Fisheries Research 193 (2017) 15–20

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Short communication

Efficiency of trap type, soak time and bait type and quantities for harvesting the sea urchin *Strongylocentrotus droebachiensis* (Müller) in Norway

P. James*, T. Evensen, R. Jacobsen, S. Siikavuopio

Nofima, Aquaculture Production, Muninbakken 9–13, Tromsø 9291, Norway

A R T I C L E I N F O

Article history:
Received 5 July 2016
Received in revised form 27 March 2017
Accepted 28 March 2017
Handled by Bent Herrmann

Keywords:
Strongylocentrotus droebachiensis
Sea urchins
Trap harvesting
Soak time
Baits

A B S T R A C T

Two trials were conducted to test the following: i) the efficacy of three sea urchin trap types ii) the effect of trap soak time (1-8 days) and iii) the efficacy of two bait types fed at various quantities. The results showed that the round flat, hinged trap design was the most effective and had the highest catch rate. The highest catch rate occurred after 5 days and the authors recommend 3–8 day soak periods for commercial trapping operations. The trials showed that fish bait attracted much higher diversity and quantities of by-catch than algae baits. The more bait stations (of either algae or fish bait) used the greater the catch. However, increasing the number of bait stations also increases the cost and time required to set the bait stations. The authors recommend a minimum of two bait stations per urchin trap to optimize CPUE. Comparisons of trap catch rate and associated costs and logistics indicate that trapping is an economically viable alternative to SCUBA diving and other harvest techniques in Norway.

1. Introduction

In Norway the biomass of the green sea urchin (*Strongylocentrotus droebachiensis*) is estimated to be 80 billion individual animals, or approximately 56,000 tons (Gundersen et al., 2010). Despite this biomass the harvesting of sea urchins in Norway has been sporadic (between 10 and 100 tons per annum over the past two decades and the current annual harvest is estimated to be less than 20 tons (Sivertsen, 1997; Sivertsen et al., 2008; James and Siikavuopio, 2014). One of the primary bottlenecks restricting the development of a sea urchin fishery in Norway is the ability to collect sea urchins reliably, efficiently and consistently, particularly in the northern parts of Norway where conditions can be severe and the cost of diving is restrictive. In order to establish a resilient and viable sea urchin fishery in Norway, based on live capture and immediate sale, or based on live capture and subsequent holding and fattening, a cost-efficient and reliable harvesting method is required. Alternatively, it may be that varieties of methods are used, depending on the characteristics of different areas, such as environmental conditions, time of year and the conditions on the seafloor topography (James et al., 2016).

SCUBA diving is the most commonly utilized method of harvesting sea urchins in fisheries around the world (Andrew et al., 2002; James et al., 2016). In Norway, commercial efforts have primarily focused on the use of SCUBA diving and more recently there have been both research and commercial use of a remotely operated underwater vehicle (ROV) for harvesting sea urchins (and other benthic species) (Sivertsen et al., 2008; James, 2012; James et al., 2016). Both SCUBA and the ROV harvesting face a number of difficulties in the conditions experienced in Norway, particularly in winter in the northern regions between 63 and 71°N where there are periods with frequent storms, low temperatures and very limited daylight.

An alternative method of harvesting sea urchins is trapping and this technique is successfully used to harvest a number of other benthic invertebrate species around the world (Gabriel et al., 2005) such as whelks (Shalack et al., 2011) and a variety of crabs (Bellchambers and de Lestang, 2005; Xu and Millar, 1993). Sivertsen et al. (2008) started investigating the use of traps in Norway but apart from this study there is a paucity of information regarding the efficacy of trapping to harvest sea urchins with most of the available literature being 'grey literature' (for this reason these are included in this manuscript).

