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Sea Urchin Fishing techniques Report

(Activity A3.1.1 of the NPA URCHIN project)

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Report

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Summary/recommendation:

This report gives a brief introduction to the URCHIN project, funded by the Northern Peripheries and Arctic Programme (NPA), followed by a summary of the fishing techniques that are used in sea urchin fisheries around the world. The main sea urchin fisheries around the world are then briefly described, together with the fishing techniques that are used in each fishery. This gives some indication of the frequency of use for the different techniques in various countries around the world. The current status of the fishery and fishing methods utilized in participating NPA countries (Norway, Iceland, Greenland and Ireland) are described. A brief description of the history of roe enhancement in Norway is also included. Finally, the factors that contribute to define the optimal sea urchin fishing techniques for any given country and company are outlined. The efficacy of a fishing technique will depend on a number of these factors and the interactions between them. In the following NPA report a cost/benefit analysis will be conducted for each of the participating NPA countries on what method of fishing is most effective. Finally, Nofima and Pure Arctic AS undertook a trial testing a new and novel collection system in 2017. The results from this trial are included as an Appendix in this report.

Summary/recommendation in Norwegian:

Denne rapporten gir en kortfattet innføring i kråkebolleprosjekt og ulike fangst teknikker som brukes i kråkebollefiskerier verden rundt. Prosjektet er finansiert av Northern Periphery og Arctic Programme (NPA), etterfulgt av en oppsummering. Rapporten gir også en oversikt over omfanget av de ulike fangstteknikker i ulike land rundt om i verden. Dagens status for fiskeri- og fiskemetoder er beskrevet for NPA land (Norge, Island, Grønland og Irland). En kort beskrivelse av historien til prosessering av kråkebollerogn i Norge er også inkludert i rapporten. Til slutt er de faktorer som bidrar til å definere optimale kråkebollefisketeknikker for et gitt land og selskap skissert. Effekten av en fisketeknikk vil avhenge av en rekke av disse faktorene og samspillet mellom dem. I neste NPA-rapport vil det bli gjennomført en kost-/nytte-analyse for hver av de deltakende partnerne i neste prosjekt for å finne ut hvilken fiskemetode som er mest effektiv.

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1 Executive summary

This report gives a brief introduction to the URCHIN project, funded by the Northern Peripheries and Arctic Programme (NPA).

This is followed by a summary of the fishing techniques that are used in sea urchin fisheries around the world. This includes SCUBA diving, diving using surface air supply, dredges, breath hold diving, trapping and a number of alternative methods that have been used in the past, are in development, or have potential to enhance current practices. The latter includes the use of novel trap designs, Remote Operated Vehicle (ROV) and attractant techniques for conventional harvesting methods.

The main sea urchin fisheries around the world are then briefly described, together with the fishing techniques that are used in each fishery. This gives some indication of the frequency of use for the different techniques in various countries around the world.

The current status of the fishery and fishing methods utilized in participating NPA countries (Norway, Iceland, Greenland and Ireland) are described. A brief description of the history of roe enhancement in Norway is also included.

Finally, the factors that contribute to define the optimal sea urchin fishing techniques for any given country and company are outlined. These include the size of the existing fishing fleet, the fishing regulations in any particular area, the technical availability of the company, the logistics and infrastructure available, the urchin species, its distribution and quality, the topography of the area to be fished, the history of the fishery and the intended market and product. The efficacy of a fishing technique will depend on a number of these factors and the interactions between them. They will vary significantly in each NPA country, depending on where the venture is within the country (eg proximity to major airports, climatic differences), the size of the company carrying out the fishing and the size and scale of the fishing venture. In the following NPA report a cost/benefit analysis will be conducted for each of the participating NPA countries on what method of fishing is most effective.

2 Introduction

2.1 URCHIN project (Utilisation of the Arctic Sea Urchin Resource)

The URCHIN project aims to utilise the sea urchin resource present in the northern arctic regions. The challenges of fishing, sustainable and responsible harvesting of stocks, legislation and supply chains for sea urchin products from isolated and environmentally harsh and challenging areas in the Northern and Arctic region will be addressed. The challenges will be overcome through innovation and national and transnational technology transfer.

Currently there are small scale (<150 tonne p.a.) intermittent fisheries for sea urchins in the NPA. This is despite there being enormous sea urchin resources present in the area. There are a number of challenges that have prevented the expansion of sea urchin fisheries in the NPA. These include environmental challenges to fishing, inadequate and inappropriate legislation and fisheries management and lack of technology and knowledge regarding sea ranching and roe enhancement of poor quality urchins. Research to overcome these challenges has been disparate and there has been no previous transfer of knowledge between the NPA partner countries.

This project aims to gather the existing expertise from Norway, Iceland, Ireland and Greenland, together with knowledge from Canada to optimise the fishing of high value sea urchins in Northern and Arctic areas. Furthermore, roe enhancement technology from Norway for roe fattening to increase the value of low value sea urchins once they have been collected in the northern arctic regions will be developed in Greenland and Iceland. The project would also investigate sea ranching to repopulate areas that have been extensively overfished in the past in Ireland. Issues regarding the provision of adequate legislation and fisheries management will be identified and legislative organisations will be provided with the appropriate knowledge to provide sensible and sustainable management of sea urchin fisheries. The project will also estimate market needs for sea urchin roe as well as establishing logistic routes from the NPA to markets.

2.2 Scope of this report

The aim of this report (Activity A3.1.1 of the URCHIN project) is to review the fishing techniques that have been used and are currently used in sea urchin fisheries around the world, including similar geographic areas to the NPA. It will also review the fishery and the current and previous fishing techniques used in the NPA countries.

The following NPA report (Activity A3.2.2 of the URCHIN project) will include a cost/benefit analysis on the most appropriate fishing technique for the NPA countries participating in the URCHIN project. It will also make recommendations on optimal fishing techniques for each of these countries.

