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Efficiency and environmental impacts of three different Queen scallop fishing gears

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EXECUTIVE SUMMARY

Three Queen scallop fishing gears were tested for their catch efficiencies and their environmental impact on benthic communities. The new design Queen scallop dredge together with the Otter trawl showed high catch efficiencies and relatively low by-catch to catch ratios. Contrary to this, catches made with the traditional, 'Newhaven' type, dredge were considerably lower while catching larger amounts of non–target species. Studying the direct impacts of these gears on benthic communities on the sea floor highlighted that the otter trawl had only minor effects on benthic biota while both new and traditional dredge showed similar negative effects. Due to its higher catch efficiency the new dredge causes less damage per unit catch compared to the traditional dredge yet compared to the Otter trawl it appears less environmentally friendly. A possible way to mitigate the impact of the New Dredge would be to either modify the dredge design or to restrict fishing effort of this gear type if used within Isle of Man waters.

INTRODUCTION

General introduction

Fishing has direct effects on the population of target species but can also affect non-target species and their habitats (Jennings & Kaiser 1998). In particular towed fishing gears that are dragged over the sea floor affect benthic organisms such as starfish, sea urchins and similar animals. Benthic organisms are caught as by-catch, suffering pressure changes, air exposure, crushing by inert or biotic material leading low survival rates even if discarded back into the sea. Additionally, benthic organisms are often directly damaged or killed by the physical impact of the fishing gear while it is towed across the sea floor. The amount of damage a fishing gear causes can vary considerably depending on its design and operational deployment (Collie et al. 2000, Kaiser et al. 2002). Furthermore the amount of damage to benthic biota depends on its faunal composition and its respective susceptibility to this type of physical disturbance (Kaiser et al. 2006).

A necessary pre-requisite to the development of sustainable fisheries, is to understand the impact of fishing activities on both the target and non-target species. Once negative impacts are identified they can be mitigated through management approaches or through technical measures.

Main objectives

Since the early 1970s, queen scallops (*Aequipecten opercularis)* traditionally have been caught with 'Newhaven' spring tooth dredges in the Isle of Man. These dredges are similar in design to those currently used to catch the King scallop (*Pecten maximus)*. During the past few years many fishermen have changed gear, targeting Queen scallops in the majority with small otter trawls, while other parts of the industry have developed their own new Queen scallop dredge that is designed to be more efficient and less damaging to the marine environment. This new type of queen dredge differs in its design, compared with the traditional Newhaven dredge, such that it is wider, having a higher front opening and instead of metal teeth it possesses a rubber lip to stimulate queen scallops to swim into the water column such that they are caught up into the metal mesh belly bag. While the impacts of otter trawls and Newhaven type dredges are relatively well known (Kaiser et al. 1996, Kaiser et al. 2006) no knowledge exists about the effects of the newly

developed Queen scallop dredge relative to the other Queen scallop gears.

The main objectives of this study were three fold: a) to study and compare the impacts of all three gears used in the Isle of Man on benthic communities, b) to study the by-catch of commercial and non-commercial species, c) to assess the efficiency of each gear in catching queen scallops versus the potential damage to benthic communities.

METHODS

Site selection

For the study a site of 4.6 km^2 was chosen located between Laxey Bay and Maughold head on the north east coast of the island (Fig 1). The site had relatively homogenous depth ranging between 20-23m and substratum type i.e. fine sand with shell and dead maerl debris a typical substratum type for queen scallops around the Island (see Fig 2). The area of the site is an active fishing ground for King and Queen scallops, although fishing effort for the past two year was relatively low for Queen scallops within this area. As one of the main aims of this study was to compare the impacts of the three different fishing gears on the biota of a typical queen fishing ground, as opposed to the impacts on a pristine area, the site was judged to be suitable for the purposes of this study.
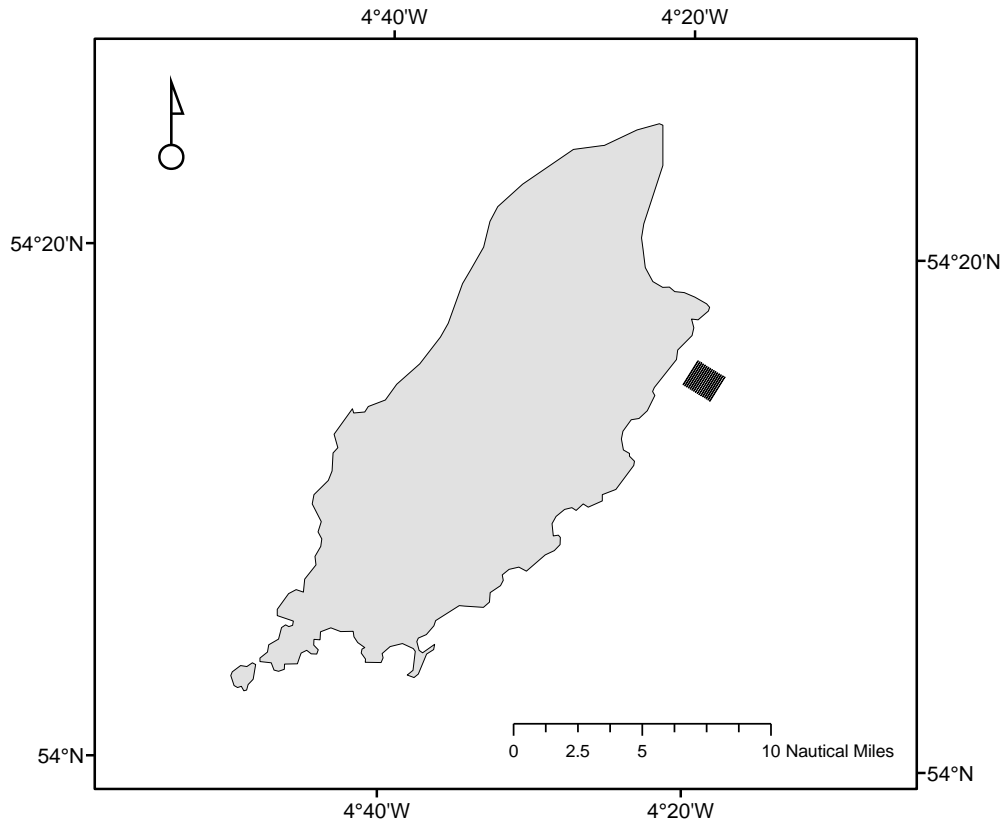
Fig 1. Sampling site of the experimental fishing to the east of the Isle of Man.