In the current study the aim was to test the following: i) the efficacy of three different, novel and low cost sea urchin trap designs, ii) the effects of soak time, and iii) the effects of different baits types and bait quantities. The catch rates and associated costs of

* Corresponding author.
E-mail address: philip.james@nofima.no (P. James).

http://dx.doi.org/10.1016/j.fishres.2017.03.021
0165-7836/

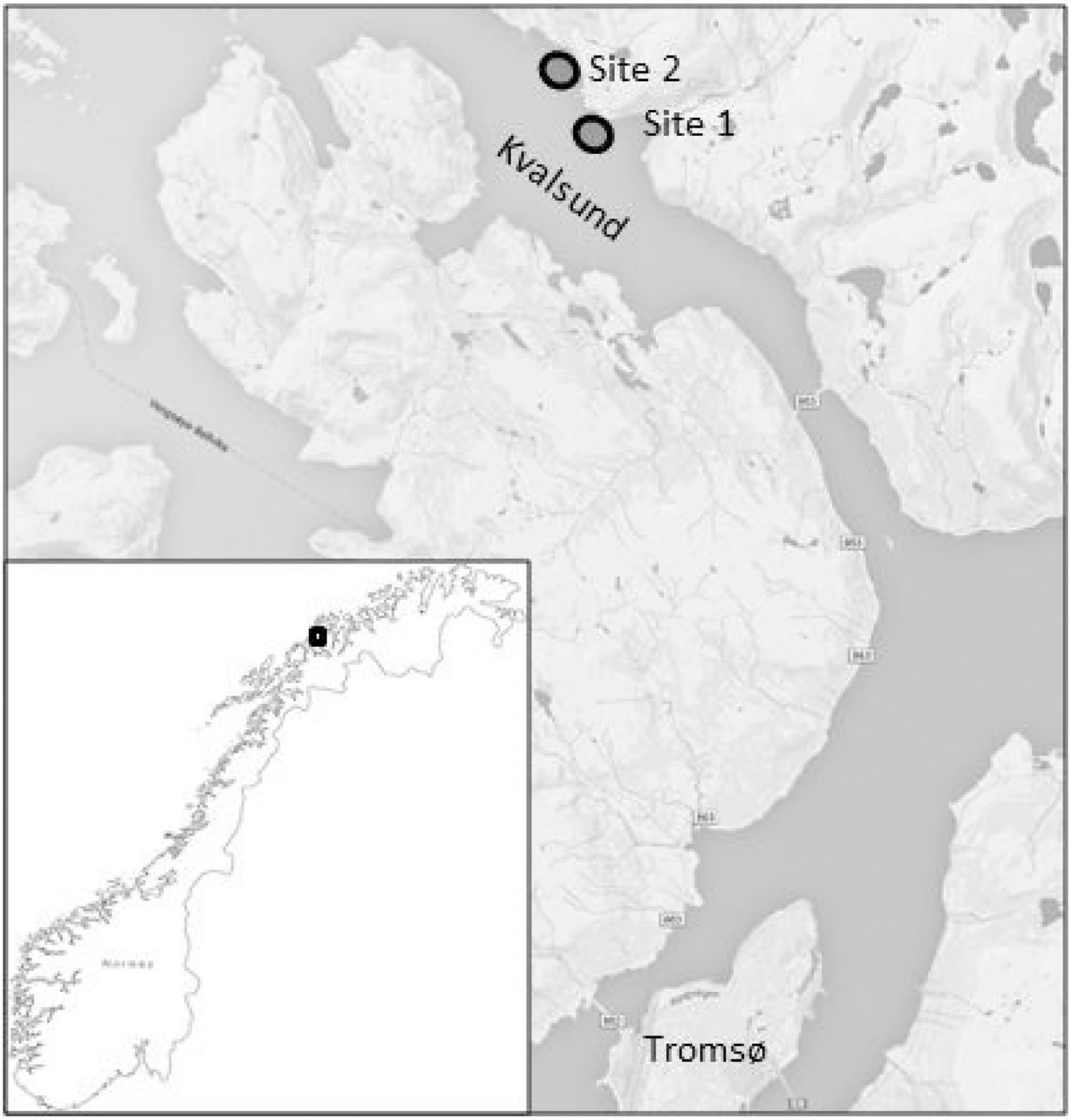

Fig. 1. The location in Kvalsund, Tromsø, Norway of the two sites where the Trials were conducted.

trapping are compared with other harvesting techniques used for sea urchins in Norway.

2. Materials and methods

2.1. General

Two trials were conducted to test the efficacy of three trap types, varying soak times, two bait types and the effects of using increasing quantity of baits. The trials were conducted at two sites near Kårvika, Kvalsund (69°50′N, 18°55′E) near Tromsø (See Fig. 1), in the north of Norway.

