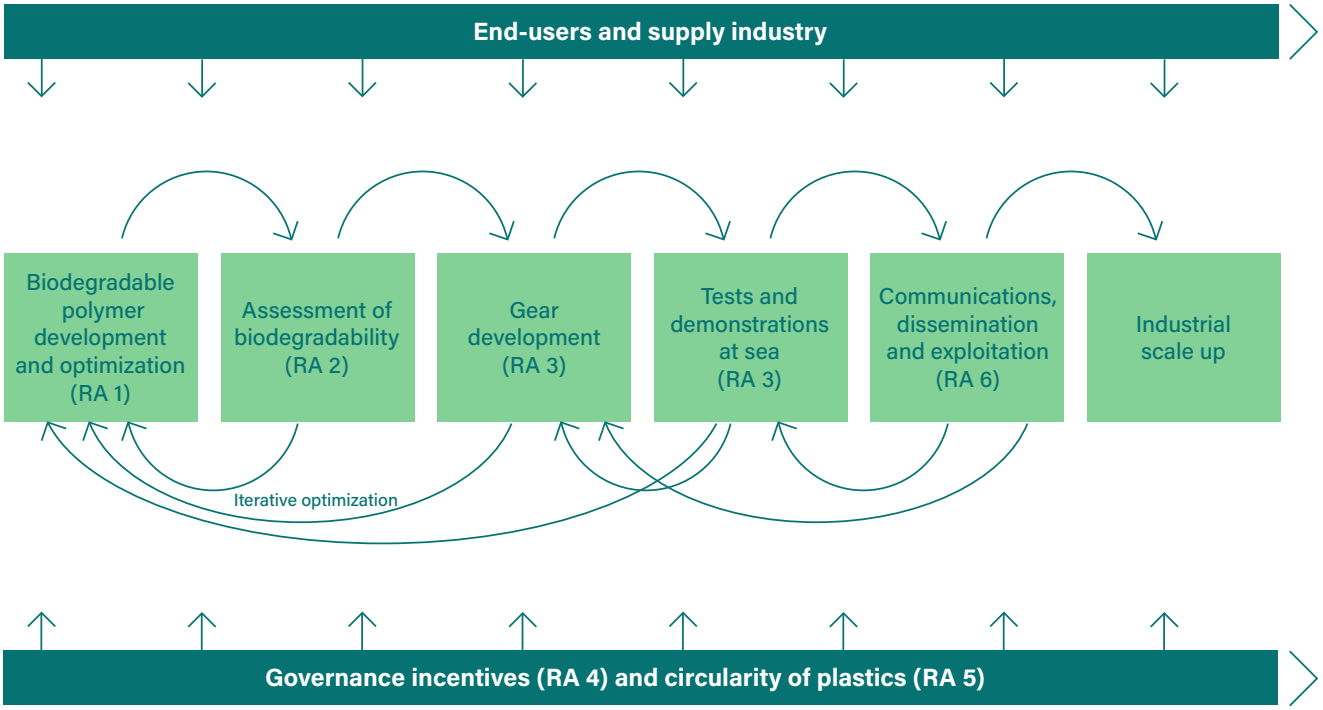
The **main objective of SFI Dsolve** is to reduce plastic litter and its associated problems such as macro-, microplastics and ghost fishing in the marine environment caused by fishing and aquaculture industries, by replacing the traditional plastics used in gears and gear components with new biodegradable materials. This primary objective will be achieved by the following **secondary objectives:**

- Develop new smart biodegradable polymers with controllable (non-linear) degradation in the marine environment.
- Develop biodegradable filaments, twines, ropes, and netting for fisheries and aquaculture purposes.
- Create governmental incentives and restrictions to incorporate biodegradable plastics in an ecosystem-based management approach.
- Help to establish a supplier industry that can deliver biodegradable gears and services to the end-user sectors (fisheries and aquaculture).
- Develop sustainable downstream solutions and LCA for biodegradable fishing gear.
- Optimize and validate waste sorting technologies and circular waste processing options for biodegradable materials.
- Educate at least 8 PhD candidates, 4 post docs, and 30 MSc candidates.

Research plan/strategy

SFI Dsolve aims to reduce plastic litter and associated problems such as ghost fishing, macro and microplastic, caused by fishing and aquaculture industries. The goal is that traditional plastics in these sectors can be replaced with new biodegradable materials. The **main research hypotheses** for the centre are:

- By replacing traditional non-degradable plastics with smart biodegradable and controllable ones, we can reduce marine litter caused by the fishing and aquaculture industries.
- By reducing ghost fishing and macro/microplastic pollution, value creation will increase in the fishing and aquaculture industries.
- By introducing effective incentives, the fisheries management can facilitate the use of biodegradable plastics in order to enhance the ecosystem-based management approach.
- New sustainable downstream solutions and LCA can facilitate the circularity of existing fossil-based non-degradable and biodegradable plastics.
- Dsolve will focus on six Research Areas that jointly address these hypotheses:



Conceptual structure of SFI Dsolve

Specific objectives for the Research Areas (RAs) are:

RA 1

Dr. Siw Fredriksen
Norner Research AS

Develop a range of biodegradable plastic materials with controlled biodegradability and the properties needed for products used in the fishing and aquaculture industries.

RA 2

Dr. Christian Karl
SINTEF Industry

Create a sustainable framework for testing biodegradability and environmental impact. Lab and field testing will be carried out in conditions representing different marine environmental factors, and marine biodegradation tested in different marine habitats and climate zones. Biodegradable and conventional tools will be compared.

RA 3

Prof. Bent Herrmann
SINTEF Ocean

Sea trials in the Norwegian, North, Baltic and Adriatic Seas including performance, catch pattern, and efficiency analyses of existing and new technology. Obtain data about the performance of biodegradable twines and ropes, the catch efficiency of nets, and how degradation varies in relation to different environmental conditions.

RA 4

Prof. Claire Armstrong
UiT Arctic Univ. of Norway

Assess the economic effects of non-biodegradable materials used in fisheries and aquaculture and evaluate costs and benefits on ecosystem services from introducing biodegradable materials in the marine industries. Further analyse institutional incentive mechanisms and assess public support systems to reduce risk and promote implementation of biodegradable innovations.