Fig 2. Image of the substratum type of the study area taken 300 metres west of the site during the habitat survey in 2008.

Benthic sampling design and methodology

The study site was composed of 16 trawling lanes each 40 metres wide and approximately 1 nautical mile in length. Each trawling lane was allocated to one of four treatments with each treatment replicated four times (see Fig 3): 4 x Control site (no fishing), 4 x Otter trawls (current standard gear), 4 x Queen dredge (traditional gear), 4 x New Queen dredge.
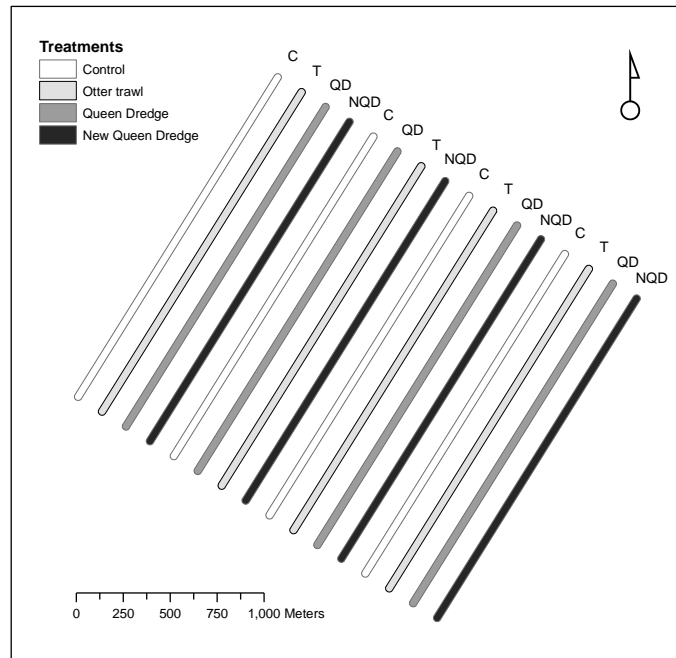

Fig 3. Layout of experimental trawl lanes in the study area.

Sampling of benthic fauna was undertaken before and after fishing impacts using a standard 2-m beam trawl to sample epibenthic animals and a Day-grab (0.1 m²) for infaunal sampling. Three 5 minute beam trawls and six grabs were taken haphazardly spaced along the trawling lanes (total number of beam trawls 96 and 192 grabs). Beam trawl catches were sorted, identified, counted and weighed (precision > 1g) onboard the RV Prince Madog. While larger fauna could be directly counted, the abundance and weights of smaller species e.g. small hermit crabs (mainly *Anapagurus laevis*) living in *Turitella* shells, the small brittlestar *Ophiura albida*, and small *Psammechinus miliaris* were estimated from a sub-sample of approximately 500g as they were mixed with a lot of shell debris and other inert material. This procedure was necessary to be able to process samples in a tolerable timeframe.

Infauna samples were fixed in 4% buffered formaldehyde solution for later identification and enumeration in the laboratory. Sediment samples of approximately 25g were taken from three day grabs in each lane before fishing impacts. Sampling before experimental trawling impacts took

place between 8th - 10th June 2009 followed by the experimental trawling on the 13th June 2009. The post-impact sampling took place 7 days later, between the 21st and the 23rd of June 2009.

Gear configuration, experimental fishing manipulations, and by-catch observations

Three fishing vessels were involved in the experimental fishing trials: Silver Viking (Otter trawl, Skipper: Alex Ironside), Heather Maid (Toothed dredges, Skipper: Michael Inglesfield), and King Challenger (New dredges, Skipper: Dougie White).

The Silver Viking was equipped with an otter trawl with a net opening of 18.3 m. The trawl was equipped with a rock hopper ground rope and the net had a mesh size of 80mm. The otter boards were metal and approximately of 1 metre height (see Fig 4).

Fig. 4 The Silver Viking trawling and during fishing operations on the experimental site.

The Heather Maid was fishing with 4 spring loaded traditional Scallop dredges on each side (see Fig 5). Each dredge was 0.76 m wide and had a chain mail belly bag with a mesh size of 60 mm. Each dredge had 17 metal teeth of around 6 cm length. The total swath width of this fishing gear was 7.28 metres.

Fig 5 Heather Maid at sea and during fishing operations during the experimental fishing trial.

King Challenger deployed four new design Scallop dredges. Each dredge had a width of 1.95 metres. The total swath width was therefore 15.6 metres. The dredges were equipped with a rubber lip instead of the traditional dredge teeth. Additionally the front part of the dredges consisted of a metal grid mounted on four rubber rollers, two on each side of the grid (see Fig 6). Attached to the metal grid is a traditional metal mesh belly bag with a mesh size of 60mm. For more detailed illustrations of this gear type see Seafish reports No 612 and 613.

Fig 6. King Challenger in Douglas Harbour after the gear trial with New dredges hanging over the side and during fishing operations at sea.

Each vessel impacted its 40 m lanes with a trawling intensify of 1 times trawled. This fishing was thought representative of the fishing effort experienced around the Isle of Man. Between November 2007 and October 2008, the mean area of seabed swept by the new queen dredges was 3.7 ± 1.0 per $25km^2$ (0.15 ± 0.04 per km^2), including only $25km^2$ statistical cells that were fished. The mean area of seabed swept by otter

trawls was 1.9±0.6 per 25km^2 (0.08±0.03 per km^2), again including only those statistical cells that were fished.

The vessels were instructed to cover the whole trawling lane approximate evenly. As the swath width of each gears differed which meant that the each vessel had to steam up and down the trawling lane a different number of times. To cover the trawling lane the otter trawl was towed twice up and down each respective treatment lane, the new dredge 3 times and the toothed scallop dredge 6 times.