2.2. Trap type and soak time trials

The following three trap types were tested:

1. *Rope:* Three replicates of 10 m of weighted (using a smaller weighted rope coiled around the main rope) 42 mm braided polyethylene (PE) rope line (commonly used as mooring rope). Each 10 m rope had a bait station every 1 m (10 bait stations per 10 m rope section) (See Fig. 2A).
2. *Panels:* Three replicates of 10 m long, 1 m wide mesh panels (nylon 28 mm mesh, 1.5 mm twine thickness). The panels had weighted ropes along either side to weigh the edges down and a rope bridle on either end to attach to weights and anchor ropes. Each 10 m panel had a bait station every 1 m (10 bait stations per 10 m panel section) (See Fig. 2B).
3. *Round traps:* Three replicate lines with 5 round (1 m diameter), flat, hinged urchin traps (Fig. 3) attached at 2 m intervals on each line. Each trap consisted of two semi-circles of 12 mm reinforcing steel connected with a short piece of rubber tubing (which acted like a hinge) to create a round flat, hinged trap capable of folding in the middle as it was retrieved (Fig. 3). This prevented any of the urchins from falling out of the trap. The steel frames were covered in mesh (nylon 28 mm mesh, 1.5 mm twine thickness). Each trap had two bait stations (10 bait stations per 10 m line of 5 traps) (See Fig. 2C).

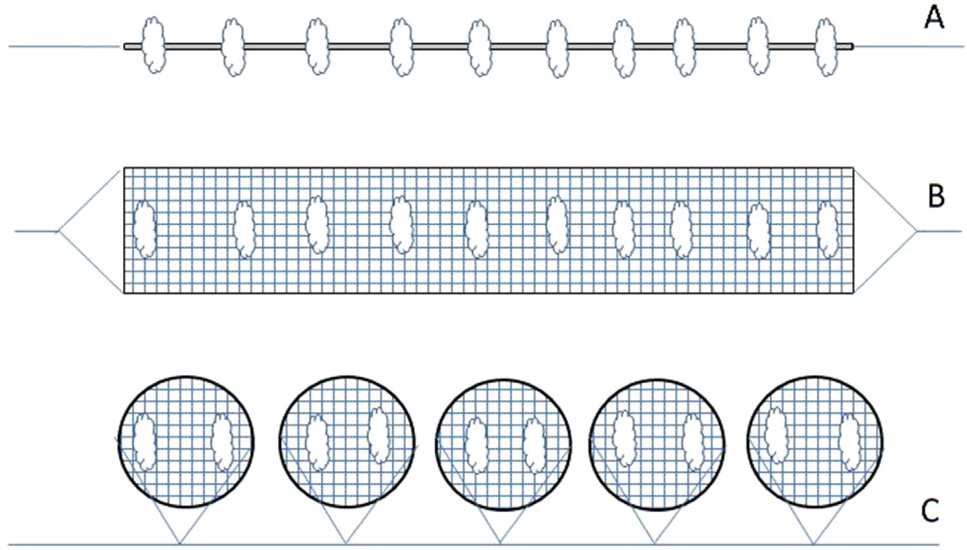

Fig. 2. The three types of traps used in the 'trap trial'; A) rope line with 10 algae bait stations, B) panel trap with 10 algae bait stations and C) round traps with 10 algae bait stations.

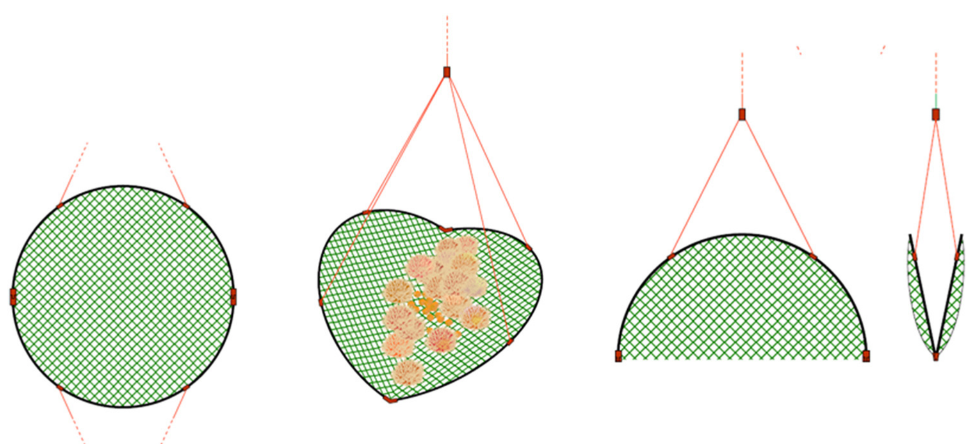

Fig. 3. The round, flat, hinged traps used in the trap trial; from left to right the top view of the trap laid flat, the trap full of urchins and being hauled from the sea floor, the trap hinged in the middle and being retrieved (side and front view).