3 Summary of fishing techniques used in sea urchin fisheries around the world

3.1 SCUBA diving

This is most common technique used for fishing sea urchins around the world. It requires basic SCUBA equipment to dive to depths between 2-20m and although depths as far as 40m can be achieved shallower depths are most common. This type of diving can be made using single or double tanks and using basic compressed air or mixed gases to extend dive times. The latter is very technical form of diving and has many safety implications. The major restriction to the collection of sea urchins using SCUBA is the limit on the amount of time available for each dive (restricted by the air in the tank), the regulations on diving protocols to maintain safety standards and the cost of having a boat, together with a full dive team, including back up divers, available. There are many inherent risks associated with SCUBA diving for sea urchins with a number of fatalities being recorded in various fisheries around the world.

Divers tend to use hand tools to scrape the urchins into catch bags that are either carried to the surface by the diver or are raised to the surface using air lift bags. Because the urchins are handpicked they can be size selected and there is no bycatch. The selection of mature size sea urchins by divers means that undersized specimen can be returned without significant mortality, adding to the sustainability of this method of catching sea urchins.

Similar to most harvesting techniques SCUBA diving operations are susceptible to poor weather conditions, cold conditions and the dark period experienced in a number of NPA countries (the technology available now in the form of GPS trackers and dive lights may mitigate the dark period for some dive operations) would also restrict dive operations. In Greenland there are extensive areas that are covered by ice in the winter months that would severely restrict dive operations. However, this would also depend on the season that there is good quality roe available in the area.

Figure 1 A typical SCUBA diver operation with a diver using compressed air, a catch hook and a catch bag with a tether to the surface.

3.2 Diving using surface air supply

This technique is widely used for the collection of benthic invertebrates such as abalone. It involves a surface compressor pumping air down an air-line to a diver working on the sea floor. This can be a single diver or a group of divers working from a single compressor. This scope of this type of diving is dictated by the diver only being able to cover the area immediately around the boat and the depth is restricted by the length of airline available. However, dive times are longer than on SCUBA and the diver is not restricted by bulky dive gear (although they are restricted by the air hose). This technique is not suitable in rough weather or in areas with strong currents. As with SCUBA diving the urchins are handpicked and any bycatch is avoided.

Similarly to SCUBA, using surface air diving operations is also susceptible to poor weather conditions, cold conditions (although warm water can be pumped into the dive suits from the surface) and the dark period experienced in a number of NPA countries would also restrict dive operations. The technology available now in the form of GPS trackers and dive lights may mitigate the dark period for some dive operations.

Figure 2 A typical abalone diver operation using surface air supply.

3.3 Dredge

Using a towing dredge is a fast and efficient method of harvesting large quantities of sea urchins and is widely used in a number of shellfish fisheries, particularly for harvesting scallops, mussels and cucumbers as well as sea urchins. Iceland has a considerable history of using dredges to harvest sea urchins and it has proved to be an economically viable method of collection. It does rely on a relatively flat substrate in order to avoid the dredge getting snagged on the bottom and a relatively high density of urchins to be present. Because the dredge is physically dragged across the seafloor there can be damage to the urchins although the dredge used in Iceland is designed to minimize the damage to the seafloor, the urchins and the bycatch. Dredge size is dictated by the size of the boat that is used to drag them and larger dredges can be used from many existing small fishing vessels used in the NPA. Researchers in Iceland are currently investigating the selectivity and efficiency of their dredge for sea urchin fishing. Fishing catch data including; catch, location, depth, and length of the tow are analysed to determine the stock distribution and size, CPUE and the impact of the fishery on the stock.

A number of countries (e.g. Norway) do not currently allow/or discourage the use of dredges because of the perceived negative effects on the sea floor.

Similar to diving operations the use of a dredge is also susceptible to poor weather conditions. However, this techniques is not as restricted by cold conditions and could also operate during the dark period experienced in a number of NPA countries.

Figure 3 A dredge used to commercially fish sea urchins in Iceland.

3.4 Breath hold diving

This is another technique that is widely used around the world to harvest benthic invertebrates such as abalone and sea urchins. It involves divers equipped with snorkel, mask and flippers breath holding and diving to depths up to 15m to collect sea urchins. This is the cheapest form of diving as it has minimal demands for equipment and it also avoids the dangers posed by breathing compressed air. However, there are some dangers posed by repetitive breath hold diving (eg shallow water blackout) as well as coping with environmental conditions and predators in some countries. There are also no regulations on the length of time a diver can be in the water and the depth is dependent on the skill and experience of the diver. Although the time spent on the sea floor is restricted by the ability of the diver, this a very efficient method of collection if the urchins are present at high densities and the divers have sufficient skills. The urchins are also handpicked and there is no bycatch. Because the diver is free floating they can also cover a wide area of terrain very rapidly looking for suitable areas to fish. This makes it an ideal method for surveying new sites and it has been used in NPA countries such as Norway (Arctic Caviar AS).

Similarly to SCUBA, using breath hold diving operations is also susceptible to poor weather conditions, cold conditions and the dark period experienced in a number of NPA countries would also restrict dive operations.