During the impact trial, onboard each fishing vessel were two observers who together with the crew sorted and recorded the catch as well as the by-catch.

Statistical analysis

Analysis of catch and by-catch data

Catches of the target species *Aequipecten opercularis* made by the different gear types where compared using a one-way ANOVA using trawling lanes as replicate samples. Similarly, the total abundance of non-target by-catch was compared using a one-way ANOVA. The composition of the by-catch was described by reporting the species which made up 90% of the total catches of each respective gear.

Analysis of trawling impacts on benthic biota

Univariate - Epifauna

Prior to analysis, all beam trawl tows were standardized to a common town length of 1000 m². Furthermore, all small species, whose abundances were estimated from sub-samples, were removed from the analysis. Abundances and weights estimated in this way introduce too strong a bias into the analysis, as the presence or absence of a species in a sub-sample can have a large influence once it is being extrapolated to the total catch. Similarly, the target species data was removed from the faunal data and it was analyzed separately applying the same methodology outlined below for the large epifauna.

For the analysis of abundance and biomass data the percentage difference between before and after for all four treatments was calculated see equation 1.1 (each treatment having four replicates represented by the trawling lanes).

$$1.1: \quad \%\text{difference } X = [(A_a - A_b)/A_b] \times 100$$

Where A_a represents abundance or biomass after impacts and A_b before impact.

Prior to any analysis the data was transformed by equation 1.2. This transformation achieves normalizing percentage change data that in its most extreme negative cases is restricted to -100% while being limitless in its positive extremes.

$$1.2: \quad Y = \log_e(1 + [X/101])$$

To determine whether there was a significant before and after effect of respective gear types, the percentage difference graphs with their percentage confidence interval were inspected. Significant differences were defined by the 95% confidence intervals (CI) not intersecting the zero difference line. Conversely, if the 95% CI of a treatment intersected the zero difference line there was no significant difference between before and after impact. Subsequently, the percentage differences between the gears/treatments were compared by a one-way ANOVA.

In addition to analyzing the total abundance and biomass of all large epifauna, species were grouped into functional groups: scavengers, attached species and mobile vulnerable species (for the species list underlying this grouping see Appendix). Furthermore, the differences in

abundance of individual species before and after impact for each treatment were analyzed considering only species with an occurrence of over 20% in all samples.

Multivariate-Epifauna

Multivariate ordinations were carried out using Primer v.6 to investigate if trawling impacts caused significant changes in community composition. Bray-Curtis similarity matrixes were calculated for each fishing impact and control group separately (three analyses in total). Differences before and after fishing impacts as well as differences with the control sites were investigated using the ANOSIM routine which is equivalent to a univariate ANOVA.

The multivariate dispersion of samples has been proposed as an indicator for perturbed communities (Clark & Gorley 2006). In general it is expected that the variability or dissimilarity between samples increases in a disturbance event. The Index of Multivariate Dispersion (IMD) were calculated for the different gear types as well as for the control sites. Positive values approaching +1 indicate that there has been an increase in the variability in the community data while values towards -1 indicate a decrease in variability (increase in similarity).

Infauna and sediment samples.

Infauna samples are currently being identified and enumerated in the laboratory. Only preliminary results from 4 grabs per experimental lane at low taxonomical resolution are available thus far. Likewise, the analysis of sediment has not yet been completed. Total infauna abundance and biomass were analyzed as described above for the epifauna.

RESULTS

Queen scallop catches and by-catch

Queen Scallop catches were significantly different between the three gear types [ANOVA results with Welch adjusted f and d.f. due to violations of homogeneity of variance: $F_{(2, 5.57)}$ = 12.8 $p=0.008$] with the new dredge catching significantly more Queens compared to the toothed dredge. There was no significant difference between otter trawl catches and either toothed or new dredge catches (Fig 7).
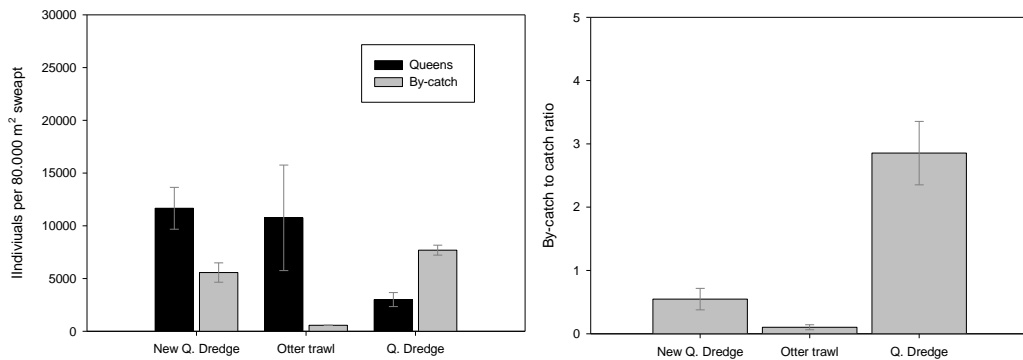
Fig 7 Mean number of Queen scallop catches and by-catches standardized by trawling lane (± S.E.) and the by-catch to Queen scallop catch ratio (± S.E.).

Similarly there were significant differences in the by-catches (F(2,11) =160.9, p<0.001) with otter trawl catches significantly lower than in both new and toothed dredges. There was no significant difference in the abundances of by-catches from the two dredges (Fig 7). The by-catch to catch ratios of all three gear types (Fig 7) differed significantly from each other (F(2,11)=40.4, p<0.001).

The by-catch composition of both dredges were relatively similar, mainly catching invertebrate species (Table 1), especially *Asterias rubens* and the King scallop *Pecten maximus*. The new dredge also caught a significant number of Dogfish *Scyliorhinus canicula*. In comparison, the otter trawl, besides invertebrate species such as *Asterias rubens*, caught various fish species, in the main Plaice (*Pleuronectes platessa*), Whiting (*Merlangius merlangus*) and Dab *(Limanda limanda)*.

Table 1 Relative abundance of by-catch species caught by the three different gear types. Cut-off point 90% of cumulative occurrence. Fish species in bold.