RA 5

Dr. Hanne Lerche
Raadal, NORSUS AS

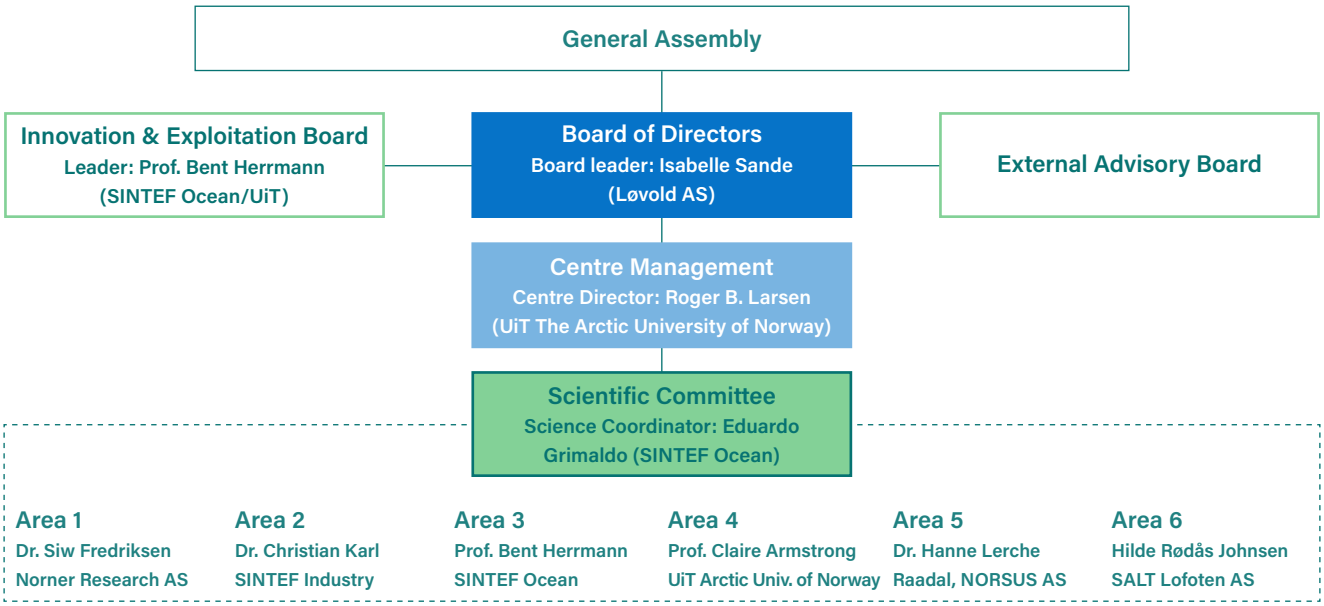
Develop sustainable circular solutions for existing non-degradable and future biodegradable fishing gear. The goal is to develop environmentally sustainable value chains which also take the level of circularity into account.

RA 6

Hilde Rødås Johnsen
UiT/SALT Lofoten AS

Develop and carry out a dynamic plan for outreach through communication, dissemination and exploitation of results in order to maximise the impact of the project results.

Organisation



Centre organisation

The centre is organized as shown in the figure above. The General Assembly, consisting of representatives from each partner, will have the uppermost decision-making power in the centre. The Centre Board of 11 members is chosen among the centre partners. All partners will be represented in the board for a minimum of two years of the centre lifespan. Research partners and the host institution (UiT) will have a permanent representation throughout the centre lifespan. The Centre Board will decide on organisation, budget, activities and working plans, and is responsible for the progress and scientific quality of the centre research activities.

Members of the Centre Board 2020 - 2022

ROLE	MEMBER OF CENTRE BOARD	AFFILIATION
Leader of the Board	Isabelle Sande	Løvold AS
Host Institution	Kathrine Tveiterås	UiT-BFE
Research Partners	Klaus Schöffel	Norner Research AS
	Hans Bjelland	SINTEF Ocean
	Einar Hinrichsen	SINTEF Industry
	Ellen-Marie Forsberg	NORSUS AS
Industry and organisations	Bent Gabrielsen	Øra AS
	Arne Birkeland	Opilio AS
	Lasse Rindahl	Mustad Autoline AS
	Terje Lindal	Mørenot AS
	Jan-Henrik Sandberg	Norges Fiskarlag
Observer	Inger Austrem	The Research Council of Norway

The Centre Board will be advised by the Innovation and Exploitation Board and the External Advisory Board. The Innovation and Exploitation Board is led by Professor Bent Herrmann, chief scientist at SINTEF Ocean. The External Advisory Board (EAB) is selected from experts in policy and bioeconomy, governance institutions, public organisations, and NGOs. The goal of the EAB will be to guarantee quality of the research and maximise its impact.

Partners

Host Institution

UiT – The Arctic University of Norway

National Research Partners

Norner Research AS

SINTEF Ocean

SINTEF Industry

NORSUS AS

International Research Partners

DTU-Aqua (Denmark)

Thünen Institute of Baltic Sea Fisheries (Germany)

University of Split (Croatia)

LG Chem (South Korea)

S-EnPol (South Korea)

National Industry partners - suppliers

Nofi Tromsø AS

Mørenot Fishery AS

Løvold AS

Mustad Autoline AS

National Industry partners - users

Øra AS (coastal gillnetting)

Tustern AS (demersal seining)

Hermes AS (demersal trawling)

Legøy Rederi AS (gillnetting)

Martin Solhaug (longlining)

Opilio AS (snowcrab potting)

Loran AS (mechanical longlining)

Kvarøy Fiskeoppdrett AS

Organisations

Norges Fiskarlag

Norges Råfisklag

External Advisory Board

Senter for Hav og Arktis

Miljødirektoratet

Fiskeridirektoratet

Fiskeri- og Havbruksnæringens Forskningsfinansiering (FHF)

Scientific activities and expected results

The activities of SFI Dsolve in 2020 have been focusing on consolidation of the centre and the establishment of administrative routines, including organisation, finalising the consortium agreement, and confirming partners and their contribution. The section below describes the status for the various research areas, plans and achievements in 2020, as a basis for future research and development within the centre and related projects. Each research area is described with a summary of the state of the art, research- and innovation questions, impact and goals, and the status of first year plans and achievements.

RA 1 Biodegradable polymer development and optimization

State of the art

Plastics are essential materials in most fishing gear as well as equipment used in aquaculture industry. The most common plastics used in fisheries and aquaculture are Nylon, Polypropylene (PP), Polyethylene (PE), and Polyethylene terephthalate (PET). These plastic materials have a long degradation time in marine environment. This means that gear and equipment lost at sea will remain in the environment for a long time and lead to marine littering and ghost fishing.

Photo: Fjellfrosk Media

Recently, biodegradable plastic alternatives, mainly polybutylene succinate (PBS), Polybutyrate adipate terephthalate (PBAT) and Polybutylene succinate co-adipate-co-terephthalate (PBSAT), have been explored in fishing gear and aquaculture industry. The research studies indicated that biodegradable gillnets have experienced 10-20% strength reduction due to degradation after one year in sea [1]. At the same time, the biodegradable gillnets have reported to be about 10-15% poorer in fishing efficiency than conventional gillnets [2],[3].

