A review of Moana New Zealand's efforts to reduce seabed contact by fishers engaged in bottom trawl, Danish seining, and bottom longline fishing in New Zealand

Short Version Modified From Major Report

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About Terra Moana

Terra Moana Ltd and Associates (TML) bring a highly experienced team with expertise in natural resource management and collaboration. We focus on primary industries, especially fisheries and oceans. Our areas of expertise include research, policy, business, analysis, management, valuation, facilitation, regenesis, extensive global networks, cultural intelligence, and business development.

Terra Moana's mission is grounded in natural capital "know how" and recognition of the need to regenerate human and natural systems. This is predicated on a respect for, and understanding of, the multiple factors that must be considered to enable wise stewardship of natural resources and the communities reliant upon them. We can support teams, executives, divisions, and individuals to do the right thing.

TML seeks to bring tailored, best practice evidence, assessment, and valuation to these areas to enable sound decision-making support for businesses and governments. Using careful design and sensitive engagement principles we work with both those who seek economic development and those who may be affected by it.

Author biographies

Stephen (Steve) Eayrs

Steve is an ex-commercial fisher and fishing technologist with over 40 years' involvement in the fishing industry. His fishing career commenced in the early 1980s fishing for prawns in northern Australia, Saudi Arabia, and Burma, and for orange roughy in Tasmania. Between periods on the water he completed an undergraduate degree in fishing technology at the Australian Maritime College. Later, he returned to the Australian Maritime College to lecture in fishing technology and shipboard safety, and for a period managed the flume tank. Whilst there he also completed a number of brief, international assignments for the Food and Agriculture Organisation of the United Nations (FAO) and others, collaborating with researchers and fishers in other countries to develop selective fishing gears, as well as a Master's degree in fisheries, studying the vertical distribution and behaviour of fish and shrimp in response to prawn trawls.

In recent years Steve was a Research Scientist at the Gulf of Maine Research Institute in Portland, Maine, working closely with commercial fishers to improve fishing gear performance and reduce environmental impacts. He also completed a Doctoral degree investigating the application of change management theory and practice in the commercial fishing industry to foment change. In addition to his own consultancy, Steve is currently an Extension Officer for the Fisheries Research and Development Corporation in Australia.

Tony Craig

Tony has spent the past 35 years in the New Zealand Seafood Sector principally as a policy and business analyst. He is known for his innovative and lateral thinking which always comes with a creative twist. An achievement oriented and "ideas" individual, Tony has the skills and drive to turn concepts into reality. Tony has been described as "one of those people who can transcend relationships from the fishermen on the wharf to politicians in Parliament". He also has a unique ability to assess complex negotiations and broker solutions that deliver reasoned and timely solutions.

Tony's previous experience includes business policy manager of Seafood New Zealand, business innovation and quota manager Aotearoa Fisheries Ltd (now Moana New Zealand), FishServe founding CEO (a seafood industry owned company delivering statutory administrative and registry services on contract to Government).

Tony is also the creator of Fish4all - New Zealand's recreational fishing App.

Executive Summary

During the 2021–2022 fishing season, Terra Moana Ltd were commissioned by Moana New Zealand (Moana) to review and study efforts by fishers to modify their fishing gear and practice to reduce contact and subsequent impact on the seabed. This report summarises these efforts. It also identifies and suggests future steps that could be taken to further reduce seabed contact, including the application of new technology and best practice.

The fishers involved in this study were Contract Harvesters that had entered into a formal agreement with Moana for the supply of annual catch entitlement (ACE) harvesting rights held by Moana, the sale of landed fish to Moana, and the provision of harvest information. Initially, all fishers were invited to complete a brief written survey to provide basic vessel information and fishing gear specifications. They were then interviewed online and asked to provide additional information about their fishing gear, fishing operation, and voluntary efforts to reduce seabed contact and environmental impacts, including sea bird interactions and by-catch reduction.

For trawl and Danish seine fishers, a cited driver for gear change was reduced seabed impact and the entry of non-target benthic species, shell and other debris into the gear, some of which can damage the gear or catch. The modifications included lighter sweeps and bridles and modified ground gear. Some trawl fishers also reported using high aspect ratio trawl doors designed to reduce both seabed contact and fuel consumption.

The study also found some unexpected innovations, such as the use of pink towing warps to avoid seabird interaction, the use of rubber discs to lift short sections of the sweep clear of the seabed, and modifications to allow unwanted fish to escape over the trawl headline.

The authors were surprised and impressed by the enthusiasm and progress made by all fishers in this study to change their fishing gear to reduce seabed contact. Prior to this work it was unclear if they were using relatively heavy and potentially damaging gear commonly in use decades ago or had voluntarily made changes to reduce contact. Fortunately, it was the latter. Noting that these individuals also cited economic or other benefits from these changes is a clear sign that any future related efforts should similarly focus on win-win solutions that benefit both the environment and the individuals themselves.

