Application for Approval of the

Inshore Modular Harvesting System (MHS) Trawl Net

2 November 2018

Contents

A. Executive Summary

The Modular Harvesting System (MHS) is a revolutionary new design s 9(2)(b)(ii) [redacted] The MHS provides a s 9(2)(b)(ii) [redacted] fish are less fatigued and damaged which allows for much improved fish quality and higher survivability of inshore species, particularly for unintended catch of juvenile fish and by-catch species. These MHS designs have the ability to transform the seafood industry both in terms of sustainability and utilisation by supporting an on-going move from a quantity to a quality basis.

In order to approve the MHS for use in the inshore northern fisheries, the performance of the MHS net has been compared to a conventional 125mm (5”) mesh cod-end trawl net across 4 criteria:

i. Species Composition
ii. Size Composition
iii. Protected Species
iv. Benthic Impacts

Analysis of data from commercial catch effort data, observer data and a comparative trial has been undertaken to determine if the Inshore MHS gear performs ‘no worse than’ conventional mesh gear in relation to these four criteria.

The species composition of catch from MHS gear was found to be very similar to conventional gear but with higher catch rates for SNA and for QMS species in total. Results from the comparison trial found the MHS gear caught more juvenile snapper (SNX) however analysis of the commercial catch effort data has found the actual performance of the MHS gear has provided at least a 10% reduction in the amount of SNX caught compared to conventional gear. This is due to the MHS gear enabling fishers to operate further from shore and in deeper water to avoid the SNX but still land premium quality fish. In addition to the sustainability benefits of the reduction in the catch of SNX, it also lessens the spatial conflict between the commercial and recreational/traditional sectors with commercial vessels being able to fish further out and therefore away from areas where these fishing activities overlap.

The analysis of data for protected species has found that MHS gear certainly performs ‘no worse than’ conventional gear and indeed it is performing better in relation to the number of interactions with seabirds and cetaceans. From the comparative trial the overall higher total catch rate of QMS species would indicate that the MHS gear would have an improved performance in terms of benthic impacts when compared to conventional gear. An analysis of MHS catch rates for individual species has identified a range of results, including each of equivalent, higher and lower, than conventional gear. Across a mixed inshore fishery the MHS can be considered 'no worse' than conventional gear in terms of benthic impacts.

Across the approval criteria it has been demonstrated that the MHS gear performs 'no worse than' conventional gear and indeed performs much better in most areas. It can provide significantly improved sustainability benefits in terms of both through-mesh mortality and discard survivability plus the longerterm potential to allow the live release of incidentally captured marine mammals. The MHS also provides additional utilisation benefits by providing significant uplifts in value (not only in revenue but also the direct return to fishers), operational efficiencies (production & harvest benefits plus fuel savings), and health & safety outcomes (reduced crew fatigue and crew injuries from strains & sprains).

B. Application

On 29 March 2018 an application was submitted to the Ministry for Primary Industries (MPI) under regulation 71A of the Fisheries (Commercial Fishing) Regulations 2001 for approval of a Trawl Net - an Inshore Modular Harvesting System.

Following feedback and discussion on the application with MPI, further research and analysis has been undertaken to support a revised application as detailed below.

C. Background

Precision Seafood Harvesting (PSH) is a limited partnership that was set up to manage the commercialisation process of unique and innovative seafood harvesting systems over a seven-year period. These new "modular harvesting systems" (or MHS) are a truly New Zealand concept that came out of initial work done by scientists at Plant & Food Research (PFR).

These designs have since been patented and are now set to transform the NZ (and global) seafood industry by setting new standards in sustainability and seafood quality. The PSH partnership was established under the Primary Growth Partnership (PGP) structure that was introduced and managed by the Ministry for Primary Industries (MPI). The PGP is a 50:50 funding arrangement between MPI and the industry partners, for PSH these are the fishing companies; Moana NZ, Sealord and Sanford.

The industry partners account for close to 50% of the total NZ commercial seafood sector in volume and value.

Together these partners have committed to achieving several key objectives and goals that offer benefits to the co-investors, the NZ seafood industry and the wider NZ economy. The goals can be separated into the following broad categories:

- Improved sustainability performance for seafood harvesting operations in terms of selective fishing and reducing the mortality rate for unintended catch such as juvenile fish or by-catch species. This by improved performance in both selectivity and discard survival rates.
- Developed and proven performance in terms of testing methods, data collection and reporting metrics.

- Validation of the improved market values for the low damage, high quality seafood outcomes achievable using the MHS as a fishing technology.
- Providing tools to commercial fishers that will enable improved sustainability performance

The PSH programme is projected to create the basis for substantial wider economic impacts. These are estimated to be, by 2026, an improved Trade Balance of $88 million pa and a net GDP increase of $46 million pa together with a domestic economy increase of $112 million.

The PSH programme supports an ongoing shift within the seafood industry from a quantity to a quality driven business model.

Key quality outcomes that this research will deliver include:

- Reducing defects to increase the quality of product from the same volume of catch.
- Lifting the landed value of a range of inshore and offshore species sold into current markets, moving product up the product/value cascade.
- Creating higher value branded seafood product category that will offer opportunities into new, high value markets. This added value is linked to the provenance story around the Tiaki brand.

New Zealand seafood researchers are leading the world in the design and development of innovative wildfish harvesting technologies. These initial concepts that form the basis of the PSH development programme have been developed through previous investments in R&D and work conducted by the science team at Plant & Food Research.

The initial stages of the harvesting technologies have demonstrated a lift in the quality of fish landed while reducing the overall mortality rate in unintended catch such as juveniles and by-catch species resulting from the trawl process. The critical steps to deliver this transformation in thinking and practice to the seafood industry have been to:

1. Further the design and development of innovative wildfish harvesting, handling and processing technologies to the stage of commercially viable equipment for inshore and deepwater vessels, and deliver training programmes to fishermen to ensure their implementation.

2. Work with the Ministry for Primary Industries to demonstrate that the new harvesting technologies meet or exceed their standards for current harvesting methodologies in terms of sustainability to support and allow regulatory change for the new harvesting methodologies. This included the development and approval of new testing methods and reporting metrics for sustainable performance.

3. Develop a market strategy for seafood products caught and handled using these new rested harvesting technologies.

D. Modular Harvesting System (MHS)

The development of the Modular Harvesting System (MHS) has focussed on delivering low-damage, lowfatigue capture of wild fish and the unharmed escape and release of unintended catch.

The MHS is a new technology s 9(2)(b)(ii) [redacted]

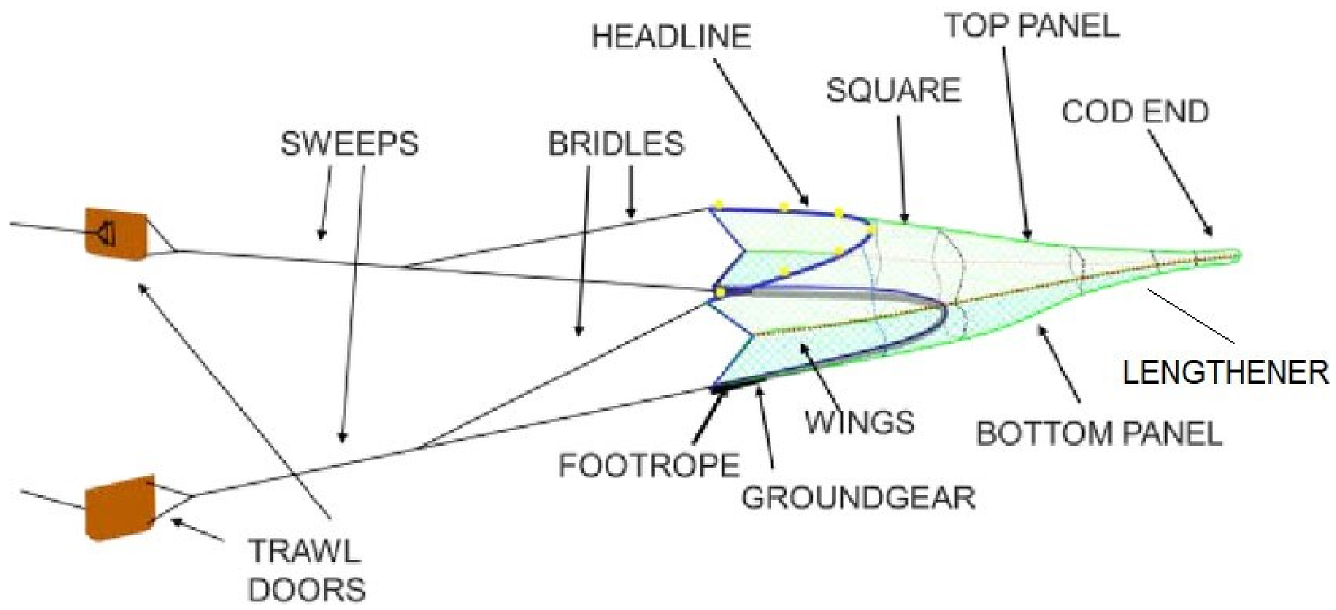


Figure 1. Diagram of Traditional Trawl Net Configuration

It is designed to be fish friendly with a s 9(2)(b)(ii) [redacted] This enables fish to regain control, individualise and take care of themselves, allowing the catch to be landed with minimal damage and reduced fatigue, maximising post-harvest opportunity and extracted value and is the fundamental difference between all MHS designs and traditional mesh cod-ends.

In a traditional mesh trawl net the fish swim against the turbulent water flow until exhausted and then collect at the back end of the cod-end (refer video: Turbulence inside mesh trawl SNA.mpg). The water flow compresses these exhausted fish and mortality rates are high, fish are damaged and the flesh is lower quality due to the lactic acid built up in a fatigued fish.

The MHS consists of a s 9(2)(b)(ii) [redacted] the fish do not get fatigued and are not compressed into the mesh in the cod-end. While inside the MHS environment the fish can maintain their station and this allows for much improved fish quality and higher survivability rates for inshore species (refer video: Snapper holding station inside MHS during tow.mpg).

Precision Seafood Harvesting

1. Application for Approval to Use MHS (Net A)

1(a) Details of Fisheries

This application is for the use of the inshore MHS technology as a replacement for traditional mesh-based trawl systems when targeting inshore finfish species. This includes, but is not limited to, the following species:

1. Common name: **Snapper**

   Scientific name: *Pagrus auratus*

   Species code: SNA

2. Common name: **Tarakihi**

   Scientific name: *Nemadactylus macropterus, Nemadactyus* sp.

   Species code: TAR

3. Common name: **Trevally**

   Scientific name: *Pseudocaranx dentex*

   Species code: TRE

4. Common name: **Red gurnard**

   Scientific name: *Chelidonichthys kumu*

   Species code: GUR

5. Common name: **John dory**

   Scientific name: *Zeus faber*

   Species code: JDO

The application is for year-round usage for single trawl (ST) tows using the MHS in FMAs 1, 2, 8 & 9 but excluding use in Statistical Areas 005 and 006 in the Hauraki Gulf within FMA 1.

At present the application has been restricted to these FMAs as the species composition within these areas is similar to FMA 1 where the testing of the MHS gear has been undertaken and for which the analysis of the catch effort data has been completed. It is intended that further testing of MHS designs will be carried out in the South Island fisheries to allow for use in the remaining FMAs.

In addition, it was decided to exclude Statistical Areas 005 and 006 from the application due to the higher risk of SNX capture based on catch effort data from commercial single trawl vessels and where the percentage of SNX has been recorded in double digits. This avoidance strategy will offer a further reduction of risk for any decision to allow the use of the new MHS designs in the inshore fishery.

1(b) Net A (MHS) Specifications

The specifications of the MHS designs for which approval is being sought are detailed in Table 1.

s 9(2)(b)(ii)

[redacted]

s 9(2)(b)(ii)

[redacted]

s 9(2)(b)(ii)

[redacted]

1(c) Fisheries Plans

There has been no Fisheries Plan approved under section 11A of the Fisheries Act 1996 in relation to inshore fisheries and therefore no criteria under which net A has been assessed.

1(d) Practices or Procedures

A. Mitigation of Adverse Effects

Any potential, unintended effects arising from the use of the Inshore MHS will be mitigated by the following procedures, protocols and management plans which are adhered to by each vessel that will be using the MHS designs:

- Agreements of fisheries, quota owners and LFRs in Snapper 1 Commercial (Rev Jan 2014) https://www.inshore.co.nz/fileadmin/Documents/Other/SNA1_Agreement_-_2014.pdf including:
  - Use science to fish smarter
  - 'Move On' rule when areas with a high percentage of small fish are encountered
  - Record and report on all snapper caught sub Minimum Legal Size (<MLS)
  - Install VMS across the SNA1 commercial fleet where catch exceeds 5 tonne a year
  - Participate in a tagging programme to better estimate SNA1 stocks
  - Share our knowledge with scientists and fisheries managers
  - Support the investigation and practicality of electronic monitoring (EM) on vessels to address specific management objectives
  - Positively contribute to the development of a long term SNA1 management plan

B. Improvement of Performance

The performance of Net A will be improved by the users of the MHS operating under the guidelines set out in the document "Standard Operating Procedures for Inshore PSH Modular Harvest Systems & OnBoard Fish Handling" (refer Appendix 2).

Improvements in design will also be considered by the Research Advisory Group for decisions on testing and implementation.

2. Comparison of MHS (Net A) with Conventional Mesh (Net B)

For comparison across the 4 approval criteria a conventional net with 125mm (5") mesh was selected. It is worth noting that PSH is not looking for comparison against 150mm (6") mesh which is being used in Stat Areas 005 & 006 nor against 100mm (4") mesh which is used outside 100m and in the South Island fisheries.

2(a) Net B (Conventional Mesh) Specifications

A typical trawl net design s 9(2)(b)(ii) [redacted] with 125mm mesh as used in inshore fisheries is as follows:

s 9(2)(b)(ii)

2(b) How Net B Meets the Criteria under R71A(2)

Regulation 71A(2) provides that if a trawl net includes mesh, it cannot be used if it has 1 or more of the following features:

(i) more than 1 layer of mesh;
(ii) liners, sleeves, or flappers of any material;
(iii) a method of strengthening with centres less than 1 m;
(iv) net mesh size less than 100 mm unless a fishing permit authorises the use or possession of the mesh.

The specifications for net B (as detailed in the net plans in section 2(a) above) meet all the requirements as set out under R71A(2).

2(c) Comparison of Characteristics for Net A and Net B

As previously noted the MHS is designed to s 9(2)(b)(ii) [redacted] The characteristics of the trawl net remain unchanged between net A and net B both in terms of physical and performance characteristics, except in respect of the terminal end sections as detailed below.

In terms of physical characteristics, the main difference between net A and net B is the method of construction and the materials used in relation to the terminal end sections s 9(2)(b)(ii) [redacted] In this regard, Net A s 9(2)(b)(ii) [redacted] whilst net B is made from mesh panels that are sewn together.

With respect to the performance characteristics, for net A, through the design of these modules, there is a considerable difference in the in-trawl environment when compared to net B. s 9(2)(b)(ii) [redacted] a fish friendly environment where the fish exhibit normal behaviour. This results in the harvest of low fatigue, high quality fish along with the unharmed escape and release of unintended catch when compared to net B where the fish are subjected to turbulent flow and fatigue.