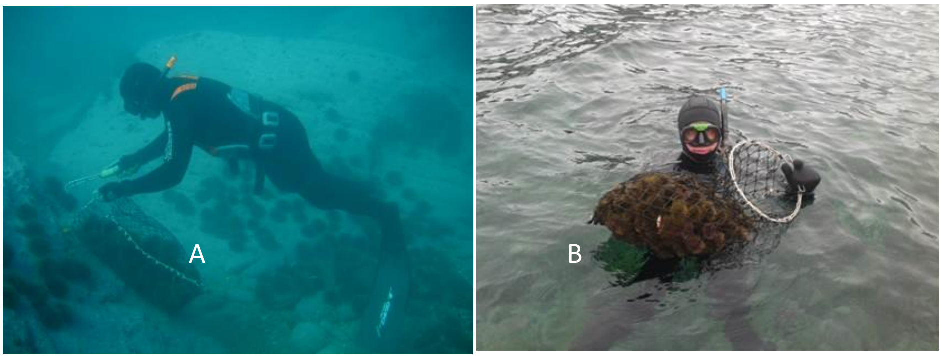

Figure 4 *(A) A breath hold diver in NZ with catch hook and catch bag (B) The sea urchin catch from breath hold diving in Tromsø, Norway.*

3.5 Trapping

This is not a technique that has been widely used for harvesting sea urchins although there are examples from around the world where trapping has been used commercially (Canada and Japan). There are a wide variety of trap types and shapes as part of the NPA URCHIN project, together with previous research (Sivertsen K. *et al.*, 2008, James and Siikavuopio 2014), Nofima has developed a round trap (that folds in half for easy retrieval) that is simple and cheap to make. A number of trials have now been undertaken and the results will be compared in the following report which looks at the economics of the varying harvesting techniques. Trapping has a number of advantages over diving. These include the lack of any technical equipment, the traps can be set from large or small boats, and trapping is not so dependent on weather and water visibility conditions and avoids any of the safety implications of using divers. The urchins are also in very good condition as they have not been handles at all prior to being bought to the water surface. Depending on the bait used there can be considerable bycatch from fish baits (some of this is also valuable species) whilst virtually no bycatch from macro algae baits. There is no size limitations on the urchins that can enter the traps and so size sorting of the catch is necessary. Traps must be left for periods of 5-7 days and poor weather conditions can damage trapping gear.

Trapping is not as restricted by cold conditions and could also operate during the dark period experienced in a number of NPA countries. However, trapping in winter months in Greenland could be a problematic due to the presence of ice and its ability to lift and move traps. Traps may also not be suitable for sites with very high currents and a very rocky, uneven or complex substrate.

Figure 5 *(A-B) The simple trap design developed and tested by Nofima in Norway (C) The traps laid on a backbone on the sea floor in Norway.*

Figure 6 *The trap used in Quebec (Canada) for whelk which has shown promise as a sea urchin trap.*

3.6 Alternative methods

There are a number of alternative methods that have been used to harvest sea urchins but the economics and efficacy of these systems id still not proven. These include the following:

3.6.1 Remote Operated Vehicle (ROV)

Nofima in Norway has carried out a number of trials aimed at testing the economic feasibility of fishing commercial quantities of sea urchin during winter conditions in northern Norway using a modified ROV. A commercial scale trial was conducted from 16-21 January 2012 in Båtsfjord, Norway.

The results of the trial showed that in 4.5 days of fishing (the first 1.5 days was spent looking at a number of different sites and selecting a site where the vessel could anchor) a total catch of 1.88t was recorded with 34.9 % of the total catch (659.5kg) consisting of export quality sea urchins (> 45mm test diameter). The authors suggest that the amount of sea urchins from the total catch that could be sold could have been increased to 52.1 % of the total catch (807kg) by lowering the minimum size of the urchins that were kept to the industry recommended size of 40mm test diameter and processing any damaged sea urchins to utilize the roe in these animals. The bycatch landed (30.8 % of the total catch) during the trial (the remainder of the catch was made up of small sea urchins) consisted primarily of mussels and sea cucumbers but there were small quantities of other benthic marine species present (James, 2012).

The use of an ROV is also susceptible to poor weather conditions as calm weather is required to launch and retrieve the ROV and the boat must remain relatively still (normally at anchor) whilst the ROV is fishing. However, this techniques is not as restricted by cold conditions and has been shown to be capable of operating during the dark period experienced in Norway. This is a high tech solution to sea urchin fishing and requires a large investment in equipment.

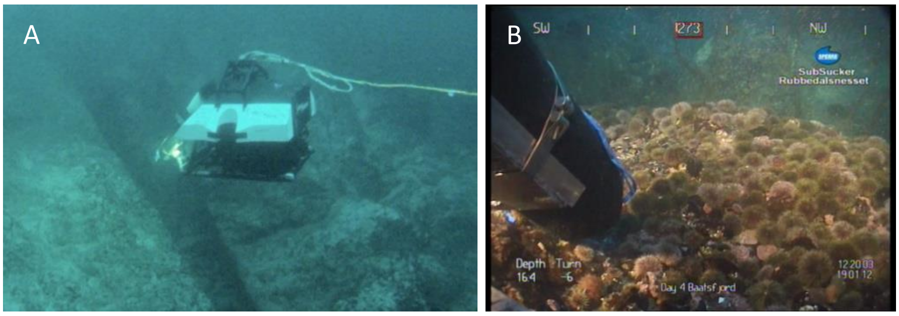

Figure 7 *(A) The ROV designed and used in Norway in action (B) the view from the ROV camera during fishing operations.*

Figure 8 *(A,B,C) launching of the ROV (D, E) the ROV driver fishing sea urchins from onboard the vessel.*

3.6.2 Attractant techniques for conventional harvesting methods

A range of urchin species (including *Strongylocentrotus droebachiensis* found in Norway, Iceland and Greenland) have shown the behavioral trait of collecting on and around any debris or structure sitting on the sea floor. This behavior could be utilized to concentrate the urchins for remote collection (ROV or other novel techniques) or more traditional techniques such as diving or breath hold diving.

Figure 9 The green sea urchin (Strongylocentrotus droebachiensis) collecting on mooring ropes in shallow water in Norway.