This study also describes a need to establish a Seabed Impact Working Group that includes fishers, researchers, environmentalists, managers, and other stakeholders. This working group needs to be funded and charged with establishing and applying a considered plan of action to further minimise fishing gear impacts on the seabed. This includes working with fishers to provide them opportunities to learn about additional gear modifications, developing appropriate testing protocols, testing new gear modifications in a low-risk environment, and introducing incentives to encourage and reward their innovation. Importantly it also includes ensuring substantial extension activity so that all stakeholders including the public are aware of developments, to recognise and acknowledge their efforts, and to improve the social licence of the commercial fishing industry.

Introduction

Globally, bulk harvest trawl fisheries have been in the spotlight for their impact on marine ecosystems since the late 1880s. Particularly over the last 20 years or so, civil society campaigns, Government policy and management, independent certification, and many industry initiatives have all contributed to increased understanding of the impacts of these fisheries and efforts designed to limit these impacts. In New Zealand, similar concerns exist over the impact of commercial fishing activity on marine ecosystems, particularly impacts associated with bottom trawling and other fishing methods that contact the seabed, including Danish seining and bottom longlining.

In the last decade significant investment has been directed into innovations designed to increase our understanding of the impacts of these fisheries as well as to mitigate their impact. These innovations include the Acoustic Optical System, which makes it possible to observe deep water target and non-target species living in their habitat, and the Precision Seafood Harvest (PSH) codend, designed to improve the selection and quality of the trawl catch. Anti-bottom trawl campaigns have been vocal in their support for banning this fishing method, or at minimum, supporting area limitations and the use of lighter, less damaging fishing gear, while seeking to increase marine ecosystem protection overall. However, commercial fishing is a valuable source of food, economic activity, and cultural well-being in New Zealand, and significant opportunities still exist to improve commercial fishing methods and management of fisheries.

Whilst undoubtably commercial fishing methods have changed parts of the marine environment, commercial fishers continue to be criticised by other stakeholders over their ongoing impact on the environment, both perceived or otherwise. There is significant misunderstanding about the detail, extent, and impact of bottom trawling and other fishing methods, and in particular the need for greater transparency and education describing the importance and necessity of bulk harvesting methods.

Those on different sides of any argument will often present information in a manner that suits their perspective. In the case of bottom trawling, **it is essential to have New Zealand information rather than it being inappropriately assigned from fisheries elsewhere,** where the design, operation, and impact of the gear is different, sometimes vastly so.

Moana New Zealand began its sustainability journey in 2013 and developed as part of that journey a harvest footprint project in 2020 that included a study on its fishing and fisher operations. The aim of this study was to document the fishing gear used by some Moana Contract Harvesters, including their past voluntary efforts to reduce seabed contact.

Moana New Zealand Sustainability Journey (Harvest Footprint Project – HFP)

This study represents one step in a broader initiative by Moana New Zealand (Moana) to understand and evaluate the seabed footprint and environmental impact of its contracted commercial fishing activity. As a Māori owned company katiakitanga, the concept of guardianship for the sky, the sea, and the land, is paramount in its modus operandi, with the objectives of this initiative being:

The Moana harvest footprint project has three phases: *understand how and where we fish today (phase one), understand how and where we will fish in the future (phase two), and, understand how innovative fishing techniques can lighten our footprint (phase three)*. This study focuses on phase one of the Moana Harvest Footprint project by documenting the fishing gear used by Moana Contract Harvesters and their voluntary efforts to reduce seabed contact to date. This information is essential to help identify modifications that may be introduced in the future to further reduce seabed contact and it also serves as a baseline against which future modifications can be considered, contextualised, and perhaps, voluntarily introduced by fishers.

Method Applied

The vessel owners or skippers from 11 bottom trawl vessels, 2 Danish seine vessels, and 2 longline vessels participated in this study in 2022. These individuals were first sent a brief survey to provide basic vessel information and fishing gear specifications (Figure 1). Particular attention was paid to components of the fishing gear that are typically in contact with the seabed. In the case of a bottom trawl this includes the trawl doors (sometimes known as otter boards or boards), sweeps, bridles, (Table 1) and groundgear (Table 2). In the case of Danish seining, components that contact the seabed include the seine ropes, used to herd fish into the path of the seine net (**Error! Reference source not found.**). The footline of the seine may also contact the seabed, and any chains or weights attached to the footline. Components of a bottom set longline that may contact the seabed include the mainline, mainline anchors, and branch lines (**Error! Reference source not found.**).

Figure 1. The process used to collect vessel specific information.

Vessel owners or skippers then participated in an online meeting with the authors and Moana staff to provide additional relevant detail, including voluntarily gear modifications and changes in fishing behaviour to reduce seabed contact, and to describe future desirable steps they would like to take to further reduce this contact. The duration of each meeting was between 90-120 minutes. A draft vessel report was prepared, and the boat owner or skipper was provided an opportunity to review the report specific to their vessel and check for inaccuracies. They were also invited to share photos of their fishing vessel and gear, and in particular those gear components usually in contact with the seabed. The vessel report was amended based on feedback from the boat owner or skipper. When necessary, the authors sought clarifying vessel and gear details from these individuals via email or telephone.