Research and innovation challenges

- Developing biodegradable plastic materials that are fit for processing and fit for applications in fishing gear and aquaculture equipment.
- Developing smart biodegradable plastic materials for fisheries that can degrade quickly once they have been lost in sea.
- Developing biodegradable plastic materials for fisheries with high fishing efficiency similar to conventional materials or higher.
- Developing the new materials design concepts for quick degradation in the marine environment after their service life.

Research questions

- What are bioplastics that are relevant to investigate in the project?
- Which modification concepts (additivation, blending, compatibilization) are beneficial for developing bioplastic materials that are fit for processing and applications in fisheries and aquaculture?
- What kind of enzymes can be utilized to modify the speed of biodegradation?
- Which surface coating approaches are utilized to speed-up or delay the degradation of bioplastics?
- What kind of new design concepts with variable surface and bulk material concepts can be utilized to achieve quick degradation of fishing gear after their service?

Impact and goals

RA 1 will develop a range of biodegradable plastic materials with the properties needed for products used in fishing gear and aquaculture industries (e.g., twines and netting, ropes, gillnets, pots and traps, foils and boxes, pipes, and connectors). The developed materials shall meet a range of processing and performance requirements, including tailored biodegradability. A range of modification concepts, such as additivation, blending and compatibilization shall be evaluated in the process of material development. In addition, new design concepts shall be evaluated in order to achieve materials with required performance and biodegradability. Finally, the materials will be verified through small-scale pilot studies.

First year plans

- Identify state-of-the-art material solutions for fisheries and aquaculture applications.
- Identify critical performance requirements of polymers for fishing gear applications.
- Sourcing and characterization of relevant bioplastic materials.
- Conduct desktop study to look into the state-of-the-art fiber processing methods and equipment.
- Identify potential biodegradable plastics that meet process and performance requirements for fiber applications.
- Identify methods for microplastics investigation and characterization methods.

First year achievement

- Restructuring the work package
- Updating work package plans
- Aligning with partners

References

[1] Su, B., et al., E, A comparative study of the mechanical properties of biodegradable PBSAT and PA gillnets in Norwegian coastal waters. OMAE2019-95350 2019.

[2] Grimaldo, E., et al., Comparison of fishing efficiency between biodegradable gillnets and conventional nylon gillnets. Fisheries Research, 2019. 213: p. 67-74.

[3] Grimaldo, E., et al., Effect of Using Biodegradable Gill Nets on the Catch Efficiency of Greenland Halibut. 2018. 10(6): p. 619-629.

RA 2 Assessment of biodegradability

State of the art

The introduction of synthetic fibres, such as those made of polyamide (PA6 or nylon), in the late 1950s was a technological improvement that increased fishing capacity and the economic viability of fisheries worldwide. Gillnets made from synthetic materials are durable and have high tensile strength. Unfortunately, it happens that they are lost, left behind and/or discarded in many important fishing areas. Impacts include ghost fishing, changes to the benthic environment, marine plastic pollution, hazards to shipping, beach litter/trash, introduction of synthetic material into the marine food web, a variety of costs associated with clean-up and impacts on business. The problem has become much more acute with the introduction of synthetic fibres and the subsequent increase in fishing activities. As a replacement for traditional nylon (PA) gillnets, biodegradable gillnets (e. g. PBSAT) that can be completely degraded by naturally occurring microorganisms in seawater have been increasingly discussed and researched in recent years. The catching efficiency of these nets made of biodegradable polymers is in some cases comparable to nets made of polyamide (PA), polyethylene (PE) and polypropylene (PP). Initial studies have shown that biodegradable nets have similar mechanical properties during fishing, but that they can be completely degraded in seawater if left in the marine environment. However, there is still a great need for research to improve the mechanical properties, fishing efficiency and biodegradability of these gillnets and other devices of interest for future applications. The SFI will work closely with academic and industrial partners to make biodegradable plastics commercially available and economically accessible to end users and to help the industry to develop sustainable innovations for the global market.

Photo: LG Chem

Research and innovation challenges

- Investigation of smart biodegradable polymers with a controllable (non-linear) degradation profile having stable mechanical properties during the period of use and rapid degradation, thereafter

- Analysis of the microbiological, UV, thermal, and chemical degradation and the degradation mechanisms in a long-term study

- Degradation of traditional and biodegradable polymers in seawater and sediments: quantification of microplastics produced during the degradation of polymers

Research questions

The key tasks of RA 2 are:
Task 2.1 Testing the marine biodegradation of gillnets and twines (PBSAT as test and PA as control) in situ in different marine habitats (seafloor, water column) in different climate zones (Skagerrak Sea, North Sea, Baltic Sea, Adriatic Sea, and Norwegian Sea) to cover a wide temperature range of 4 to 27°C and analysis of the samples.

Task 2.2 Test biodegradation in lab-based systems consisting of natural seawater and marine sediments and microbial biodegradation and microbiome analyses (PBSAT and PA as reference) as well as analysis of the materials after degradation.

Task 2.3 Assess the effects of UV radiation while modifying temperature, humidity, pollutants (and the combination of these factors) on the physical properties of PBSAT nets and twines (and PA controls).

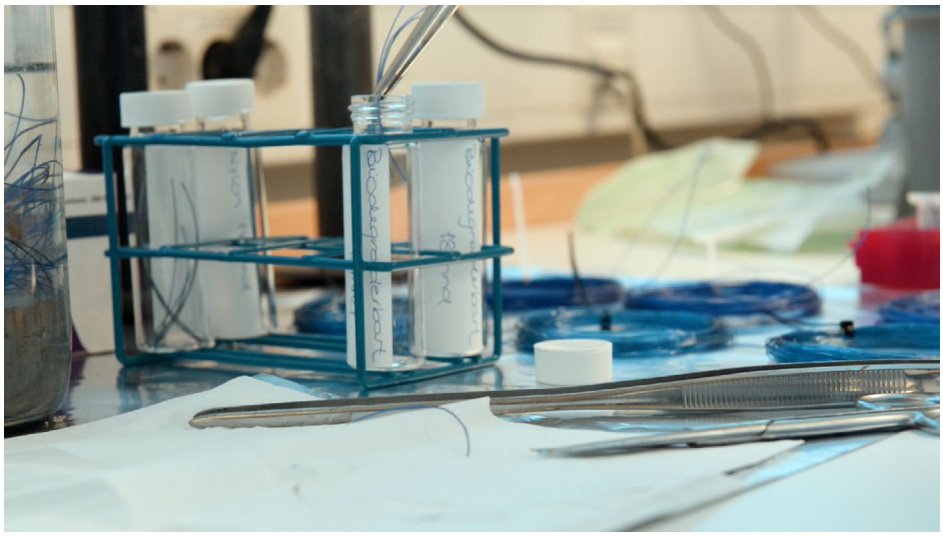


Photo: Zenteno

Impact and goals

RA 2 will create a framework for testing of biodegradability and environmental impacts. It is the aim to investigate modified and unmodified biodegradable polymers for fishing gear with the same or improved mechanical properties and fishing efficiency as the non-degradable plastics currently used by the fisheries and aquaculture industry to reduce plastic litter and its associated problems. The physical and chemical integrity and degradation of biodegradable and conventional

