Report 8/2017 • Published April 2017

Cost/benefit analysis of sea urchin fishing techniques

Activity A3.2.2 of the NPA URCHIN project

Philip James and Colin Hannon

Nofima is a business oriented research institute working in research and development for aquaculture, fisheries and food industry in Norway.

Nofima has about 350 employees.

The main office is located in Tromsø, and the research divisions are located in Bergen, Stavanger, Sunndalsøra, Tromsø and Ås.

Company contact information:
Tel: +47 77 62 90 00
E-mail: post@nofima.no
Internet: www.nofima.no

Business reg.no.:
NO 989 278 835 VAT

Main office in Tromsø:
Muninbakken 9–13
P.O.box 6122 Langnes
NO-9291 Tromsø

Ås:
Osloveien 1
P.O.box 210
NO-1433 ÅS

Stavanger:
Måltidets hus, Richard Johnsensgate 4
P.O.box 8034
NO-4068 Stavanger

Bergen:
Kjerreidviken 16
P.O.box 1425 Oasen
NO-5844 Bergen

Sunndalsøra:
Sjølseng
NO-6600 Sunndalsøra

Alta:
Kunnskapsparken, Markedsgata 3
NO-9510 Alta

Report

Title: **Cost/benefit analysis of sea urchin fishing techniques** Activity A3.2.2 of the NPA URCHIN project	ISBN: 978-82-8296-491-3 (printed) ISBN: 978-82-8296-492-0 (pdf) ISSN 1890-579X
	Report No.: 8/2017
Tittel: Kostnad-nytte-analyse av fangstteknikker brukt i fangst av kråkeboller Aktivitet A3.2.2 av NPA URCHIN prosjekt	*Accessibility:* **Open**
Author(s)/Project manager: Philip James[1] and Colin Hannon[2] [1]Nofima – The Food Research Institute [2]GMIT – Galway Mayo Institute of Technology	*Date:* 24.April 2017
Department: Production Biology	*Number of pages and appendixes:* 19+1
Client: Northern Periphery and Arctic Program	*Client's ref.:*
Keywords: Sea urchin, fishing techniques, cost/benefit	*Project No.:* 11259

Summary/recommendation:

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 (based on the Nofima report Number 15/2016, Activity A3.1.1 of the NPA URCHIN project) describing the main fishing techniques that are used in sea urchin fisheries around the world.

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. They will vary significantly in each NPA country, depending on where the venture is within the country (e.g. proximity to major airports, climatic differences), the size of the company carrying out the fishing and the size and scale of the fishing venture. Included in this report are recommendations for optimal fishing techniques for each of the participating NPA countries to define what method of fishing is likely to be most effective in each.

Summary/recommendation in Norwegian:

Denne rapporten gir en kortfattet innføring i kråkebolleprosjektet URCHIN, finansiert av Northern Peripheries and Arctic Programme (NPA). Rapporten er en oppfølging av Nofima-rapport 15/2016, aktivitet A3.1.1 av NPA URCHIN, som beskriver de viktigste fangstmetoder som brukes ved høsting av kråkeboller rundt om i verden.
Rapporten tar for seg ulike faktorene som brukes for å velge de mest optimale fangstmetodene for ulike land og selskaper. Effekten av en fangstmetode avhenger av en rekke av disse faktorene og samspillet mellom dem. De vil variere betydelig i hvert av NPA-landene, avhengig av naturgitte forutsetninger og infrastruktur (f.eks. nærhet til store flyplasser, klimatiske forskjeller). Rapporten gir anbefalinger om optimale fangstmetoder i de deltakende landene og oppsummerer hvilken fangstmetode som er mest effektiv.

Table of Contents

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 from the Sea Urchin Fishing Techniques Report (Activity A3.1.1 of the NPA URCHIN project) describing the main fishing techniques employed in sea urchin fisheries around the world.

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. Fishing techniques will vary significantly in each NPA country, depending on where the venture is within the country (e.g. proximity to major airports, climatic differences), the capacity and size of the company carrying out the fishing and the size and scale of the fishing venture. Recommendations are included (highlighted in green below) for optimal fishing techniques for each of the participating NPA countries.