The vessels used by fishers surveyed ranged in size from 15m (50ft) to 22 m (72.2 ft.) and aged from 5 years old to >50 years old.

Method Types

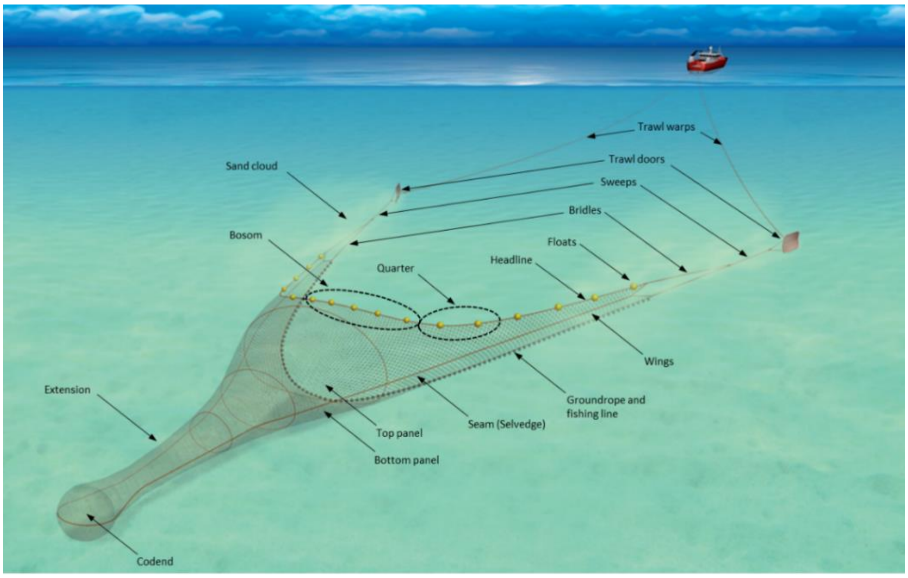

Figure 2. Bottom trawl with key sections and components labelled (not to scale).
Image courtesy of Seafish Asset Bank.

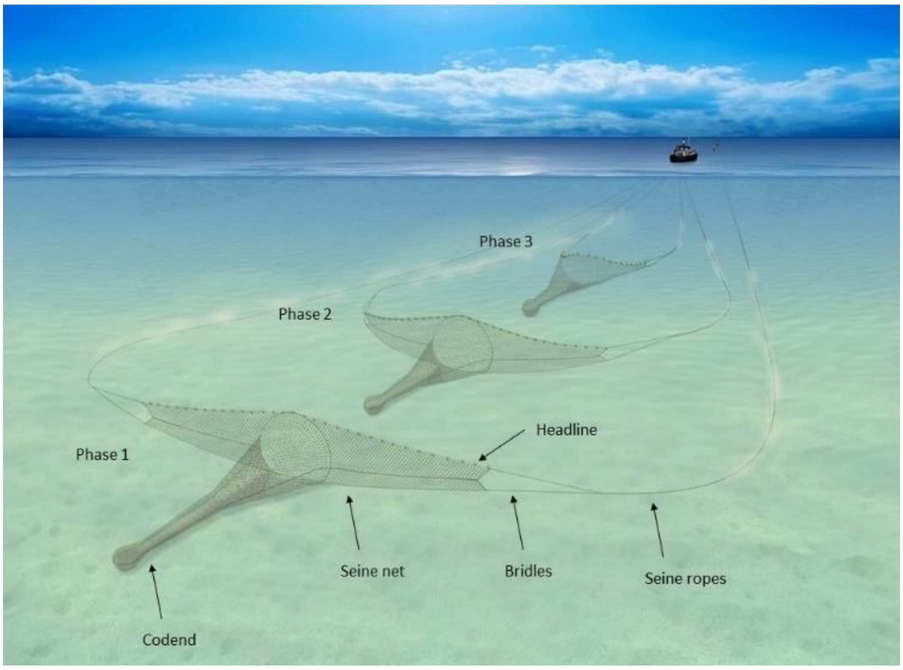

Figure 3. Phases of Danish seining with key gear components labelled (not to scale).
Image courtesy of Seafish Asset Bank.