2(d) Comparison of Performance for Net A and Net B

For the purpose of a comparison of the performance of net A compared to net B the following sources of information were used:

a. Trials to compare net A to net B – refer to section 2(e) below for details.
b. MPI Observer Data – Analyses of observer data – Trident (refer Appendix 12)
c. Commercial Reporting – specific reporting as set-up by Trident Systems to monitor the use of the MHS designs:
   i. SNX catches by BT and PSH (refer Appendix 3)
   ii. NFPS Catch Rates (refer Appendix 4)
d. Equivalence analysis of UCK in MHS & conventional gear – Russell B. Millar (refer Appendix 5)
e. Exploratory analyses of UCK – Trident Systems (refer Appendix 6)

(i) Species composition of the catch

From the trial when comparing the tows of the uncovered gear, the MHS gear and the 5” diamond mesh cod-end had similar ratios of QMS species caught to non-QMS species. The ratio was 9.2:1 QMS to nonQMS for MHS and 10.2:1 for the 5” diamond mesh cod-end (refer Appendix 7: Table 5-2). The area swept per tonne of all QMS catch was also similar between the MHS and the 5” diamond mesh at 2.25km^2 for the MHS compared to 2.14km^2 for the diamond mesh (if the large ‘hit’ of trevally is excluded the swept area per tonne for the uncovered diamond mesh increases to 2.7km^2).

The total catch rate of QMS species was higher in the diamond mesh cod-end compared to the MHS codend (477 kg km^{-2} compared to 445 kg km^{-2}). However, if the tow containing a one-off high catch of trevally is excluded then the overall catch rate of QMS species is higher in the MHS cod-end and slightly higher for non-QMS species combined as well.

Snapper was the dominant catch in both MHS & traditional gear, comprising around 60% of the total. However, overall the catch rate of snapper in the MHS cod-end was almost 30% higher than the diamond mesh cod-end with the MHS gear having a ratio of snapper to total catch of 0.53 compared to 0.39 for the diamond mesh cod-end. Trevally was the next most abundant species with a ratio of 0.32 in the diamond mesh cod-end compared to 0.11 for the MHS (but if the single large tow of trevally is excluded the ratio drops to 0.19 whilst the snapper ratio increases to 0.46). The remaining QMS species generally accounted for 5% or less of the catch for both MHS & diamond mesh cod-ends with some caught in greater numbers in the MHS, eg. leatherjackets, and some in greater numbers in the diamond mesh, eg. john dory and red gurnard. Total catch ratios of non-QMS was similar between MHS & the diamond mesh cod-end at 0.1 and 0.09 respectively with the MHS gear, with some indication that the catch rates of non-QMS skates and rays was slightly lower in the MHS cod-end.

Overall in terms of species composition of the catch the performance of the MHS cod-end was similar to the diamond mesh cod-end.

(ii) Size composition of the catch

SNA

From the Kaharoa trial length data was collected for snapper but due to a significant cover net effect, selectivity could only be estimated using the alternate-haul data from the uncovered gears. For snapper, the diamond mesh cod-end had an L_{50} of 29.5 cm (95% CI = 27.7-30.7 cm) and a selection range (SR) of 6.2 cm (95% CI 3.8-6.8 cm). For the MHS cod-end the estimated L_{50} was 3 cm lower at 26.3 cm (95% CI = 25.1-28.9 cm) and the SR was 4.5 cm (95% CI = 3.7-7.3 cm) - refer Table 8-1 of the report). A randomized test of the null hypotheses that the diamond mesh and MHS gears had identical selection curves indicated only modest evidence of a difference in selectivity (p = 0.10), though not statistically significant at the 5% level.

The length range of snapper caught was from 10-80 cm, with a main modal peak at between 24 and 26 cm. The MHS had higher catch rates of legal snapper compared to the diamond mesh cod-end, particularly in the 25-30 cm range. This higher catch rate with the MHS gear gave a ratio of 0.655 (±0.11) for the count of undersize snapper to weight of legal snapper (UCK) compared to 0.508 (±0.11) for the diamond mesh cod-end, however the difference was not found to be significant (p = 0.33).

A further comparison between the UCK of MHS and conventional gear was undertaken by analysing the commercial catch effort data from FMA 1 (refer Appendix 5). This analysis found that the UCK of MHS was 30% higher compared to conventional gear for tows targeting snapper and 18% higher across all tows in FMA 1. It was found that all UCKs were lower (especially outside stat areas 005 & 006) averaging 0.0550 and 0.0713 for tows targeting SNA in FMA 1 by BT & MHS respectively when compared to the results from the Kaharoa trial of 0.137 and 0.177 for BT & MHS respectively.

Given the Kaharoa trial was undertaken in Stat Areas 005/006 and the higher incidence of SNX in these areas, additional analyses (refer Appendix 5) were conducted excluding these stat areas as a potential avoidance strategy. It was found that outside of the Hauraki Gulf for tows targeting SNA the UCK of MHS gear is 11% lower than that of conventional gear and when compared across all tows in FMA 1 (excluding

Stat Areas 005 & 006) the UCK for MHS is 12% less. Depth was found to have a strong effect on the difference in UCK between MHS & conventional gear.

On this basis the decision was made to exclude Stat Areas 005 & 006 from our application and further analysis of the commercial catch effort data from the FMA 1 excluding Stat Areas 005 & 006 was undertaken to compare the performance of MHS to BT (refer Appendix 6).

For fishers targeting SNA outside Stat Areas 005 & 006 (refer Figure 23 and Table 12 – Appendix 6 as shown below) it was found there was a 53% probability that MHS catches less SNX compared to BT.

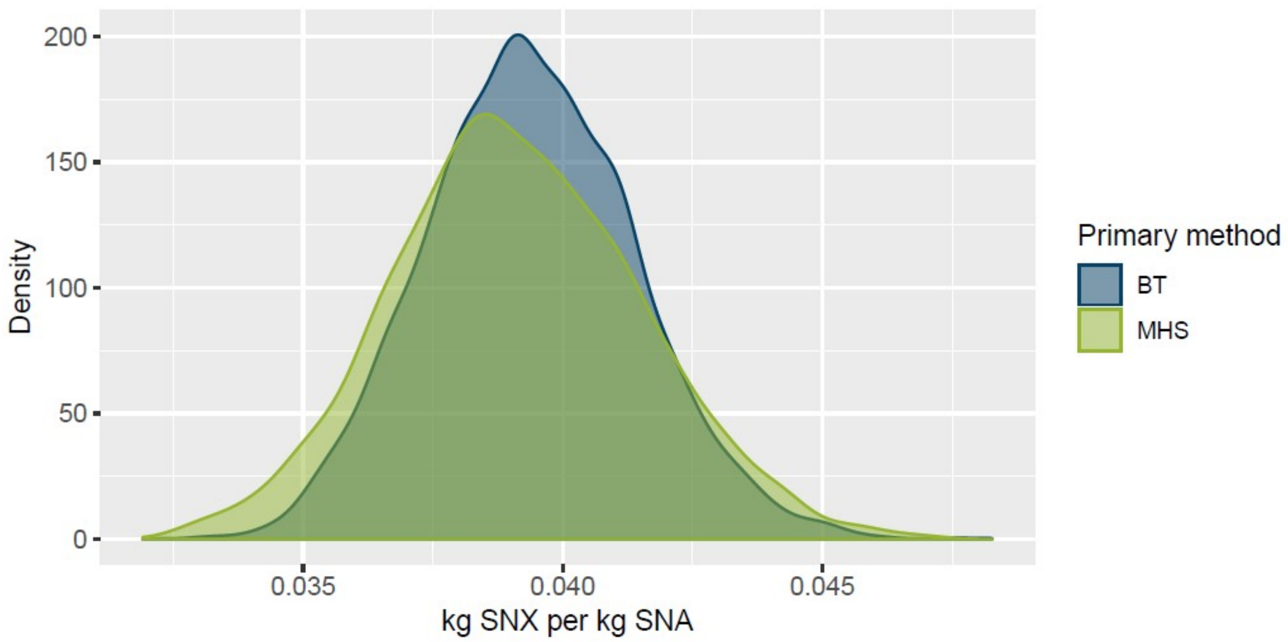


Figure 23: Calibrated posterior predicted kg SNX per kg SNA from 2554 BT tows and 1348 MHS tows targeting SNA excluding statistical areas 005 and 006 based on historical fishing behaviour.

Table 12: Table of probabilities of maximum relative difference in kg SNX per kg SNA MHS relative to BT considering behavioural differences. Fishers targeting SNA outside statistical areas 005 and 006.

Maximum relative difference	Probability satisfied
0.50	1.000
0.25	0.999
0.10	0.902
0.00	0.533
-0.10	0.107
-0.25	0.000
-0.50	0.000

An alternative analysis of the same data that compared MHS to BT assuming equivalent variables of depth, time, etc for vessels targeting SNA showed there was a 59% probability that the predicted UCK for MHS could be up to 25% worse that BT (refer Figure 28 & Table 14 – Appendix 6 as shown below).

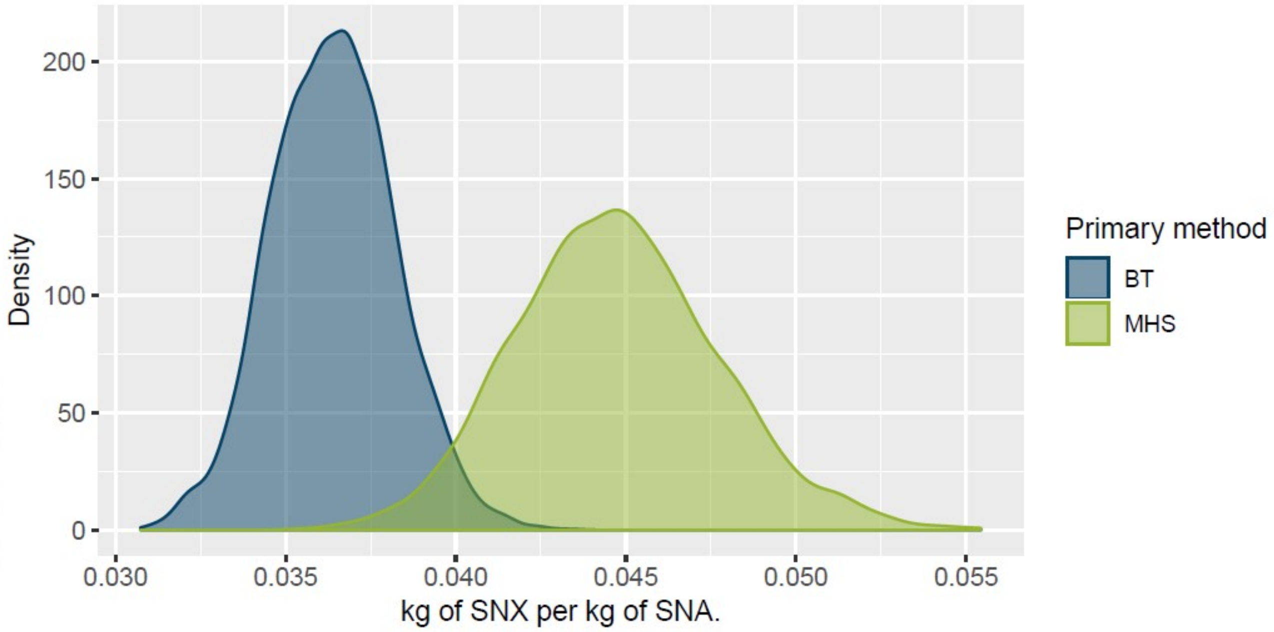


Figure 28: Calibrated posterior predicted kg SNX per kg SNA assuming, alternatively, all tows used BT and MHS gear (equivalence test) excluding statistical areas 005 and 006. Tows targeting SNA.

Table 14: Table of probabilities of maximum relative difference in kg SNX per kg SNA MHS relative to BT assuming identical behaviour (equivalence). Fishers targeting SNA outside statistical areas 005 and 006.

Maximum relative difference	Probability satisfied
0.50	0.981
0.25	0.586
0.10	0.109
0.00	0.011
-0.10	0.000
-0.25	0.000
-0.50	0.000

When looking at all tows targeting SNA, JDO, GUR, TAR & TRE in FMA 1 but excluding Stat Areas 005 & 006 it was found there was an 89% probability that MHS catches less SNX than BT (refer Figure 19 and Table 11 – Appendix 6 as shown below).

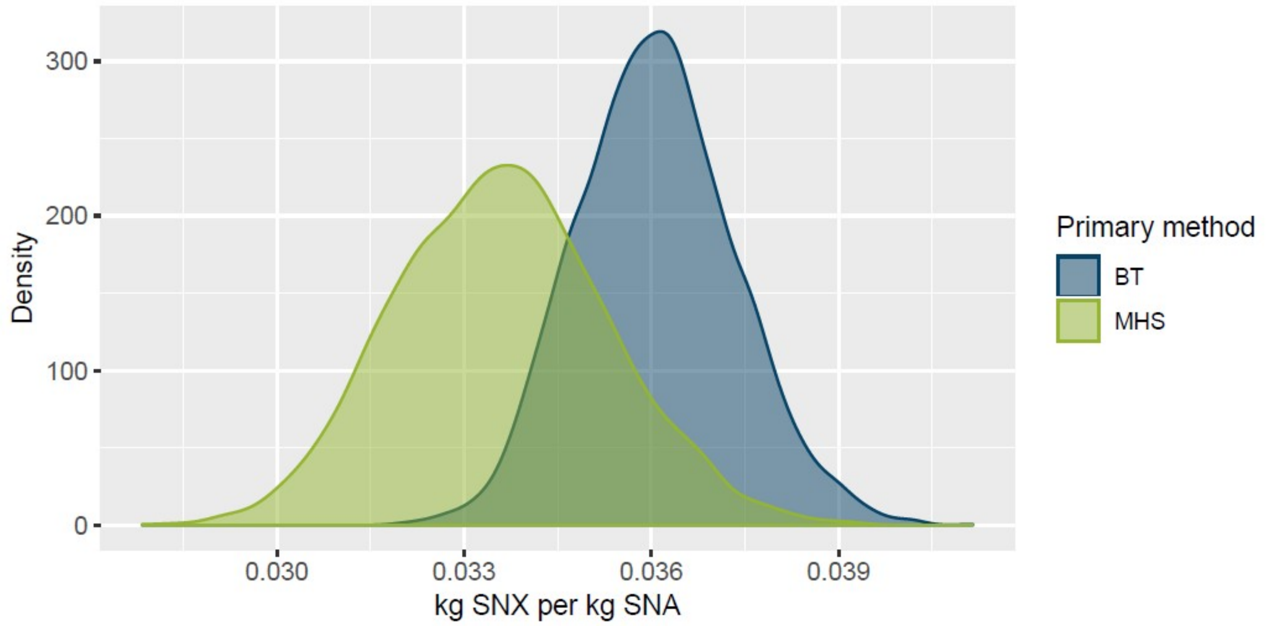


Figure 19: Calibrated posterior predicted kg SNX per kg SNA from 10813 BT tows and 2736 MHS tows targeting GUR, JDO, SNA, TAR and TRE in FMA1, excluding statistical areas 005 and 006 based on historical behaviour.