Recommended technique in Norway:
For small owner/operator ventures with a diver associated with them SCUBA diving remains the most optimal fishing technique. For smaller and larger ventures that do not have a diver associated with them, the authors suggest that the optimal technique may be to combine different techniques. Currently, the best options are SCUBA and trapping.

Recommended technique in Ireland:
Historically SCUBA diving is the traditional method of collection in Ireland and due to the relatively mild climate and availability of commercial divers is still the optimal method of collection. Trapping may be worth considering and hand collecting in shallow waters is still also practised.

Recommended technique in Iceland:
Dredging is seen as the only viable method of collection in Iceland

Recommended technique in Greenland:
Dredging is seen as the most viable method of collection in Greenland with the potential to also develop a trap fishery.

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 peripheral, environmentally harsh and challenging areas in the Northern and Arctic region will be identified and addressed.

Currently there are small scale (<150 tonne p.a.) intermittent fisheries for sea urchins in the NPA. This is despite there being extensive under utilised 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.

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 to increase the value of low value sea urchins once they have been collected in the northern arctic regions will be transferred to Ireland, 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 A3.2.2 of the URCHIN project, see Appendix 1) is to provide a basic cost/benefit analysis of the various fishing techniques available for fishing sea urchins in the NPA. The report includes sections from the earlier report titled 'Sea Urchin Fishing techniques Report', Activity A3.1.1 of the Northern Periphery and Arctic (NPA) URCHIN project (James *et al.*, 2016; Nofima report Number 15/2016, Published in March 2016). Report 15/2016 gives a more comprehensive description of the fishing techniques utilised around the world as well as a description of the fishery techniques utilised in participating NPA countries (Norway, Iceland, Ireland and Greenland). The authors intend that the recommendations included in the current report, on the most cost effective sea urchin fishing techniques for each of the countries participating in the URCHIN project, will provide guidelines for any fishers attempting to start a sea urchin venture in the NPA.

3 Primary fishing techniques used in sea urchin fisheries around the world

This section is a review taken from the 'Sea Urchin Fishing Techniques Report' (Activity A3.1.1 of the NPA URCHIN project, Report Number 15/2016, Published March 2016).

3.1 SCUBA diving

This is most common technique used for fishing and harvesting of sea urchins around the world. This method 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, utilises single or twin tanks, uses compressed air, enriched oxygen (NITROX) or mixed gases to extend dive times. The latter are very technical form of diving and has many safety and training implications. The following are some of major restrictions to the collection of sea urchins using SCUBA. The limit on the amount of time available for each dive being restricted by available breathing gas and bottom time. The regulations and diving protocols to maintain safety standards. The ancillary boat costs and the cost of maintaining a full professional dive team. The inherent risks associated with SCUBA diving for sea urchins (a number of fatalities have been recorded in various fisheries around the world). Periods of very poor visibility (e.g. in Norway in summer algal blooms lower the underwater visibility significantly for extended periods).

Divers tend to use hand tools (or just their hand in some instances) to selectively remove the urchins into catch bags that are carried to the surface by the diver, or are raised to the surface using lifting bags inflated underwater. Sea urchins are hand-harvested by the diver and can be graded by size. There is no associated bycatch or harvesting of undersized sea urchins. The selection of mature and market sized sea urchins by divers means that undersized specimens can be returned or avoided without significant mortality, adding to the sustainability of this method of harvesting sea urchins.

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

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 (left) and a compressed air tanks and a catch bag (right).

3.2 Diving using surface supply

This technique is widely used for the collection of benthic invertebrates such as abalone in the southern hemisphere. This method involves a diving air compressor supplying a high pressure air bank which supplies air to a diver working on the sea floor via an umbilical. This can be a single diver or a team of divers working from a surface supply panel. This scope of this type of diving is dictated by the following; the diver can only cover the area around the boat and the depth and the available umbilical length restricts the accessible area. However, dive times can be longer than on SCUBA and the diver is not restricted by a bulky SCUBA unit and has the added redundancy of an emergency bailout system. This technique is not suitable in rough weather or in areas with strong currents. As with SCUBA diving, the sea urchins are hand-harvested and any bycatch is avoided. The use of surface supply diving in NPA regions can be heavily regulated and requires extensive training, equipment and experience.