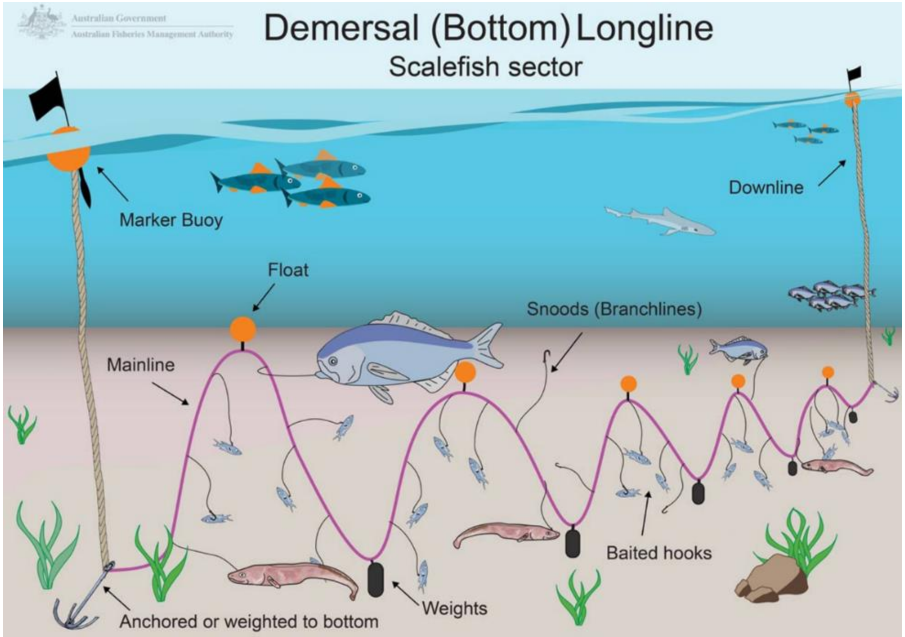

Figure 4. Bottom longlining with key gear components labelled. *Source.* https://www.afma.gov.au

Findings – Bottom trawl

This study found that all individuals engaged in bottom trawling have taken voluntary steps over recent years to modify their trawl gear and reduce impacts on the seabed (Table 1 & 2). Some of these modifications have resulted in win-win outcomes for the habitat and the individual, including fuel savings, ease of gear handling, and improved catch quality. They include replacing traditional, low-aspect ratio trawl doors with high aspect ratio trawl doors.

In some instances, fishers reported other modifications that also provided environmental benefits. For example, many individuals had modified their codend to reduce the capture of small or unwanted fish, while several reported using low opening trawls to avoid the capture of species such as snapper and trevally. Presumably such trawls simply pass below many fish swimming near the seabed, thus avoiding their entry into the trawl. Some fishers also reported using trawls designed with little or no veranda (overhang) in the top panel of the trawl. This modification provides fish near the seabed an opportunity to rise from the trawl mouth and swim over the trawl. The majority of fishers had moved away from steel wire warps and sweeps in preference to softer Dyneema, a high strength polyethylene twine. One individual also reported that since replacing his wire trawl warps with pink dyneema warps that the risk of seabirds colliding with the warps had been dramatically reduced, presumably because they are easier for the seabirds to observe and avoid.

Table 1. Summary of bottom-tending gear components (door, sweep, and bridle) specification for each vessel engaged in bottom trawling. Wt. = estimated weight in water. Ø = diameter. nk = not known (detail either not provided by boat owner or skipper or could not be determined).

Vessel name	Doors				Sweeps			Bridles		
	Brand/Type	H x W (m)	Wt.[1] (kg)	Material	Length (m)	Wt.[1] (kg)	Material and description	Length (m)	Wt.[2] (kg)	Material (U – Upper, L – Lower) and description
XXXX	Thyboron Type 14	nk	225	Steel	162		160 m 14 mm Ø wire rope wrapped in 10 mm Ø polypropylene rope + 2m chain	15		Same material as the sweeps (U & L)
XXXX	Thyboron Type 4	1.6 x 1.1	287	Steel	240		32 mm Ø Maletta combination rope	5		9 mm Ø wire rope (U), 14 mm Ø wire rope + 49 mm Ø rubber cookies (L)
XXXX	Thyboron Type 14	nk	435	Steel	170	65	32 mm Ø Maletta combination rope	20	14.6	76 mm Ø multi-plait rope (U), 18 mm Ø wire rope threaded through 65 mm Ø rubber cookies (L)
XXXX	Mørenot Kiwi Injector	nk	261	Steel	193	46	80 m 32 mm Ø Maletta combination rope + 110 m 38 mm Ø polypropylene mooring rope + 3 m chain	40	28	10 mm Ø stainless steel wire rope (U), 38 mm Ø of 4 strand Maletta combination rope (L)
XXXX	Thyboron Type 11	1.1 x 0.9	143	Steel	65	18	50 m 32 mm Ø Maleta combination rope + 15 m 12 mm Ø Dynex rope	30	0	12 mm Ø Dynex rope (U & L)
XXXX	Polar	1.5 x 1.5	287	Steel	168		115 m 32 mm Ø Maletta combination rope + 50 m 38 mm Ø Maletta combination rope + 3 m 22 mm Ø chain	33		36 mm Ø multi-plait rope (U), 16 mm Ø wire rope wrapped in 12 mm Ø multi-plait rope (L)
XXXX	Thyboron Type 14	nk	609	Steel	273	6	270 54 mm Ø multi-plait mooring rope + 3 m chain	50	0	54 mm Ø multi-plait mooring rope (U & L)
XXXX	Thyboron Type 4	nk	278	Steel	80	29	32 mm Ø combination rope	34	12	14 mm Ø multi-plait dyneema rope (U), 32 mm Ø combination rope (L)
XXXX	Thyboron Type 14	2.8 x 1.8	870	Steel	300		2 x 100 m 42 mm Ø Maletta combination rope + 100 m 64 mm Ø multi-plait mooring rope, 23 cm Ø rubber disc between each 100 m length	50[3]		48 mm Ø polypropylene multi-plait rope (U), 42 mm Ø Maletta combination rope (L)
XXXX	Thyboron Type 2	nk	207	Steel	75	27	32 mm Ø Maletta combination rope	40	14	5 mm Ø wire rope (U), 32 mm Ø Maletta combination rope (L)
XXXX	Thyboron Type 2	1.8 x 1.4	305	Steel	166	40.4	50 m 38 mm Ø combination rope + 110 m 58 mm Ø multi-plait mooring rope + 6 m chain	30	27	14 mm Ø wire rope (U), 38 mm Ø combination rope (L)