Table 11: Table of probabilities of maximum relative difference in kg SNX per kg SNA MHS relative to BT considering behavioural differences. Fishers targeting GUR, JDO, SNA, TAR and TRE outside statistical areas 005 and 006.

Maximum relative difference	Probability satisfied
0.50	1.000
0.25	1.000
0.10	0.997
0.00	0.886
-0.10	0.284
-0.25	0.000
-0.50	0.000

Assuming identical behaviour between MHS & BT for fishers targeting SNA, JDO, GUR, TAR & TRE in FMA 1 but excluding Stat Areas 005 & 006 there was a 34% probability that the predicted UCK for MHS could be up to 10% worse that BT (refer Figure 26 & Table 13 – Appendix 6 as shown below).

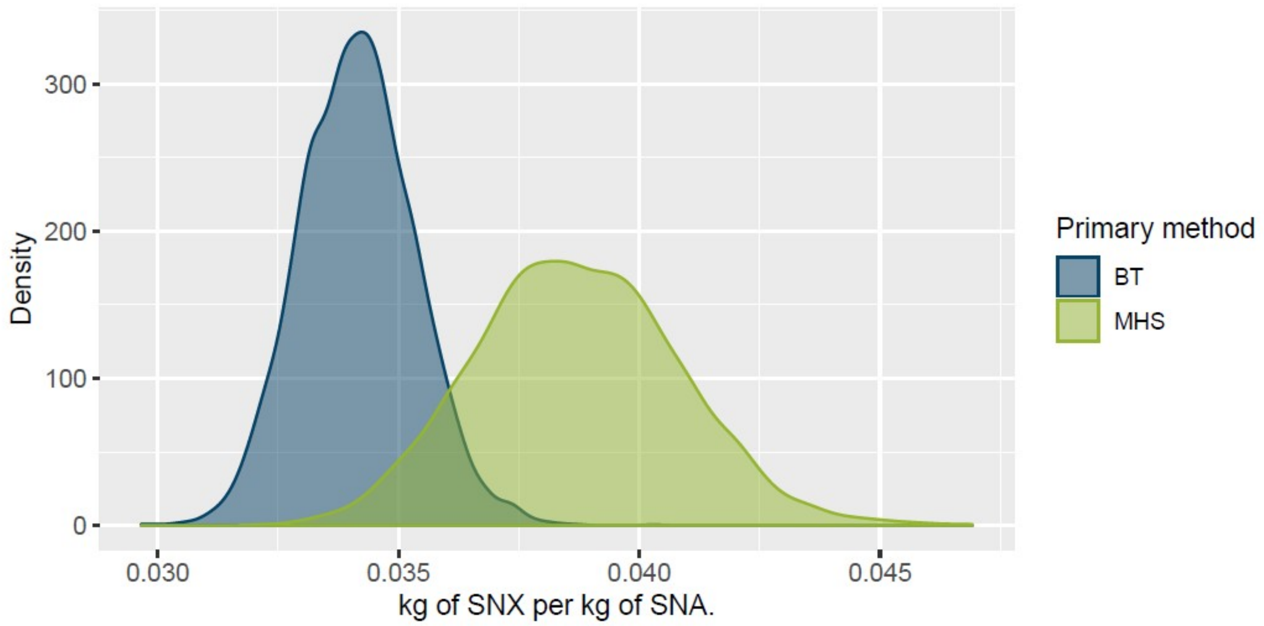


Figure 26: Calibrated posterior predicted kg SNX per kg SNA assuming, alternatively, all tows used BT and MHS gear excluding statistical areas 005 and 006. Tows targeting SNA, GUR, JDO, TAR and TRE.

Table 13: Table of probabilities of maximum relative difference in kg SNX per kg SNA MHS relative to BT assuming equivalent behaviour. Fishers targeting GUR, JDO, SNA, TAR and TRE outside statistical areas 005 and 006.

Maximum relative difference	Probability satisfied
0.50	1.000
0.25	0.922
0.10	0.342
0.00	0.035
-0.10	0.001
-0.25	0.000
-0.50	0.000

The difference in the analyses between actual performance and the theoretical equivalent behaviour reflects MHS performance outside the criteria that is further enabling fisher's ability to avoid capture of SNX. The reasons for this are that small wooden 50ft trawlers and Danish Seiners have historically been a key part of the inshore fishing fleet with the continued reliance on these smaller vessels due to the quality of fish off these small vessels being far superior compared to a bigger inshore 65-90ft vessels. However, with the advent of MHS, this is no longer the case.

For small wooden 50ft vessels the benefits of MHS are less, so most will stick with mesh as:

- Using traditional mesh and short tows they already land a quality product.
- They are limited to where and when they can fish. Hence, they generally fish in shallow areas, lee side of wind and close to land where small fish are becoming more and more abundant. This small fish abundance issue is becoming more prevalent and with many small trawlers/seiners now transiting to 6" mesh to avoid the small SNA.

- Limited safe working limits for booms so vessels with MHS bags are often doing split side lifts, reducing MHS quality as fish wash in the water between lifts.
- Stability restrictions limiting the ability to incorporate fluid onboard handling systems.

Benefits of MHS for larger trawlers are:

- Less limited by weather conditions, so they can fish further out where the fish are generally bigger and of a far better mix.
- Social licence pressure which is advocating for commercial fishing to be further offshore and therefore lessen the spatial conflict with recreational & traditional fishing.
- Danish seiners have historically been used to quickly catch volumes of quality clean SNA for market demand purposes. MHS allows larger trawlers to catch large volumes of quality SNA on demand, with the bonus of catching mix at the same time.
- Increased stability and safe working limits, meaning better options for onboard handling.
- Build costs difference between new big and small vessels isn't far apart. So, economics dictate that any future builds ideally should be bigger boats that would benefit from MHS.

The drivers to avoid small fish are no different to what exist for conventional gear and unlikely to change in the near future. These same drivers have seen a move to use 6" mesh in Stat Areas 005 & 006 that has seen a further reduction in SNX capture in those areas.

The variability and similarity in catch rates of undersize snapper between MHS and conventional gear is further demonstrated from a comparison of SNX catches by vessels using MHS and conventional gear during the 2017/18 fishing year to date (refer Appendix 3). As detailed in that report the percentage of SNX caught by vessels operating in the SNA 1 fishery during the 2017/18 year varied between sub-areas (Bay of Plenty, East Northland and Hauraki Gulf) and time of year (Q1, Q2 and Q3).

For Bay of Plenty and East Northland the %SNX captured was lower for PSH compared to BT for all quarters except Q3 where it was higher in the Bay of Plenty whilst in the Hauraki Gulf it was the opposite with BT having lower % captures compared to PSH for all quarters. The difference in % capture rates varied between 0.1% to 10.4% with sub-area and time of year appearing to impact on the level of SNX catches by either BT or PSH gear.

These analyses all demonstrate that under normal commercial operations the level of SNX catch is around 10% less or at worse similar for MHS compared to conventional gear.

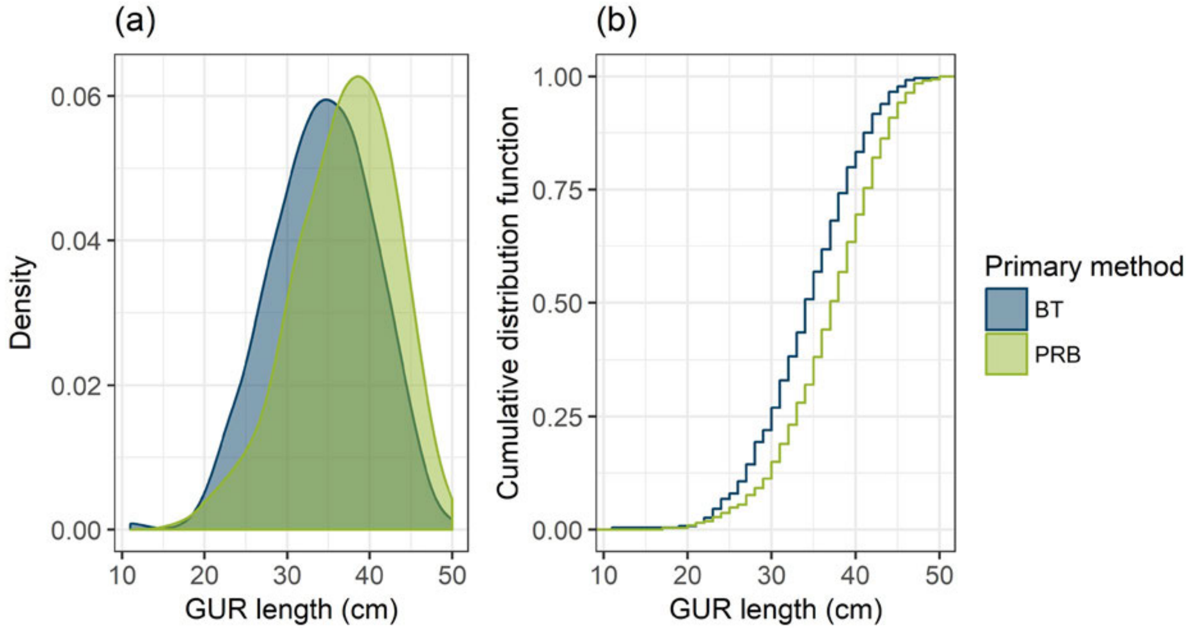
Other Species

The Kaharoa trial also examined selectivity for trevally, red gurnard, john dory and tarakihi but due to low and/or patchy catch rates, plus limited numbers of smaller fish in some species, feasible selection curves were only achieved for trevally in the standard gear (L_{50} = 35.3 cm and SR=2.6 cm – refer Figure 8-6 of the Report) and for red gurnard in the MHS gear (L_{50} = 29.2 cm and SR=4.3 cm – refer Figure 8-7 of the Report). The main modal peak for trevally, red gurnard, tarakihi and john dory were all above 30 cm, and with low numbers of smaller fish.

GUR

From the Kaharoa trial the estimated selectivity curve fitted for red gurnard in the MHS can be compared to previous results from diamond mesh codends. In this experiment, the fitted selection curve gave an L_{50} of 29.2 cm for this species, which is very similar to two previous experiments; Scott et al. (2011) estimated an L_{50} for red gurnard of 29.4 cm (SE = 1.9), and selection range of 8.6 cm (SE=1.2) in a 130 mm diamond mesh codend using twin trawl, and Massey (1988) estimated an L_{50} of 31.5 cm with a coveredcodend experiment for slightly larger 132.7 mm diamond mesh. Given the similarity between the selectivity curves and the resultant L_{50} for red gurnard the MHS gear can be seen to be performing 'no worse than' standard gear.

Length data from observer measurements were also analysed with GUR caught be MHS appearing to be larger (refer Figure below – Appendix 12)



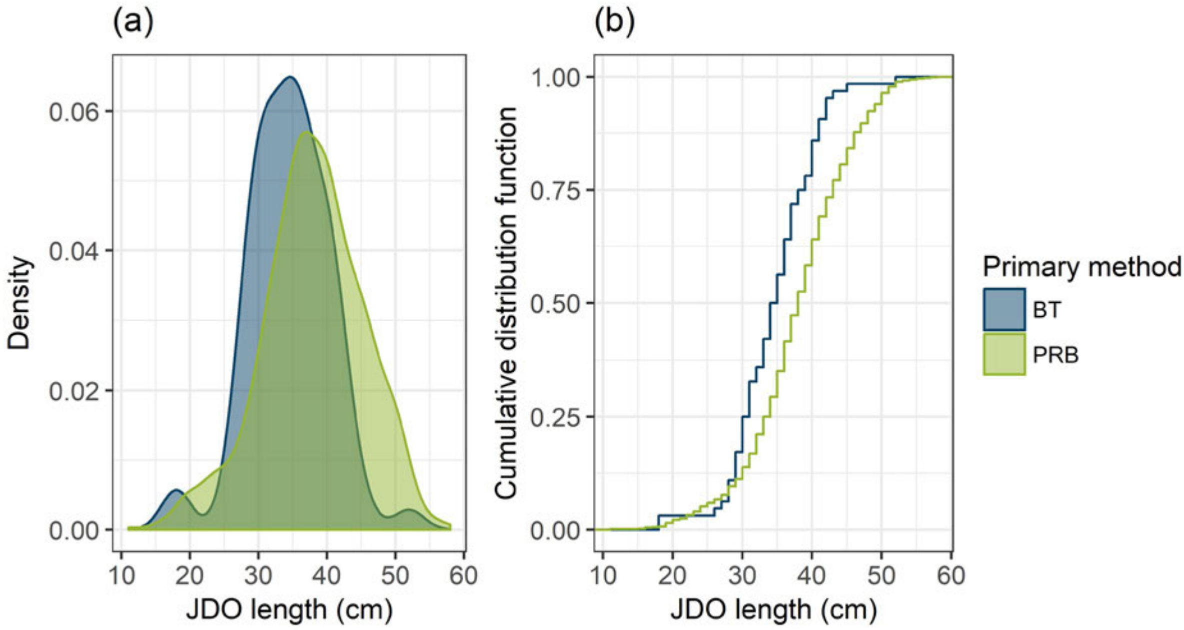
The model suggests (with high statistical significance) that GUR caught by MHS are on average expected to be 3cm longer than fish caught by conventional trawl. In addition, further modelling finds that MHS is 2.3 times more likely to catch GUR 30cm or above compared to GUR caught by BT.

Factory grading data supplied by Moana (see table below) would support these findings with the percentage of GUR greater than 400g being much higher on average (0.71) when compared to BT (0.46).

	+400G		Medium		Small	
Year	PSH	TR	PSH	TR	PSH	TR
2013-14		0.45		0.43		0.12
2014-15		0.44		0.46		0.10
2015-16	0.39	0.36	0.31	0.55	0.30	0.10
2016-17	0.77	0.56	0.19	0.38	0.04	0.06
2017-18	0.75	0.56	0.20	0.39	0.06	0.05
Total	**0.71**	**0.46**	**0.21**	**0.45**	**0.08**	**0.09**

JDO

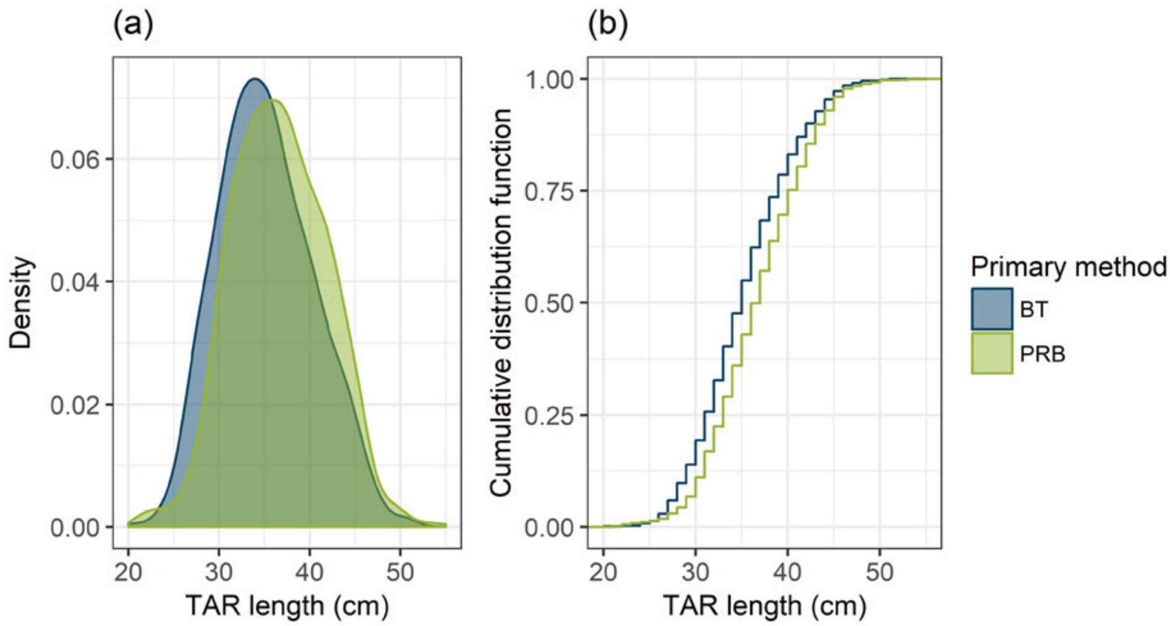
The analysis of observer length data for JDO also found that the average size caught by MHS was larger compared to BT (see figure below – Appendix 12).