New Queen Dredge		Otter trawl		Queen dredge	
Species	% Ab.	Species	% Ab.	Species	% Ab.
Asteria rubens	72	*Asteria rubens*	14	*Asteria rubens*	27
Scyliorhinus canicula	33	***Pleuronectes platessa***	14	*Pecten maximus*	16
Pecten maximus	6	***Merlangius merlangus***	10	*Ophiura ophiura*	15
Pagurus bernardhus	4	***Limanda limanda***	4	*Astropecten irregularis*	12
Echinus esculentus	3	*Suberites spp.*	3	*Pagurus bernardhus*	10
Astropecten irregularis	2	*Anapagurus laevis*	2	*Neptunea antiqua*	3
Buccinum undatum	2	***Aspitrigla cuculus***	2	*Buccinum undatum*	3
Others	10	*Ophiura ophiura*	2	*Echinus esculentus*	2
		Blennius ocellaris	1	*Pagurus prideauxi*	2
		Echinus esculentus	1	Others	10
		Eutriglia gurnardus	1		
		Pagurus prideauxi	1		
		Alloteuthis subulata	1		
		Others	10		

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Response of the target species

Catches of Queen scallops made with the 2-m beam trawl before and after impact at the four treatment sites varied considerably. The only treatment which showed a significant decrease in abundance and biomass after impact was the New Queen dredge, signified by the 95% confidence intervals not intercepting the zero, no difference line (Fig 8). The other two gear types showed negative trends while the control site showed slightly positive abundance and biomass trends (Fig 8). Comparing percentage changes in abundance and biomass between treatments revealed no significant differences.
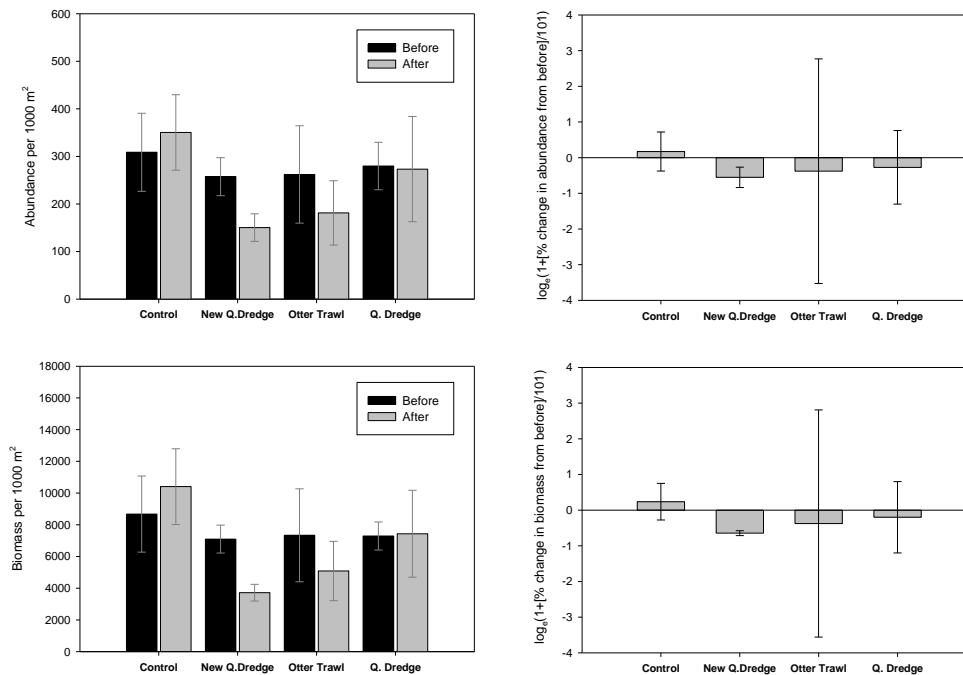

Fig 8 Abundance and Biomass of *Aequipecten opercularis* and the transformed percentage difference between before and after fishing impacts per treatment. Error bars in absolute abundance and biomass plots ± Standard error. Error bars in percentage change plots represent 95% Confidence Intervals.

Response of large epifauna to trawling impacts

While both new and old dredges appeared to cause negative trends in abundance of large epifauna after fishing impacts, otter trawling did not cause any obvious changes. The control site also showed a decrease in abundance at the after sampling event; however, this was of lower magnitude. Significant negative differences ($p < 0.05$; Fig 9) before and after fishing impacts were only apparent for epifauna biomass in the new queen scallop dredge lanes. Otter trawl sites showed on average a negative change in biomass, while the lanes impacted by the traditional queen dredge showed a positive trend. The control site showed a slight

positive trend in biomass. Comparing percentage changes in abundance and biomass between treatments by one-way ANOVAs revealed no significant differences.
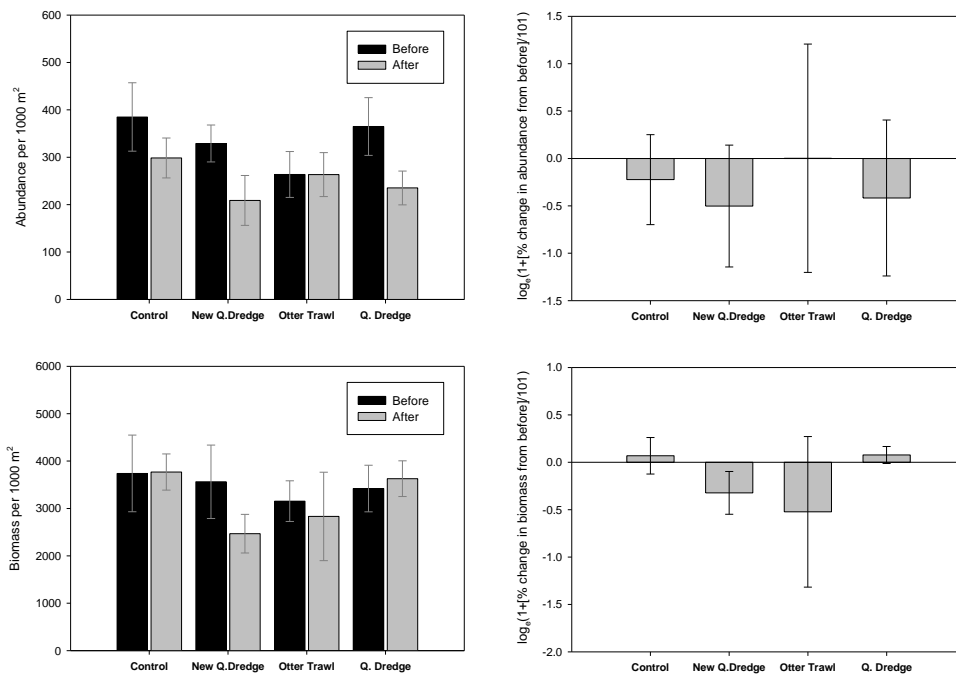