Table 2. Summary of groundgear specifications for each vessel engaged in bottom trawling. Wt. = estimated weight in water. Ø = diameter

Vessel name	Groundgear		Material and description
	Length (m)	Wt.[1] (kg)	
XXXX	37		16 mm Ø steel wire rope wrapped in rope
XXXX	39.6		14 mm Ø steel wire rope (6x19) threaded through 48 mm Ø cookie
XXXX	61	46.4	16 mm Ø steel wire rope threaded through 65 mm Ø rubber cookies
XXXX	37.8	47.0 [2]	16 mm Ø steel wire rope wrapped in 10 mm Ø polypropylene dan line rope + 3 lengths of chain
XXXX	45.5	76.8	1 x 15 m section comprised of a 10 mm Ø wire rope threaded through 75 mm Ø rubber cookie discs. Either side is a 12 mm Ø polyethylene rope wrapped around a 10 mm Ø wire rope
XXXX	40		16 mm diameter 6-strand galvanised wire rope threaded through 60 mm diameter rubber cookies
XXXX	36.5		22 mm Ø stainless steel wire rope threaded through 100 mm Ø rubber discs, each measuring
XXXX	24.5		@@ mm wire rope threaded through 75 mm Ø rubber cookie discs
XXXX	35.5		16 mm diameter stainless steel wire rope threaded through 102 mm (4 inch) cookies
XXXX	90	31	10 mm wire rope threaded through 50 mm Ø rubber cookie discs
XXXX	30		20 mm diameter stainless steel wire rope double wrapped in 14 mm rope

Reflections

The authors were impressed by the progress and development reported by all fishers to voluntarily and systematically change their fishing gear to reduce seabed impacts at their own cost. In the absence of prior knowledge, the authors were uncertain if these individuals had made any such attempts to do so. The presumption was that relatively heavy and potentially damaging fishing gear may be in use and that substantial modification may have been necessary in the future. Instead, we found that each fisher had been proactive and were eager to share their experiences. We also found some unexpected innovations that may have wider application, such as the use of pink towing warps to avoid seabird interaction, the use of rubber discs to lift short sections of the sweep clear of the seabed, and the use of modified trawl gear to allow unwanted fish to escape over the trawl headline. **In the authors minds this is evidence of a thoughtful and innovative group of individuals.**

It is tempting to ask why bottom trawl fishers cannot simply transition to Danish seining or bottom set longlining given these fishing methods are generally considered to cause less seabed disturbance. The methods are also clearly sufficiently profitable, otherwise individuals would not apply these fishing methods. The answer lies in the fact that all species cannot be efficiently harvested by one fishing method and bottom trawling is usually of a size and design that allows large volumes of fish to be landed and processed over a relatively short period of time.

To reiterate, the modifications reported here have been made by each fisher voluntarily and at their own cost. Modifying fishing gear is a risky proposition with no guarantees of success. Failure can mean loss of catch, damage to fishing gear, and lost fishing time, and while the potential economic and operational benefits of these modifications was an important driver for change, it was clear in our conversations with fishers that care for the habitat was also an important consideration. All fishers were aware of stakeholder concerns over the impact of bottom trawls on the seabed and proud of their efforts and achievements to reduce seabed contact. All expressed an interest and willingness to realise further reductions, as well as an interest in further reducing bycatch and fuel consumption. Many also noted a need and desire to better understand fishing gear design and performance, including training in an experimental flume tank to evaluate the performance of scale model trawl gear and modifications, to aid future efforts to reduce environmental impacts.

To build on this momentum and interest it is useful to consider what gear modifications could be tested and introduced in the future by these fishers. Here the report by Eayrs *et al*. (2020) provides important insight and guidance and describes the findings of a global review of research to reduce seabed contact in bottom trawl fisheries. These findings included

a) two potential door modifications were identified that can eliminate seabed contact, replacement with semi-pelagic doors or the use of controllable doors

b) two sweep and bridle modifications were identified with potential to substantially reduce seabed contact and

c) two ground gear (ground rope) modifications were also found to have proven successful in reducing seabed contact, the use of a semi-pelagic trawl and modifications to raise the fishing line.