3.6.3 Surface rakes and collectors

There are still some countries that collect sea urchins from the surface using long handled rakes and collectors. These normally involve two long handles connected to a two claw like rakes that manually pick up the sea urchins from a boat on the surface. This technique is obviously reliant on an abundance of sea urchins in shallow waters and also requires very calm and settled weather. It is also very labour intensive but requires minimal investment in equipment.

4 Techniques used in the main sea urchin fisheries around the world

The following is a brief summary of the techniques used in various countries with established sea urchin fisheries (in order of the size of the fishery from large to small):

4.1 Chile

Chile has the largest catch of sea urchins in the world and is reliant on a fleet of small boats and SCUBA divers to harvest the catch.

4.2 Japan

Japan is the largest market for sea urchin roe but also has a substantial fishery. The majority of the harvest is conducted using SCUBA divers but traditionally urchins have also been caught using hand held rakes and set nets.

4.3 USA

The USA is made up of a number of different fisheries from the different coastal areas. SCUBA diving is the main method of harvest (approximately 80 %) with dredges used for the remainder and a very small amount are still collected using hand held rakes in the intertidal zone (Andrew et al 2000). Some of the diving in California is very technical with gas mixing equipment on board the dive boats. This extends the depth and time that divers can remain in the water but also has inherent risks.

4.4 Canada

The Canadian fishery is also divided into regions and because the Canadian fishery is very close to the climate and geographical conditions in NPA countries (particularly parts of the pacific area, the Quebec area and the Newfoundland and Labrador areas). The harvesting techniques in each region are outlined in detail here (all Canadian fisheries and fishing information supplied by Janet Lochead, a Pacific Region Aquatic Science Biologist at the Fisheries and Oceans Research Institute in Canada)

4.4.1 Pacific Region

Green Sea Urchins (Strongylocentrotus droebachiensis) in the Pacific Region are hand-picked by SCUBA divers who work from small fishing vessels. In this, and all Regions where fishing is by dive, harvesters remove high quality urchins from the feed line, a narrow strip usually just two or three urchins thick located along the edge of a kelp bed. These removals allow other urchins to move into the prime feeding area and develop quality roe for subsequent harvesting.

4.4.2 Quebec Region

There are two authorized methods for harvesting Green Sea Urchins in the Quebec Region: SCUBA diving and whelk traps, although traps have not been used in the last decade (there is currently renewed interest in the use of traps in this area as part of the URCHIN project). Towed harvesting gear is prohibited except in very restricted areas.

4.4.3 Gulf Region

There is currently no Green Sea Urchin fishery in the Gulf Region. Attempts were made to develop a Green Sea Urchin dive fishery in the 1990's, however these attempts failed due to harvesting cost, harvesting conditions (ice cover) and low density of the resource.

4.4.4 Maritimes Region

Green Sea Urchins in the Maritimes Region are harvested by SCUBA dive and by drag. In the Bay of Fundy, the fishery is separated into two management areas: in one area harvest is conducted mainly by diving and to a lesser extent by dragging; and in the other area harvest is exclusively by drag. The fishery on the outer coast of Nova Scotia is exclusively a SCUBA dive fishery.

4.4.5 Newfoundland and Labrador Region

In the Newfoundland and Labrador Region, Green Sea Urchins are harvested in shallow sub-tidal areas by SCUBA divers utilizing a hand held rake and net bag for collection.

4.5 Mexico

The Mexican sea urchin fishery is exclusively harvested by SCUBA divers.

4.6 Russia

There is little information on the collection methods in Russia but it is estimated that the entire catch is taken using SCUBA divers.

4.7 South Korea

South Korea has a very old and traditional sea urchin fishery. Ninety percebt of the catch is collected by woman using breath hold diving techniques (collecting from depths up to 10m). Urchins are also collected from divers using surface air supply, these divers are normally diving for a range of species at depths greater than 10m (Andrews et al, 2000).

4.8 Philippines

In the Philippines sea urchins are harvested by shore collecting and diving on shallow reefs.

4.9 New Zealand

Sea urchin fishery regulations in New Zealand restrict the use of SCUBA diving for commercial collection and so virtually all the harvest is done using breath hold divers. This restricts the depth that sea urchins can be taken to between 10 and 15m depending on the skill of the diver. A very small percentage of the catch is harvested using dredge at greater depths in a very restricted area (Miller and Abraham, 2011).

4.10 Other

Other smaller fisheries include Spain (combination of SCUBA and breath hold diving), China (combination of dredge, SCUBA and hand collection using rakes), Australia (SCUBA diving) and France (dredges and SCUBA). The fisheries in Iceland and Ireland are covered in the following section but the size of these fisheries would rank after France (Andrews et al, 2000).

5 Current fishery and fishing methods utilized in NPA participating countries

5.1 Norway

5.1.1 The Fishery

Norway has a number of endemic sea urchin species, but the focus of the sea urchin fishery has been solely on the green sea urchin, *Strongylocentrotus droebachiensis*. Because of this species wide distribution it has also been the focus of fishing and aquaculture research in a number of other countries such as the USA and Canada.

One of the key constraints to the development of both the sea urchin fishing and the aquaculture industries in Norway has been the lack of a domestic market for sea urchin roe. Unlike those countries that have a reliable domestic market for sea urchins, the sea urchin products harvested or produced in Norway must be exported overseas, which requires a substantial amount of investment, knowledge and logistical support from the very beginning of any venture. The lack of a historical and consistent fishery for wild sea urchins has, in itself, been a constraint to developing sea urchin fisheries and aquaculture in Norway. The lack of a collection, transport and processing infrastructure already in place for sea urchins in Norway adds to the difficulty of establishing a new sea urchin aquaculture venture. The start-up roe enhancement company, ScanAqua AS, was a good example of how the establishment of an operation that includes everything from wild capture to exporting requires an enormous amount of knowledge and support, which can prove too exhaustive for staff, managers and investors and is discussed in Section 5.1.3.