Fig 9 Abundance and Biomass of large epifauna and the transformed percentage difference between before and after fishing impacts per treatment. Error bars in absolute abundance and biomass plots ± Standard error. Error bars in percentage change plots represent 95% Confidence Intervals.

Response of functional epifauna groups

Species with a scavenging life mode did not show any significant responses in abundance or biomass after the fishing impacts (Fig 10). Within the lanes impacted by the two dredges positive trends were observed. While negative trends were visible in the control and otter trawl treatment sites, only the otter trawl treatment sites showed a negative trend in biomass after impact by the fishing gear. Comparing percentage changes in abundance and biomass of scavengers between the different treatments by one-way ANOVAs revealed no significant differences.

Species classified as vulnerable due to their more fragile body structures showed decreasing trends for all three gear types after fishing impacts for abundance and biomass (Fig 11). The control site showed slight increases in abundances and no visible change in biomass. Except for the traditional Queen scallop dredge on biomass, none of the trends of the other gear types and the control sites were significant (Fig 11). Comparing percentage changes in abundance and biomass of vulnerable species

between the different treatments by one-way ANOVAs showed no significant differences.
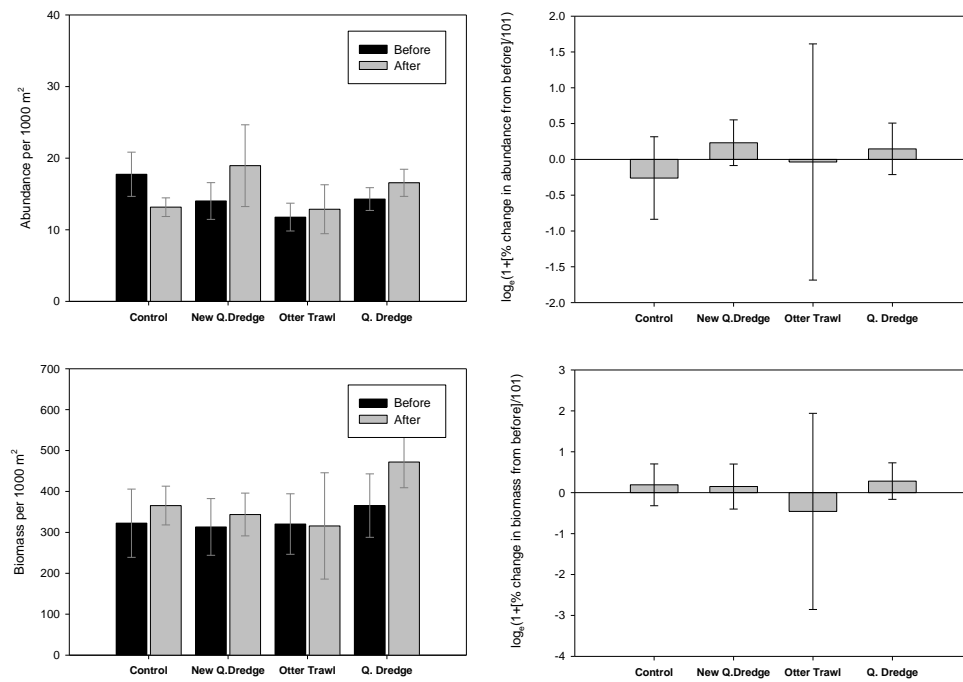

Fig 10 Abundance and Biomass of scavengers and the transformed percentage difference between before and after fishing impacts per treatment. Error bars in absolute abundance and biomass plots ± Standard error. Error bars in percentage change plots represent 95% Confidence Intervals.