The three trap types were tested by simultaneously setting three replicates of each trap type in a specified area (Site 1 in Fig. 1) which had a flat area of seafloor (approximately 500 m × 50 m) at a constant depth of 4–5 m with fine gravel substrate. Each trap type was randomly placed in the designated area with a minimum distance of 5 m between them. Each replicate of the trap types had 10 bait stations which consisted of a handful of algae attached with cable ties. The traps were set and left for 1 day after which they were retrieved, the catch measured and removed and the trap was rebaited. The same procedure was followed except the traps were left for 5 days, then 8 days and finally for 3 days. The number of urchins was recorded every time the traps were hauled and the catch rates were measured as numbers/line of 10 bait stations/soak time for the rope and panel traps and round traps. The size of the urchins was measured twice for each soak time (1, 3, 5 and 8 days) and each of the trap types. Vernier calipers were used to measure the widest test diameter (TD) of each urchin. Prior to the trapping the number and size of urchins in four randomly allocated 1m^2 quadrats was measured in the fishing area in order to estimate the average size and number of urchins per m^2 in the area.

2.3. Bait trials

The round traps used in the trap type experiments were subsequently also used in the bait trials. Two bait types were tested;

1. Algae (*Laminaria hyperborea*)
2. Whole fish, herring (*Clupea harengus*)

In addition to bait types, varying the quantity of bait were also tested. The algae bait was presented as 1 bait station, 4 bait stations and full coverage per trap (See Fig. 4A, B and C). The fish baits were presented as whole fish in a bait bag (1 bait station) or 4 bait stations per trap (See Fig. 4D and E).

The bait types were tested by setting three replicates of each bait treatment (n = 15) in a specified area (Site 2 in Fig. 1) which had a flat area of seafloor (approximately 600 m x 100m) of approximately 5 m depth with fine gravel substrate. The traps were set on a single longline in random order and were left in the water for a soak period of 5 days. At the end of the test period, they were hauled from the water and the number and size of the urchins and other species in each of the traps were measured (number/trap/soak time). Prior to

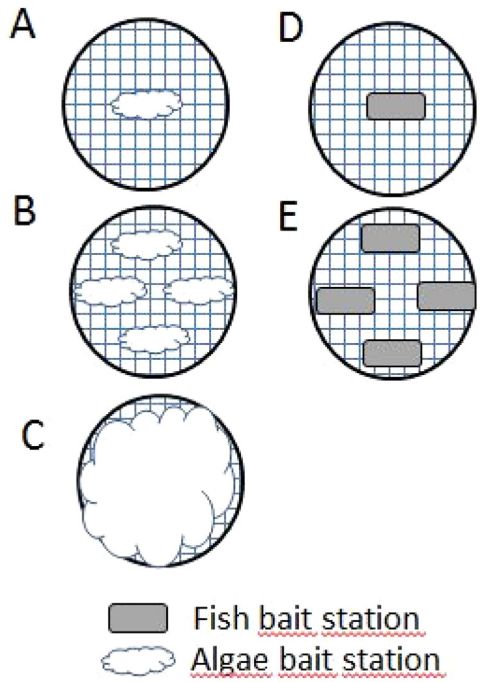

Fig. 4. The type, positioning and number of bait stations used in the 'bait trial'; A) single algae bait station, B) 4 algae bait stations and C) entire area of trap covered with algae bait, D) single fish bait station and E) 4 bait stations.

the trapping the number and size of urchins in 4 randomly allocated 1 m^2 quadrats was measured in the fishing area in order to estimate the average size and number of urchins per m^2 in the area.

2.4. Statistical analysis

Two-way analysis of variance was used to check for interactions and differences between urchin catch rate from the main effects in the trap trial (trap type and soak time) and the bait trial (bait type and bait amount). These were followed by a Tukey-Kramer Multiple-Comparison test to show where significant differences occurred. Statistical tests were considered significant if $P < 0.05$. Data are presented as means ± one standard error. The homogeneity of variances was tested using Modified Levene's. Statistical analyses were conducted using NCSS 10, 2015 (Number Crunching Statistical Systems, Kaysville, Utah, USA).