Another factor which has had a negative impact on the development of a sea urchin industry in Norway is the number of companies that have tried and failed, with a substantial amount of investment funding being lost. This has left existing investors reluctant to invest into any new sea urchin ventures.

5.1.2 Fishing techniques

There is no tradition of consuming sea urchins in Norway. As a result there is a very limited domestic market for sea urchin roe and a very limited history of fishing sea urchins. Consequently, there is no stock management (no TACC or quota management system) for sea urchins in Norway, and although it is a free entry fishery to anybody who wishes to participate there are now a number of restrictions in place that have become increasingly expensive. These include that fishing sites have to be classified by the food health authority in Norway, the boats have to be within the fishing register and all sea urchins that are harvested are owned by the Norges Råfisklag (The Norwegian Fisherman's Sales Organisation) that in turn pays the fisher. Before sea urchins can be exported from Norway they also have to be registered with a catch certificate.

Over the past 30 years there have been numerous small scale ventures that have attempted to establish a sea urchin fishery, but these have experienced a number of logistical issues that have restricted development. These issues include the use of SCUBA divers to collect the urchins (the most commonly used method), which in Norway requires rigorous health and safety regulations and demands very high salary levels, making it an extremely expensive fishing method. In addition, the best season for fishing sea urchins in Norway (that is when the gonads are largest and when they have the highest quality) is from October to February (Falk-Petersen and Lønning, 1983). This is a period with frequent storms, very low air and ambient seawater temperatures and extremely limited daylight hours in winter at latitudes between 63 and 71°N. During this midwinter dark period from November to February (or 'mørketid'), daylight is restricted to just a few hours of twilight around midday and in the far north there is no daylight at all. Such conditions make sea urchin collection difficult during this time of the year, regardless of the techniques used. The longest (and currently one of the only) running sea urchin fishing company in Norway (Arctic Caviar AS) has been harvesting and selling sea urchins for more than a decade and relies on SCUBA diving for its sea urchin collection. The owner/operator/diver (Roderick Sloan) relies on small high quality catches which are sold into exclusive and lucrative European markets. This type of harvesting technique works well for relatively small companies such as Arctic Caviar AS. An ongoing issue in Norway is the availability of divers with the appropriate handling and collection skills for sea urchins and are willing to work in this industry. SCUBA diving on a larger scale in Norway has shown to be very expensive when larger catch rates are considered. In the example described below (Scan Aqua AS) divers were imported from other European countries at considerable cost and there was significant downtime when the divers were unable to dive due to weather or sea conditions. They also spent considerable amounts of time searching for urchin populations to fish rather than harvesting sea urchins.

As described in the previous Section (3.6.1) there have also been attempts to use a specifically designed remotely operated vehicle (ROV) to collect sea urchins in Norway.

5.1.3 Roe enhancement

In the early 1970's it was observed that the *S. droebachiensis* population along the Norwegian coast (north of 63 °N) had started to increase. This subsequently resulted in extensive overgrazing of the kelp forests in many areas, with an estimated 4500 km^2 of seafloor being transformed into barren grounds by the late 1990's (Sivertsen, 1997; Gundersen *et al.*, 2010). A recent report has estimated the current sea urchin population in Norway to be a massive 80 billion individual animals (Gundersen *et al.*, 2010) and somewhere between 50,000 to 100,000 tons of harvestable stock (Sivertsen, 1997). Despite the presence of such a large population of green sea urchins along the Norwegian coast, approximately two-thirds are found in barren grounds where the gonad quantity and quality is both extremely variable and normally very low. These urchins often have a gonad yield well below 10% of the total weight, which is considered to be the minimum yield required to provide an economic return (this figure can vary considerably from area to area and country to country) (Sivertsen, 1997; James, 2007; Siikavuopio, 2009). These low quality sea urchins found in such abundance in some areas provide an ideal opportunity for the development in Norway of a roe enhancement industry based on *S. droebachiensis*. There have been a number of previous attempts at sea based sea urchin aquaculture in Norway, most notably by ScanAqua AS, the world's first commercial scale sea urchin roe-enhancement farm. ScanAqua AS was established in 2001 close to Hammerfest in the northern part of Norway. The farm had holding capacity of 50 tons and an intended production of 150 tonnes per year. Being the first of its kind, ScanAqua had to develop the entire sea urchin roe enhancement process, from catching sea urchins alive to exporting the end product. In order to achieve this ScanAqua established a sea based farm, using the SeaNest™ system. Sea urchins were harvested by SCUBA divers, but other methods were also tested including traps and a newly designed remotely operated vehicle (ROV). ScanAqua built an especially designed boat to handle both fishing and feeding operations. This boat carried the SeaNest automation for feeding and other husbandry routines. ScanAqua undertook considerable research on post-harvest treatment of the roe prior to packing for the international market (primarily the Japanese market for live urchins, but also European markets for both live urchins and roe). ScanAqua cooperated closely with Nofima and other research institutions to develop a proper dry feed for gonad enhancement and to improve processing methods to ensure top quality roe. However, marketing and logistics were challenging, particularly in Hammerfest in northern Norway, and in 2010 the company was forced into bankruptcy. Subsequently, much of the equipment has been redistributed to other companies interested in sea urchin aquaculture, including companies in Norway and Australia. Despite the venture closing, their experiences and the associated research has provided much valuable information for future roe enhancement ventures in Norway and other countries (Data from unpublished report).