The model found with statistical significance that the average size of JDO was likely to be just over 2cm longer compared to fish caught by BT and that the odds of MHS catching a fish being 32cm or above were 1.9 times that for BT.

TAR

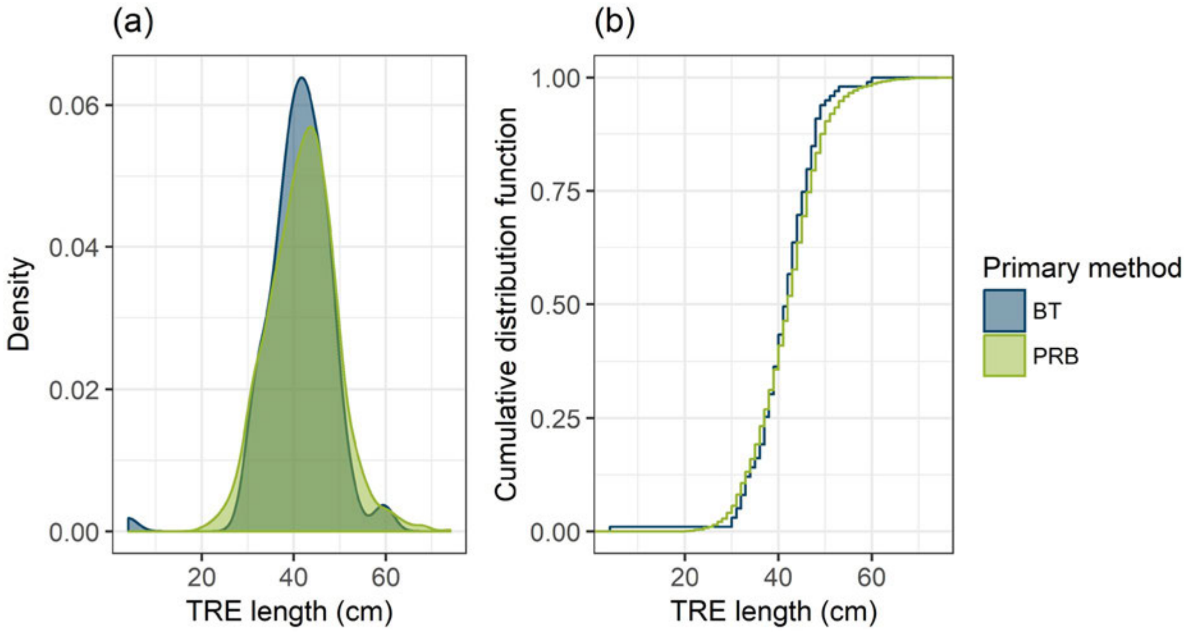
For TAR there is some suggestion that MHS catches larger fish compared to BT (see Figure below – Appendix 12) but not to the same degree as either GUR or JDO.



The model found with statistical significance that TAR caught by MHS are expected to be around 0.9cm larger compared to fish caught by conventional gear. Further modelling suggested that MHS would probably catch more TAR 32cm or greater when compared to BT but the effect was not statistically significant.

TRE

From the observer length data for TRE there was little evidence of a difference in the size caught between MHS & BT (see Figure below – Appendix 12) but there was very little data to make a comparison with only seven BT tows with TRE being measured since Oct 2015.



(iii) Impact on protected species

No protected species were caught during the trials. Skates and rays made up around 5-6% of the catch of the diamond mesh cod-end tows and slightly less in the MHS at 3-4% (refer Appendix 7: Table 5-2). The catch rates of all elasmobranchs was slightly higher for the diamond mesh cod-end at 36.5 kg km^{-2} compared to the MSH cod-end at 33.1 kg km^{-2} (refer Appendix 7: Table 5-1).

A comparison of seabird captures between conventional gear and MHS gear from the Non-Fish and Protected Species (NFPS) catch reports over the 2016, 2017 & 2018 (Oct-Jan) fishing years (refer Appendix 4: Table 1) found no difference in capture rates between BT and PSH gear (0.005 captures/tonne) but MW having a much lower rate.

For marine mammals (refer Appendix 4: Table 2) again the capture rates per tonne were the same for BT & PSH gear (0.001 captures/tonne) with MW having a higher rate (0.004 captures / tonne). It should be noted that since Dec 2016 there have been no reported dolphin captures with 100% observer coverage in place and an increased number of tows using MHS gear.

Capture rates for other protected fish and reptiles (refer Appendix 4: Table 4) were negligible for both BT & PSH gear (0.06% and 0.03% respectively) with capture rates effectively zero.

Further analysis of the reported NFPS[1] interactions and the commercial catch effort data from FMA 1 has been undertaken for seabirds, cetaceans and pinnipeds (refer Appendix 6).

Seabirds

A comparison of tonnes of target species catch per seabird interaction between MHS & BT showed there was high quantities of target species catch per seabird interaction for both MHS & BT, with a 99.8% probability that MHS realises more target species per catch per seabird interaction (see Figure 58 & Table 35 – Appendix 6 as shown below).

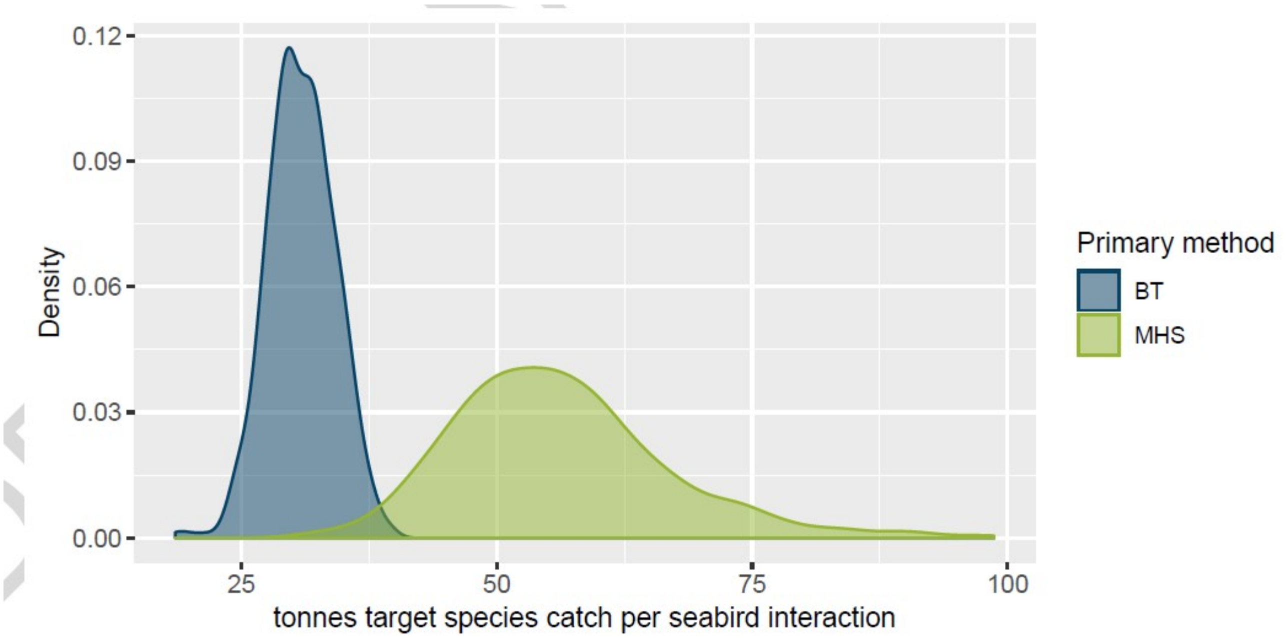


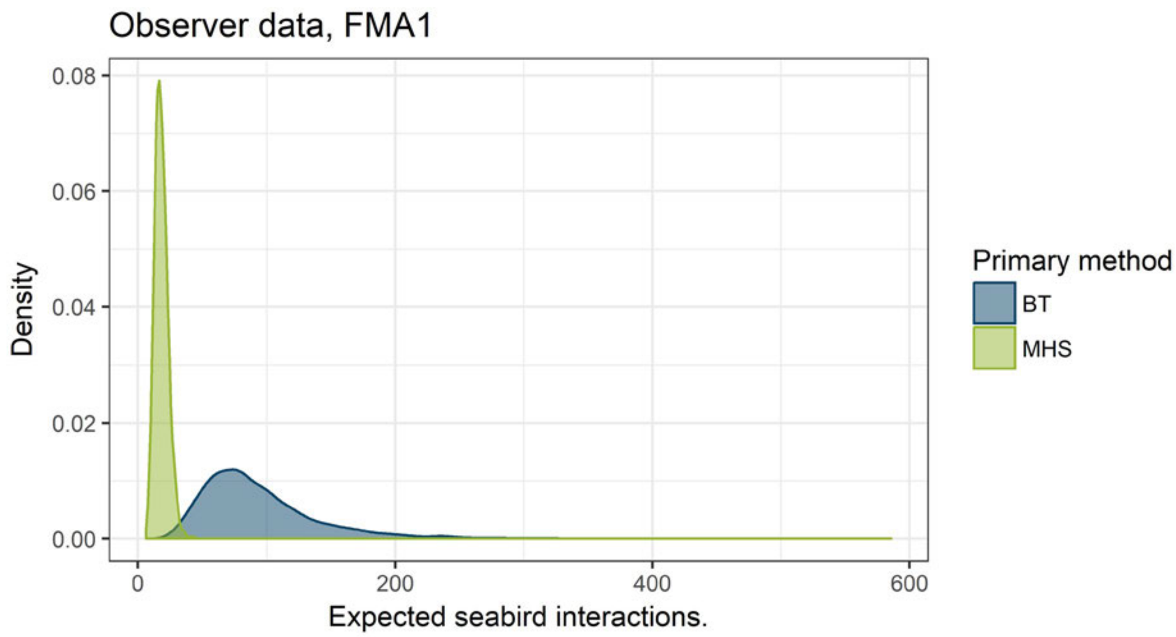
Figure 58: Calibrated posterior fitted seabird interactions from 14015 BT tows and 4151 MHS per kg of target species catch.

Table 35: Table of probabilities of minimum relative difference in target species catch per seabird interaction, MHS relative to BT based on historical reported behaviour. Inferences based on tows targeting all species.

Maximum relative difference	Probability satisfied
0.50	1.000
0.25	1.000
0.10	1.000
0.00	0.998
-0.10	0.988
-0.25	0.954
-0.50	0.806

[1] It should be noted that all trawl vessels targeting SNA in FMA 1 have for the past 3 years been part of the video observation trials with cameras installed in the vessels giving greater certainty around the accuracy of the NFPS reporting.

An analysis of observer data from 1984 tows (460 BT & 1524 MHS) that recorded 16 seabird interactions from BT tows and 14 from MHS tows found there was a 99% probability that MHS catches 25% less seabirds than BT.



Cetaceans

For cetaceans there are far fewer interactions with the comparison between MHS & BT on the target species catch per cetacean interaction finding no evidence that MHS is worse than BT (see Figure 65 & Table 39 – Appendix 6 as shown below).

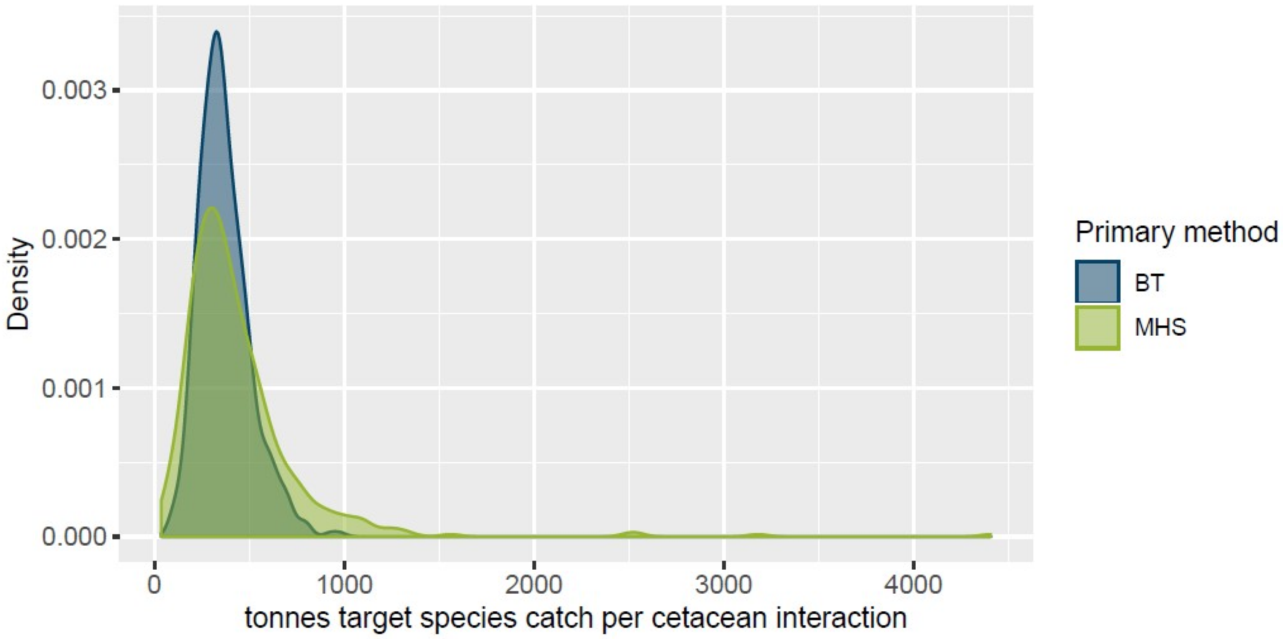


Figure 65: Calibrated posterior fitted cetacean interactions from 14015 BT tows and 4151 MHS per kg of target species catch.

Table 39: Table of probabilities of minimum relative difference in target species catch per cetacean interaction, MHS relative to BT based on historical reported behaviour. Inferences based on tows targeting all species.