nets and twines will be evaluated in lab and field tests during an extended test period (5 years or full degradation). Accelerated weathering tests in the lab (especially influence of UV and temperature) will be compared with field tests. The planned activities addressing these goals are described in the work plan.

First year plans

- Literature overview about polymer degradation
- Developing a work plan (experimental plan) for further development in 2021
- Preparation of a job advertisement (PhD position) in collaboration with the UiT (Roger Larsen)
- Writing the content for the description of the work package and the degradation of polymers for the website of SFI Dsolve

First year achievement

- Conduct a literature study and identify important degradation processes and mechanisms of different polymers
- The work plan for 2021 was updated (aligning with partners)
- The experiments for the year 2021 have been developed within the end of 2020 and will be further developed in 2021.
- The job advertisement for a PhD position (start in 2021) has been written in cooperation with the UiT and published online on the Dsolve website and on JobbNorge.no/euraxess.no (The job offer was prolonged at the beginning of 2021).
- The content of RA 2 was published on the Dsolve website and the website was linked to existing research networks (ResearchGate, ORCID ID).

Related projects

POCOplast — Pathways to sustainable post-consumer plastics in aquaculture
In-No-Plastic: Innovative approaches towards prevention, removal and reuse of marine plastic litter

RA 3 Tests and demonstrations at sea

State of the art

Research and industrial development during the last decade have revealed the potential to develop special biodegradable materials to replace the conventional plastics commonly used in the marine sector, those used by the fishing and aquaculture industries. The use of such materials would help to reduce the amount of marine plastic litter and its associated effects (macro-/microplastics and ghost fishing) on the marine environment. Prototype testing of first-generation biodegradable materials shows promising results for application in fisheries and aquaculture worldwide. However, small-scale tests carried out in South Korea and Norway have revealed that further research and industrial development is necessary for the incorporation of biodegradable plastics in these ocean-based industries. Specifically, one major problem identified relates to the capture efficiency of fishing gears based on first-generation biodegradable materials, mainly gillnets, as results from comparable fishing (in Norway) have revealed challenges with capture efficiency for the gears based on the existing biodegradable materials in comparison to the efficiency of gears based on the traditional materials used by the fishing industry today.

Photo: Fjellfrosk Media

Research and innovation challenges

The main challenge will be related to the creation of new biodegradable gears (twines, ropes, nets, etc.) that have equal or improved mechanical properties and fish capture efficiency as the non-degradable plastics currently used by the fishing and aquaculture industries but based on new biodegradable plastic materials developed with a smarter degradation profile, meaning that they should have stable mechanical properties during service time and a rapid degradation thereafter.

Therefore, RA 3 will develop, test, validate, and optimize biodegradable gears for specific applications in fisheries and aquaculture. The industry will need robust and convincing results before production, sales, and practical use (fishing) on a large

scale can take place. We expect that identification of accurate needs, development of products, and testing (documentation) will take several years for each research area. Furthermore, a change from traditional to new smart biodegradable materials must include performance, catch pattern, and efficiency analyses (in the case of fishing gears) of existing and new technology. Sea trials will be conducted in Norway, Denmark, Germany and Croatia.

Research questions

The research questions for this RA are linked to the following key research and development tasks:

- Task 3.1: For gillnets (inshore and deep-sea gillnetting), find a combination of strength/elasticity and catchability that is comparable to or better than existing PA twines during multiple trials conducted on board commercial gillnet vessels.
- Task 3.2: Develop pots and traps based on biodegradable materials targeting brown crab, snow crab, red king crab, and lobster, including recreational pot fisheries.
- Task 3.3: Develop biodegradable ropes and components for coastal and deep sea longlines, because millions of nylon and polyester snoods are used every season and a large proportion of these get lost at sea.
- Task 3.4: Identify several possibilities for replacing PE, PA, and PES fibers with biodegradable fibres for use in twines, ropes, and netting (all fishing gears), as all fishing gears and aquaculture equipment are composed of a range of twines with various tensile strengths, abrasion resistance, twine surface area, etc.
- Task 3.5: Full-scale tests of dolly-ropes and chafing mats for use in demersal (bottom) trawling.
- Task 3.6: Develop an alternative to combination ropes (30–60 mm thick PE coating with steel-wire core) for demersal seining; while they help to herd fish, thus increasing catch efficiency, they lose almost half their mass as microplastics during their service time due to abrasion by the seabed.

Impact and goals

Testing in the Norwegian, North, Baltic, and Adriatic Seas will ensure that we obtain data about the performance of biodegradable twines and ropes, the catch efficiency of nets, and how degradation varies in relation to different environmental conditions. This will enable extrapolation to other fisheries and help to promote use of biodegradable fishing gears internationally. In Norway, sea trials will be conducted under commercial conditions on board fishing vessels. Catch comparison analysis will be based on comparing length size distributions of species caught and will be carried out using appropriate software and following published statistical methods and models. Catch quality will be assessed if needed. Assessing the extent of unaccounted for fishing mortality of gillnets and pots will be conducted by simulating lost gears in pre-defined and controlled areas. Full-scale testing will be conducted by building codends with dolly-ropes made of conventional PE rope and bio ropes. The codends will be fished simultaneously in a twin trawl setup and used by a trawler during an entire fishing season. Researchers will weigh the amount (and measure the length) of dolly-ropes in the codend before and after the fishing trials, and they will measure the length of the dolly-rope fibers monthly. In Denmark, Germany, and Croatia, a similar methodology will be used to evaluate catch efficiencies and gear degradation.

First year plans

- Developing a detailed work plan for activities in 2021
- Preparation of a job advertisement for the first PhD position linked to RA 3
- Writing the content for the description of the work package for the website of the SFI Dsolve
- Develop methodology for the analysis of capture mode data for gillnets and longlines.
- Conduct the first experiments associated with RA 3 in terms of gillnet experiments in Denmark.