(This summary is based on the information available in the book, Echinoderm Aquaculture: James *et al.*, 2015)

5.2 Iceland

5.2.1 The fishery

The green sea urchin (*Strongylocentrotus droebachiensis*) is common around Iceland but the distribution is very patchy. It is commonly associated with laminarian kelp which it feeds on. Harvesting started in 1983 using divers which was not economically feasible and stopped in 1989. In 1993 the fishing started again using large scale dredges and peaked in 1994 when 1 500 tonnes was landed. After that the fishery declined rapidly and a government ban was enforced to stop the fishery in 1997. In 2005 exploitation of the stock started again but only in Breidifjördur, west Iceland. Since 2007 the yearly landings have been about 150 tonnes until 2014 when it reached 230 tonnes. Since 2007 CPUE has been steady, ranging from 365-478 kg/hour fished. The main fishery has been in a small area of the southern part of Breidifjördur and is focused on particular smaller areas, or hot spots.

5.2.2 Fishing techniques

Since 1993 sea urchins have only been harvested by dredging as it was considered to be the best solution for the Icelandic fisheries because of the weather, cost and efficiency. In the beginning two types of dredges were used, both modified scallop dredges. However, since 2005 a new version of modified scallop dredge has been used, a kind of a ski dredge. The selectivity and efficiency of this dredge is unknown. In an investigation carried out at two small sites in northern Iceland in 2012-2013 on size distribution and roe filling, traps were used for sampling (Magnúsdóttir et al 2013).

The sea urchin fishery operates without a fishery management plan, where no restrictions on catch, effort, number of boats, dredge constructions, area closure or fishing seasons exists. The only requirements for the fishermen to be able to catch sea urchins are that the boat is legally operated and has fishing permit. No regulations regarding size limits exist but the market demand is that the urchins have reached 40-50 mm in diameter. There are no limited fishing seasons but because of market demands for roes of good quality (> 10 %, right colour and quality) which can only be reached between September and April in Icelandic waters, the fishery is conducted in these months only. However, logbook information is required weekly, where catch, location and effort is reported for every fishing day and the stock status (CPUE) has been determined annually from that information by the MRI.

Most of the sea urchins landed in Iceland are shipped alive to a market in France. For the time being only one boat is fishing and one processing company operating.

5.3 Greenland

5.3.1 The fishery and fishing techniques

There is currently no commercial fishery for sea urchins in Greenland, although there have been attempts to fish for sea urchins in mid-1990's. In 2006 there were a project funded by NORA (North Atlantic Cooperation) with the aim of locating where sea urchins best thrive and when the roe content was suitable for fishing. In 2009 a report was published by scientists from Nofima, Norway describing an initial investigation to search for areas in Greenland where sea urchin stocks may exist (Siikavuopio S.I. and Labansen, J.P., 2009). Several searches were made along selected sections of the Greenland coastline to chart stocks, assess the quality of these and investigate whether commercialisation of this resource is possible. Using traps the roe size, colour, taste and consistency was assessed at different sites with promising results. However, in order for sea urchins to demand the highest market prices, they need to be delivered to a processing plant or to markets relatively quickly. Such plants do not currently exist in Greenland and the road network is not sufficiently developed. Therefore, sea urchins must be transported by boat to the airport which adds time and cost. An alternative is to store the sea urchins until sufficient quantities are available to transport more economically. This is also challenging as they are vulnerable to damage, frost, temperature and sunlight.

In 2014-2015 Royal Greenland A/S had a trial fishery for sea urchins in Maniitsoq and Nuuk, both West Greenland. There appeared to be sufficient sea urchins present in these areas. Royal Greenland A/S ran trial fisheries over a year, where the main objective was to find out what time of the year the roe were in prime quality and a seasonal variation was detected. Royal Greenland A/S recommends that fishing season should be from September to March where the roe content is good. Different types of fishing gear was tested, the traps developed by Nofima were shown to be effective. A bottom dredge developed from Thorisholmi was also very effective, especially when modified to bottom conditions in Greenland, and the return for catch effort was high. These trials showed that there are popular spaces for the sea urchins to accumulate around archipelagos with a lot of currents and good seaweed. In these conditions it is possible to fish the sea urchins from a small area then return a day later and larger sea urchins have returned. It appears that these areas are surrounded by sea urchins that will replenish those removed from the fishery. As this is a virgin fishery there is no way of knowing how long this replenishment would continue without adequate population monitoring over time. As yet there is still no commercial fishery in Greenland.

5.3.2 Management of sea urchin fisheries

If a sea urchin fishery was established in Greenland there are legislative tools available to regulate it but as there has never been a fishery there is no experience at managing the species. Greenland Institute of Natural Resources (the national institute that monitors the use of both terrestrial and marine species and gives scientific advice to the government) has not undertaken surveys on sea urchins and has no plans to do so in the near future.

5.4 Ireland

5.4.1 The fishery and fishing techniques

Paracentrotus lividus or the purple sea urchin is the main species of urchin fished in Ireland due to its high market value. *Paracentrotus lividus* inhabits subtidal rock pools and rocky shorelines. Harvesting of this species of urchin can be carried out by hand picking in the intertidal zone or by divers operating from boats.

In certain parts of the west coast of Ireland, in particular the inner Galway bay large colonies of urchins lived buried below the surface of coral sand. These areas were the first areas to be completely harvested in the late 1970s, and since then there has been little or no recovery (Fig. 10 and 11). These confined areas in the inner Galway bay were subject to increased fishing pressure from divers during slack tides. Large harvests were reported in some cases up to two metric tonnes per day. During this exploitation of the fishery competing groups of harvesters and divers traveled the west coast once catch volumes began to decline in fished areas.

This decline in the fishery was due to lack of regulation and collection of catch data during the boom years of the fishery.

Figure 10 Diver and boat crew harvesting one metric tonne of sea urchins in the 1970's in inner Galway bay near Newquay (Image courtesy of Patrick Bigand).

Figure 11 Boat crew and diver with 800kg of sea urchins at Newquay (Image courtesy of Patrick Bigand).