We found or heard no evidence of such modifications reported by Eayrs *et al*. (2020) being used or considered by individuals involved in this study.

Of all the gear modifications with high potential to reduce or eliminate seabed contact, the introduction of semi-pelagic trawl doors and cluster discs is considered most highly relevant and recommended for further consideration in New Zealand. While a suite of groundgear innovations exist that could potentially be applied in this fishery, as per the findings by Eayrs *et al*. (2020), it is unclear if their application would result in substantial catch loss or not. These modifications may also pose a significant risk to profitability.

Next steps

The social licence of bottom trawl fishers is contingent upon their further efforts to demonstrably reduce seabed contact, notwithstanding their excellent efforts to date. This is most clearly demonstrated by trawl campaigns calling for banning of bottom trawling activity. In this environment, fishers are under pressure to reduce seabed contact to the greatest extent practicable, although it is worth reiterating that the efforts to date by individuals in this study were done so voluntarily. As such they bore the cost associated with any lost fishing time and catch loss as they developed and refined these modifications for optimal performance.

The progress by these individuals to date begs two questions, why did they voluntarily alter their gear to reduce seabed contact and why did they not take further steps? In answer to the first question, many individuals stated that it was the right thing to do. They indicated being aware of concerns over the impact of bottom trawling on the seabed – and flagged these concerns themselves – and they sought ways to mitigate their impact. In some instances, the benefits of this change were also cited, including ease of handling and reduced fuel consumption.

There is little doubt that fishers would if they could (ie. be financially neutral to them) continue to think about, design and trial further modifications. To do so requires an encouraging and empowering environment and therefore (at least in the authors view) the following steps should be considered as part of any future initiative to further reduce seabed impact from bottom trawling:

- Develop a Seabed Impact Working Group that includes fishers, researchers, environmentalists, managers, and other stakeholders.

    - This group should also be charged with providing balanced, factual, and appropriate information about fishery performance to their respective communities and stakeholders. This group should also counter any misinformation or falsehoods by other stakeholders.
    - This group should develop a coordinated vision and plan of action that considers the needs and aspirations of all stakeholder groups and identifies forward pathways to mitigate seabed impact. The vision should identify desirable fleet characteristics by the end of a predetermined period, including the size and design of fishing vessels and gear, and how the gear is operated. This group should also identify and develop research priorities, targets, and mitigation strategies, and source funding opportunities for related research.
- Explore the readiness of fishers to further adapt and change their fishing gear. There are numerous reasons why fishers may not wish to change their fishing gear, including cost of outlay, perceived negative impacts on their fishing operation and profitability, perceived complexity of proposed options, and lack of understanding of the need to change. Change readiness is an important construct to explore because it informs and guides efforts to improve readiness and realise desired change.
- Provide fishers and others an opportunity to share and learn about additional options to reduce seabed impact, including alternative gears.
    - This could be in the form of industry meetings or gatherings, preferably with appropriate fishing gear on display and gear suppliers and other experts avaialble to chat and discuss the gear.
    - Many fishers in this study spoke of a desire to receive training about how their fishing gear works, new net designs, and other recent developments, including those that reduce seabed impacts and discards. Some spoke of training at the flume tank at the Australian Maritime College in Tasmania, while others spoke of the use of underwater cameras as a learning tool to observe their gear in operation. It is unclear to the authors how to progress this need.
- Develop a dedicated program designed to facilitate the evaluation of semi-pelagic trawl doors, raised sweeps and lower bridles, and groundgear modification, and encourage their uptake by fishers. This may take two forms, one, a dedicated, funded testing program to evaluate the efficacy of new gear modification to futher reduce seabed contact, and two, a gear-loan program for fishers to test this gear at low- or no-cost.
    - A dedicated testing program will likely require substantial government support to fund rigorous controlled testing of this gear at sea. It will require a dedicated scientific testing program and charter of commercial fishing vessels.
    - A gear-loan program is a useful option to encourage testing of this gear by fishers on their own vessel at a convenient time and place, at no- or low-cost. In this way the fisher receives support and guidance from the supplier regarding door size, rigging, and operation and can test the new doors in a relatively low-risk environment.
    - Consideration should also be given to potential sustainable finance options to assist fishers in the purchase of semi-pelagic doors. The price of these doors is typically over $10,000 depending on their size. In this way fishers are no worse off financially in the short term, and upon settling the loan they will fully enjoy the savings accrued by using less fuel.
    - The above approaches can also be applied to raised sweeps and lower bridles, and groundgear modification. For example, the use of rubber discs to raise the entire sweep clear of the seabed is also worthy of consideration.