First year achievement

- The work plan for 2021 was updated.
- The job advertisement for a PhD position (start in 2021) has been written and published online.
- The content of RA 3 was published on the Dsolve website and the website was linked to existing research networks (ResearchGate, ORCID ID).
- The method for analysis of capture mode data for gillnets and longlines was developed and implemented in the statistical analysis tool SELNET.
- First experiments associated to RA 3 in terms of gillnet experiments in Denmark was conducted and data regarding modes of capture was assessed for cod in traditional as nylon gillnets (Fig 1). Data analysis was initialized to obtain provisional quantification of fish size dependent relative contribution of each mode of capture (Fig. 2).

Figure 1. Capture modes for cod in traditional gillnet. Source: DTU Aqua.

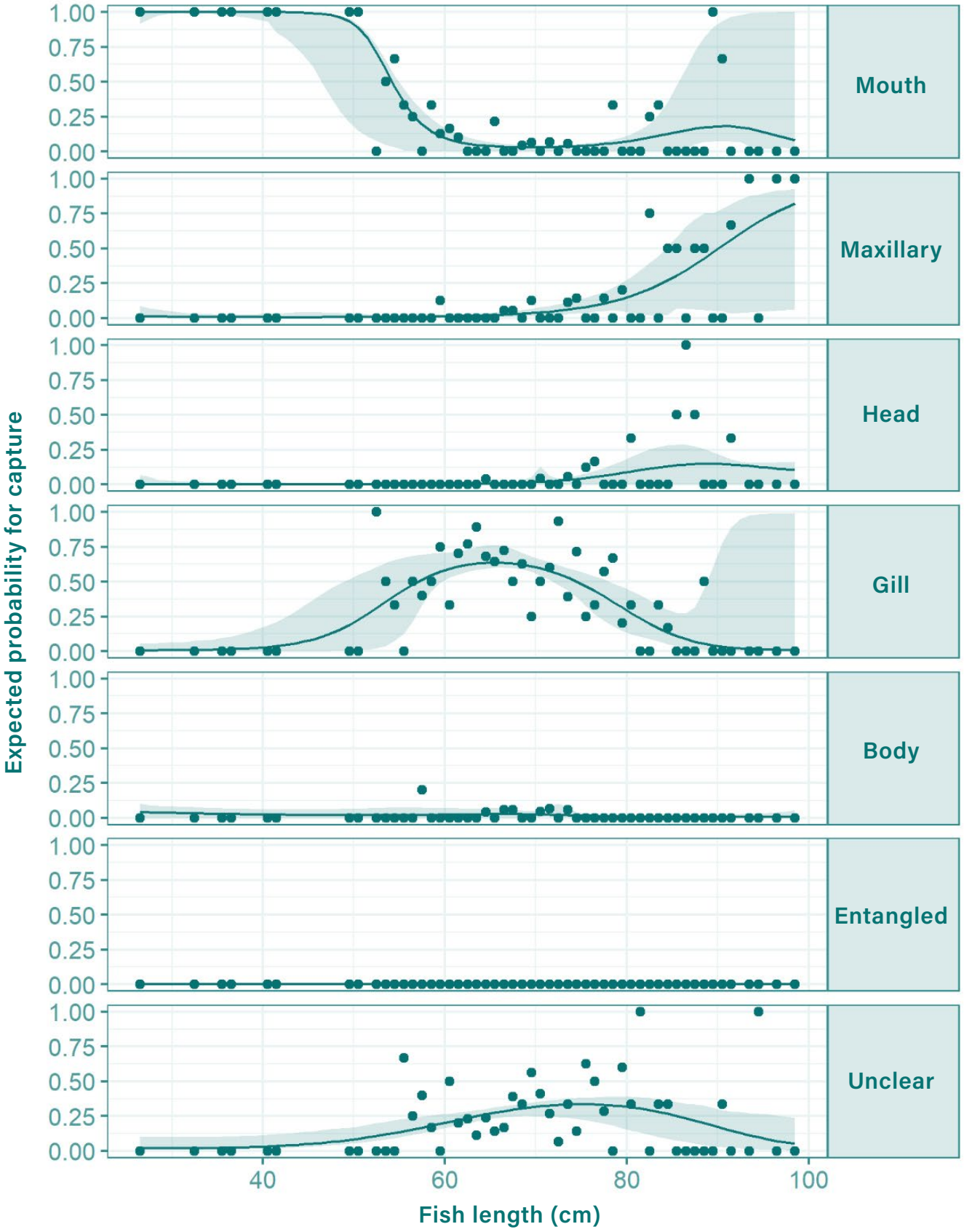


Figure 2. Probability for capture for cod in traditional nylon gillnet by mode conditioned capture. Source: DTU Aqua.

Photo: Retrieved part of a lost gillnet containing many fish (ghost fishing). Source: Roger Larsen (UiT)

RA 4 Governance incentives

State of the art

RA 4 will perform case studies within fisheries and aquaculture to describe and quantify possible effects on marine resources from using biodegradable materials, given different objectives and management scenarios. In order to assess these effects, the impacts of non-biodegradable materials on ecosystem services are a vital knowledge base that must be ascertained, hereunder the assessment of ghost fishing, the continual fishing of lost and derelict fishing gear, as well as different aspects of plastic pollution from aquaculture. A multitude of issues connected to potential plastic pollution, animal welfare and stock impacts, all feeding back into negative effects on ecosystem services, both commercial and otherwise, require further study. Based on the initial assessments we will outline how institutional restrictions- and incentives may be implemented in the governance system, to increase the use of biodegradable materials. To quantify potential effects under different scenarios, assessment of biological- and economic costs and gains of using biodegradable fishing gears and aquaculture equipment will provide inputs to governance decisions. Our objective is to investigate the potential changes needed in current regulations to facilitate the use of biodegradable applications in the fisheries and aquaculture industry.

Research and innovation challenges

- Data-driven economic assessment of non-biodegradable plastic impact on ecosystem services provided by the ocean.
- Estimation of costs and gains from introduction of biodegradable plastics in fisheries and aquaculture equipment.
- Identification and assessment of realistic potential regulatory innovations in order to facilitate the use of biodegradable materials in the fisheries and aquaculture industry.

Research questions

The key research questions in RA 4 are:

4.1 Assess economic effects of non-biodegradable materials used in fisheries and aquaculture.

4.2 Determine costs and benefits related to ecosystem services from introducing biodegradable materials in the fisheries and aquaculture industries.

4.3 Investigate institutional incentives to increase the use of biodegradable applications used in marine industries and help supporting the public support systems to reduce risk and promote implementation of biodegradable innovations.