Due to the nature of this species of sea urchin, fishing or harvesting is mainly carried out by hand picking at low spring tides or by teams of divers on SCUBA (Fig. 12). The season is traditionally from the end of September to the beginning of May before the risk of spawning during shipping occurs.

Figure 12 Sea urchins in a rock pool at low tide in Connemara County, Galway. Urchins in these deep exposed rock pools can usually be found under a layer of shells, pieces of debris and sea weed.

Demand for *P. lividus* is driven by markets and due to the undersupply of this important urchin the price remains high. Harvesters can expect to attain €8 - €10/kg from buyers (Fig. 13). However, inconsistent supply from the wild fishery doesn't allow for consistent supply to main European markets but allow for supply to the high value low volume restaurant trade.

Figure 13 Sea urchins for sale at Galway market with a market value of €18/kg. Urchin are not eaten in Ireland as they do not form part of traditional cuisine here, therefore the quantities sold are quite low. The main market for P. lividus is typically France and congenital Europe where it is a delicacy and forms part of the traditional dishes.

6 Introduction to cost effective fishing techniques

There are a number of factors that must be considered when considering sea urchin fishing techniques. This includes the following:

- *The existing fishing fleet:* The number, size and type of boats in the existing fishing fleet. Do they have experience fishing with traps and/or divers for benthic invertebrates? Is it possible to incorporate new entry fishers into the fleet with existing boats or with small, relatively cheap vessels?

- *Fishing regulations:* How do these apply in each country and do they restrict the type or timing of sea urchin fishing.

- *Technical availability:* The cost (per day/per hour) and availability of divers.

- *Species, distribution and quality:* The species of urchin and the value of the species. The population size and distribution of the species and the quality of the sea urchins. For example what % of the population is economically viable to fish (has enough gonad to make the product marketable). Is roe enhancement necessary to increase the value of the catch?

- *Topography:* The topography of the sea floor is important when considering what type of fishing is optimal. Dredges and trapping work best on a flat topography whilst divers can operate in complex bottom topography.

- *Logistics and infrastructure:* The logistical support and infrastructure (airports, roads etc) available in any particular country.

- *The history of the fishery:* Does the country have a history of fishing sea urchins with experienced fishers, routes to market, holding and processing facilities etc.

- *Market:* Will the urchins be presented as whole live product or will they be processed in the country of origin and sent to market as roe product.

The efficacy of a fishing technique will depend on a number of these factors and the interactions between them. They will vary significantly in each NPA country, depending on where the venture is within the country (eg proximity to major airports, climatic differences), the size of the company carrying out the fishing and the size and scale of the fishing venture. In the following NPA report a cost/benefit analysis will be conducted for each of the participating NPA countries on what method of fishing is most effective. It will also make recommendations on optimal fishing techniques for each of these countries.

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Appendix 1

URCHIN project Work Package 3 Outputs

Part 1: Sea Urchin Fishing Techniques Report
(Activity A3.1.1 of the URCHIN project)

Description: Review and report on techniques previously and currently used in the NPA as well as in other similar geographic areas			*Deliverables:* Report to all particpating SME's on fishing techniques in arctic areas
3.1.1	*Deliverable* Report	*Target value* Make report available to a minimum of 10 SME's in NPA	*Delivery month* 06.2015

Part 2: Optimal Sea Urchin Fishing Techniques for the NPA Report
(Activity A3.2.2 of the URCHIN project)

Activity 3.2	*Activity title* Fishing techniques review	*Start month* 03.2015	*End month* 08.2016
Description: Development and testing new and novel methods especially designed for collecting urchins in extremely harsh environments. Assess optimal fishing techniques for various NPA areas			*Deliverables:* Supply design and protocols for new/novel fishing techniques
3.2.1	*Deliverable* Designs and protocols	*Target value* Supply design and protocols to a minimum of 10 SME's in NPA	*Delivery month* 08.2016
3.2.2	*Deliverable* Provide cost/benefit analysis report on fishing techniques appropriate to each participating NPA country	*Target value* Supply report to a minimum of 10 SME's in NPA area	*Delivery month* 08.2016

Appendix 2

Pathfinder trial: A novel new technique for harvesting sea urchins

Philip James & Tor Evensen
Appendix submitted in November 2017, to be released in April 2018.

Aim: The aim of this report is to describe a sea trial of the 'Pathfinder' harvesting system conducted in Tromsø in October 2017. The trial will provide proof of concept that the Pathfinder's is a potential harvesting system for collecting wild sea urchins from a boat in Norway and elsewhere in the world.

General description: Pure Arctic AS is a newly founded company that is focusing on the developing a new method for harvesting species living on the seabed, such as sea urchins, sea cucumbers and scallops. **The Pathfinder** is a self-tracked unit that harvests species from the seabed. The unit leaves a minimal footprint on the seafloor and provides gentle handling of the catch. The unit used in this test will perform a proof of concept trial before the product is further developed and finally made available for the market.

Equipment and Methodology

- The pathfinder equipment was installed and set up on the 'Morild' on Monday 9th Oct.
- The 'Morild' is a 14m x 7m catamaran designed for servicing the Nofima Marine Research Farm in Tromsø.
- On Tuesday 10th Oct the forecast was for fine weather and a light SE breeze of 1-2m/sec
- The 'Morild' left dock at 9.00am and arrived at the harvesting site (Ytre Kårvika: 69.87022°N 18.88849°Ø) at approximately 10.00am.
- Nofima have collected sea urchins from this site on numerous occassions. It has a shallow hard shingle bottom with large numbers of small urchins.
- The pathfinder equipment was assembled for deployment and the following actions were taken throughout the course of the day:
  - Assembly of equipment for first boat trial
  - Hydraulic issues the boats hydraulic system (resulted in insufficient effect)
  - Switched to back up pump (firepump)
  - Issues priming pump from deck (3.5m above sea level)
  - Everything connected and started trial
  - Successfully fishing but discovered urchins had been blown out of the open top of catch unit due to excessive turbulence. Collected large urchin remaining in catch system for survival test
  - Wind speed increased through the day and there were issues with wind/current and the boat drifting (Anchor didn't hold)
  - Attempt to reset anchor failed and a decision was made to shift to a second site (approximately 3.00pm)
  - 10 minute steam to second site (Inner Kårvika)
  - Back up pump problems/failure
  - Equipment reconnected and set
  - Hydraulic issues on boat overcome during second fishing trial
  - Full suction available for 20-30 minutes of final fishing trial
  - Collected urchins in basket for weight and bycatch evaluation