Very few species of attached epifauna were caught during the survey (Fig 12) and no obvious pattern was visible. Negative trends in abundance were observed in the control, new queen dredge and traditional queen dredge sites. The otter trawl sites showed an increase in abundance after fishing impact. None of these trends were significant (Fig 12). With respect to biomass, control, otter trawl and traditional queen dredge data showed positive trends while only the new queen dredge data showed a decreasing trend. Again none of these changes after impact were significantly different from zero. Comparing percentage changes in abundance and biomass of attached epifauna between the different treatments by one-way ANOVAs showed no significant differences
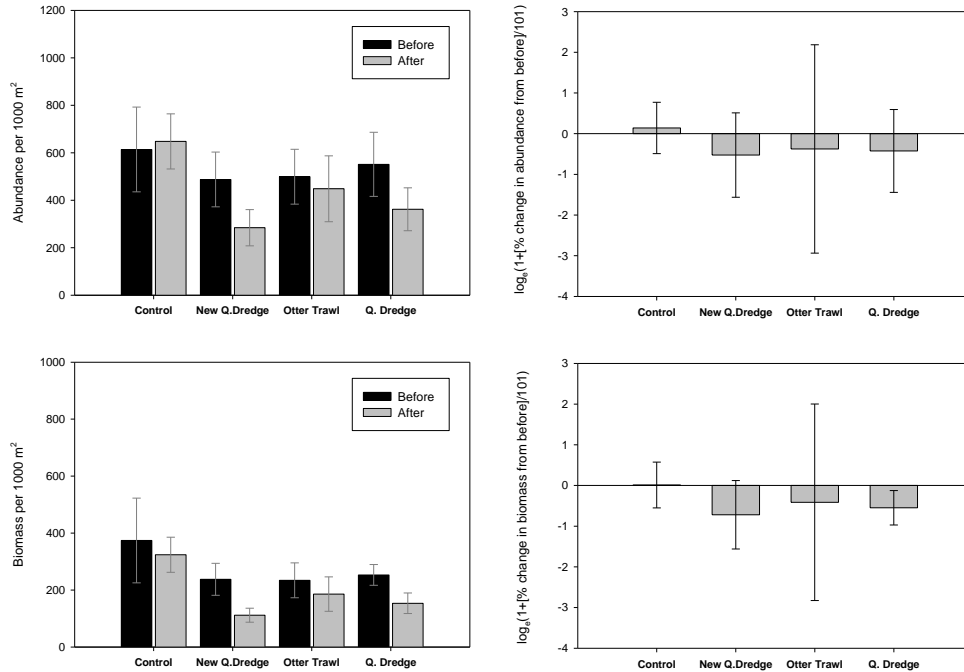
Fig 11 Abundance and Biomass of vulnerable species and the transformed percentage difference between before and after fishing impacts per treatment. Error bars in absolute abundance and biomass plots ± Standard error. Error bars in percentage change plots represent 95% Confidence Intervals.
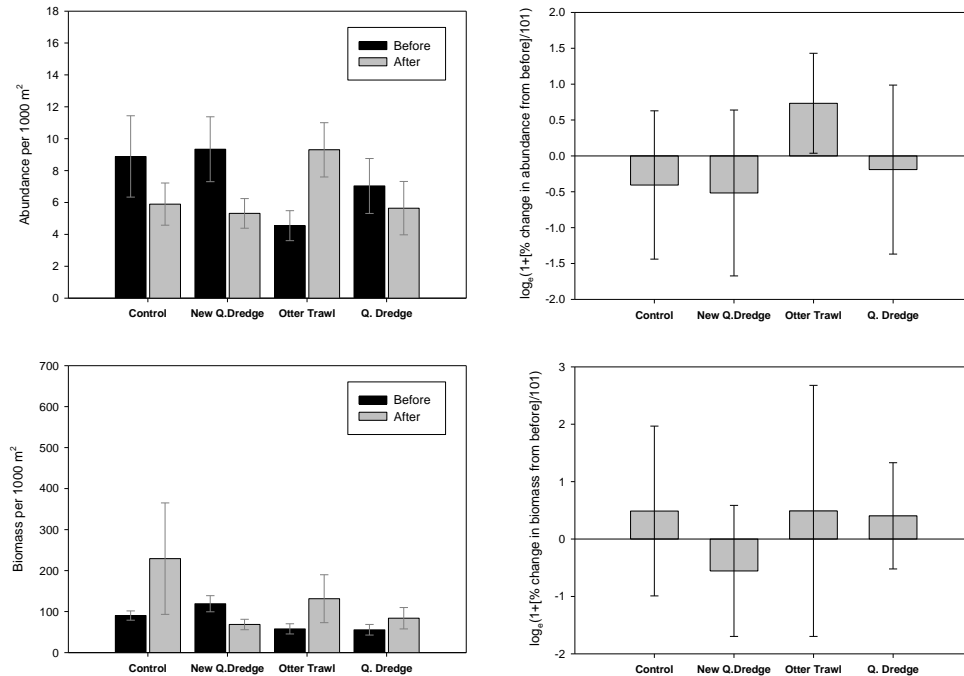

Fig 12 Abundance and Biomass of attached fauna and the transformed percentage difference between before and after fishing impacts per treatment. Error bars in absolute abundance and biomass plots ± Standard error. Error bars in percentage change plots represent 95% Confidence Intervals.

Response of individual epifauna species

Table 2 Responses of individual species expressed as transformed percentage change in abundance. Significant changes before and after fishing impacts are highlighted in bold. The p-values of the ANOVA's comparing all treatments are given. (w) signifies p-values with Welch adjustments in case of homogeneity of variance violations. Letters signify significant differences of the Tukey post-hoc test between the different treatments.

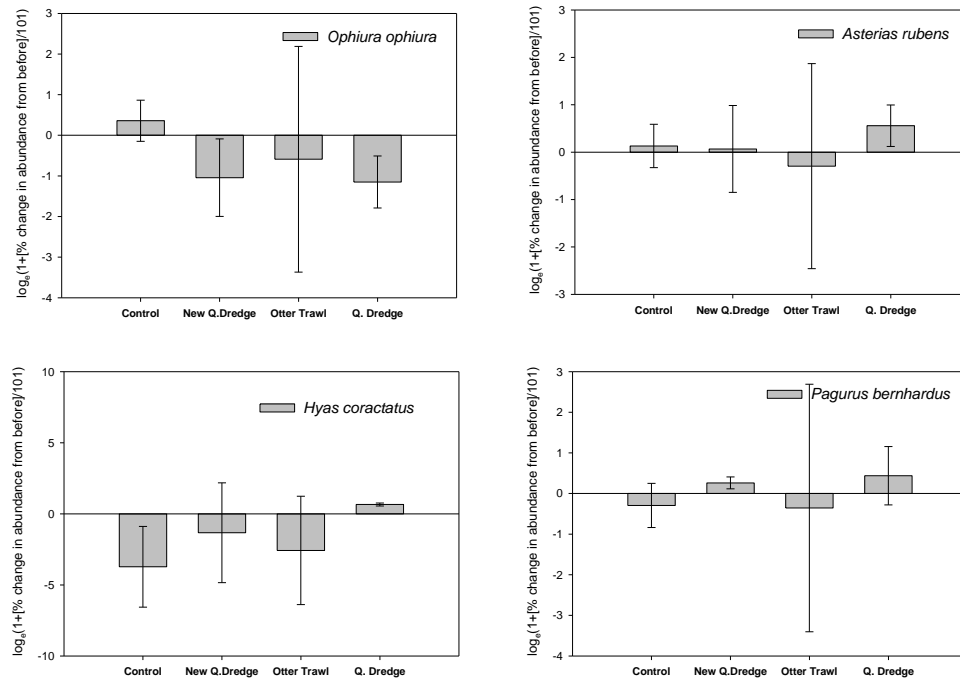| Species	% Occurrence in samples	Control	New Queen Dredge	Otter trawl	Queen Dredge	ANOVA p
Ophiura ophiura	90	0.36	**-1.04**	-0.59	**-1.15**	0.160
Asterias rubens	87	0.13	0.07	-0.30	**0.56**	0.256 (w)
Adamsia carciniopados	86	0.19	-0.54	-0.24	-0.33	0.789
Pagurus bernhardus	86	-0.29	**0.26**	-0.35	0.43	0.130 (w)
Pagurus prideaux	86	0.00	-0.68	-0.28	-0.36	0.822
Inachus dorsettensis	77	-0.78	0.37	0.10	0.14	0.456
Macropodia spp	74	-0.73	-0.20	0.32	-0.56	0.656
Alcyonium digitatum	65	-1.25	-1.03	1.10	0.03	0.063
Psammechinus miliaris	53	-2.38	**-3.32**	-3.13	**-3.34**	0.858
Astropecten irregularis	49	0.14	-2.15	0.08	-1.86	0.277 (w)
Ophiothrix fragilis	48	-1.98 [NQD]	1.43 [C]	0.02	0.38	**0.02**
Echinus esculentus	47	-0.25	-1.62	-1.5	-0.88	0.747
Liocarcinus pusillus	43	-0.06	-1.96	-1.92	-1.22	0.693.
Neptunea antiqua	40	-2.52	-0.77	-0.46	-0.04	0.48
Aporrhais pespelecani	34	-0.88	-1.14	-0.99	0.14	0.758
Colus gracilis	32	0.46	-2.08	-0.10	-2.34	0.223
Hyas coarctatus	29	-3.72 [QD]	-1.77	-3.43	**0.66** [C]	**0.018** (w)
Buccinum undatum	26	-0.64	-2.19	0.17	-1.05	0.56
Botryllus schlosseri	23	-0.93	-1.57	0.34	0.05	0.410