One way ANOVA was used to compare the size of the urchins caught in the trap and bait trials to urchins collected in the area from dive quadrats. A Tukey-Kramer post hoc test was used to show where significant differences occurred.

3. Results

3.1. Trap trials

A Two-way ANOVA showed significant differences in catch rate both between the three trap types and between soak times (days left in the water) (Table 1). Post hoc tests showed the round flat, hinged traps had significantly higher ($P < 0.05$) catch rates than both the Panel and Rope traps (Fig. 5). The round traps had higher catch rates than the other trap types regardless of the soak time. The catch rates in all 3 trap types increased over time, peaking at a soak time of 5 days for the round trap and continuing to increase for both the Panel and Rope traps until a soak time of 8 days. However, Post hoc tests showed there were no significant differences in catch rate between 3, 5 and 8 days. The catch rates were significantly lower after 1 day soak time compared to the 3, 5 and 8 day soak times (Fig. 5).

Table 1
Significance tests and related statistics (degrees of freedom, mean square, F ratio, *p* value) for the ANOVA analysis of Trial 1 (trap type and soak time) and Trial 2 (bait type and bait amount).

Effect	*df*	Mean square	Fratio	*P*
Trial 1: Urchin catch rates				
Trap type	2	95822.89	32.96	<0.05
Soak time	3	22787	5.23	<0.05
Trap type × Soak time	6	4798.67	0.55	0.76
Error	36			
Trial 2: Urchin catch rates				
Bait type	1	7704.17	4.34	0.06
Bait amount	2	7781.78	4.38	<0.05
Bait type × Bait amount	2	486	0.27	0.77
Error	15			

There was little difference in the size of the urchins caught in the Rope (23.1 mm TD ± SE 0.37) and the Panel traps (24.2 mm TD ± SE 0.46) but these were significantly smaller (One way ANOVA: $F_{2,947} = 11.51$, $P < 0.05$) than the urchins caught on the Round traps (25.4 mm TD ± SE 0.27). The rope traps attracted smaller urchins than the average wild size in the area (average size 24.2 mm TD ± SE 0.42) whilst the Panel and Round traps attracted the same size or larger urchins than the average wild size in the area. The density of urchins in the trapping area calculated from the quadrat measurements taken during the trial was 27.3 urchin/m^2.

3.2. Bait trials

The numbers of urchins, starfish, crabs and common whelk caught in traps baited with algae and with fish and at different bait quantities are shown in Fig. 6. There were no significant differences in sea urchin catch rate depending on the type of bait ($P = 0.06$) (Table 1). However, there were significant differences in catch rate depending on the quantity of bait used ($P < 0.05$) (Table 1). The number of bait stations was positively correlated to the catch of sea urchins and fish bycatch. A single algae or fish bait station had significantly lower catch rates than full algae coverage of the trap and the use of 4 fish or algae bait stations ($P < 0.05$) (Fig. 6). There was no difference in urchin catch rates between traps with full coverage of algae compared to traps using 4 fish bait stations but these were both significantly higher than traps using 4 algae bait stations.

The size of the urchins caught when using fish baits (27.8 mm TD ± 0.53) was significantly larger ($P < 0.05$) than the urchins caught when using algae baits (24.0 mm TD ± 0.37). This in turn was larger ($P < 0.05$) than the average size of the urchins found in the area from the quadrat sampling (21.1 mm TD ± 0.37) (One way ANOVA: $F_{2,520} = 56.44$, $P < 0.05$). The density of urchins in the trapping area calculated from the quadrat measurements taken during the trial was 30.3 urchins/m^2.

4. Discussion

The trials in the current study show that the most effective trap/bait combination was the round flat, hinged trap with multiple fish or algae bait stations. The ideal soak time for these traps was between 3–8 days with peak catches occurring at day 5. The catch rates in the 'Bait trials' at Site 2 using these optimal conditions were on average 143 urchins per trap (urchin density at the site was 30.3 urchins/m^2). The sites used in the trials were ideal for the experiments with large flat areas with urchins present evenly across them but the urchins were relatively small. If similar optimal catch rates were achieved at sites with market size urchins (40 g) the traps would yield 5.7 kg/trap/soak time, or 1.1 kg/trap/day.