Similarly, to SCUBA, surface supply diving operations are also susceptible to poor weather conditions, cold conditions (dry suits and possibly hot water suits can be used) and the dark period experienced in a number of NPA countries would restrict dive operations, as well as periods of poor underwater visibility. The technology available now in the form of GPS trackers and dive lights may mitigate the dark period for some dive operations. In some systems, the surface supply diver will have hard wire communications with the surface thus adding another level of safety.

Figure 2 Left: typical abalone diver using surface supply, Right: surface supply diver using surface supply in Ireland this equipment is transferable for cold water conditions throughout the NPA.

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, oysters, mussels and sea cucumbers as well as sea urchins. Iceland now has a history of using dredges to harvest sea urchins and operators have proven dredging to be an economically viable method of fishing. The efficiency of the dredge relies on the experience of the fisherman, relatively flat substrate in order to avoid the dredge getting fouled on the bottom and a relatively high density of urchins. As the dredge is physically dragged across the seafloor there can be damage caused to the sea urchins although the dredge used in Iceland is designed to minimise sea urchin damage and the associated bycatch. Dredge size is dictated by the vessel size towing them. Larger dredges can be used from many existing fishing vessels used throughout 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, Catch per unit effort (CPUE) and the impact of the fishery on the stock.

A number of countries (e.g. Norway) do not currently allow/or discourage dredging because of the perceived negative effects on the benthic environment.

Similar to diving operations the use of a dredge is also susceptible to poor weather conditions and current. However, this technique is not as restricted by cold conditions or poor visibility and could also operate during the dark period experienced in a number of effected 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 breath hold divers equipped with snorkel, mask and fins 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 (e.g. 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 sea urchins are also handpicked and there is no associated bycatch. The free diver is not restricted by equipment and 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.

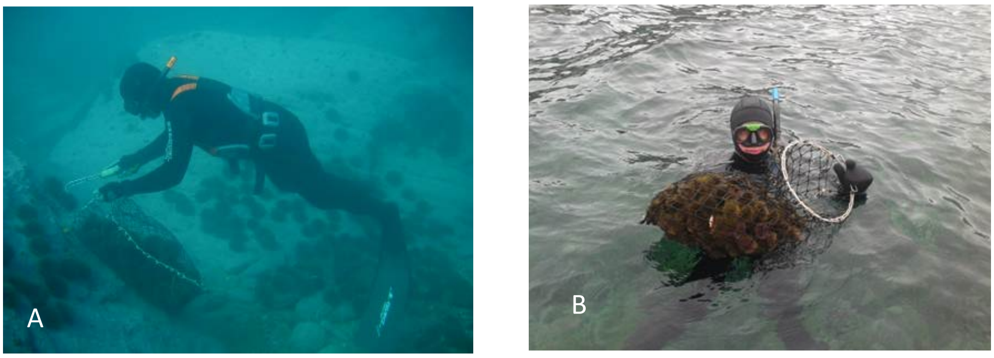

Figure 4 *(A) A breath hold diver in New Zealand with catch hook and catch bag (B) The sea urchin catch from breath hold diving in Tromsø, Norway.*

3.5 Trapping

Although there are examples from around the world, where trapping has been used commercially used to harvest sea urchins (Canada and Japan) this is not a commonly used technique for harvesting sea urchins. There are a wide variety of trap types and shapes and 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, retaining catch and storage) that is simple and cheap to make. Trapping has a number of advantages over diving and dredging. 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 sea urchins are also in very good condition as they have not been handled at all prior to being bought to the water surface. Depending on the bait used there can be considerable bycatch from fish bait (some are also valuable species) whilst virtually no bycatch from macroalgae bait. There are no size limitations on the sea urchins that can enter the traps and so size sorting of the catch is necessary. Traps should ideally be set for periods of 5-7 days of a soak and poor weather conditions can damage or displace 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.