Maximum relative difference	Probability satisfied
0.50	0.867
0.25	0.693
0.10	0.606
0.00	0.516
-0.10	0.448
-0.25	0.384
-0.50	0.297

Pinnipeds

For pinnipeds the number of interactions is even fewer with only 1 interaction recorded for MHS gear and 6 interactions for BT. A comparison of the target species catch per pinniped interaction found there was an 83% probability that MHS had higher target species catch per pinniped interaction but these results were highly uncertain given the low number of recorded interactions.

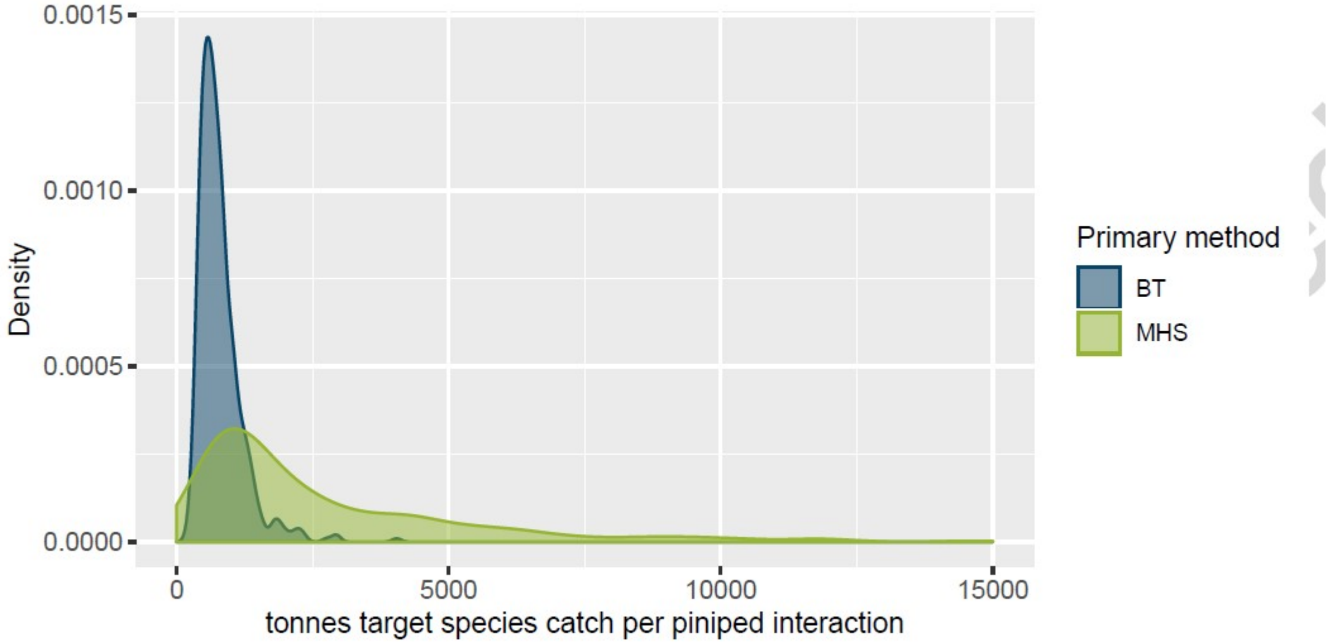


Figure 72: Calibrated posterior fitted piniped interactions from 14015 BT tows and 4151 per kg of the target species catch

Table 42: Table of probabilities of minimum relative difference in target species catch per pinniped interaction, MHS relative to BT based on historical reported behaviour. Inferences based on all tows.

Maximum relative difference	Probability satisfied
-0.50	0.956
-0.25	0.892
-0.10	0.864

0.00	0.830
0.10	0.802
0.25	0.778
0.50	0.720

In summary the data and analyses demonstrate that the MHS gear has less impact or is at least no worse than conventional gear with regard to protected species.

(iv) Impact on benthic species

Benthic invertebrates accounted for 2-3% of the catch in the diamond mesh cod-end compared to 5-6% in the MHS cod-end (refer Appendix 7: Table 5-2) with catch rates slightly lower in the standard gear at around 1.6 kg km^{-2} compared to 2.8 kg km^{-2} for the MHS gear (refer Appendix 6: Table 5-1).

The comparison between conventional gear and MHS gear for benthic captures (corals, sponges and other benthos) found captures rates for MHS gear was slightly higher at 0.062 captures / tonne compared to conventional gear at 0.019 captures per tonnes (refer Appendix 4: Table 3). The higher capture rates mainly resulted from one vessel's higher reporting of sponge captures.

It should be noted that the disturbance of benthic material between the MHS and conventional gear would be no different as the configuration of the net is no different with respect to front end of the net such as the ground gear, headline height, floatation, wing spread, etc. However, as the terminal end differs for the MHS gear with the liftbag being a solid membrane the retention of sessile species such as corals & sponges will be higher when compared to a mesh cod-end where such species can fall through the meshes.

Overall catch rates for the MHS were higher for QMS species (excluding the single large 'hit' of trevally which is considered an outlier given the trial was targeting snapper). The catch rate of snapper was 28% greater for the MHS gear (261.33 kg km^{-2}) compared to convention gear (204.16 kg km^{-2}) so there would be significant benefit from the increased catch rate due to the consequent 28% reduction in benthic impacts and carbon emissions.

Additional analyses of the commercial catch effort data from FMA 1 were undertaken to examine catch rates (catch per nm) of SNA, GUR, JDO, TAR & TRE in relation to potential benthic impacts (see Appendix 6) as detailed below.

SNA

The analysis indicates there is little difference in catch rates of SNA between the two gear types based on historical catch (refer Figure 29 and Table 15 – Appendix 6 as shown below).

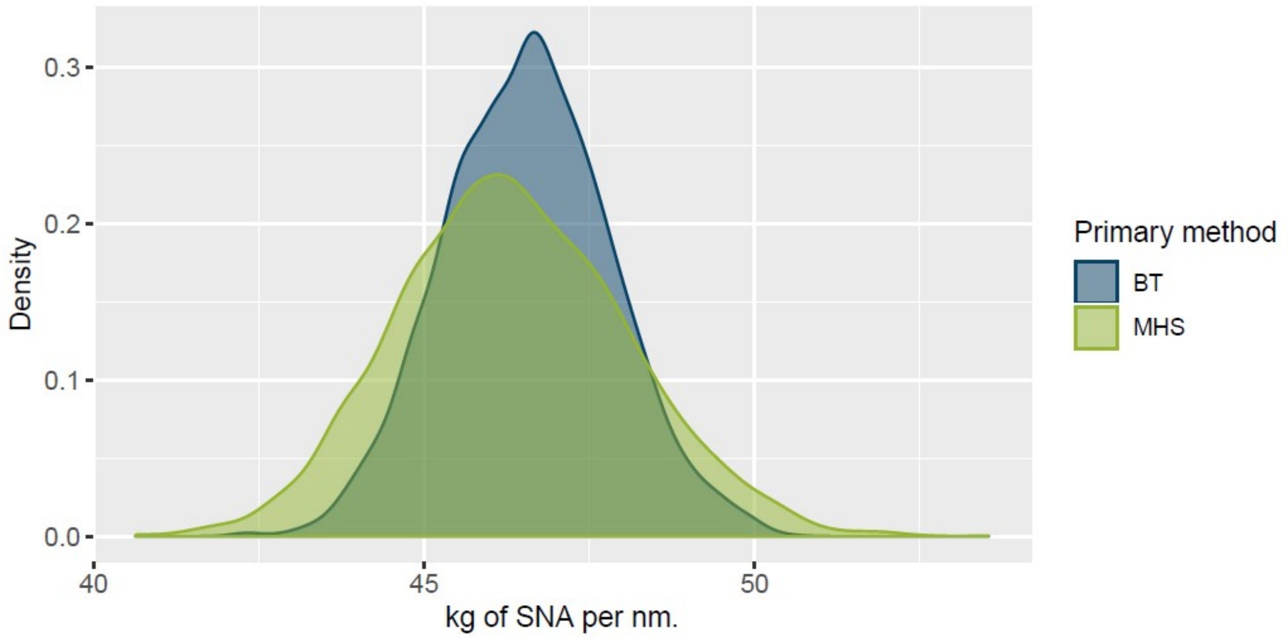


Figure 29: Calibrated posterior predicted SNA catch (kg) per nm, for BT and MHS tows targeting SNA in FMA1 excluding statistical areas 005 and 006.

Table 15: Table of probabilities of minimum relative difference in SNA per nm MHS relative to BT considering behavioural differences. Tows targeting SNA excluding statistical areas 005 and 006.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	1.000
-0.10	0.987
0.00	0.452
0.10	0.016
0.25	0.000
0.50	0.000

When catch rates are compared on an equivalent basis there is 55% probability that MHS catches more than 10% less SNA per nm compared to conventional gear.

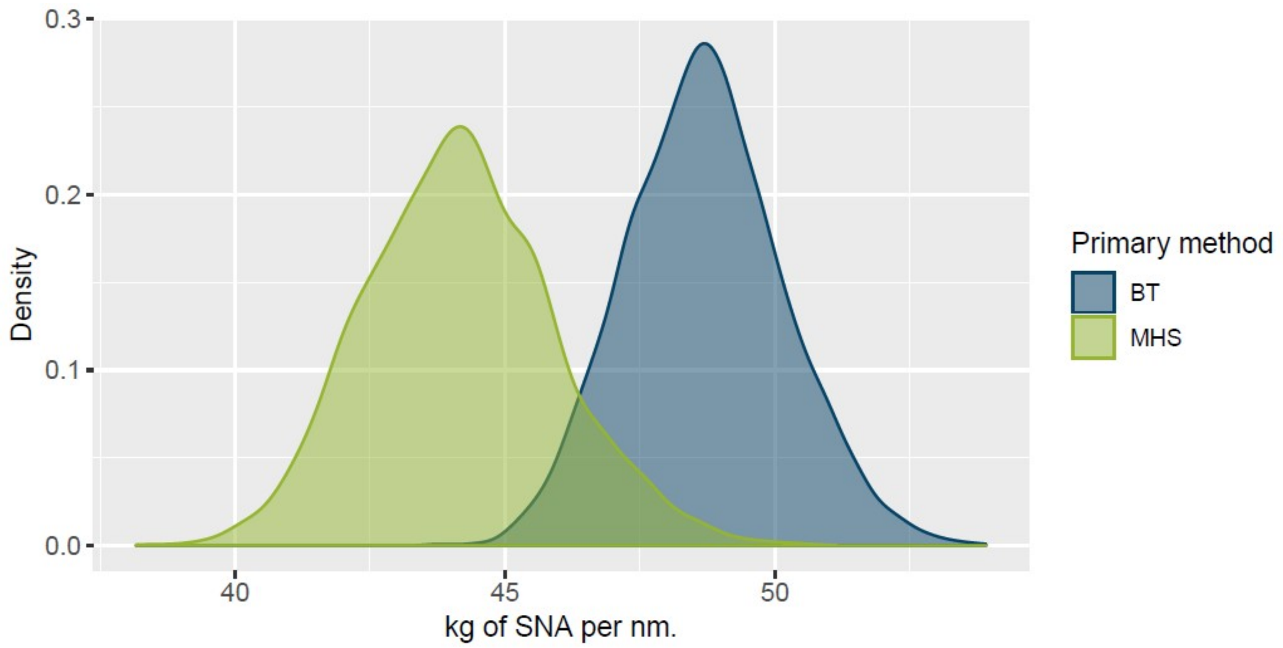


Figure 30: Calibrated posterior predicted SNA catch (kg) per nm, for BT and MHS tows targeting SNA excluding statistical areas 005 and 006 assuming all tows were undertaken by each gear type in turn (equivalence test).

Table 16: Table of probabilities of minimum relative difference in SNA per nm MHS relative to BT assuming identical targeting behaviour. Tows targeting SNA excluding statistical areas 005 and 006.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	1.000
-0.10	0.551
0.00	0.037
0.10	0.000
0.25	0.000
0.50	0.000

GUR

As there has been very little targeting of GUR using MHS gear the analysis to compare catch rates was modelled using tows targeting both GUR and SNA. The analyses show that BT has higher catch rates of GUR compared to MHS (see Figure 35 and Table 19 – Appendix 6 as shown below).

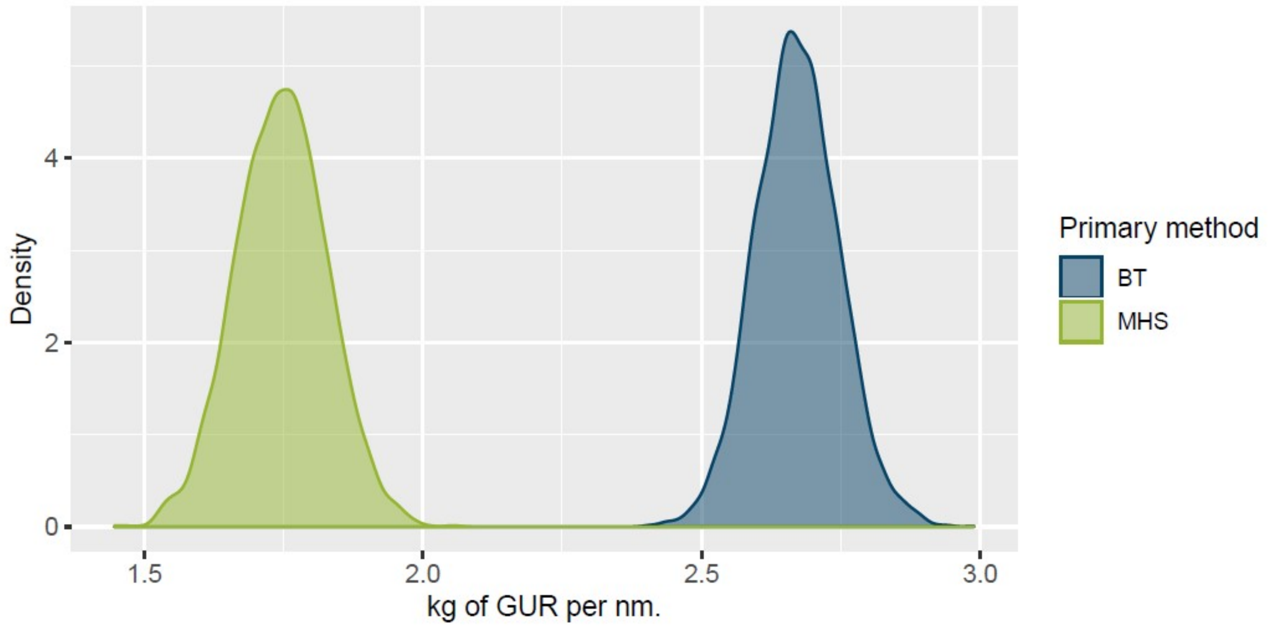


Figure 35: Posterior distribution of red gurnard catch (kg) per nautical mile towed from (a) 4053 BT tows and (b) 2539 MHS targeting gurnard and snapper.

Table 19: Table of probabilities of minimum relative difference in GUR per nm MHS relative to BT targeting behaviour to differ by gear types. Inference based on tows targeting SNA and GUR.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	0.002
-0.10	0.000
0.00	0.000
0.10	0.000
0.25	0.000
0.50	0.000

When assuming identical behaviour the catch rate of GUR per nm for MHS is the same (see Figure 36 and Table 20 – Appendix 6 as shown below).