Findings - Danish Seine

Two Danish seine fishers were interviewed for this study. Both fishers reported predominately setting their gear over smooth substrates devoid of rock, corals, sponges, and other benthic invertebrates. They reported fishing predominately over established, well-known fishing grounds to not only to minimise the risk of gear damage or loss, but potentially lost catch as well. They also reported avoiding fishing grounds where a risk of catching undersized commercial species or bycatch was increased.

The general design and operation of the fishing gear used by these fishers is consistent with that used in other Danish seine fisheries around the world. Large diameter ropes several thousand metres in length are set over the seabed and hauled slowly to herd fish on or near the seabed inwards and towards the path of the approaching seine net. As hauling continues, these ropes move closer together. Weighted groundgear attached to the groundline of the seine net is kept to a minimum, being sufficient only to keep the groundline close to the seabed to minimise fish escape below the net. Hauling speed is so low that the vessel often barely makes forward progress, being selected to optimise the herding capability of the ropes and keep the seine close to the seabed.

Both fishers reported using large mesh in the wings and mouth area of the seine, with mesh size decreasing towards the codend. These large meshes provide some opportunity for small fish escape and they also reduce seine drag and fuel consumption. Both also reported frequently using square-mesh codends to reduce the capture of small fish. While not stated explicitly, this likely also reduces catch sorting times and potentially, improves catch quality.

Reflections

The authors found that both Danish seine fishers were aware of the need to reduce seabed impacts to the greatest extent practicable. The weight of the sweeps is clearly sufficient for effective fishing and in all likelihood they have only modest impact and penetration of the seabed, with impact limited to light scuffing and resuspension of surface sediments. Given the shallow waters fished by these individuals, it is possible that any seabed disturbance caused by these ropes is no worse than that caused by natural storm events.

Danish seining is also renowned as a relatively efficient, selective, and environmentally benign fishing method (Noack *et al*., 2019; O'Neill & Noack, 2021; Suuronen *et al*., 2012). This is a characteristic that both fishers have enhanced using square-mesh codends to allow the escape of small fish. The use of such netting by these fishers, with a mesh size of 127-152.4 mm (5-6 inches), is also consistent with practice by the bottom-trawl fishers in this study. It is considered unlikely that a further increase in mesh size would be economically viable despite allowing a greater size range of fish to escape.

Next steps

In the opinion of the authors there are currently no known gear modifications that could be applied by these individuals to further lessen or eliminate seabed contact by the sweeps or groundgear.

Findings - Bottom set longlining

The fishing gear reported by both fishers is designed to ensure the baited hooks are located close to the seabed. Subsequently, it is essential that the mainline is weighted and the weights are in contact with the seabed.

The authors found that both longline fishers were aware of concerns over the impact of commercial fishing on the seabed, as well as those related to the potential stripping of localised fishing grounds by longline fishing. They had also taken steps to mitigate the risk to seabirds caused by this type of fishing using regulated tori lines and new regulations on additional line weights to ensure the baits drop deeper more quickly to avoid seabird interaction. Both fishers also expressed interest in using stern tubes to guide the baited hooks deep in the water and out of reach of seabirds, once related research and development was completed.

Reflections

The weights used by these fishers are essential to keep the baited hooks close to the seabed and land the target species. The weight of other gear components is already very light and designed and rigged to avoid seabed contact. Seabed contact by the mainline is not desirable due to the risk of abrasion and fouling, both of which can result in mainline breakage and lost fishing gear. Mainline breakage can also result in lost fishing time as the vessel searches to locate both ends of the broken line.

Any further reduction in weight could potentially result in greater disturbance to the seabed, as tide, current, or weather is likely to have a greater influence on gear movement and dragging of weights across the seabed. This may also result in loss of catch and profitability. In the opinion of the authors there are currently no known alternatives to the use of such weights in longline fishing.

Bottom set longline fishing in New Zealand is generally considered a selective operation in comparison to other fishing methods (Department of Conservation, n.d.). This characteristic has been reported in other similar bottom set longline fisheries around the world (e.g., Lokkeborg & Bjordal, 1992; Suuronen *et al*., 2012; Berninsone *et al*., 2020), and should be distinguished from the impacts surface or pelagic longline fisheries, which can be responsible for the mortality of a range of protected and other species including marine mammals, elasmobranchs, sea turtles, seabirds, and teleosts (Waugh *et al*., 2008; Griggs *et al*., 2018; Gilman *et al*., 2020).

Next steps

Similar to Danish seining, in the opinion of the authors there are no known gear modifications that could be applied by these fishers to further lessen or eliminate seabed contact. This fishing method likely has the least impact on the seabed compared to bottom trawling and Danish seining.

Conclusion

The study was, through research and interviews with fishers, successful in documenting gear used by individual fishers and highlighting their efforts to reduce seabed contact, voluntarily in their own time and at their own cost. It also concludes that fishers with the right support and incentives would be highly likely to consider additional modifications to further reduce seabed contact.