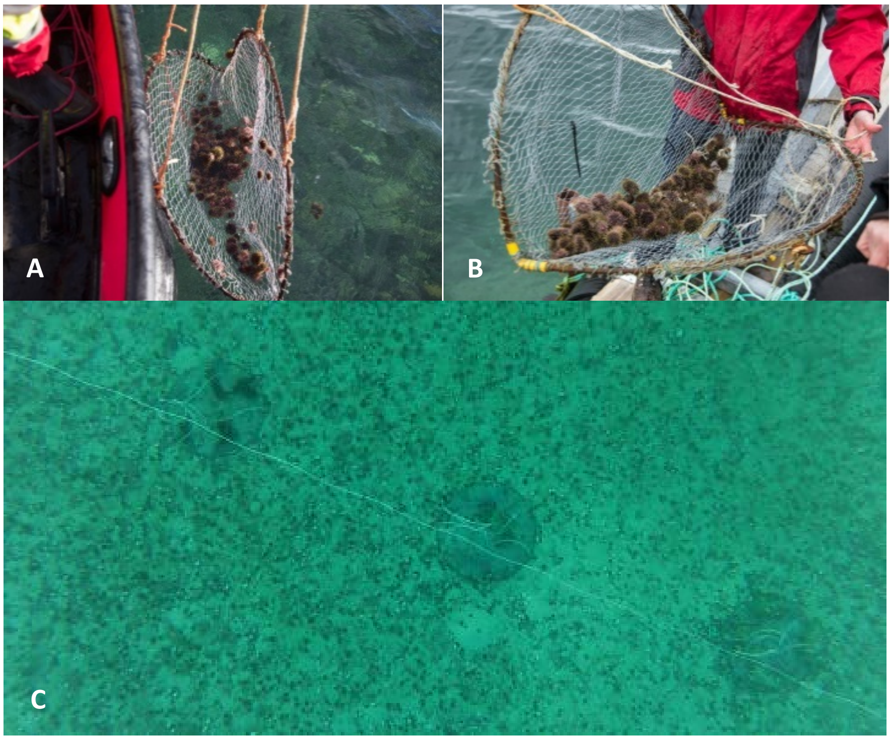

Figure 5 *(A-B) The simple trap design developed and tested by Nofima in Norway (C) The traps laid on a string/backbone on the sea floor in Norway.*

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

3.6 Remote Operated Vehicle (ROV)

The five fishing techniques described above are the primary methods of catching sea urchins used around the world. In Norway there has been considerable research into the use of remote operated vehicles and so this method has also been included in this report.

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 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 sea urchins that were kept to the industry recommended size of 40mm test diameter. Any damaged sea urchins could also be utilized by processing the roe in these animals. (James, 2012).

The use of an ROV is 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. Reasonable underwater visibility is required for the ROV driver to be able to fish effectively. 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 and training.

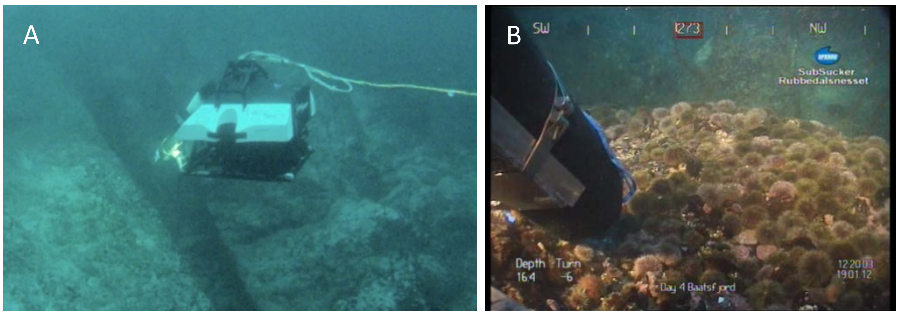

Figure 7 *(A) The ROV designed and used in Norway in action (B) the view from the ROV camera during fishing operations.*

4 Cost/benefit analysis for sea urchin fishing techniques

A cost benefit analysis is used to evaluate the total anticipated cost of a project compared to the total expected benefits in order to determine whether the proposed implementation is economically viable for an operator or an industry.

A cost-benefit analysis lists all potential costs that will be incurred and all anticipated benefits. From these it is possible to determine whether the positive benefits outweigh the negative costs. In the case of sea urchin fisheries, there are additional factors that must be take into consideration that are not listed in the anticipated financial benefits (e.g. social or ecological benefits). These are included in section 4.3.