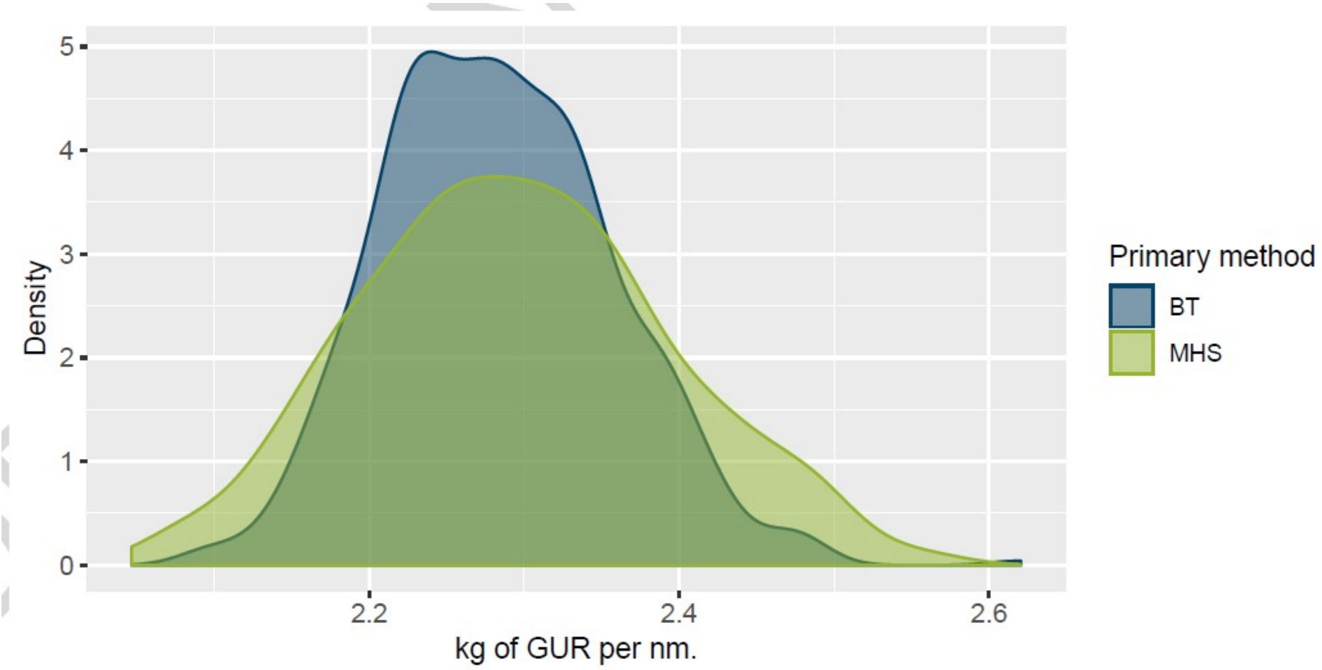


Figure 36: Posterior distribution of red gurnard catch (kg) per nautical mile towed from 4053 BT tows and 2539 MHS targeting gurnard and snapper assuming each gear type in turn.

Table 20: Table of probabilities of minimum relative difference in GUR per nm MHS relative to BT assuming identical targeting behaviour. Tows targeting SNA and GUR.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	1.000
-0.10	0.970
0.00	0.546
0.10	0.050
0.25	0.000
0.50	0.000

The lower catch rates of GUR for MHS matches to results from the Kaharoa trial which reported lower catch rates for GUR when compared to BT which is due to the design of MHS which allows for improved escapement of the smaller GUR. As catch of GUR is limited by available SNA quota there would not be any increased benthic impact from the lower catch of GUR and indeed there would be some offset in terms of the benefit to the stock status with the release of the smaller fish.

JDO

For JDO the analyses show that MHS catches more JDO per nm compared to BT with a high probability that MHS catches 10-25% more than BT (see Figure 40 and Table 20 – Appendix 6 as shown below).

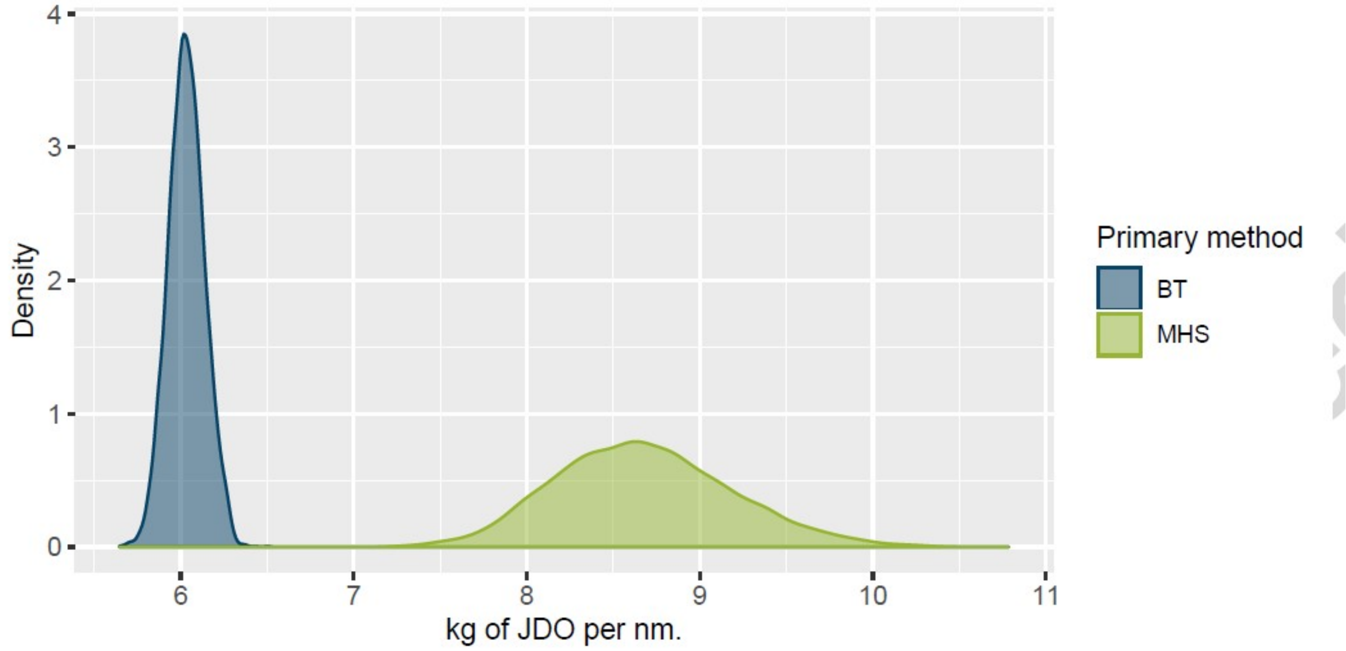


Figure 40: Calibrated posterior distribution of John Dory catch (kg) per nautical mile towed from 2719 BT tows and 220 MHS tows targeting John Dory.

Table 23: Table of probabilities of minimum relative difference in JDO per nm MHS relative to BT allowing different targeting behaviour. Tows targeting JDO.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	1.000
-0.10	1.000
0.00	1.000
0.10	1.000
0.25	0.992
0.50	0.234

When compared on an identical basis the difference is reduced but MHS still has a higher catch rate for JDO compared to BT (see Figure 41 and Table 24 – Appendix 6 as shown below).

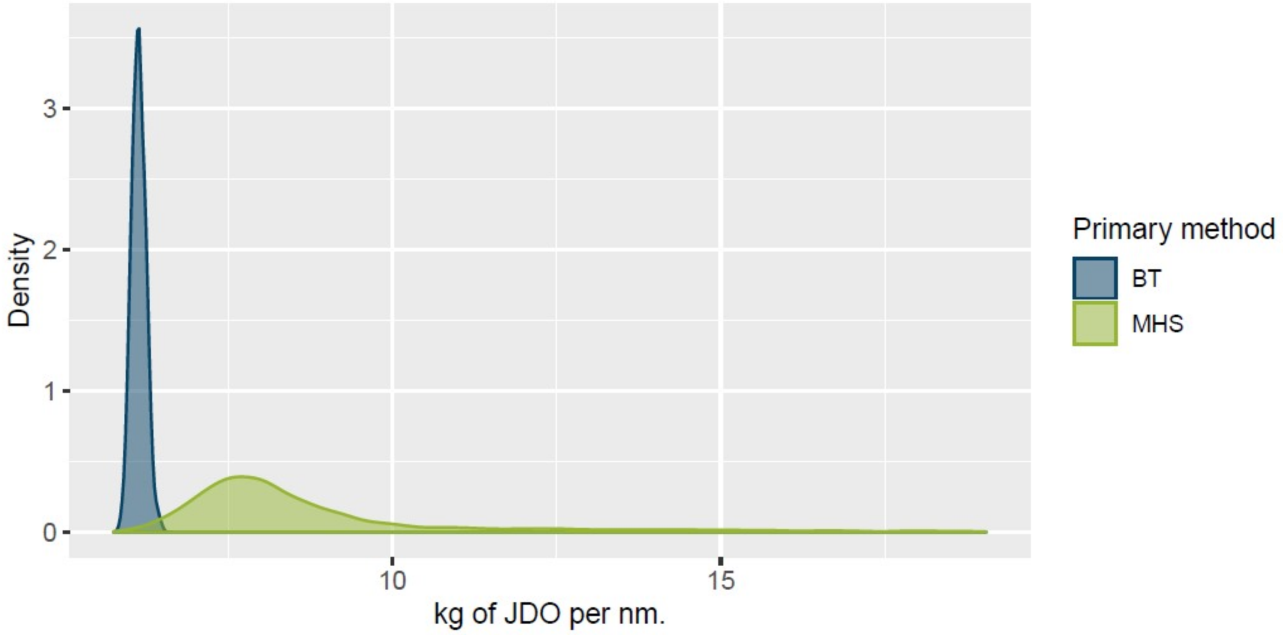


Figure 41: Calibrated posterior distribution of John Dory catch (kg) per nautical mile towed from 2719 BT tows and 220 MHS targeting John Dory assuming all tows were made by each gear type in turn.

Table 24: Table of probabilities of minimum relative difference in JDO per nm MHS relative to BT assuming identical targeting behaviour. Tows targeting JDO.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	1.000
-0.10	1.000
0.00	0.994
0.10	0.941
0.25	0.656
0.50	0.238

This does not match the findings from the Kaharoa trial which reported lower catch rates for JDO for MHS when compared to BT but given the trial was targeting SNA could explain the difference. Whilst the analyses indicate that MHS would have less benthic impact compared to BT when targeting JDO, again as with GUR, as catches are constrained by SNA quota it is unlikely there would be any change in the overall benthic impact.

TAR

The analyses of TAR catch rates from actual data show that there is an 83% probability that BT catches greater than 10% more compared to MHS (see Figure 44 and Table 27 – Appendix 6 as shown below).

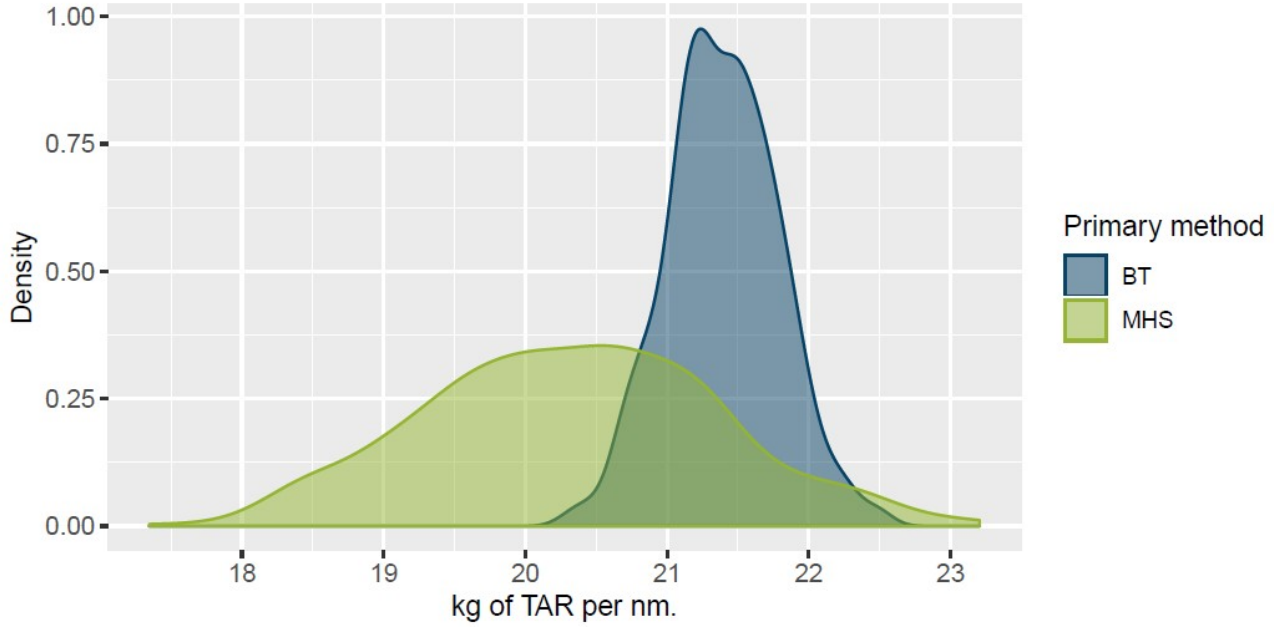


Figure 44: Posterior distribution of tarakihi catch (kg) per nautical mile towed from (a) 4119 BT tows and (b) 506 MHS targeting tarakihi.

Table 27: Table of probabilities of minimum relative difference in TAR per nm MHS relative to BT allowing different targeting behaviour. Tows targeting TAR.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	1.000
-0.10	0.832
0.00	0.146
0.10	0.002
0.25	0.000
0.50	0.000

When compared on an identical basis the difference is greater with a very high probability that BT catches 25-50% more than MHS (see Figure 45 and Table 28 – Appendix 6 as shown below).