Impact and goals

The research in RA 4 will result in information regarding the potential costs and benefits of moving from non-biodegradable to biodegradable plastics in the

fisheries and aquaculture industries, taking into account a broad ecosystem service perspective. This will provide the foundation for assessing the governance of these industries in relation to material input, and analysis of alternative management features that could potentially be applied to encourage movement towards biodegradable plastic use.

First year plans

- Desk-top study of state-of-the-art regarding the economics of non-biodegradable plastics.
- Identify relevant ecosystem services impacted by non-biodegradable plastics.

First year achievement

- Recruitment of PhD student (still awaiting entrance to Norway)
- Project meetings and planning
- Collaborative meetings within RA 4

RA 5 Circularity of plastics

State of the art

The work in RA 5 will be based on LCA (Life Cycle Assessment) methodology, an established method that evaluates the environmental burdens associated with a product system by identifying and describing the energy and material use and release into the environment. An LCA includes the entire life cycle of the product, from raw material extraction, through materials processing, transport, use and disposal or recycling at the end of the product's life (from "cradle to grave" or "cradle to cradle"). LCA can be used to understand if changes in one part of a product life cycle can lead towards greater overall sustainability. It focuses on the function(s) that the product system fulfils. LCA does not currently account for the impacts of plastic losses in value chains (e.g., littering). Hence, the issue of how macro and microplastic emission data are translated into environmental impacts represents a knowledge gap in the international LCA field.

Research and innovation challenges

The research and innovation challenges of this RA are to develop sustainable circular solutions for existing non-degradable and future biodegradable fishing gear.

Photo: Erling Svensen

Research questions

The research questions are related to task 5.1 – 5.4 in the project plan:

1. Define the status quo for the material flow of the fishing gear on a national and regional level documenting:
   - The proportion of used fishing gear delivered for further processing and depositing
   - Loss of mass due to wear and tear
   - Documented loss of gear, and
   - Undocumented loss of gear
2. Perform LCA assessments of specific fishing gear systems and materials, taking into account the entire value chain from production to end-of-life in order to:
   - Develop circular value chains for fossil-based non-degradable and biodegradable fishing gear by linking the value chains and continuously providing value chain actors with valuable information in order to develop beneficial upstream and downstream processes.
   - Enable increased and environmentally beneficial recycling by investigating different ways of recycling fossil-based non-degradable and bio-based-/ biodegradable plastics from fishing gear and converting them into innovative products. Identifying solutions further up the waste pyramid (towards reuse or recycling of materials) will be in focus.
   - Assess the potential leak of plastics from fisheries and aquaculture to the sea (both non-degradable and degradable plastics) and their potential environmental effects.
   - Provide information and new knowledge regarding the areas described above in order to achieve interactive processes for developing sustainable systems.
3. Identify research gaps and suggest future research activities.
4. Cooperate with ongoing international relevant work associated with the MarILCA project https://marilca.org/ in order to contribute to the development of LCA methodology to also account for impacts of plastic losses and marine litter.

Impact and goals

The impact and goals of RA 5 are to develop environmentally sustainable value chains which also take the level of circularity into account.

First year plans

Start-up meetings and developing working plan and budget for 2021.

First year achievement

Developed working plan and budget for 2021.

RA 6 Communication, dissemination and exploitation

State of the art

The results of SFI Dsolve will provide valuable and fact-based knowledge essential for research, innovation, documentation and design of new biodegradable products for the sustainable and circular economy. These innovations are important to enhance Norway`s leading global fishery and aquaculture positions, and the ambition to be in the forefront of research and innovation addressing the problems of marine plastic pollution. SFI Dsolve will have a comprehensive communication approach and agenda to maximise the visibility of the centre, its goals, challenges, and results towards industry, the scientific community, authorities, policy makers, and the general public.

Communication, dissemination and exploitation of results within Dsolve is organised in RA 6, led by UiT, and carried out in cooperation with SALT Lofoten (SALT) as subcontractor.

Photo: Zenteno

Research and innovation challenges

1) Develop and carry out measures to maximise the impact of the SFI research. 2) Ensure wider dissemination and uptake of the results of the SFI. 2) Ensure close relations between the academic community and industrial partners at the operative level and a low threshold for later exploitation of the results and technology transfer.

Research questions

The key task of this research area is 6.1 Dissemination activities, 6.2 Communication activities and 6.3 Exploitation of results.

Impact and goals

The aim of this RA is to develop and carry out a dynamic plan for outreach to maximise the impact of the results from the SFI. A plan for communication, dissemination and exploitation of results (DEP) is to be developed in the beginning of the SFI and updated on a regular basis during the centre's life span. The plan includes not only plans for suitable conferences, trade fairs, and national and international exhibitions, but also specifications about the promotion channels to be used, the timing for awareness raising about results, and the responsible partner. The main communication measures are described in the yearly annual plans.

First year plans

Task 6. 1 Dissemination and exploitation plan

- Developing the foundation for a dynamic dissemination and exploitation plan (DEP) for further developing in 2021.

Task 6.2 Communication activities

- SFI Website
- Logo and graphic profile
- Photo and graphics
- Video production

First year achievement

Task 6. 1 Dissemination and exploitation plan

- The foundation for a dynamic dissemination and exploitation plan (DEP) is developed within the end of 2020 and will be further developed in 2021.

Task 6.2 Communication activities

- A website is built to provide public information about the project, including goals, status, major deliverables and events, towards stakeholders and the general public, as well as internal target groups. https://uit.no/research/biodegradableplastics. The website is available in both English and Norwegian language.
- A graphic profile including logo and acronym for the SFI is built up to raise awareness and recognizability amongst stakeholders and public audience.
- A pool of relevant photos for dissemination purposes is made available for the project partners.
- An introduction video about the SFI has been produced and is to be completed in 2021.

International cooperation

SFI Dsolve has initially three research partners and two industry partners that will contribute with expertise in specialized fields important for the centre, especially within the field of polymer chemistry, degradation experiments, and field testing. The international science partners are DTU Aqua (Denmark), Thünen Institute of Baltic Sea Fisheries (Germany) and University of Split (Croatia). All three of them are well known for their international effort in developing sustainable fisheries, including the ambition of introducing biodegradable materials in fisheries.

The two international industry partners, S-EnPol and LG Chem, are both from South-Korea. South-Korea is one of few countries that has started to implement biodegradable fishing gears. The company S-EnPol is producing twines for production of fishing gears and they build nets and ropes for marine applications. They have worked together with SINTEF Ocean and UiT for several years and has become a world-leading company in the production of biodegradable fishing gears. The production of resin (for instance PBS, PBAT and PBSAT as the basis for twine production) requires large industrial facilities. One of the leading companies in this area is LG Chem, a rather small area of the LG company, but with more than 8000 employees dedicated developing new products like for instance biodegradable materials, including resin for production of twines for marine applications.