4.1 Potential Costs

The following is a list of potential costs that must be considered when deciding on the optimal fishing technique to employ in potential sea urchin fishing operations:

- Set up costs (Boat)
- Set up costs (Fishing equipment)
- Running costs
- Regulatory costs
- Maintenance costs
- Labour costs
- Freight costs
- Roe enhancement costs (if applicable)

4.2 Anticipated Benefits

4.2.1 Monetary

- Catch rates (quantity of catch)
- Value of catch
  - Wild catch value
  - Wild catch and roe enhancement value

4.2.2 Non-monetary

- Ecological benefits
- Social benefits

4.3 Additional factors

There are a number of additional factors that are not directly included under the cost or benefit list but should be considered when calculating optimal sea urchin fishing techniques, or the best technique to implement in a new fishery. This will vary significantly between countries and may be as important as the factors listed under cost and benefit above. They include the following:

- *The existing fishing fleet:* The number, size and type of vessels 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 inexpensive 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 which will vary significantly between countries.

- *Diving regulation:* There are regulations on commercial diving activities in most NPA countries that must be taken into consideration (e.g. divers in Norway must have a diving license). In Scotland there is a regulated diving based shellfish fishery however the collection of echinoderms is unregulated in most other NPA regions.

- *Species, distribution and quality:* The species of sea 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 (e.g. proximity to major airports, climatic differences), the size of the company carrying out the fishing and the size and scale of the fishing venture.

4.4 Analysing the cost/benefits of the main fishing techniques

The following Table (Table 1) shows the relative general cost/benefit relationship for the 4 main fishing techniques used in sea urchin fisheries as well as the ROV technique trialled in Norway.

Table 1 A guidance framework for analyzing the relative cost/benefits for the four main fishing techniques and for ROV fishing.

Fishing technique	**SCUBA**	**Dredge**	**Trapping**	**Breath hold***	**ROV**
COSTS					
Set up costs (Fishing gear)					
Set up costs (Boat)					
Running costs					
Regulatory costs					
Maintenance costs					
Labour costs					
BENEFITS					
Catch rates					
Value of catch					
Ecological/social Benefits					
Suitability for roe enhancement					

Costs

Low
Medium
High

Benefits

Low
Medium
High

5 Optimal fishing techniques for NPA 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*. The lack of a historical and consistent fishery for wild sea urchins has been a constraint to developing sea urchin fisheries in Norway. The lack of a collection, transport and processing infrastructure for sea urchins in Norway adds to the difficulty of establishing a new sea urchin aquaculture venture.

There is no stock management (no total allowable catch TAC 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 listed on 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 sea 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°N and 71°N. Such conditions make sea urchin collection difficult during this time of the year, regardless of the techniques employed. The longest 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 (Mr Roderick Sloan) relies on small volume 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. Previous large scale companies (e.g. ScanAqua AS) used divers that were brought from other European countries at considerable cost as there was significant downtime when the divers were unable to dive due to weather or sea conditions. The divers also spent considerable amounts of time searching for sea urchin populations to harvest rather than actually 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 and in recent years there has also been considerable research into trapping as a viable technique.

5.1.2 Summary of factors effecting fishing technique choice in Norway

SCUBA:

- High cost of diving (unless an owner operator such as Arctic caviar AS).
- Unavailability of a diving workforce experienced and willing to undertake sea urchin diving activities.
- Very limited history of diving for benthic invertebrates (NB: there is a small scallop diving industry in specific parts of Norway).
- Diving is still the most tried and tested method of fishing urchins in Norway.
- Suitable for smaller business models such as Arctic Caviar AS with an owner/operator/diver.
- Diving is a very tansferable method of harvesting for operators in remote peripheral areas.

Dredge:

- The laws around dredging are unclear in Norway and it is not considered a suitable method of fishing for benthic invertebrates such as scallops, sea cucumbers and sea urchins. A change would be needed in the current legislation to allow dredging on a commercial scale.

Trapping:

- There has been a significant amount of testing regarding the use of traps in Norway in recent years showing that trapping is a relatively cheap and effective method of harvesting.
- Trapping is non-selective so there may be the need for extensive catch sorting.
- It is a fishing method that is suitable for relatively inexperienced fishermen to use that requires relatively small financial investment (small boat and traps).
- Trapping is also a very tansferable method of harvesting for operators in remote peripheral areas.

Free diving:

- This is not a method that has been explored in Norway other than for occasional collections.
- The major restriction is the lack of a free diving base (e.g. abalone divers such as in many. other countries where both abalone and urchins are harvested by free divers).