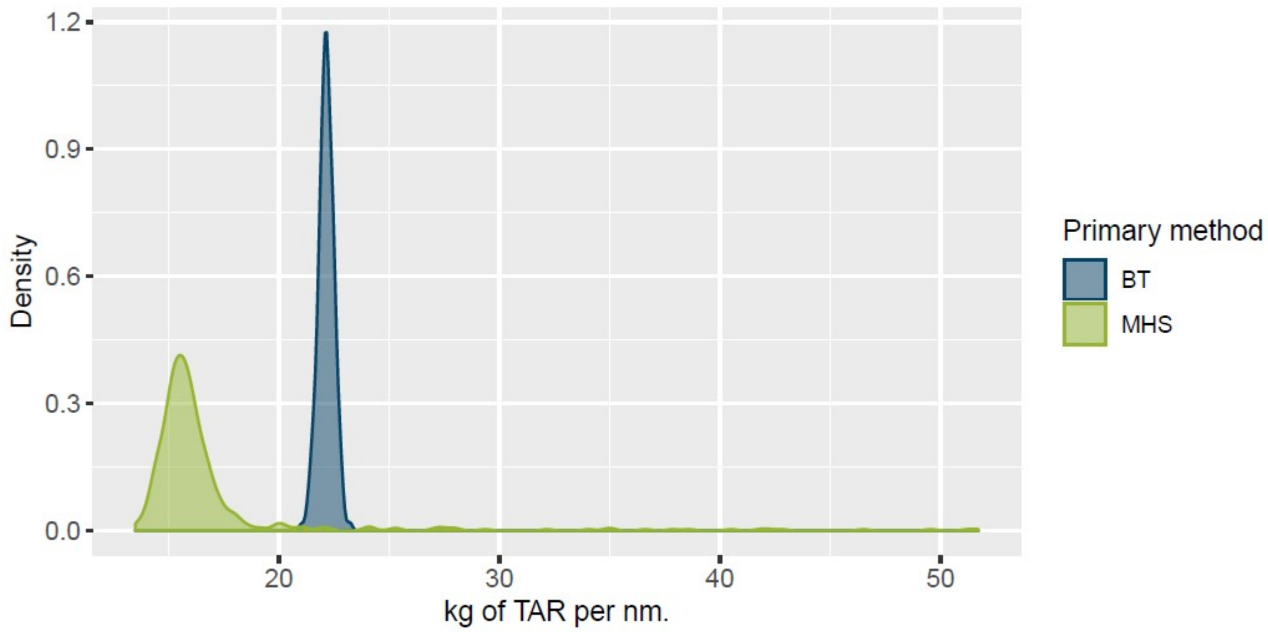


Figure 45: Posterior distribution of tarakihi catch (kg) per nautical mile towed from (a) 4119 BT tows and (b) 506 MHS targeting tarakihi assuming all tows using each gear type in turn.

Table 28: Table of probabilities of minimum relative difference in TAR per nm MHS relative to BT assuming identical targeting behaviour. Tows targeting TAR.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	0.250
-0.10	0.082
0.00	0.068
0.10	0.048
0.25	0.038
0.50	0.000

The targeting of TAR with conventional gear occurs mainly using 4" mesh so it is unsurprising that the MHS catch rates are less in comparison.

TRE

Comparison of catch rates for TRE based on historical data show a clear difference that MHS catches more TRE compared to conventional gear (see Figure 50 and Table 31 – Appendix 6 as shown below).

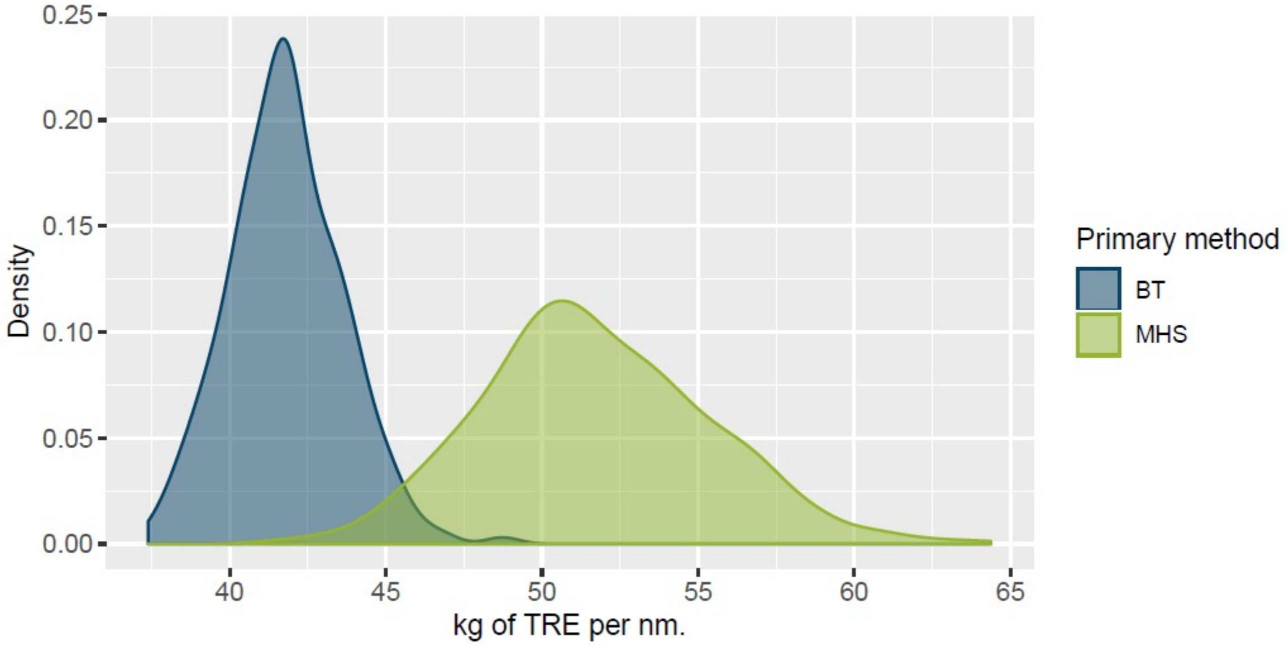


Figure 50: Posterior distribution of trevally catch (kg) per nautical mile towed from 2283 BT tows and 781 MHS targeting trevally.

Table 31: Table of probabilities of minimum relative difference in TRE per nm MHS relative to BT allowing for behavioural differences. Tows targeting TRE.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	1.000
-0.10	1.000
0.00	0.994
0.10	0.916
0.25	0.408
0.50	0.008

However, when assuming identical targeting behaviour the situation is reversed with BT catching more TRE per nm when compared to MHS (see Figure 51 and Table 32 – Appendix 6 as shown below).

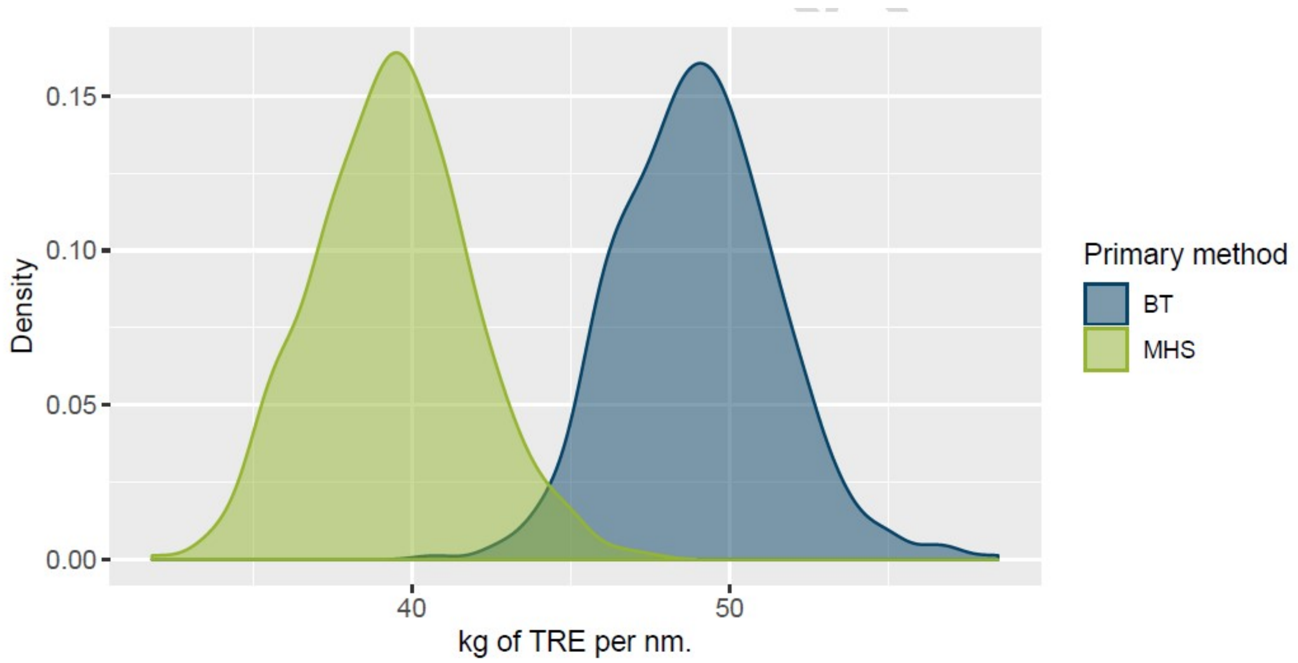


Figure 51: Calibrated posterior distribution of trevally catch (kg) per nautical mile towed from 2283 BT tows and 781 MHS targeting trevally assuming all tows were made by each gear type in turn.

Table 32: Table of probabilities of minimum relative difference in TRE per nm MHS relative to BT assuming identical targeting behaviour. Tows targeting TRE.

Maximum relative difference	Probability satisfied
-0.50	1.000
-0.25	0.796
-0.10	0.064
0.00	0.002
0.10	0.000
0.25	0.000
0.50	0.000

The difference between actual and assumed equivalent behaviour in terms of catch rates and therefore benthic impacts is due to MHS enabling fishers to land premium quality TRE that has seen a value uplift to the vessel return from s 9(2)(b)(ii) and therefore more targeting fishing occurring.

In summary, in terms of benthic impacts the performance of the MHS gear compared to conventional gear is variable subject to target species. On an individual target species basis, the MHS gear can be seen to perform as well as BT, worse than BT and better than BT but as demonstrated in the trial the total catch rate for QMS species is better for MHS compared to BT which would therefore lead to less benthic impacts overall.

2(e) Trials Conducted to Compare MHS (Net A) and Conventional Mesh (Net B)

A trial to compare the new Inshore Modular Harvesting System (MHS) cod-end and a ‘standard’ 128 mm diamond mesh cod-end was carried out onboard the RV *Kaharoa* between 15 July and 24 August 2017.

The configuration of the gear used for the trials is contained in the report (refer Appendix 7).

The following is the Executive Summary taken from the NIWA report titled "SNA 1 Fishery Selectivity Trials":

Executive Summary

An experiment to estimate absolute selectivity of snapper and other target QMS species for an Industry "standard" 128 mm diamond mesh cod-end and lengthener configuration, and a s 9(2)(b)(ii) [redacted] *was undertaken onboard RV Kaharoa between 15 July and 24 August 2017. The aim was to use a covered cod-end approach to estimate selectivity, but the experimental design allowed for any effect of the novel cover to be assessed by collecting alternate paired tows of covered and uncovered gear.*

A total of 102 paired selectivity tows were achieved: 28 pairs of the covered and uncovered diamond mesh cod-end; and 23 pairs of the covered and uncovered MHS cod-end. The catch rates of target species, particularly snapper, were highly variable both within and between days, making pairing of alternate hauls challenging. Following initial selectivity analysis, a set of minimum criteria were used to select a sub-set of 18 across-day pairs of diamond mesh cod-end tows, and 16 across-day pairs of MHS tows for the full selectivity analysis.

The catches were dominated by snapper, which made up 39 % and 53% of uncovered diamond mesh and MHS tows, and almost 60% of covered tows of both gear types. The length range of snapper caught was from 10–80 cm, with a main modal peak at between 24–26 cm. Proportionally more snapper below 25 cm were caught in the covered gear (cover and cod-end combined) compared to the uncovered gear for both the diamond mesh and MHS, with overall similar catch rates for both covered gears of around 400 kg km^{-2}. When the catches of the within-cover gear were compared with those of the uncovered gear for each gear type, the uncovered diamond mesh gear retained less fish with increasing length up to about 35 cm. Conversely the MHS retained an increasing proportion of fish as length increased up to 35 cm. Randomization tests to account for between-haul variability confirmed significant cover effects with both gears. Therefore, selectivity was estimated using the alternate haul data, with the combined cod-end and cover catches being used to represent the unselective control against which the uncovered paired tows were compared.

For the 128 mm diamond mesh cod-end the logistic curve fitted to the combined hauls data gave a length at which 50% of snapper are retained, L_{50}, *of 29.5 cm (95% CI = 27.7-30.7) and a selection range (difference between* L_{25} *and* L_{75}*) of 6.2 cm (95% CI = 3.8-6.8 cm). For the MHS gear, an asymmetric Richards curve gave the best fit. The estimated* L_{50} *was lower, at 26.3 cm (95% CI = 25.1-28.9 cm), but the selection range was narrower at 4.5 cm (95% CI = 3.7–7.3 cm). The large variability in catches, and relatively small sample size (18 and 16 accepted pairs) resulted in a high level of statistical uncertainty associated with these estimates. A randomized likelihood-ratio test of the null hypothesis that the selectivity of the two gears was the same indicated only modest evidence for a difference in selectivity (p = 0.10).*

Due to the sharper selection curve fitted to the MHS data, particularly to the right of the LL_{50}, *the catch rates of legal snapper in the uncovered MHS gear, particularly in the 25 – 35 cm range were higher than in the uncovered diamond mesh gear. These catch rates offset the higher catch rates of sub-legal snapper in the MHS, giving a UCK (undersize catch per kilo, ratio of undersized snapper count to weight of legal* *snapper caught) that was 30% greater, but not significantly different (p=0.33) to the diamond mesh gear; 0.655 (±0.11) for the MHS, compared to 0.508 (±0.11) for the diamond mesh cod-end.*

Trevally was the second most abundant species in both gears, with higher catch rates in the diamond mesh cod-end compared to the MHS. The remaining quota species each accounted for around 5% or less of catches, with john dory and red gurnard also caught in somewhat greater numbers in the diamond mesh cod-end, whilst leatherjackets, were more numerous in the MHS gear. Overall area swept per tonne of QMS species was greater for the MHS (2.25 km^2) than for the diamond mesh codend (2.14 km^2), but lower when the value for the diamond mesh gear was adjusted for a single very large catch of trevally. The non-QMS bycatch was dominated by porcupine fish and elasmobranchs, with some indication that the catch rates of non-QMS skates and rays were slightly lower in the MHS codend. Benthic invertebrate bycatch consisted mainly of sponges, making up between 2 and 3% of the total catch in diamond mesh cod-end catches compared to 5.3–5.7 % in the MHS catches.

Covered-cod-end selection curves were achieved for red gurnard, john dory, trevally and tarakihi, but were not considered reliable due to the cover effect detected in the snapper analyses. The numbers and size range were too limited to properly assess any differences in selectivity using the paired haul data, with the main modal peak for trevally, gurnard, tarakihi and john dory all being above 30 cm, with very low numbers of smaller fish.

In conclusion, the MHS gear had lower selectivity and higher UCK than the 128 mm diamond mesh gear for snapper, but the differences were not statistically significant (i.e. at less than 5% probability), due to the variability between alternate tows and relatively small sample size. It was not possible to use the more powerful covered cod-end approach because of a clear cover effect on both gears. Numbers of other species were too low to estimate selectivity using an alternate-tows approach.

Given the results from the selectivity trials which found the MHS gear was more selective of sub-mls snapper than standard trawl at the 0.10 level of significance (Jones and Millar 2017), further analysis was undertaken to investigate the implication of selectivity differences between standard trawl and MHS on snapper sustainability and yield (refer Appendix 8).

The following is the Executive Summary taken from the NIWA report titled “Implications of the Precision Seafood Harvesting ‘Modular Harvest System’ on snapper stock yield relative to standard trawl”:

Executive Summary

A comparative analysis of Under-sized snapper Caught per Kilo (UCK) for MHS and standard trawl gears, factoring in uncertainty in the method selectivity estimates, found strong statistical evidence that the MHS UCK derived ratio was “worse than” that of standard trawl.