The international partners have significant laboratory facilities for laboratory and field testing and accompanying expertise that will be important for the research infrastructure of Dsolve. Funding is allocated in the budget for the international partners to carry out specific research activities, participate in Dsolve activities, and for exchange of scientists and students. In addition, DTU Aqua will finance its own activities in 2020–2021. The international partners will also be an instrument for quality control to assure that the research conducted within Dsolve is of high scientific quality and relevance. We will encourage exchange of PhD and MSc students, including using our international partners as hosts.

DTU Aqua (Hirtshals, Denmark) conducts research, advice and education at university level and contributes to innovation in sustainable utilization and management of aquatic resources. The Department of Aquatic Resources (DTU Aqua) is a department at the Technical University of Denmark. Until 2008, the institute was called the Danish Fisheries Survey. DTU Aqua's mission is to carry out research, advice and education at university level as well as contribute to innovation in sustainable utilization and management of aquatic resources. They research the biology and population ecology of aquatic organisms, physical and chemical processes in the aquatic environment and the structure and dynamics of ecosystems and involve all relevant natural and man-made influences. DTU Aqua's vision is to support an environmentally and economically sustainable utilization of aquatic resources. We do this by using an integrated ecosystem approach, which exploits synergies between science and technical science. Our work encompasses all components and trophic levels in aquatic ecosystems, includes both natural and man-made impacts, such as fisheries, pollution, shipping and offshore energy production, and integrates modern technologies. In order to realize the vision, DTU Aqua's research and education must be innovative and of the highest international standard. DTU Aqua's advice must be practical, quality-assured and relevant, and communication with users and actors must be open and understandable.

Photo: Fishing gear trials conducted by DTU Aqua. Source: DTU Aqua (https://www.aqua.dtu.dk/english/research).

Thünen Institute of Baltic Sea Fisheries (Rostock, Germany) research activities focus on the Baltic Sea, i.e., the largest brackish water body in the world. Fisheries are diverse but have a simple structure. Small-scale coastal fishing prevails in the mostly structurally weak coastal regions of the littoral states. They investigate the reasons for fluctuating reproduction rates of the most important herring stock for German fisheries. Cod represents another important fish species, and the focus is on growth, fecundity and stock separation of the two stocks in the Baltic Sea. The institute record direct human impact on commercially used fish stocks as well as the effects of fishing on the marine environment. They develop and test approaches for fostering the desirable behavior of fishermen through incentives. Especially within fishing and survey technology they develop environmentally friendly, energy-efficient fishing gear, in addition to automated methods of data collection. That helps to meet the requirements concerning data volume and precision which support the implementation of an ecosystem-based approach to fisheries management. Some of the methods can also be used for monitoring marine mammals or enable fishermen to document compliance.

Photo: Research vessel "Solea".
Source: Thünen institute.

The University of Split, Department of Marine Studies (Split, Croatia) is the branch and organizational unit of University of Split offering undergraduate, graduate and postgraduate studies about the sea, its richness, marine fishery, biological oceanography and marine ecology. Today University Department of Marine Studies organizes two undergraduate and two graduate studies and one inter-University postgraduate study. They offer undergraduate and graduate programmes in marine biology and ecology and marine fisheries. The main purpose of Marine biology and ecology study is a systematic education of personnel for work in areas of marine biology and ecology, which includes a wide range of biological investigations from the diversity of marine organisms to their distribution, characteristics, mutual relations and interactions with the marine environment. Further, due to the increasing threat of marine pollution caused by the dumping of various toxic and dangerous substances into the sea, and the irrational use of marine resources, special attention throughout the study will be given to the protection of endangered species and ecologically endangered areas.

Photo: Tuna is a common species in Adriatic waters. Source: http://more.unist.hr/en/

S-EnPol (Gangwon-do, South Korea) use a unique proprietary catalyst technology and polymerization process to develop fishing gears from environmentally friendly polymers (enpol), which is next-generation eco-friendly plastics produced. Enpol is resistant to hydrolysis and features outstanding mechanical strength and good processability thus making them suitable for diverse applications. Biodegradable EnPol fishing nets and gears have comparable qualities as traditional products made of Nylon, PE and PET. However, unlike the traditional ones, when biodegradable fishing nets and gears made of EnPol are lost at sea, they protect the marine environment and do not cause ghost fishing.

Gillnet

Monorope

Photo: Examples of products for fisheries from S-EnPol in South Korea. Source: S-EnPol.

LG Chem (Seoul, South Korea) is the largest Korean chemical company, and was the 10th largest chemical company in the world by sales in 2017. It was first established as the Lucky Chemical Industrial Corporation, which manufactured cosmetics. It is now solely a business-to-business company (consumer products division was spun off into LG Household & Health Care). The company has eight factories in South Korea and a network of 29 business locations in 15 countries. LG Chem is a supplier of petrochemicals ranging from basic distillates to specialty polymers. For example, it is a large producer of common plastics such as acrylonitrile butadiene styrene (ABS), styrene-acrylonitrile resin (SAN), and polyvinyl chloride (PVC). It also produces raw materials and liquids, including plasticizers, specialty additives, alcohols, polyolefins, acrylic acid, synthetic rubber, styrenics, performance polymers, engineering plastics, elastomers, conductive resins, and other chemicals. In the petrochemicals business, the company has built a vertically integrated system from the basic raw materials such as ethylene and propylene to the downstream products such as PE, ABS and synthetic rubber.

Photo: LG Chem have started test-production of biodegradable plastics. Source: LG Chem (https://www.econotimes.com/LG-Chem-introduces-worlds-1st-biodegradable-plastic-1594516).

Recruitment

The aim of SFI Dsolve is to educate a minimum of 8 PhD candidates, 4 post-docs, and 30 MSc candidates, and to support their subsequent employment both within the academic and non-academic sector. These candidates will have the unique opportunity to collaborate closely with leading industry and research groups, and to work on highly relevant challenges and applications. UiT will have the main (but not exclusive) educational responsibility for PhD candidates, post-docs, and MSc candidates. This will enable close contact with key scientists at the host institution. Other universities may also be included in the education of students, and the centre will promote exchange of PhD candidates and post-docs with the international research partners (i.e., DTU Aqua, Thünen Institiute of Baltic Sea Fisheries and University of Split), to encourage research fellow mobility. Specific activities, such as workshops, will enable cross-disciplinary collaboration among the PhD candidates and post-doc fellows.

Three PhD positions were announced by the end of 2020, and the elected candidates will start in 2021.