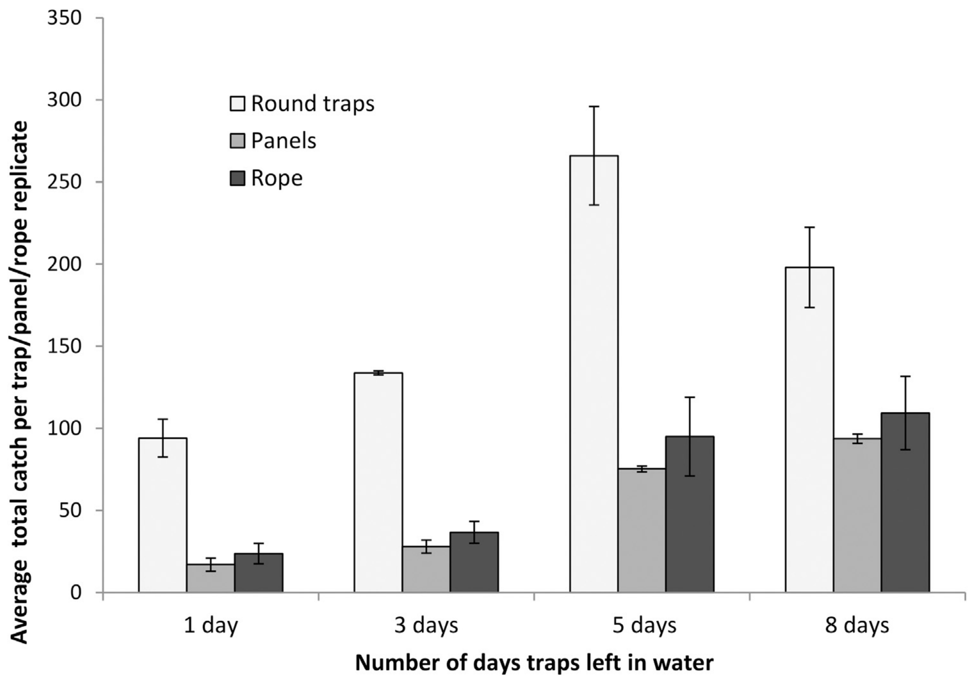

Fig. 5. The average number (± SE) of urchins caught in replicates of the three trap types (Round, Panel and Rope) over increasing soak periods (1, 3, 5 and 8 days).

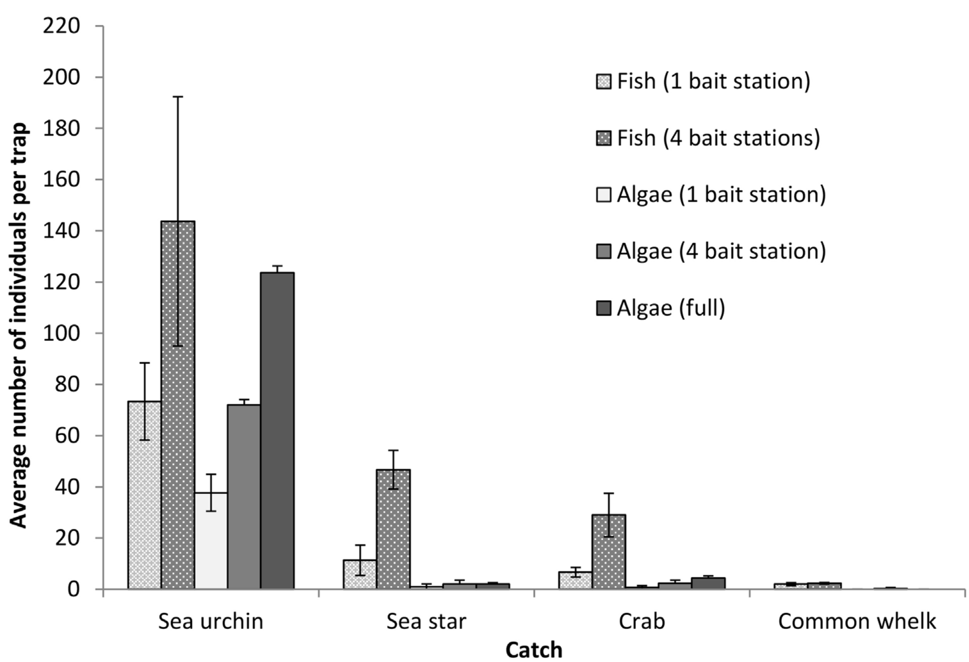

Fig. 6. The average number (± SE) of urchins, starfish, crabs and common whelks caught in individual traps with various bait types and bait quantities in the 5 day bait trial.