Fig 13. Transformed percentage change of selected species after trawling impact. Error bars represent 95% Confidence Intervals.

The responses of individual epifauna species to the different fishing impacts are summarized in Table 2. Only few species showed a significant change comparing abundances before and after trawling impacts. *Ophiura ophiura* showed a significant negative change at sites impacted by the both new and traditional queen dredge (Table 2, Fig 13). *Asterias rubens* and *Hyas coractatus* showed a significant increase at the sites impacted by the traditional queen dredge (Table 2, Fig 13). While *Pagurus bernhardus* increased at sites impacted by the new queen dredge (Table 2, Fig 13). Comparing percentage changes in abundance between the different treatments by one-way ANOVAs showed significant differences for *Ophiothrix fragilis* and *Hyas coractatus* (Table 2).

Response of epifauna community composition

The multivariate analysis using the ANOSIM routine revealed no significant differences in the community composition of epifauna before and after impact as well as with respective control sites for the three different gear types. For all gears the global r statistic was non-significant (New Queen Dredge p = 0.097; Otter trawl p = 0.207; Queen Dredge p = 0.064) therefore not allowing further investigation into pair wise comparisons (Clark & Gorley 2006).

The IMD, using individual beam trawl samples (i.e. not pooled by lane as for the analysis above), showed that after impact the variability between individual samples increased for all gear types (Table 3). An increase in the variability/dissimilarity between sampling stations after the impact has been described as a possible indication of perturbation in itself (Clark & Gorley 2006). The traditional Queen dredge showed the highest IMD value, while the New Queen dredge had the lowest. Control sites had negative index values indicating that samples increased in similarity (Table 3).

Table 3 Index of Multivariate Dispersion (IMD) of the different gear types. Positive values indicate an increase in variability or dissimilarity after impact while negative values indicate the reverse.

IMD	New Q. Dredge	Otter trawl	Q. Dredge
After - Before Impact	0.129	0.185	0.226
After - Before Control	-0.597	-0.531	-0.598

Response of infaunal communities

Infauna abundance and biomass showed similar trends as a response to the different trawling activities as described for the epifauna. However, only infauna biomass in the lanes impacted by the New Scallop Dredge showed a significant difference after impact signified by the 95% CI not intercepting the zero line (Fig 14). Again due to the high variability within the data, percentage changes in abundance and biomass between the different treatments were not significant.
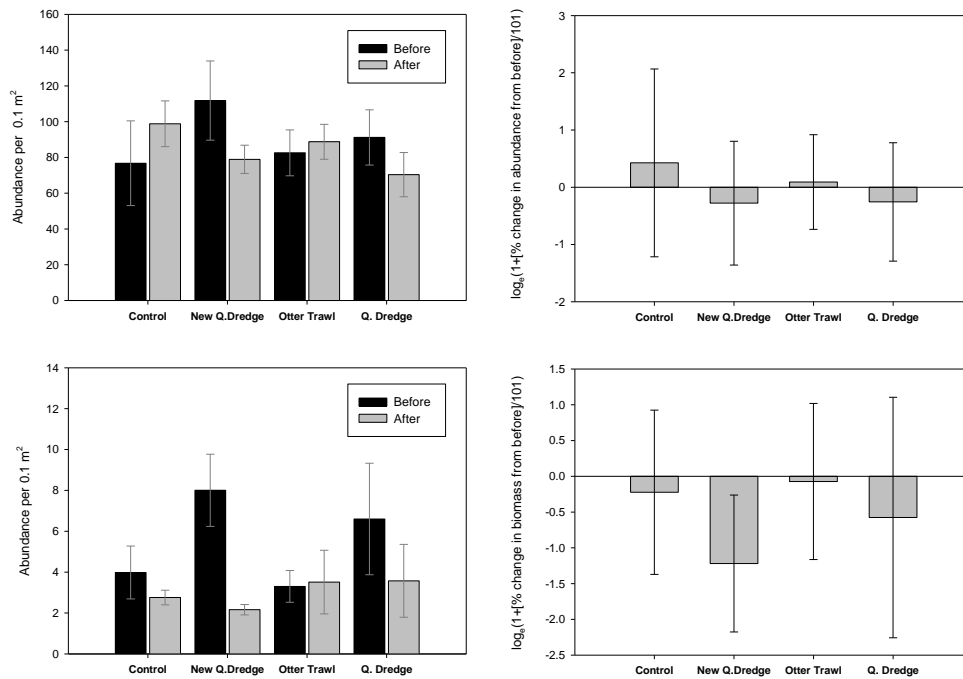
Fig 14 Transformed percentage change of infauna abundance and biomass after trawling impact trials. Error bars in absolute abundance and biomass plots ± Standard error. Error bars in percentage change plots represent 95% Confidence Intervals.