ROV:

- The investment required for ROV harvesting is very high and this is unlikely to prove an economic method of fishing sea urchins unless significant improvements are made in catch rates and the investment costs required to use an ROV for fishing are reduced.

Recommended technique in Norway:

For small owner/operator ventures with a diver associated with them SCUBA diving remains the most optimal fishing technique. For smaller and larger ventures that do not have a diver associated with them the authors suggest that the optimal technique may be a combination of different techniques. Currently, the best options are SCUBA and trapping.

5.2. Ireland

5.1.3 The fishery

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 SCUBA 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. 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.

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. The season is traditionally from the end of September to the beginning of May before the risk of spawning during shipping occurs.

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. However, inconsistent supply from the wild fishery does not allow for consistent supply to main European markets but allows for supply to the high value low volume restaurant trade.

5.1.4 Summary of factors effecting fishing technique choice in Ireland

SCUBA:

- SCUBA was used at the beginning of the fishery and still is in some cases used where conditions suit. Due to the nature of the species they are found predominantly in the intertidal as the sub littoral populations never recovered after the extensive harvests from the 1970-1990s’. The conditions in some areas are suitable for SCUBA diving. Without catch data it is not possible to know what is currently harvested by means of SCUBA.

Dredge:

- Sporadic catches are reported by dredge during oyster fishing activities. Dredging has not been used as a commercial means of collection however occasional animals are landed or reported. Where *P. lividus* exist predominantly is not suitable for dredging due to high currents and exposed rocky conditions.

Trapping:

- As a collection method trapping is not used in Ireland. *P. lividus* is unlikely to be collected by trapping due to the environmental conditions they inhabit and as a species they do not forage like other urchins for example *S. droebachiensis*. *P. lividus* are gregarious by nature and tend to remain sedentary maintaining a home scar due to the exposed conditions they inhabit. However, this technique has not been trailed in Ireland.

Free diving:

- Free diving can be used as a means of collection in rock pools too deep for hand harvesting during low water spring tides. Commercial collection of urchin has not been reported using this method in Ireland.

Recommended technique in Ireland:

Main recommended techniques for collection of *P. lividus* is the use of SCUBA divers where conditions suit with respect to depth and environmental conditions. Hand collection during low water tides in rock pools is recommended. Due to the nature of the species, trapping and freediving have not been used as methods of commercial harvesting. Dredging as means of commercial collection has not been readily used in Ireland due to the conditions the species inhabit not being suitable for dredging.

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 1994 the fishery declined rapidly and fishing activity stopped completely. A government ban was enforced to stop the fishery which resulted in a complete closure in 1997. In 2005 harvesting of the sea urchin stock started again but only in Breidifjördur, west Iceland. Since 2007 the yearly landings have been 150 tonnes per annum until 2015 when it reached a total of 276 metric tonnes. Since 2007 CPUE has been constant, ranging from 365-478 kg/hour effort. The main fishery is confined to a small area of the southern part of Breidifjördur.

Since 1993 sea urchins have only been harvested by dredging as it was considered to be the optimal solution for the Icelandic fishery because of the weather, cost and efficiency. In the beginning two types of dredges were used, both modified scallop dredges. However, since 2005 an improved version of a modified scallop dredge has been used, a type of beam trawl. The selectivity and efficiency of this dredge is unknown. An investigation carried out at two small sites in northern Iceland in 2012-2013 on size distribution and roe content, traps were used for sampling.

The current Icelandic 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 existed until 2016 when a quota of 250 metric tonnes were decided for the fishing area in Breidifjördur. The only requirement for the operator to be able to catch sea urchins is that the boat is legally operated and has a fishing permit. No regulations regarding size limits exist but the market demand is that the urchins are 40-50 mm in test diameter. There are no limits on fishing seasons but because of market demands for good quality roe (>10 % GI, preferred colour and quality) which can only be achieved 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 Marine Research Institute.

The majority of the sea urchins landed in Iceland are shipped alive to the French market. Currently there is only one operator fishing and one processing company operating in Iceland.