When comparing the efficacy of various sea urchin trapping techniques it is important to take into consideration not just the catch rates but also the cost of fishing, the logistics of each technique and the commercial viability of each technique. Sivertsen et al., 2008 investigated trapping as a viable alternative to diving to harvest sea urchins in Norway in 2008 and showed that ring traps were more effective than drop-nets or box traps. This is a similar result to the current study where the round collapsible traps were the most effective trap type tested. The study by Sivertsen et al. (2008) recorded an average daily catch of 1.43 kg/trap/day and estimated that a one or two-man fishing boat operating 300 traps over 10 trap lines, could theoretically capture 300–600 kg per fishing day. The results of the current study indicate a similar average daily catch of up to 1.1 kg/trap/day is feasible using optimal trap type, bait regimes and soak times.

The current study shows that it is possible to select for larger urchins depending on the type of trap and bait that is used. This may be an important consideration when fishing areas with a wide range of urchin sizes. Why urchins of different sizes would be attracted to different trap types is unclear.

Trials in northern Norway using remotely operated vehicles (SeabedHarvester ROV) showed that in 4.5 days of fishing a total catch of 1.88 tons was recorded with 34.9% of the total catch (659.5 kg) consisting of export quality sea urchins (>45 mm test diameter) (James, 2012). This equates to a daily catch of 154.4 kg/urchin/day which is less than the estimated catch for trapping. Although the results of the ROV trial showed that it was possible to collect sea urchins in winter conditions in northern Norway, the economic viability of ROV fishing is unproven. Not only were catch rates lower but using an ROV is also more labour intensive than trapping and requires extensive investment in equipment. Harvesting urchins using the ROV requires a suitable boat, use of the ROV (rental or purchase), a boat driver and 1–2 crew to operate the ROV.

There is limited data on the catch rates for SCUBA divers harvesting urchins in Norway. The only available catch records are from a commercial company operating in Båtsfjord, Northern Norway (Norway Sea Urchin AS). These show that between 2010 and 2012 a team of two divers and one boat skipper had an average daily catch (a day was approximately 8 h long) of 90.9 kg export quality sea urchins (minimum catch/day = 21 kg; maximum catch/day = 198 kg) (Tangaraas, *pers com.;* former owner/operator Norway Sea Urchin AS). The large variation in catch rates by divers reflects the inherent difficulties with dive operations. Divers have a limited time underwater and often spend much of this time searching for urchins which reduces the catch rates. However, if an area has very high densities of urchin in relatively shallow water (the largest catch rates were recorded when the urchins had migrated into very shallow water) then catch rates can be relatively high for dive operations. The longest running sea urchin fishing company in Norway (Arctic Caviar AS in Bodø, central Norway) also uses SCUBA as the collection technique. Catch figures are not available from this operation but it supplies small quantities of high quality urchins to exclusive markets and one of the owner operators is also the diver.

There are a number of advantages to fishing sea urchins with traps over other harvesting techniques such as SCUBA diving and using an ROV. Traps can be used in both summer and winter and this method of fishing is very flexible regarding extreme weather events. Sea urchins caught using traps are alive and undamaged and are of very high quality (Sivertsen et al., 2008). Logistically trapping is much easier than other collection techniques as the fisherman does not rely on dive crews and/or expensive equipment. The traps continue to collect urchins each day they are deployed, unlike active harvesting methods such as diving which only harvest urchins during periods of activity. It is also possible to incorporate trapping into other fishing activities. In northern latitudes such as Canada and Greenland, permanent winter ice may inhibit the use of traps in winter. However, in Norway there are no issues with permanent ice in the winter months and trapping could be carried out throughout winter.