- Finished trial at 6.30pm and steamed home
- Summary of day during trip back
- Unload boat and finish at 8.30pm

Figure 1 Driving controls onboard the 'Morhild'.

Figure 2 The simple holding systems used to test for survival for 2 weeks following the harvesting trial.

Results:

- Live sea urchins were collected from the 'Pathfinder' catch system from site 1 and 2 to monitor post-harvest survival. After 2 weeks in sea-based holding systems the survival rates of the two groups was as follows:
  - Site 1: 75 % Survival after 2 weeks
  - Site 2: 91.7 % Survival after 2 weeks

- Catch rates from approx. 20 minutes harvesting at site 2 with a modified catch system = 64kg
  - Approx. 15.6kg of the catch consisted of sea urchin
  - Approx. 82 urchins/kg so total catch approx. 1093 individual urchins
  - Average size 33.2mm TD

- Minimum size measured 27.2mm TD
- Bycatch including king snail, sea cucumbers and sea stars
- A substantial amount of fine debris, stones and rocks were also in the catch.

Figure 3 The catch from the last test run at Site 2 (top and bottom left) and a sample of the bycatch (bottom right)

Conclusions from trial:

- The trial showed that the pathfinder was a very efficient means of collecting sea urchins (and other benthic invertebrates) from a flat seafloor.
- The trial showed that urchins collected by the pathfinder have a good survival rate. This increased significantly in the second trial when the catch system was altered to retain the urchins. The urchins collected would be suitable for both immediate sale as well as holding in land or sea-based systems for roe enhancement.
- The trial showed the pathfinder can be deployed from a boat (Catch efficiency will be much higher on a vessel with the system better integrated and more operational experience).
- The catch data obtained in the trial was limited. However, the trial results indicated that the pathfinder is capable of collecting virtually 100 % of the invertebrate species it passes over whilst harvesting.

- During the trial there was a limited window where the catch was actually harvested due to issues with the catching system and the pump system. The catching system needs to be improved and optimized for sea urchins, Pure Arctic already have design plans in place to overcome this issue. The pump was an issue specific to the boat and would be overcome with better integration to the vessel.
- Therefore, catch rates will be limited only by sea urchins abundance and the amount of seafloor the pathfinder can cover.
- The current speed of the pathfinder is 12m/min, the estimated coverage rate for this speed is 1100m^2/hr (assuming a flat substrate).
- It is feasible that the harvesting speed will be increased to further improve coverage rates.
- Positioning technology will enable remote setting of the harvest area, meaning the driving of the pathfinder can be fully automated (this technology is available but needs further development and implementation).
- Further research and development is required to show whether the pathfinder can be equally effective on the seafloor when it is not flat (the current trial tested the pathfinder on a virtually flat seafloor).

Summary statement:

The pathfinder shows tremendous promise as a harvesting technology suitable for benthic invertebrate species (such as sea urchins, sea cucumbers, scallops) found on flat substrates. In addition, it has clearly demonstrated its suitability for providing a suction system capable of removing silt and sludge from the seafloor. This has tremendous application potential in sea-based aquaculture.

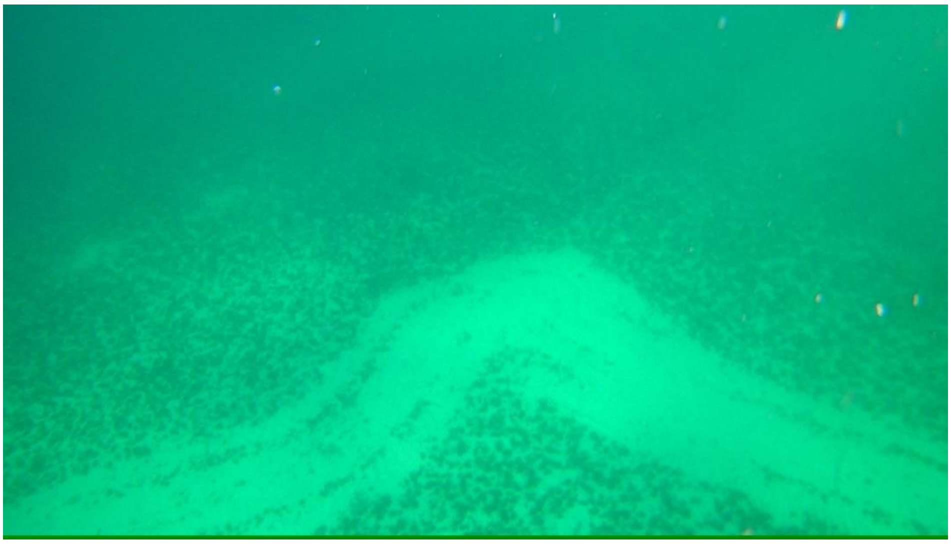

Figure 4 The track of the pathfinder clearly showing its efficacy of collecting everything in its path when functioning on the seafloor.

Figure 5 The seafloor at Site 2 during the trial.

Figure 6 An example of the first sea-based sea urchin catch from the 'Pathfinder' trial held by Rune Svendsen from Pure Arctic AS.

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