To facilitate future changes commercial fishers must be given assistance, to be informed of potential options for improvement and assisted in their testing and development of such improvements. This includes the provision of incentives or subsidy to minimise their economic risk. In the absence of such assistance, future gear modification will likely occur in a piecemeal and ad hoc fashion.

A more structured and coordinated approach to fast-track ground gear modification is the engagement of fishers in a dedicated and collaborative effort with government, other fishers, researchers, and other experts. Such a nuanced approach introduces additional expertise and resources that may be beyond that held by an individual fisher and is more likely to be cognisant of the need to seek win-win solutions that benefits both fishers and the environment.

This study recommends considering the establishment of a Seabed Impact Working Group. This group should include fishers and all relevant stakeholders. It will need to be charged with, and funded, to develop and apply a considered plan of action designed specifically to further minimise fishing gear impacts on the seabed. Importantly it includes ensuring substantial extension activity so the public and other stakeholders are aware of all developments, can recognise and acknowledge their efforts, and in doing so improve the social licence of the commercial fishing industry.

We conclude that, while more can still be done, the efforts of the Moana Contract harvesters to understand wider environmental impact mitigation and impliment initiatives to reduce that impact, as highlighted in this study, should be acknowledged.

Alignment with 'The Future of Commercial Fishing in Aotearoa New Zealand' report

The establishment of a Seabed Impact Working Group to identify, prioritise, coordinate, and guide future research is suggested by the authors to further refine bottom trawl gear and reduce seabed contact to the greatest extent practicable.

The establishment of this working group is also consistent with the recommendations of: *The Future of Commercial Fishing in Aotearoa New Zealand: A report from the Office of the Prime Minister's Chief Science Advisor, Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia* (see Office of the Prime Minister's Chief Science, 2021), in particular Theme 6, sub-theme h and Theme 7 (**Error! Reference source not found.**).

This report recommends a partnership approach between relevant stakeholders to seek options to minimise or eliminate the impacts of fishing gear on the seabed. It recommends prioritising research, incentivising the development and uptake of less impactful gear, reducing barriers to development, and fast-tracking the gear permit process.

The establishment of this group should occur sooner rather than later. This group must include commercial fishers. It should also include fishing gear technologists or other researchers with a close understanding of fishing gear. Government representation includes Fisheries New Zealand and the Department of Conservation, to ensure a deep understanding of the challenges, limitations, and realities of gear modification to reduce seabed impact, and so that the process of introducing (any) future gear regulations can be commenced in a timely and informed fashion. As a collective this group can exert pressure where necessary and guide developments associated with Theme 7, such as developing pathways to testing new gear, incentivising innovation, and reducing barriers.

Recent development

Moana New Zealand has recently completed another chapter in understanding its harvest footprint by conducting a peer reviewed ArcGIS mapping exercise overlaying government required catch effort data (approved for release by Moana fishers) against geographical maps of the ocean floor to calculate the total area of seabed contacted by trawlers per annum. The results found that Moana trawlers annually contact on average less than 3% of the total seafloor within 12 nm from the shoreline, and less than 1% of the seafloor inside the entire New Zealand Exclusive Economic Zone (EEZ)

What this means for Moana

Clearly the report shows that Moana New Zealand, through the actions of its contract fishers, is ahead of the game in respect of awareness of public expectations and interest in avoiding and mitigating impacts to the environment.

- The fishers provide good examples of innovation, at their own cost, as they constantly develop their gear and operations in practical terms to lighten their footprint.
- The report also highlights the challenges that fishers face trying to balance ongoing innovation in this space with the realities of the daily commercial fishing pressures.
- The report provides an important baseline of the state of the harvest fleet in 2022 that can underpin any prospective fleet transformation analysis, investment required quantification, etc moving forward.
- The report should act as a lever for Moana New Zealand to:
    - Pressure government to:
        - recognise the role of the wild harvest sector in providing sustainably caught, quality seafood, and food security for New Zealand.
        - support and partner with the sector to enable further innovation, and,
        - where necessary consider transitional financial support mechanisms.
    - Partner with the financial sector to:
        - Develop sustainable financing models that enable ongoing innovation towards such transition (with or without Government) e.g. financing net and door monitors, hybrid engine solutions etc.
    - Underpin Moana New Zealand’s values
        - Kaitiakitanga
            - lightening footprint
            - providing credible information which
    - requires agreement on the communications strategy and approach going forward to share the report contents appropriately with the public, media, customers etc.
        - Whakatipuranga
            - Underpinning brand and therefore profitability
            - Deepening the evidence for brand provenance
        - Manaakitanga
            - Better understanding the working conditions and fleet configuration to have insights into how to better care for its contract harvesters.

End

Schedule 1 Participating Vessels


FV TraditionII


FV Kawhai


FV Lord Nelson


FV Margaret Phillipa


FV William Rose


FV Santy Maria


FV Southern Cross


FV Ocean Wanderer II


F/V L'Avenir


FV Hikurangi


FV Bianca


FV Atlantic Dawn


FV San Colville


FV Eight Bells