In summary, the current study shows that passive trapping can be more effective than both ROV and SCUBA diving collection in Norway and at significantly lower cost (minimal daily labour cost and much reduced infrastructure costs). Particularly using the round flat, hinged traps in combination with the bait types and frequencies and soak times described in this study. The infrastructure investment for passive trapping is considerably less than for ROV fishing and the operational running costs are much less than for harvesting using SCUBA diving (in Norway). Passive trapping can be undertaken by a range of vessel sizes and types (in the current experiment vessels ranging from 3 m to 8 m were used) and larger commercial fishing vessels with pot haulers could also be used if they can get access to shallow inshore waters. This would enable fishermen to fish sea urchins during periods of low activity without extensive modification to their boats. The density of sea urchins present at any given site and the type of bottom terrain play an important role in determining the catch efficiency and so it will be important to undertake preliminary mapping of an area prior to committing time and capital resources into sea urchin harvesting.

Acknowledgements

The authors gratefully acknowledge FHF funding (FHF contract number: 900714) and the Northern Peripheries and Arctic Program funding (Project 1.14, Utilisation of the Arctic Urchin Resource – URCHIN). The authors would also like to acknowledge the significant contribution of two anonymous reviewers who have reviewed the manuscript a number of times and helped to improve this manuscript considerably and the patience of the Editor who enabled this.

References

Andrew, N.L., Agatsuma, Y., Ballesteros, E., Bazhin, A.G., Creaser, E.P., Barnes, D.K.A., Botsford, L.W., Bradbury, A., Campbell, A., Dixon, J.D., Einarsson, S., Gerring, P., Bebert, K., Hunter, M., Hur, S.B., Johnson, C.R., Juinio-Menez, M.A., Kalvass, P., Miller, R.J., Moreno, C.A., Palleiro, J.S., Rivas, D., Robinson, S.M.L., Schroeter, S.C., Steneck, R.S., Vadas, R.L., Woodby, D.A., Xiaoqi, Z., 2002. Status and management of world sea urchin fisheries. Oceanogr. Mar. Biol. Ann. Rev. 40, 343–425.

Bellchambers, L.M., de Lestang, S., 2005. Selectivity of different gear types for sampling the blue swimmer crab, *Portunus pelagicus* (L.). Fish. Res. 73, 21–27.

Gabriel, O., Lange, K., Dahm, E., Wendt, T., 2005. Fish Catch Methods of the World, 4th edition. Blackwell Publishing, Oxford, England, pp. 536.

Gundersen, H., Christie, H., Rinde, E., 2010. Sea Urchins –From Problem to Commercial Resource. Estimates of Sea Urchins as a Resources and an Evaluation of Ecological Gains by Sea Urchin Exploitation. NIVA Report No. 6001-2010.19 (ISBN 978-82-577-5736-6).

James, P., Siikavuopio, S.I., 2014. Alternative Low Cost Methods of Fishing Sea Urchins. Nofima Internal Report No. 38B/2014.18 (ISBN 978-82-8296-225-4).

James, P., Noble, C., Siikavuopio, S., Sloan, R., Hannon, C., Zeimer, N., Lochead, J., 2016. Sea Urchin Fishing Techniques Report. Nofima Internal Report No. 15/2016.21 (ISBN 978-82-8296-371-8).

James, P., 2012. Test of ROV-Based Harvesting Methods for Sea Urchins and Scallops. Part One: Preliminary Report on Sea Urchin (Kråkebolle) Collection Trial. Internal Nofima Report No. 13/2012.8 (ISBN 978-82-7251-971-0).

Shalack, J., Power, A., Walker, R.L., 2011. Whelk pot trapping and its implications for inshore fisheries development in coastal Georgia. Univ. Ga. Mar. Ext. Serv. 10, 25.

Sivertsen, K., Dale, T., Siikavuopio, S.I., 2008. Trap catch of green sea urchins *Strongylocentrotus droebachiensis* in kelp beds and barren grounds on the norwegian coast. J. Shellfish Res. 27 (5), 1271–1282.

Sivertsen, K., 1997. Geographic and environmental factors affecting the distribution of kelp beds and barren grounds and changes in biota associated with kelp reduction at sites along the Norwegian coast. Can. J. Fish. Aquat. Sci. 54, 2872–2887.

Xu, X., Millar, R., 1993. Estimation of trap selectivity for male snow crab (*Chionoecetes opilio*) using the SELECT modeling approach with unequal sampling effort. Can. J. Fish. Aquat. Sci. 50 (11), 2485–2490.