The point estimate discard survival MHS would need to attain achieve equivalence to standard trawl in B40% equilibrium yield was 63% as derived from a stock assessment model. This contrasts to the point survival estimate of 35% MHS would need to attain to achieve an equivalent UCK ratio to standard trawl assuming the “available” snapper population length structure to both gears was the same as that observed in the recent PSH Kaharoa selectivity survey. The reason the UCK and model B40% point survival estimates differ is due to the SA model predicting a greater proportion of available snapper being above the 25 cm *mls at B40% to that observed in the Kaharoa selectivity survey. This difference highlights a limitation with using UCK as a comparative measure for commercial fishing gears in that UCK ratios can change if the available snapper length composition to the gear changes.*

Taking into account uncertainty in the selectivity estimates, the B40% equilibrium yield modelling predicted MHS would need to achieve discard survival rates in the order of 80% to achieve statistical equivalence at a 95% or better confidence level.

A similar analysis looking at shifting the MHS selectivity curve closer to that of standard trawl indicated a right-shift greater than 40 mm would be needed to achieve statistical equivalence at a 95% or better confidence level. However the degree of shift could be reduced to ~30 mm assuming mean discard survival is 30%.

Through-mesh snapper mortality levels of 5% or higher have the potential to significantly alter MHS's predicted snapper impact relative to standard trawl. This source of mortality needs to be factored into the MHS accreditation process.

As noted in the Executive Summary above, discard survival rates of around 80% would be required to demonstrate that the performance of the MHS gear is 'no worse than' conventional gear based on this data, but it is acknowledged by NIWA that these simulations do not take in account mortality associated with snapper passing through the meshes of MHS and conventional gear which should be considered in the assessment of the PSH gear.

It is widely acknowledged that it is unlikely there is 100% survival from mesh contact and whilst there have been no direct studies involving snapper there has been overseas research that show mortality rates greater than zero[2]. In addition, escape mortality rates between 2.5% to 7.5% have previously been used for snapper in New Zealand:

Mortality Rate	**Reference**
5% (base) 2.5% (low) 7.5% (high)	Harley, S.J., Millar, T.B. and McArdle, B.H. 2000. Estimating Unaccounted Fishing Mortality Using Selectivity Data: an Application in the Hauraki Gulf Snapper (*Pagrus auratus*) Fishery in New Zealand. Fisheries Research 45(2):167–78
5%	Millar, R.B., Akroyd, J.M. and Walshe, K.A.R. 2001. Incidental Mortality of snapper in SNA 1 and SNA 8. New Zealand Fisheries Assessment Report 2001/78

Given the NIWA statement on the significance of through mesh mortality to the findings PSH does not accept the use of the B_{40} model for performance comparison between the MHS and the ST gear. PSH agrees with NIWA that through-mesh mortality needs to be accounted for in any comparison between the gear types.

[2] Broadhurst, M.K.. 2006. Collateral mortality from towed gear. Fish and Fisheries 7:180–218

NIWA provides further consideration on the issue of through-mesh mortality in the report (refer Appendix 8: Section 4) and provides a comparison between MHS and conventional gear based on a level of 5% through-mesh mortality (see Table 4-1 below):

Table 0-1: Predicted UDK and mortality ratios for MHS and ST at 100% and 95% through-mesh mortality rates.

	MHS	ST	MHS	ST
discard survival	0%	0%	0%	0%
mesh survival	100%	100%	95%	95%
UDK	0.686	0.445	0.942	0.950
Expected catch breakdown				
% snapper landed	72%	79%	66%	64%
% snapper killed through mesh	0%	0%	9%	19%
% snapper not landed but killed by discard	28%	21%	25%	17%

As highlighted in the table a through-mesh mortality rate of 5% sees the MHS gear achieve a UDK[3] which is slightly better (or at least 'no worse than') compared to standard trawl. This assumes the through-mesh mortality rate for MHS gear is equivalent to conventional gear however based on observations of the intrawl environments there is evidence to suggest that through-mesh mortality rates for mesh gear would be higher than MHS (refer section 3(a)(i) below).

[3] The UCK (Undersized catch per kilogram) and UDK (Undersized deaths per kilogram) metrics were developed by Nokome Bentley, Trophia Ltd as part of the analysis requested by MPI to examine alternatives approaches to data gathered during sea trials to test whether MHS gear performed 'no worse than' existing gear (refer Appendix 9).

3. Additional Information on the Benefits of Net A compared to Net B

3(a) Sustainability Benefits of Net A compared to Net B

(i) Escapement Mortality

Abrasion and scale loss have been shown to be positively correlated with fish mortality[4]. As can be seen from the earlier video (refer video: Turbulence inside mesh trawl SNA.mpg) the turbulent water flow inside the mesh gear contributes to the abrasion and scale loss due to the fish coming into contact with each other as well as the mesh gear. This is further exacerbated by the direct scale loss that results from contact with the mesh gear during escapement, an example of which can be clearly seen in the video showing the escapement of hoki through a mesh net (refer video: Hoki scale – mesh escapement.mpg).

Given the differences in the in-trawl environment and therefore how fish escape between MHS & conventional gear (refer videos: snapper escapement large holes 3.mpg / COR0066 commercial snapper escapement.mpg), PSH consider that the through-mesh mortality for conventional gear would be greater compared to MHS gear.

(ii) Survivability

The MHS gear has the potential to significantly improve post-harvest survival of sub-MLS snapper and other unintended catch. As detailed in the summary report from Plant & Food Research (PFR) on the acute post-harvest survival of sub-legal snapper (refer Appendix 10) with a volume ratio (ratio of fish to water, kg fish / L lift bag volume) of 0.5 and below (ie. 1 part fish : 1 part water or more) the post-harvest survival rate averaged 50%. Above this ratio survival decreased to 16% whilst a volume ratio of 0.1 kg/L achieved 48 hr survival rates of 50-80%.

Taking into account the discard survival achievable with the MHS gear along with a difference in through-mesh mortality when compared to conventional gear as detailed in the scenarios modelled below (based on the same calculator as used by NIWA), the MHS gear at worst will perform significantly better and has the potential to almost halve the total incidental mortality of sub-MLS snapper in comparison to standard trawl gear.

[4] Refer:

Main, J. and Sangster, G.I. 1990. An assessment of the Scale Damage to and Survival Rates of Young Gadoid Fish Escaping from the Cod-end of a Demersal Trawl. Scottish Fisheries Research Report Number 46.
Kaiser, M.J. and Spencer, B.E. 1995. Survival of by-catch from a beam trawl. Marine Ecology Progress Series. Vol 126: 31-38.
Vinogradov, N.N. 1960. Survival of fish escaping from the codend of trawls. ICES CM 1960/F, Comparative Fishing Committee 172, 11 pp.

Scenario 1: Average discard survival rate 50% with difference in mesh survival rate

	MHS	ST
discard survival	50%	0%
mesh survival	98%	95%
UDK	0.445	0.950
Expected catch breakdown		
% snapper landed	80%	64%
% snapper killed through mesh	5%	19%
% snapper not landed but killed by discard	15%	17%

Scenario 2: Worst case discard survival rate 16% with difference in mesh survival rate:

	MHS	ST
discard survival	16%	0%
mesh survival	98%	95%
UDK	0.679	0.950
Expected catch breakdown		
% snapper landed	73%	64%
% snapper killed through mesh	4%	19%
% snapper not landed but killed by discard	23%	17%

Scenario 3: Conservative discard survival rate 30% with difference in mesh survival rate:

	MHS	ST
discard survival	30%	0%
mesh survival	98%	95%

UDK	0.583	0.950

Expected catch breakdown

% snapper landed	76%	64%
% snapper killed through mesh	4%	19%
% snapper not landed but killed by discard	20%	17%

(iii) Marine Mammal Interactions

Another potential benefit from the MHS gear is for the release of unharmed fish as a consequence of a marine mammal interaction. If the gear is released to allow the escape of a marine mammal since the fish are still alive in the MHS at depth then it also allows for these fish to survive. The on-going development of underwater cameras as part of the development of the PSH gear will also greatly assist in such interactions.

3(b) Utilisation Benefits of Net A compared to Net B

(i) Value

The co-investors have all reported a substantial lift of the value of the fish in the market due to the increased quality of the product being landed which has achieved the following results:

s 9(2)(b)(ii) [redacted]

a. Fisher payments
- General
  - Quality of landings has increased over all with PSH, but quality is dependent on day of catch, volumes, and on-board handling.
- GUR
  - 20% shift in volume of Med sizes to +400gm, s 9(2)(b)(ii) [redacted] which is also realised in processing efficiencies, sales benefits and profits
  - Letting more -400gm GUR swim away to be caught in the years to come, catching fewer individual fish, must be of benefit towards rebuilding stocks.
- TRE
  - Sashimi grade sales s 9(2)(b)(ii) [redacted] Market factors effect volumes.
  - TRE no longer frozen for bait, as the quality is of a high standard. Product can be sold chilled or pack to frozen orders. This has s 9(2)(b)(ii) [redacted]
- SNA

- Payments to fishers from standard trawl quality sales can s 9(2)(b)(ii) [redacted] This is not only dependent on the quality, but market conditions
- TAR
  - Has s 9(2)(b)(ii) [redacted] to fishers for small volumes out of season.

b. Sales

- General comments
  - Domestic customers no longer checking the product in the chiller before purchasing. Now product is just loaded after the sale and they take knowing they will have no issues with fish quality.
  - Complaints on fish quality is now almost nil. Previously it was a weekly occurrence. Sorting our quality issues **takes time and in turn costs money.**
  - Historically if there was not a sale for the day of reception, the balance would be frozen which reduces the value significantly. Now able to hold fish for several days, achieving the same chilled sale price as would be achieved on reception.

- Over the past 4 years:
  - GUR average chilled s 9(2)(b)(ii) [redacted] - SNA trawl quality sales volumes have reduced by s 9(2)(b)(ii) [redacted]
  - TAR chilled SKF/FIL prices are about s 9(2)(b)(ii) [redacted] **than frozen**
    - Frozen fillet volumes have s 9(2)(b)(ii) [redacted]
    - Fresh fillet, sales into higher value packs like s 9(2)(b)(ii) [redacted]
  - TRE
    - Chilled sales volume have increased to the point that TRE is frozen only if there is a sales order to fill. So the reliance on Frozen sales has reduced and have been able to drive frozen sales price up to a level which is comparable to chilled sales
    - s 9(2)(b)(ii) [redacted] • s 9(2)(b)(ii) [redacted]

s 9(2)(b)(ii) [redacted]

Realising the full potential value gains from the inshore fishing fleet using the modular harvesting system (MHS) has been impossible to gauge at this time. Until we have multiple vessels using the technology on a daily basis to assure continuity of supply, the full potential will not be realised. Currently there are small volumes of MHS fish being sold through our retail outlet and receiving premium prices. On three key inshore species we are currently receiving the following premium over the same species caught by traditional trawl gear:

- Snapper s 9(2) [redacted]
- Trevally s 9(2) [redacted]
- Gurnard s 9(2) [redacted]

Precision Seafood Harvesting

s 9(2)(b)(ii)

(ii) Operational Efficiencies

s 9(2)

a. Production efficiencies

- General comments
  - Less grading for quality issues at reception, **saving on labour, time and wastage**
  - Shelf life is extended, due to quality
  - **Sales can sell over a few days without discounting or freezing**, rather than being forced to sell fish at a discount before it goes off.
  - New markets, we are able to process volumes of inshore product for s 9(2)(b)(ii)
  - Production options increase, with better quality fish.
  - Lengthen processing times, so **less need for days with overtime** as you can process big loads over a few days rather than rush through it upon reception

- GUR
  - Anything under 400gm/150mm is undesirable. After you cut it (cf of 33-35%) you get a fillet that's under 100gms which is a processing nightmare and looks ugly on display at the counter.

b. Harvest Benefits

- We are less reliant on Danish seiners to catch volumes of quality SNA to meet market demand.
- Using Danish Seiners to catch SNA can be risky, due to:
  - generally fish in areas close to shore
  - fish lost at sea
  - bad publicity / PR footage with recreational fishers in close proximity
  - catch volumes can blow out very quickly. Catching large bags of clean SNA, can take time to get on board and ICE/slurry, fish left in the water during slurry and icing process leads to fish left in the water deteriorating quickly.
- s 9(2)(b)(ii) We now can catch volumes of SNA on demand using PSH trawlers, with the **added bonus of catching more TRE/JDO/GUR/mix** for every kg of PSH SNA we catch.
- Fisher beach price is historically s 9(2)(b)(ii) in general to Danish seiners for SNA.

c. Consistency and Quality

- Using bigger boats who can fish worse weather conditions to ensure supply
- Consistency of supply creates customer loyalty and holds consistent pricing
- Less chance of selling at a discount to move fish before it degrades

- Having many consumers, usually creates more problems as they come and go. With better consistency and quality we have been able to hold on to the better customers who take more product regularly.
- **KPI: Customer comment that we always have good fish!**

s 9(2)(b)

d. Fuel Efficiencies

- On the freezer trawlers operating the MHS gear which are equipped with a sophisticated fuel monitoring system (MOTEC) a vessel can achieve a s 9(2)(b)(ii) for a voyage. The inshore vessels are not currently equipped with such technology to be able to monitor directly but if similar fuel efficiencies can be achieved using the MHS gear this has obvious benefits both in terms of direct cost savings as well as reduced CO^2 emissions.

(iii) Health & Safety

The MHS gear and on-board handling systems have also provided health & safety benefits to the crew. These have ranged from the facility to have longer tow times but still retain fish quality thereby allowing overnight tows which assists with crew fatigue through to the on-board handling systems meaning less bending and stretching so reducing crew sprains and strains.

The on-going commitment to health & safety is further demonstrated in the development of a resource to be distributed to the users of the MHS gear (refer Appendix 11).

4. Summary

From the comparison of Inshore MHS gear to conventional gear using trial, observer and commercial data it has been demonstrated that the Inshore MHS gear performs 'no worse than' conventional gear and indeed is performing much better in a number of areas under the approval criteria. The MHS gear also provides additional significant sustainability and utilisation benefits and has the potential with continuing innovation to deliver further improvements and benefits compared to existing gear.

E. Appendices

1. MHS Module Identification Key - PSH 2. Standard Operating Procedures for Inshore PSH Modular Harvest Systems & On-Board Handling -

PSH

3. SNX catches by BT and PSH, 2017/18 Fishing Year – Trident Systems

4. NFPS Catch Rates – Trident Systems

5. Equivalence analysis of UCK in MHS and conventional gear, September 2018 – Russell B. Millar

6. Exploratory analyses of UCK, October 2018 – Trident Systems

7. SNA 1 Fishery Selectivity Trials Report, September 2017 – NIWA 8. Implications of the Precision Seafood Harvesting 'Modular Harvest System' on snapper stock yield

relative to standard trawl Report, December 2017 – NIWA 9. An analysis of catches and fish survival associated with the Modular Harvest System (MHS) and

conventional commercial trawl gear, October 2015 – Trophia Ltd

10. Acute post-harvest survival of sub-legal snapper, December 2017 – Plant & Food Research

11. Modular Harvesting Systems (MHS) Safety Guidelines, March 2018 – PSH 12.

Analyses of observer data, November 2018 – Trident Systems