- 1 PhD position in natural resource economics allocated to RA4: Governance incentives.
- 1 PhD position in fishing gear technology allocated to RA3: Gear development, tests and demonstrations at sea.
- 1 PhD position on the marine biodegradation of polymers used for fishing gears allocated to RA2: Assessment of biodegradability.

Communication and dissemination activities

Communication of results, knowledge and the development of the research within the centre is a highly prioritised task within the SFI Dsolve. Dissemination and communication are organized as a research area within the centre (RA6), with the purpose to maximise the effect of the SFI. RA 6 will create and follow a dynamic plan for communication, dissemination and exploitation of results (DEP) that will be continuously developed during the lifespan of the centre. The plan describes communication measures, scope and target audience, and will secure a comprehensive communication approach and agenda to maximise the visibility of the SFI, its goals, challenges, and results. Detailed communication activities are described annually as part of the DEP. Media, trade press and social media represents important communication channels, as well as conferences, fair trades and other relevant arenas where industry and stakeholders can be reached.

During 2020 a project webpage was established and made available both in English and Norwegian (https://uit.no/research/dsolve-en). The webpage presents information both for internal and external target groups and will also interact with the centre`s social media channels such as the Dsolve Facebook page (www.facebook.com/dsolvebiodegradableplastics). A video has been produced for the introduction of the SFI, and the formation of the centre has been presented through several media articles.

Photo: Zenteno

Reviews, articles and interviews

12.06.2020 "Rekordtildeling blir til 22 nye sentre for innovasjon", Khrono (web magazine).
30.06. 2020 "Utvikler nedbrytbare fiskeredskaper", Plastforum (trade magazine).
01.07. 2020 "Plast i fiskeredskap, fra nytte til fortvilelse", Fiskeribladet (trade press, opinion).
08.07. 2020 "Vi er bare i startfasen", Ságat (newspaper).
16. 07. 2020 "Nye materialer skal redusere skader fra fiskeriene", Ságat (newspaper).

17.07 2020 “Alsvågmann forsker på nedbrytbar plast”, Vesterålen (newspaper).
27.07. 2020 “Tar grep for å sikre dyrevelferden i havet”, iTromsø (newspaper).
30.09. 2020 Kan vi utvikle norsk sjømatindustri uten plast? BFE Backstage, UiT (blogg.uit.no/bfebackstage/2020/09/30).
23.10. 2020 “Vi skal bekjempe marin plastforsøpling”, Avisa Lofoten (newspaper).
24.10.2020 “Vi skal bekjempe plastforsøpling i havet med bionedbrytbar plast”, Forskning.no, (web magazine, chronicle).
26.10. 2020 “Det er plast overalt”, Altaposten (newspaper).
23.11. 2020 ”«Tidsinnstilt» plast skal ta spøkelsesfisket og mikroplasten ved roten”, Tekfisk, Fiskeribladet (trade press).
24.11.2020 ”«Tidsinnstilt» plast skal ta spøkelsesfisket og mikroplasten ved roten”, Fiskeribladet (trade press).

Personnel

KEY PERSONNEL	INSTITUTION
Ludvig Ahm Krag	DTU-Aqua
Signor Antonsen	Hermes
Jan Roger Lerbukt	Hermes
Håvard Olsen	Kvarøy Fiskeoppdrett AS
Kristian J. K. Kalgraff	Legøy Rederi AS
C.H. Lee	LG Chem
Jake Chang	LG Chem
Ryan Yoon	LG Chem
Y.M. Lee	LG Chem
Ståle Dyb	Loran AS
Isabelle Sande	Løvold AS
Martin Solhaug	Martin Solhaug
Terje Lindal	Mørenot Fishery AS
Lasse Rindahl	Mustad Autoline AS
Gunnar Kupen	NOFI Tromsø AS
Jan Birger Jørgensen	Norges Fiskarlag
Jan Henrik Sandberg	Norges Fiskarlag
Benedicte Nielsen	Norges Råfisklag
Klaus Schöffel	Norner Research
Ole Jan Myhre	Norner Research
Ravindra Chowreddy	Norner Research
Siw Fredriksen	Norner Research
Thor Kamfjord	Norner Research
Cecilia Askham	NORSUS
Hanne Lerche Raadal	NORSUS
Irmeline de Sadeleer	NORSUS
Arne Birkeland	Opilio AS
Bent Gabrielsen	Øra AS
Odd Hugo Schjølberg	Øra AS
Kim Seihoon	S-EnPol
Kim Seonghoon	S-EnPol
Christian Karl	SINTEF Industry
Stephan Kubowicz	SINTEF Industry
Einar Hinrichsen	SINTEF Industry
Bent Herrmann	SINTEF Ocean/UiT
Dag Standal	SINTEF Ocean
Eduardo Grimaldo	SINTEF Ocean
Heidi Moe Føre	SINTEF Ocean
Jørgen Vollstad	SINTEF Ocean
Lisbet Sørensen	SINTEF Ocean

Sigrid Hakvåg	SINTEF Ocean
Jure Brčić	The University of Split
Mirela Petrić	The University of Split
Svjetlana Krstulović Šifner	The University of Split
Željka Trumbić	The University of Split
Daniel Stepputtis	Thünen Institute of Baltic Sea Fisheries
Juan Santos	Thünen Institute of Baltic Sea Fisheries
Rune Sand	Tustern AS
Arne Eide	UiT
Claire Armstrong	UiT
Hanne Risan Johnsen	UiT
Roger B. Larsen	UiT
Terje Aspen	UiT
Hilde Rødås Johnsen	UiT/SALT

Budget and costs 2020

	FUNDING	COST
The Research Council	417 765	
The Host Institution (UiT)	179 995	376 483
Research Partners*	38 005	259 282
Industry partners		-
Equipment		-
TOTAL	635 765	635 765

*Norner Research, NORSUS, SINTEF Industry, SINTEF Ocean

Publications 2020

Grimaldo Ed, Herrmann B, Jacques N, Su B, Vollstad J. Effect of mechanical properties of monofilament twines on the catch efficiency of biodegradable gillnets. PLOS ONE. 2020

Grimaldo, Eduardo; Herrmann, Bent; Jacques, Nadine; Kubowicz, Stephan; Cerbule, Kristine; Su, Biao; Larsen, Roger B.; Vollstad, Jørgen. The effect of long-term use on the catch efficiency of biodegradable gillnets. Marine Pollution Bulletin 2020.

Standal, Dag; Grimaldo, Eduardo; Larsen, Roger B. Governance implications for the implementation of biodegradable gillnets in Norway. Marine Policy, 2020.

Dsolve