5.2.2 Summary of factors effecting fishing technique choice in Iceland

SCUBA:

- This technique was used at the start of the fishery in Iceland with divers collected the sea urchins. However, in recent years only a dredge fishery has been conducted.
- The current fishery is concentrated on sea urchin populations that are too deep for harvesting by divers.
- There is a high labour cost and diver costs in Iceland.
- There is no history of a benthic dive fishery in Iceland (e.g. scallops).
- There is limited capacity to develop a dive harvest fishery in Iceland.

Dredge:

- Dredge fishing is legal in Iceland.
- Dredge fishing has proven to be highly effective at harvesting sea urchins from the deep, flat sites where sea urchin fishing has been developed.
- There is a Icelandic fishing company (Þórishólmi ehf) that now has extensive experience with dredge fishing for sea urchins and the methodology is well established.
- Using dredges it is possible to fish deeper populations of sea urchin.

Trapping:

- Trapping has bene trialled in Iceland but not on a commercial scale.
- This method of harvesting would reduce the labour and investment costs to new entrants (e.g. small boat requirements and minimal crew).
- Catch rates using traps are yet to be quantified in Iceland.
- Traps would also allow fishing of urchin populations found in deeper water (however, strong currents may be an issue).

Free diving:

- There is a very limited history of free diving for benthic species (no experienced divers available).

Recommended technique in Iceland:

Dredging is considered the only viable method of collection in Iceland.

5.3 Greenland

5.3.1 The Fishery

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. The conclusions are that there is a south-north growth pattern, where the Young Sound and Qaanaaq populations are the slowest growing while sites in Nuuk have relatively high growth rates. There seems to be a correlation between decreased Arctic sea ice cover and increased productivity of sea urchin and possibly benthic fauna in general. 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 surveys were conducted along selected sections of the Greenland coastline to chart stocks, assess the quality of these and investigate whether commercialisation of this resource was 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 sea 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 to sustain a fishery. 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 was 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 sufficient. Different types of fishing gear were tested, the traps developed by Nofima were shown to be effective. A bottom dredge developed by Þórishólmi ehf was also very effective, especially when modified to bottom conditions in Greenland, and the return for catch per unit effort was high. These trials showed that there are high aggregations of sea urchins around certain archipelagos with strong currents and good feed availability. In these conditions, fishing trials have shown that there are large enough sea urchin numbers to replenish those removed from the fishery. As this is a non-exploited fishery, there is no information on how long this replenishment would continue without adequate population monitoring. At this point there is still no commercial fishery in Greenland.

5.3.2 Summary of factors effecting fishing technique choice in Greenland

SCUBA:

- The cost of labour and dive operations is very high in Greenland.
- There is no experienced dive workforce available for harvesting benthic invertebrates.

Dredge:

- Dredge fishing is legal in Greenland.
- Dredge fishing in Iceland has proven to be highly effective at harvesting sea urchins from the deep, flat sites.

Trapping:

- Trapping has bene trialled in Greenland but not on a commercial scale.
- This method of harvesting would reduce the labour and investment costs to new entrants (e.g. small boat requirements and minimal crew).
- Catch rates using traps are yet to be quantified in Greenland.
- Traps would also allow fishing of urchin populations found in deeper water (however, strong currents may be an issue).

Free diving:

- There is a very limited history of free diving for benthic species (no experienced divers available).

Recommended technique in Greenland:

Dredging is considered the most viable method of sea urchin collection in Greenland with the potential to also develop a trap fishery.

6 References

Falk-Petersen, I.B. & Lønning, S. (1983). Reproductive cycles of two closely related sea urchin species, *Strongylocentrotus droebachiensis* (O.F. Müller) and *Strongylocentrotus pallidus* (G.O. Sars.). Sarsia. 68. 157-164.

James, P., Noble, C., Siikavuopio, S., Sloan, R., Hannon, C., Þórarinsdóttir, G., Ziemer, N., Lochead, J., 2016. Sea Urchin Fishing techniques Report. Report Number 15/2016, pp 21.

Siikavuopio S.I. and Labansen, J.P., 2009. Mengde –og kvalitetsvurdering av kråkebolle I kystnære områder I Sisimiut commune på Grønland. Nofima Report 11/2009, Mai 20019, 24pp.

Appendix 1

The relevant output from the URCHIN URCHIN project Work Package 3:

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 of 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
3.2.2	***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**

ISBN 978-82-8296-491-3 (printed)
ISBN 978-82-8296-492-0 (pdf)
ISSN 1890-579X