DISCUSSION AND CONCLUSION

Catch efficiency and by-catch to catch ratio

The highest queen scallop catches, standardized by the area swept, were made by the New Queen Dredges demonstrating their efficiency in catching Queen scallops. Similarly the Otter trawl, although delivering less consistent catches, caught high numbers of Queen scallops. The traditional Queen dredge in comparison was far less efficient, although it should be considered that the experiment was conducted during the summer month when Queen scallops are highly mobile increasing their catchability in particular for Otter trawls with their wide net opening.

The results of the catch efficiency were mirrored by the results of Queen scallops caught by the 2-metre beam trawl after the trawling event. The greatest reduction in queen scallop abundance was found in the lanes impacted by the New Queen Dredge followed by the Otter trawl and finally the traditional Queen dredge. The reductions queen scallop abundance at the otter trawl sites were, however, highly variable. It should be noted that much less time was spent fishing with the Otter trawl

and New Dredge due to the wider swath areas compared to the traditional Queen Dredge.

Both the Otter trawl and New Queen Scallop Dredge had low by-catch to catch ratios. Catches in the new queen dredge were mainly composed of *Asterias rubens* and other invertebrates as well as the common dogfish *Scyliorhinus canicula*. Otter trawl catches had the lowest by-catch to catch ratios with catches mainly dominated by fish. In particular, Plaice (*Pleuronectes platessa)* and whiting (*Merlangius merlangus)* were found in catches. The traditional queen dredge mainly caught invertebrates such as the common star fish *Asterias rubens,* the King scallop *Pecten maximus* and the brittle star *Ophiura ophiura*.

Impact of trawling trials on benthic epifauna

Due to the high variability of benthic communities the results of the fishing experiment were not conclusive as few responses were found to be statistically significant. While for some gear types significant differences before and after impact were detected, no difference between impacts were detected (except for two epifauna species). Above all, no significant differences were detected between impact and control sites. Only if significant differences with the control sites had been found would it be possible to conclusively verify a significant impact. By the same token, the reason for not detecting a significant impact most certainly lies in the lack of statistical power. Thus it cannot be concluded that the effect of all three gear types were absent or negligible. Trends were consistent for epi- and infauna and thus may give some indications on the relative severity of impacts from the three fishing gears tested.

Lanes impacted by the New Dredge showed significant differences comparing total epifauna and infauna biomass before and after the trawling impact, while lanes impacted by the traditional Queen scallop dredge showed significant changes in the biomass of vulnerable species after impacts. Neither control nor otter trawl treatments showed significant negative changes before and after the trawling experiments.

On a species level abundance of the relatively fragile brittle star *Ophiura ophiura* showed significant negative changes between before and after impact for the two scallop dredges. No significant differences were observed for the otter trawl and control lanes. Scavenging species such as *Asterias rubens* and *Pagurus bernhardus* increased significantly in number between before and after trawling events in the New Dredge lanes, and especially in the lanes impacted by the traditional dredge.

Despite these far from conclusive results trends indicated that both New Dredge and traditional dredge had a similar impact on benthic epi- and infauna while the otter trawl generally showed little impact. The reason for the modified queen dredge and traditional dredge having similar impacts despite different designs may have several reasons. The relatively stiff rubber lip used to scare Queen scallops into belly bag may cause similar damage to metal teeth while scraping over the seabed. Additionally, the belly bags of the New Queen Dredge are considerably larger, and therefore heavier compared to the traditional dredges, further increasing the impact area of this gear type with the sea floor.

Nevertheless while impacts on benthic biota between the two dredges were similar the catch efficiency of the New Scallop Dredge was higher, ultimately leading to a lower damage per unit catch of Queen scallops (see Fig 15)
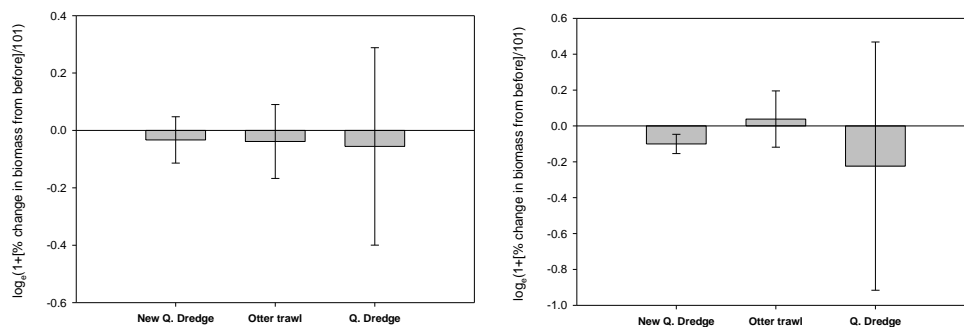

Fig 15 Transformed percentage change of epi- and infauna biomass, standardized per 1000 Queen scallops caught, after trawling impact. Error bars represent 95% Confidence Intervals.

Recommendations

Based on the available evidence and following the precautionary principle the use of the New Scallop Dredge will have to be carefully considered. The dredge had a considerably higher impact on benthic fauna and by-catch compared to the otter trawl, while having comparable, although less variable, catch efficiencies for Queen scallops. A possible way to mitigate the impact of the New Dredge would be to modify the Dredge design, in particular the stiff rubber flap and metal mesh belly bags would need to be reconsidered. If allowed to fish in the current configuration impacts may be mitigated by restricting fishing effort. Both spatial or quota based effort restrictions would potentially be feasible.

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